European Commission

DG Environment

# Classification of mining waste facilities

No. 07010401/2006/443229/MAR/G4

## Final Report
## December 2007

Prepared by

**DHI Water·Environment·Health**
**in cooperation with**
**SGI, Swedish Geotechnical Institute**
**and**
**AGH, University of Science and Technology, Krakow**

## TABLE OF CONTENTS

# Foreword

The European Commission, DG Environment, has retained DHI Water·Environment·Health and its two co-operation partners, Swedish Geotechnical Institute (SGI) and University of Science and Technology in Krakow /AGH) to undertake the study "Classification of Mining Waste Facilities", study contract no. 07010401/2006/443229/MAR/G4.

The work was carried out from September 2006 to December 2007 and has included a continuous and very constructive dialogue between the Project Team, the Commission and the Technical Adaptation Committee (TAC) for the Mining Waste Directive, in particular the TAC Steering Group for the project. In addition, the PECOMINES team at JRC in Ispra as well as several other European mining waste and risk assessment experts have provided valuable input to the project. The Project Team gratefully acknowledges the considerable efforts spent by the parties involved.

The Commission project manager has been Fotios Papoulias from DG Environment.

The project has been co-managed by Ole Hjelmar and Nils Eriksson, both DHI.

The Project Team further consisted of David Bendz, SGI, Ingar Walder, DHI and Wojciech Naworyta, AGH University of Sciences and Technology, Krakow. In addition, Dag Ygland and Annika Bjelkevik, both SWECO ABB AB, and Helle Buchardt Boyd, DHI has provided input to the project.

# Executive Summary

## Introduction

A study has been carried out for the European Commission, DG Environment, to provide the technical and scientific information to be used for defining the criteria for the classification of mining waste facilities in Category A/not Category A in accordance with the provisions in Annex III of Directive 2006/21/EC of 15 March 2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC ("The Mining Waste Directive" or "MWD"), which states that:

"A waste facility shall be classified under category A, if:

a) a **failure** or **incorrect operation**, e.g. the collapse of a heap or the bursting of a dam, could give rise to a **major accident**, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the facility; or

b) it contains waste **classified as hazardous** under Directive 91/689/EEC above a **certain threshold;** or

c) it contains substances or preparations **classified as dangerous** under Directives 67/548/EEC or 1999/45/EC **above a certain threshold**."

An additional objective has been to identify mining waste facilities within the EU that are covered by the amendments to the Seveso II Directive (2003/105/EC) and to identify and describe the major types of waste management facilities within the EU.

## Existing classification systems

A survey of 32 countries, of which 27 are EU member states, showed that only 8 countries have a system for classification of mining waste facilities in place. Most of the existing classification systems are based on schemes derived directly or slightly modified from systems aimed at classifying water retaining dams (e.g., UK, Sweden, Finland, and Austria). These systems apply mainly to tailings ponds. The Spanish system is specific for tailings ponds, and resembles the other systems derived for water retaining dams. The other methodology used is a type of scoring system (e.g., Portugal and Slovakia) where site-specific information is evaluated and assigned a weight and a score. The total score determines the classification This system is mostly applicable to existing facilities (originally developed for abandoned facilities) as it could give a priority listing of facilities to be attended to. Due to the amount of information required these systems do not seem to be optimal for classification of new (planned) facilities in a permitting procedure.

## Risk assessment methodologies

Risk assessment can be made with different degree of complexity, e.g. by using a "forward" or "backward" approach or to include uncertainties explicitly by probabilistic modelling. A forward approach to risk assessment, i.e. to assess/calculate the actual risk in the form of e.g. *x* additional cases of cancer in a certain population, is in general more complex and is typically made as an in-depth risk assessment. The forward approach is also in general used in occupational and environmental medicine for making health based risk assessments. The backward approach is typically used for developing general guideline values, preliminary remediation goals, setting criteria for leaching properties or performance of engineered system component. Using the backward approach, calculations are made based on a defined acceptable risk level at the point of compliance, and the material or the soil is compared to a certain threshold value or compliance limit (for example used by the EU Landfill Directive TAC in setting criteria for acceptance of waste at landfills). Probabilistic risk assessments, where uncertainties are explicitly estimated and used in the calculations are argued to provide a better basis for decisions. They are, on the other hand, more time consuming and should therefore be used only when there is balance between the additional costs and the magnitude of the risk (or the experienced risk!).

The risk chain concept forms a good basis for comparing environmental risk assessment methodologies. The chain consists of the identified potential contamination source(s) and receptor(s), as well as the potential migration pathways in between. It contains the processes that form the total probability of a given event, although the risk only materializes if the chain remains unbroken and there is a negative effect at the receptor. The risk chain concept is also useful for identifying the risk reducing alternative actions, since these can be applied at different points of the source – transport – receptor chain. However, the distinction between the source itself, the transport media and the receptor is by no means straightforward: for example both soil and groundwater may be both transport mediums and receptors. National soil clean-up standards, derived with a backward approach, all have as a goal to protect health and environment, including subsequent effect on ground and surface water, but the standards show a large variation. This is due to a variation in their intended use, whether they include both human health, ecological effects, exposure routes, mass transfer between different environmental compartments, the selected toxicological and ecotoxicological criteria, the level of regional natural background exposure and political considerations. Although exposure of humans to contaminated soil, sediment or groundwater can occur via various routes, generic risk assessment and modelling risks are widely used and accepted approaches.

For assessment of low frequency – high amplitude events such as the collapse of a dam it seems fully reasonable to focus on the consequences for classification of risk objects, e.g. mining waste facilities. In dam safety regulations it is normal to consider the risk of loss of human life or serious injury to persons as well as damage to the environment and infrastructure. In general, the systems studied for classification of consequences are divided into a consequence-to-life (or loss of life) category and other categories, typically e.g. economical, infrastructural, social, environmental and cultural losses. In environmental risk assessments of industrial operations a distinction is made between routinely and non-routinely release of a harmful agent. The same distinction ought to be made between the catastrophic consequences of a physical collapse of a mining waste facility with a low probability to occur, and the consequences of leaching of metals from waste rock, without potential catastrophic consequences, but with a higher probability of occurring.

In doing this, and taking into account expert advice obtained during the study, it is important:

- to ensure consistency in the assessment of criteria for a tolerable environmental and human health impact as a result of a momentary release due to a physical failure *versus* continuous leaching of contaminants followed by transport in soil and groundwater and surface water;
- that the classification system should clearly define the **type of** impact that may force a facility to be classified as category A. In this way the key forward-looking features of the directive, to create an incentive for risk reduction and to encourage operators to minimize risk related to disposal facilities, is met;
- to acknowledge that tailing dams are unique compared to ordinary dams, because they are there forever. A risk analysis should include the possibility that the surrounding conditions may change, for example land use, and demographic changes or climate changes may occur (Campbell, 2007); and
- that the risk analysis and classification should be reviewed and updated regularly to take any changes in the surroundings (including extreme hydrological or seismic events) into account.

## Major types of mining waste facilities

All sectors within the European extractive industry (Metal Mining Sector, Industrial Minerals Sector, Energy Extractive Sector and the Aggregates Industry) use similar waste management methods:

- Waste-rock and tailings are to a large extent backfilled where possible.
- Waste-rock and tailings are used as building material where suitable and possible.
- Coarse waste-rock and coarse tailings are managed on heaps or in old excavation voids, if not backfilled into the operating mine or used as construction materials on or off-site.
- Tailings from dry processing are managed on heaps or in old excavation voids, if not backfilled into the operating mine or used as construction materials on or off-site.
- Tailings from wet processing are managed in tailings ponds or in old excavation voids, if not backfilled into the operating mine or used as construction materials on- or off-site.

Tailings ponds are often built in stages at the rate of increasing need for disposal volume in the facility. Numerous methods for construction tailings pond embankments exist as well as for tailings placement into the pond. It is not unusual that methodology for raising the embankments, tailings placement methodology and tailings characteristics change during the operational period of a tailings pond.

For tailings ponds physical stability is of critical importance as a failure could lead to significant consequences due to out flowing water and tailings. In Europe, and in the world, there is a development towards tailings facilities with less free water stored in the pond, use of separate clarification ponds, thickened or paste tailings disposal. An exception is potentially acid rock drainage (ARD) generating tailings where there is also a trend towards permanent underwater disposal. A failure of a heap is likely to result in smaller consequences as heaps contain little water that could be released at a failure resulting in a more local impact of a failure.

Short- medium- and long-term risk of surface and groundwater contamination by contaminated drainage from the facility is related to the characteristics deposited waste. ARD generation potential, leaching characteristics, possible mineral processing additives in the tailings water as well as possible compounds generated in the mineral processing affects drainage water quality.

Backfilling of waste-rock and tailings into operating mines or old excavation voids may eliminate the risk of a physical failure involving release of solids and water. However, the chemical stability of the waste may still be an issue for release of contaminants into surface water and groundwater.

An assessment of the performance of a waste facility needs to consider physical and chemical stability over the entire life-cycle of the facility. A decreasing risk with time, especially after closure has been completed, is desired. For potentially ARD generating waste from the extractive industry the closed facilities need to be physically and chemically stable and provide the adequate protection of the waste for hundreds or even thousands of years.

## The amended Seveso II Directive applied to mining waste facilities

In order to obtain information on mining waste facilities falling under the scope of Directive 2003/103/EC, a multitude of sources associated with the extractive industry have been approached. These sources include:

- Representatives of mining and environmental authorities in EU Member States;
- Representatives of European mining organizations (e.g. Euromines, Eurocoal);
- Representatives of international mining consortiums (e.g. Cleveland Potash);
- Representatives of NGOs involved in legal issues in connection with the amendment of Seveso II Directive (e.g. WWF);
- Representatives of International EU Projects connected to mining in Europe (European Network Mining Regions, ReRegions);
- Several individual mining waste experts (e.g. during the project workshop on 5 March 2007);
- Major Accident Hazards Bureau at JRC, Ispra, and
- Internet sources (e.g. www.tailings.info/minesineurope.htm).

All information obtained from these sources indicates that no European mining waste facilities have been classified as SEVESO II facilities according to the amended Seveso II Directive. Many European mine sites are classified as Seveso II sites, but this is generally due to the amount of dangerous substances (e.g. explosives or NaCN) stored for use in the processes, and in no (observed) case because of their waste (tailings) disposal facilities.

However there are some doubts related to the above statement which should be emphasised:

- In the Seveso Plants Reports of each Member State waste facilities covered by Seveso II, most Member States reported their Seveso II plants to Seveso Plants Information Retrieval System

(SPIRS by MAHB at JRC, Ispra, Italy) before the amendment, and in the near future they have to update their data. As a consequence, SPIRS, which is accessible for EU Commission, is not the best source of information for identification of mining waste facilities covered by the (amended) Seveso II Directive.

- The amended Seveso II Directive was implemented into Member State law as late as mid-2006. It is possible that actual reports do not include all sites covered by amended Directive.

It should be noted that in the Seveso Plants Reports of the Member States waste facilities covered by the Seveso II Directive are reported simply as “waste treatment” without specific reference to the type of activity or operation with which they are associated. This indicates that the forms to be filled out by the Member States may need to be adjusted to the purpose if the Commission wish to obtain this information specifically for mining waste facilities in the future.

## The proposed mining waste facility classification methodology

Based on the study and the discussions with the Commission and members of the Mining Waste Directive TAC, the following classification methodology is proposed for classification of mining waste facilities:

**Introduction**
A mining waste facility shall be classified as Category A or not Category A in relation to:

a) Failure - due to loss of structural integrity or incorrect operation – that could give rise to a major accident
b) The content of hazardous waste
c) The content of dangerous substances

When classifying a mining waste facility, all three issues should be considered. If a facility is classified under Category A according to any one of the above listed issues, then the overall classification of the facility is Category A, and it is not necessary to consider the other two issues further. If none of the issues lead to a Category A classification, then the overall classification of the facility is not Category A. The procedure for classification of mining waste facilities according to each issue is described in the following.

The procedure is aiming only to establish the classification of the facility – it is not the intention to explore the potential consequences in great detail nor to perform any detailed Environmental Impact Assessments. The procedure should be based on realistic conditions and/or scenarios.

For facilities containing only inert waste or unpolluted soil, only the first part of the first indent (failure due to loss of structural integrity) is relevant. For facilities containing predominantly hazardous waste the second indent will directly lead to the classification of the facility as “Category A”.

The potential hazard constituted by a mining waste facility may change significantly between operation and closure. Therefore, a review of the classification should be undertaken, if not before, at the end of the operational period of a facility.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**

If a failure, due to loss of structural integrity of a waste facility, regardless of the type of facility, can in the short- or long-term lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A.

Similarly, if incorrect operation of a facility could in the short- or long-term lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A.

The consideration of **loss of structural integrity** is intended to include all possible failure mechanisms relevant to the structures covered in the short or the long-term. This may for example be malfunction of decanting system, over-topping, internal erosion, settlements, slides, liquefaction, construction weakness, failure in the underground, seismic activity, etc.

In the same way, the consideration of **incorrect operation** is intended to include all possible mechanisms that could give rise to a major accident, including malfunction of environmental protection measures and faulty or insufficient design. Incorrect operation could occur during the entire life-cycle of the facility and is likely to pose a significant hazard potential also in the after-closure phase, when e.g. back-pumping, water treatment etc. are likely not to function, bathtub effects may occur, acid and alkaline drainage may develop, covers or liners may not have the intended effect or may become deficient, etc. Incorrect operation could, of course, also lead to a failure due to loss of structural integrity, but that has been covered above.

A facility is classified as a Category A facility if the consequences (in terms of loss-of-lives, serious danger to human health and impact on the environment) of a failure due to loss of its structural integrity or due to incorrect operation are non-negligible. The procedure applies to all facilities.

The potential for loss-of-lives or serious danger to human health is considered non-negligible if people that might be affected are staying permanently or for prolonged periods in the potentially affected area. It does not refer to workers in the extractive industry operating the facility in question as their safety is covered by other Community legislation, in particular Directives 92/91/EEC and 92/104/EEC.

In the case of **loss of structural integrity** for tailings dams, it is assumed that human lives are threatened at water/slurry levels of 0.7 m above ground and water/slurry velocities exceeding 0.5 m/s. In assessing the potential for loss-of-lives and serious danger to human health, the following factors should be considered and, if relevant, accounted for:

- The size and properties of the facility
- The quantity and quality of the waste in the facility
- The topography, including damping features such as, e.g., lakes
- The travel time of the flood-wave to areas where people stay
- The propagation velocity of the flood-wave
- The water or slurry level
- The rising rate of water or slurry levels

Please note that the list is not exhaustive – any relevant, site-specific factors that may influence the potential for loss-of-lives or serious danger to human health must also be taken into account.

For waste heap slides it is assumed that any waste-mass in movement is likely to threaten human lives if people are staying within range of the moving waste-mass. The following factors may be relevant (list not exhaustive):

- The size and properties of the facility
- The quantity and quality of the waste in the facility
- Slope angle of heap
- Potential to build up internal groundwater within the heap
- Underground stability
- Topography
- Proximity to water courses, constructions, buildings, etc
- Mine workings

Injuries leading to disability or prolonged states of ill-health count as serious dangers to human health.

The classification procedure related to loss of the structural integrity shall consider both the immediate impact of any materials transported out of the facility as a consequence of the failure (e.g., tailings slurry, rock, contaminated and/or uncontaminated water) and the resulting short, medium and long-term effects (e.g., contamination of soil and water bodies, loss of animal life, destruction of habitats, etc). The entire life-cycle of the facility needs to be considered in the evaluation of the hazard potential of the facility.

The potential for serious environmental impact of a failure due to loss of structural integrity or incorrect operation is considered negligible if:

- the potential contaminant source strength is decreasing significantly with time,
- if the affected environment can be restored with limited clean-up and restoration efforts, and
- if the environment does not suffer any permanent or long-lasting damage.

Examples of permanent or long-lasting damage to the environment are:

- residual soil contamination leading to restrictions in land-use, risk to human health or ecological risk;
- permanent (more than 10 years) restrictions in the use of surface water or groundwater;
- lasting period of chronically toxic concentrations of contaminants in surface water;
- short period of acutely toxic concentrations of contaminants in surface water if there is risk for irreversible damage to the affected ecosystem.

An assessment of the release of contaminants with regard to incorrect operation shall take into account both the effects of short-term pulses and long-term release of contaminants and shall be carried out for two periods of time, namely:

a): The operational period of the facility;
b): The long-term period following closure.

In this assessment special consideration should be given to the potential hazards constituted by facilities containing reactive waste, regardless of the classification of the waste as hazardous or non-hazardous under Directive 91/689/EEC, e.g. waste the may produce acid drainage (ARD), waste that may produce neutral or alkaline drainage with high contents of potential contaminants, and waste that may self-ignite if exposed to air.

In establishing the potential for loss-of-life or serious danger to human health and serious environmental impact, specific evaluations of the extent of the potential impacts shall be considered in the context of the source – pathway - receptor chain. If there is no pathway between the source and the receptor, then the facility cannot be classified under Category A due to failure caused by loss of structural integrity or incorrect operation.

**Classification based on the content of hazardous waste**
A mining waste facility is classified as a Category A facility if it contains more than a certain percentage of **hazardous waste**. The classification according to the content of hazardous waste proceeds in two steps.

In **step 1** it shall be determined if any of the waste streams discharged into the facility are hazardous according to the European Waste Catalogue (EWC) and the associated procedures. A waste stream is classified as hazardous:

- If it has an “absolute entry” in the EWC (only entry 01 03 04: acid-generating tailings from processing of sulphide ore). Such tailings are considered acid generating if the ratio NP/AP between the neutralisation potential (NP) and the acidity production potential (AP) as determined by the procedure to be developed by CEN/TC 292/WG8 is < 1. For 1< NP/AP < 3, further evaluation, e.g. using a kinetic test may be necessary to determine if the waste should be considered ARD producing or not. For NP/AP > 3, the waste is considered non- acid generating.

- If it has a mirror entry (this is the case for 01 03 05, 01 03 07 and 01 04 07), and dangerous substances are present above threshold concentrations. Whether or not this is the case is determined using the results of the waste characterisation carried out according to Annex II to the MWD and checking the content of various substances against the thresholds defined by the hazard properties

(H1-H14) in Annex III to Directive )1/689/EEC and the risk phases defined in Directive 2001/59/EC). Some guidance concerning relevant H-properties is available, e.g. from the UK Environment Agency.

- If a national authority has determined that it should be classified as hazardous waste.

If none of the waste streams received by the facility consist of hazardous waste, then the facility shall not be classified as a Category A facility based on its content of hazardous waste, and step 2 shall not be carried out. If one or more waste streams have been identified as hazardous, then step 2 shall be carried out.

In **step 2** the total amount (as weight) of hazardous waste expected to be present in the facility at the end of the planned period of operation (A) shall be determined (on a dry matter basis).

The total amount (as weight) of waste expected to be present in the facility at the end of the planned period of operation (B) shall be determined (on a dry matter basis).

The ratio A/B shall be determined and compared to the limit value for the total content of hazardous waste.

Three alternatives could be considered for this comparison:

***Alternative 1:***
If the weight percentage (A/B) of waste in a mining waste facility classified as hazardous exceeds X % (e.g. 5 %) (including ARD producing tailings from the processing of sulphide ore), then that facility shall be classified as a Category A facility.

***Alternative 2:***

- If more than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste then the facility is classified as Category A.
- If less than Y % (e.g. 50%) but more than X % (e.g. 5 %) of the deposited waste streams to the facility is hazardous waste then a site specific risk assessment with specific focus on the effects of the hazardous waste shall be performed (as part of the classification based on the consequences of failure due loss of integrity or incorrect operation).
- If less than X % (e.g. 5%) of the deposited waste stream to the facility is hazardous waste then the facility is classified as not Category A based on content of hazardous waste.

***Alternative 3:***

- If more than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste then the facility is classified as Category A.
- If less than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste, then the facility is not classified as Category A based on content of hazardous waste. A content of hazardous waste must be taken into account in the classification based on the consequences of failure due loss of integrity or incorrect operation.

**Classification based on the content of dangerous substances/preparations**
A mining waste facility shall be classified as a Category A facility if it contains substances or preparations (i.e. additives or reaction products) in sufficient quantities for them to be classified as **dangerous** according to Directives 67/548/EC and 199/45/EC and subsequent amendments.

***Planned facilities (tailings ponds):***
The following stepwise procedure shall be followed for planned facilities (tailings ponds):

1. Produce an inventory of the substances and preparations used in the processing and subsequently discharged with the tailings slurry to the tailings pond (identity and mass/year). The inventory shall be based on the maximum amounts of each substance used during one year.

2. Calculate the average yearly increase in stored water within the tailings pond under steady state conditions, $\Delta Q$. This is assumed to correspond to the pore water present in the tailings deposited during one year, and shall be calculated from the mass of tailings (tonnes dry weight/year) discharged to pond, the average dry bulk density of the deposited tailings (tonnes/$m^3$) and the pore volume of the sedimented tailings ($m^3/m^3$). If exact data are not available, default values of 1.4 t/$m^3$ for the dry bulk density and 0.5 for the pore volume may be used.

3. For each substance in the inventory produced under point 1, determine whether or not it is a dangerous substance according to Annex I in Directive 67/548/EC (or, if necessary, Annex VI). Determine the limit values associated with each danger (R) category.

4. Using the information obtained under point 3, the mass/year of each substance discharged into the pond determined under point 1 and the yearly increase in pore water volume calculated under point 2, use the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous substance.

5. If the aqueous phase is a dangerous preparation as determined under point 4, then the facility should be classified as a Category A facility. If it is not classified as a dangerous preparation, then the facility is not classified as a Category A facility based on content of dangerous substances/preparations.

This procedure is relatively conservative and does not account for reactions that may reduce the level of concentration of dangerous substances/preparations in the water phase (degradation, adsorption to the solid phase) nor does it account for treatment/destruction processes that may be applied before discharging the tailings into the facility (e.g., CN destruction, neutralisation, oxidation). Dilution in the facility is also neglected. If necessary, this may be taken into account in a more sophisticated estimation using, e.g., normal treatment results, water balance calculations and/or compartmentation and degradation modelling and including the solid phase in the calculation of concentrations. Also, if with time, the concentrations fall below the threshold, the facility could be reclassified.

***Operating facilities (tailings ponds):***
For operating facilities, the classification may be based upon the described calculations, or it may be based on direct chemical analysis of the water (and solids) contained in the facility followed by use of the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous preparation. If it does, the facility shall be classified as a Category A facility.

***Heaps and heap leaching:***
Classification according to content of dangerous preparations has little or no relevance for waste heaps. Heap leach facilities are not regarded as waste heaps during operation. At closure they are normally washed out to minimise the content of any remaining leach solution. A screening for dangerous substances can be made based on an inventory of used leach chemicals and the residual concentrations of these leach chemicals in the drainage after washing has been finalised.

# 1. Introduction

The main objective of the study has been to provide the Commission with technical and scientific information to be used for defining the criteria for the classification of waste facilities in category A in accordance with the provisions in Annex III of Directive 2006/21/EC of 15 March 2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC ("The Mining Waste Directive" or "MWD"), which states that:

"A waste facility shall be classified under category A, if:

d) a **failure** or **incorrect operation**, e.g. the collapse of a heap or the bursting of a dam, could give rise to a **major accident**[1], on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the facility; or

e) it contains waste **classified as hazardous** under Directive 91/689/EEC above a **certain threshold;** or

f) it contains substances or preparations **classified as dangerous** under Directives 67/548/EEC or 1999/45/EC **above a certain threshold**."

Other objectives have been to identify mining waste facilities in MS and Accession Countries that are covered by the amendments to the Seveso II Directive (2003/105/EC) and to identify and describe the major types of waste management facilities in MS and Accession Countries.

The study covers facilities for waste from extraction and processing of metal ores, coal, industrial minerals and aggregates. When used in this report, the term "mining waste" generally refers to "waste from the extractive industries."

This Final Report documents the work carried out during the study. It describes the results of the information-gathering part of the project and presents the approach and methodology for classification of mining waste facilities developed and proposed by the project team in the form of a concise methodological guidance.

[1] Definition in article 3 of the MWD: **Major accident** means an occurrence on site in the course of an operation involving the management of extractive waste in any establishment covered by this Directive [in this context only waste facilities], leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site.

# 2. Category A classification of mining waste facilities

## 2.1 Background and intentions

According to Article 9 in the Mining Waste Directive, the competent authority is obliged to classify waste deposits from the extractive industry in accordance with the criteria in its Annex III (see chapter 1). A facility can be classified either as belonging to **Category A** or as not belonging to **Category A**. The classification should mainly be done on the basis of the facility's potential risk and environmental effects in case of an accident or incorrect operation and on the basis of the characteristics of the waste deposited in the facility.

The statements in the Preamble to the Directive should provide some guidance regarding the intentions laid down in the Articles and Annexes of the Directive. The following statements in the Preamble to the Mining Waste Directive address Category A facilities:

(9): Nor should this Directive apply to waste resulting from the offshore prospecting, extraction and treatment of mineral resources or to the injection of water and re-injection of pumped groundwater, while inert waste, non-hazardous prospecting waste, unpolluted soil and waste resulting from the extraction, treatment and storage of peat should be covered only by a limited set of requirements due to their low risks. For non-hazardous non-inert waste, Member States may reduce or waive certain requirements. However, these exemptions should not apply to Category A waste facilities.

(14) In order to minimise the risk of accidents and to guarantee a high level of protection for the environment and human health, Member States should ensure that eacht operator of a Category A facility adopts and applies a major-accident prevention policy for waste. In terms of preventive measures, this should entail the delivery of a safety management system, emergency plans to be used in the event of accidents and the dissemination of safety information to persons likely to be affected by a major accident. In the event of an accident, operators should be required to provide the competent authorities with all the relevant information necessary to mitigate actual or potential environmental damage. These particular requirements should not apply to waste facilities from the extractive industries falling within the scope of Directive 96/82/EC [the Seveso II Directive, now amended by Directive 2003/105/EC].

(15): A waste facility should not be classified in Category A solely on the basis of risks to the safety and health protection of workers in the extractive industries covered by other Community legislation, in particular Directives 92/91/EEC [Directive concerning the minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling] and 92/104/EEC [Directive on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries].

(19): It is necessary to define clearly Category A facilities used to service waste from the extractive industries, taking into account the likely effects of any pollution resulting from the operation of such a facility or from an accident in which waste escapes from such a facility.

(22): It is necessary to establish monitoring procedures during the operation and after-closure of waste facilities. An after-closure period for monitoring and control of Category A facilities should be laid down proportionate to the risk posed by the individual waste facility, in away similar to that required by Directive 1999/31/EC [the Landfill Directive].

## 2.2 The implications of being classified as a Category A facility

If a facility is classified as a Category A facility, it implies that the operator must adapt major accident prevention measures and produce the relevant documentation that this has taken place:

1. The operator shall adopt and apply a major-accident prevention policy for waste (article 6). In terms of preventive measures, this should entail the delivery of a safety management system; emergency plans to be used in the event of accidents; and the dissemination of safety information to persons likely to be affected by a major accident. In the event of an accident, operators are required to provide the competent authorities with all the relevant information necessary to mitigate actual or potential environmental damage (unless the facility falls within the scope of Directive 96/82/EC).

2. A document is required (article 5 (3)) in the waste management plan demonstrating that a major-accident prevention policy, a safety management system for its implementation and an internal emergency plan will be put into effect in accordance with Article 6 (3).

It further implies that various exemptions of or reductions in requirements possible for facilities that are not classified as Category A facilities do not apply:

3. Member States may reduce or waive the requirements of Articles 11(3), 12(5) and (6), 13(6), 14 and 16 for non-hazardous non-inert waste only if it is deposited in a facility not classified as a Category A waste facility (article 2(3)).

4. Inert waste and unpolluted soil resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries and waste resulting from the extraction, treatment and storage of peat shall be subject to Articles 7, 8, 11(1) and (3), 12, 13(6), 14 and 16 of the directive only if deposited in a Category A waste facility (article 2(3)).

5. There is no minimum time for temporary storage of waste in the facility until it is defined as a "waste facility" if it is a Category A facility (article 3(15)).

In addition, some of the requirements applying to facilities not classified as Category A facilities may have to be more demanding for Category A facilities:

6. It is e.g. necessary to establish monitoring procedures during the operation and after-closure for Category A facilities and they should be laid down proportionate to the risk posed by the individual waste facility, in a way similar to that required by Directive 1999/31/EC (recital 22).

## 2.3 The significance of being classified as a Category A facility

Some of the above mentioned requirements for **Category A** facilities have mainly administrative and organisational consequences (requirements 1, 2, 5 as well as partly 3 and 4). Others, such as requirements 3, 4 and 6, have direct economical impacts on the operation.

Requiement 3 refers to reduced or waived requirements that Member States may apply to facilities containing non-hazardous non-inert waste[2], unless the deposit is classified as a Category A facility. Of these requirements 11(3) *"notification without undue delay in case of an incident"* and 16 *"transboundary information"* are mainly of administrative nature, whilst 12(5) *"monitoring and maintenance after*

[2] This may constitute a large part of the waste produced within the base metal mining industry and coal mining industry depending on how "inert waste" is defined in relation to the sulphide content.

*closure"*, 12 (6) *"reporting and economical responsibility for closed facility"*, 13(6) *"minimized cyanide concentration in facility"* and 14 *"financial security for closure and post-closure"* have significant economical impact.

Requirement 6 is already partly captured by requirement 3. However, requirement 6 should not primarily be regarded as an additional cost, as it is in the interest of the operator to monitor the facility and make sure it performs as intended.

Requirement 4 refers to inert waste and unpolluted soil[3] which are materials with reduced requirements unless they are deposited in a Category A facility. Of these requirements some are of administrative nature, such as article 7 *"permitting requirements"*, article 8 *"public participation"*, article 11(1) *"competent person"* and article 11(3) *"notification without undue delay in case of an accident"* and article 16 *"transboundary information"*. Others have direct economical impacts on the operation, such as article 12 *"closure and after-closure procedures"*, article 13(6) *"minimized cyanide concentration in facility"*, article 14 *"financial security for closure and post-closure"*.

## 2.4 Discussion

Facilities containing waste classified as hazardous or waste containing dangerous substances above a certain threshold will all be classified as Category A facilities.

For unpolluted soil, non-hazardous inert waste and non-hazardous non-inert waste there are significant implications depending on how the disposal facilities are classified. The implications of classifying a facility as a Category A facility are both administrative and economical. Requirements of administrative nature, such as permitting and development as well as maintenance of various management plans, are significantly more comprehensive for Category A facilities. Economical consequences may be significant, especially regarding monitoring, reporting, maintenance after closure and financial security for closure and post-closure.

For non-hazardous inert waste and non-hazardous non-inert waste the Directive is formulated in such a way that it encourages mining companies to design, locate and operate the disposal facilities in such a way that it is not classified as a Category A facility, i.e., minimise risk over the life-cycle of the facilities.

This important aspect of the Mining Waste Directive, creating an incentive for risk reduction by simplified administration and lower costs for low risk facilities, is a key forward-looking feature of the Directive. For this reason, any methodology developed for the classification of waste disposal facilities should be carefully formulated in order to encourage operators to minimise risk related to the disposal facilities. The developed methodology should therefore, to the extent possible, provide possibilities for the operator to design, locate, operate and close facilities in such a way that when risk is minimised to certain levels (to be defined in the methodology) the facilities are not classified as Category A facilities.

[3] This may constitute a large part of the waste produced within quarrying, industrial mineral sector and the aggregates industry and it may constitute a large part of the waste produced within the metal mining industry and the coal mining industry – depending on how "inert waste" is defined in relation to the sulphide content. Within the aggregates industry mineral sources with elevated sulphide contents can in most cases be avoided by initial site investigations (Vanbelle, 2007).

# 3. Approach and overview

The general approach of the study is illustrated in figure 3.1, which also shows how the work has been structured.

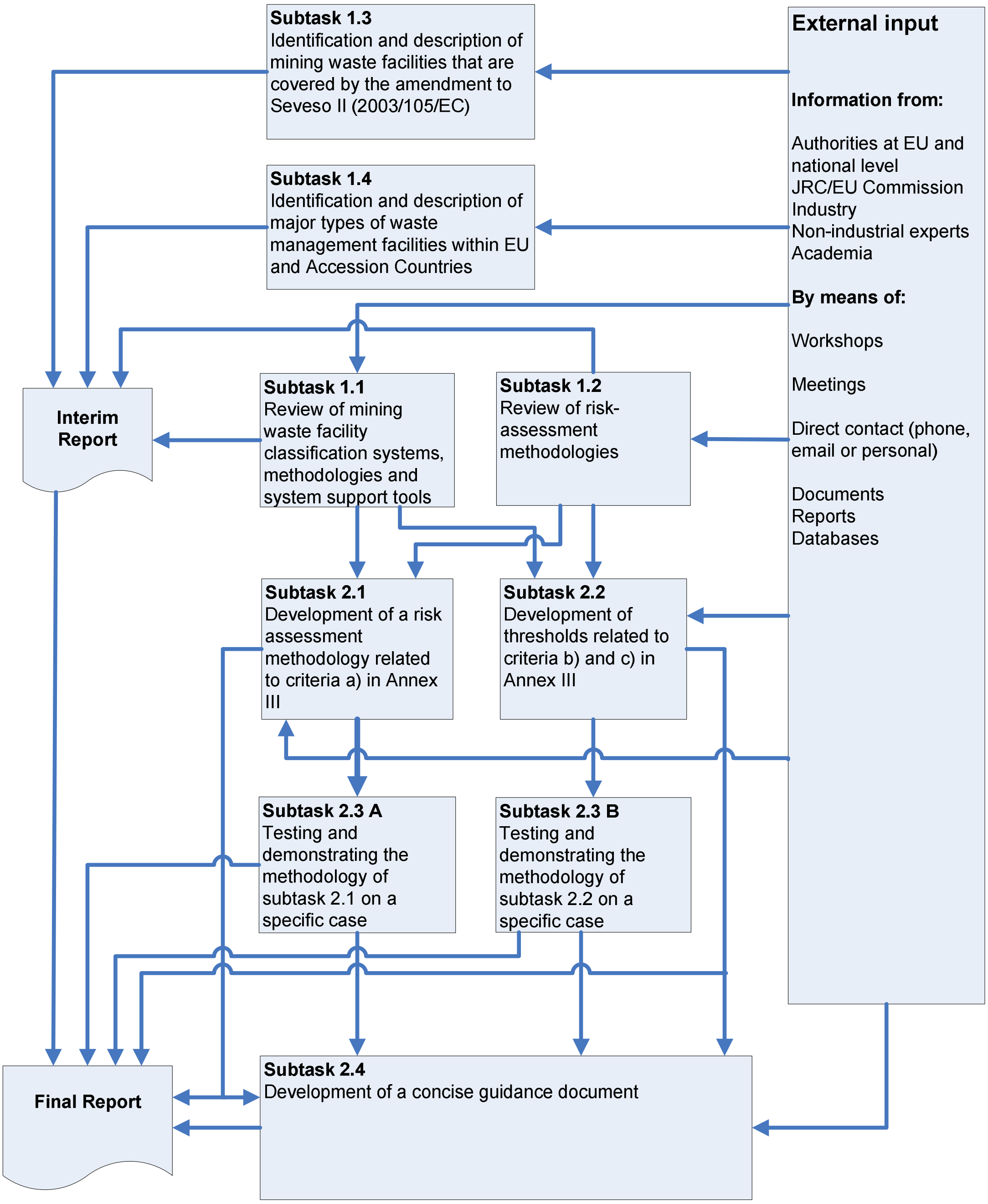


*Figure 3.1*
*Approach and structure of the work.*

The initial part of the project work, which was focused on collection and review of information, but also included development of a first proposal for a methodology for classification of mining waste facilities, consisted of four subtasks:

Subtask 1.1: Review of mining waste facility classification systems, methodologies and system support tools.

Subtask 1.2: Review of risk assessment methodologies.

Subtask 1.3: Identification and description of mining waste facilities that are covered by the amended Seveso II Directive.

Subtask 1.4: Identification and description of major types of waste management facilities within the EU.

The outcome of subtasks 1.1 to 1.4 was reported in an Interim Report in April 2007.

The final part of the project work, which was focused on development, discussion, revision and testing of the proposal for a methodology for classification of mining waste facilities, consisted of the following subtasks:

Subtask 2.1: Development of a risk assessment methodology related to indent a) in Annex III to the Mining Waste Directive.

Subtask 2.2: Development of thresholds related to indents b) and c) in Annex III to the Mining Waste Directive.

Subtask 2.3: Testing and demonstrating the methodologies developed under subtasks 2.1 and 2.2 on specific cases.

Subtask 2.4: Development of a concise guidance document.

This final report documents the work carried out during the study and presents both some intermediate methodology proposals and the final methodology proposal which is the result of an iterative process involving several interactions and discussion between the project group and stakeholders, in particular the Commission, the TAC for the Mining Waste Directive, and the TAC Steering Group for study.

**Chapter 4** presents the review of waste facility classification systems (subtask 1.1), and the review of risk assessment methodologies (subtask 1.2) is presented in **chapter 5**. **Chapter 6** presents the major types of mining waste facilities in Europe (subtask 1.4). In **chapter 7**, the results of the review of the application of the amended Seveso II Directive to mining waste facilities (subtask 1.3) are presented. In **chapter 8**, the proposed mining waste facility classification methodology (subtasks 2.1, 2.2 and 2.4) is presented in the form of a concise methodological guidance which has also been provided as a separate document. In **Appendix 7** a number of examples of application of the proposed methodology on specific cases are presented. Some of the background information, including intermediate methodology proposals and discussion papers produced by the project team, is presented in **Appendix 6**.

In the course of the study, the project team has had meetings with the researchers responsible for the PECOMINES project at JRC, Ispra, Italy (November 2006), and the Technical Adaptation Committee (TAC) for the Mining Waste Directive (February, July and November 2007). On March 5, 2007, a workshop with mining waste experts was held in Brussels (see **Appendix 1**). In May and November 2007 members of the project team met with the TAC Steering Group. The project team has had several meetings with the Commission during the project period. In addition, several members of the project team have participated in the work of CEN/TC 292/WG8: “Characterisation of mining waste”.

# 4. Review of mining waste facility classification systems

## 4.1 Introduction

The main objective of this project is to develop a methodology for classifying mining waste facilities into Category A facilities and facilities that does not belong to Category A based on the three broadly defined criteria listed in Annex III to the Mining Waste Directive, see chapter 1. The fist indent in Annex III refers to a risk posed by the facility as such (how much can be released, how far can it be transported and what can be affected) (height, size, location, downstream environment, etc) and what it contains (water, solids, etc). The second indent refers to the waste as such. The third indent refers the waste in the facility as well as the quantities and concentrations of this waste, i.e., also indirectly to the size of the facility. As can be seen, a mining waste facility classification system must take into account both the properties of the waste and the characteristics of the facility (as well as the vulnerability of the surrounding environment and humans in the vicinity). The classification of waste is briefly discussed in section 4.2, and the characteristics of mining waste facilities are addressed in chapter 6.

In order to support the development of a methodology for classifying waste facilities in the EU Members States, it would be useful to obtain and understand information on classification of mining waste facilities and mining waste and how these issues currently are being handled in the EU Member States and worldwide, if they have been dealt with at all. This type of information has therefore been pursued partly through direct contact/requests to environmental ministries, agencies and/or organisations regulating the mining and minerals industry in each of the EU Member States, partly through the review of relevant documents.

## 4.2 Mining waste classification systems within the EU

Within the European Union, all Member States are required to classify waste in accordance with the European Waste Catalogue (EWC, Commission Decision 2000/532/EC of 3 May 2000 with amendments). This includes waste from the extractive industry which belongs to class 01: Wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals. In this system, the wastes listed are generally considered non-hazardous unless they are marked as "Absolute Entries" (A), i.e. they are considered hazardous waste regardless of any threshold concentrations or as "Mirror Entries" (M), i.e. they are hazardous waste only if dangerous substances are present above threshold concentrations.

The types of waste represented in relevant types of waste under group 01 in the EWC are shown in table 4.1. It should be noted that subgroup 05: "Drilling muds and other drilling wastes" are not included in the scope of this study.

As can be seen, the only waste from the extractive industry which is "born" hazardous in this system is 01 03 04: "Acid-generating tailings from processing of sulphide ore". Three other type of waste have the so-called mirror entries and may potentially be classified as hazardous:

01 03 05: "Other tailings containing dangerous substances",

01 03 07: "Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals", and

01 04 07 "Wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals".

It should be noted that although waste rock from mineral metalliferous (01 01 01) and non-metalliferous (01 01 02) excavation are listed in EWC as inherently non-hazardous waste, waste rock with a potential for production of acid rock drainage (ARD) is in many cases as environmentally problematic as or even more so than acid-generating tailings, which are listed as hazardous waste.

***Table 4.1***
*Waste Group 01 from the European Waste Catalogue (from UK Environment Agency, 2005a).*

"*Absolute Entries*" - Hazardous waste regardless of any threshold concentrations: A
"*Mirror Entries*" - Hazardous waste only if dangerous substances are present above threshold concentrations: M

| | | |
|---|---|---|
| **01** | **Wastes Resulting from Exploration, Mining, Quarrying, and Physical and Chemical Treatment of Minerals** | |
| **01 01** | **wastes from mineral excavation** | |
| 01 01 01 | wastes from mineral metalliferous excavation | |
| 01 01 02 | wastes from mineral non-metalliferous excavation | |
| **01 03** | **wastes from physical and chemical processing of metalliferous minerals** | |
| 01 03 04* | acid-generating tailings from processing of sulphide ore | A |
| 01 03 05* | other tailings containing dangerous substances | M |
| 01 03 06 | tailings other than those mentioned in 01 03 04 and 01 03 05 | |
| 01 03 07* | other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals | M |
| 01 03 08 | dusty and powdery wastes other than those mentioned in 01 03 07 | |
| 01 03 09 | red mud from alumina production other than the wastes mentioned in 01 03 07 | |
| 01 03 99 | wastes not otherwise specified | |
| **01 04** | **wastes from physical and chemical processing of non-metalliferous minerals** | |
| 01 04 07* | wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals | M |
| 01 04 08 | waste gravel and crushed rocks other than those mentioned in 01 04 07 | |
| 01 04 09 | waste sand and clays | |
| 01 04 10 | dusty and powdery wastes other than those mentioned in 01 04 07 | |
| 01 04 11 | wastes from potash and rock salt processing other than those mentioned in 01 04 07 | |
| 01 04 12 | tailings and other wastes from washing and cleaning of minerals other than those mentioned in 01 04 07 and 01 04 11 | |
| 01 04 13 | wastes from stone cutting and sawing other than those mentioned in 01 04 07 | |
| 01 04 99 | wastes not otherwise specified | |
| **01 05** | **drilling muds and other drilling wastes** | |
| 01 05 04 | freshwater drilling muds and wastes | |
| 01 05 05* | oil-containing drilling muds and wastes | M |
| 01 05 06* | drilling muds and other drilling wastes containing dangerous substances | M |
| 01 05 07 | barite-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 08 | chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 99 | wastes not otherwise specified | |

Wastes on the EWC (with mirror entries) are considered hazardous if they have one or more of the hazardous properties (H1 to H14) defined in Directive 91/689/EEC on hazardous waste and subsequent amendments. A list of the hazardous properties is shown in Appendix 2. The UK Environment Agency has produced a guideline with advice on the dangerous substances that may be associated with the waste types with absolute and mirror entries in the EWC and the hazardous properties that may need to be considered for different hazardous waste entries. The information the hazardous and mirror entries under 01 03 and 01 04 is shown in table 4.2. The classification of waste according to the EWC is discussed in more detail in Appendix 6.

In a report prepared by JRC at Ispra, Italy, in 2002 (JRC, 2002), the authorities in the then accession and pre-accession countries Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia were asked how mining waste was defined and classified in the waste system or in another part of their legislation. The responses showed that most of the Candidate Countries already had adopted the EWC item by item. It meant that there were no specific definitions for mining waste, with the following exceptions:

- In Bulgaria, where mining waste was defined in Subsurface Resources Act, "Technological waste" was defined as rock and earth mass obtained as a result of exploration, extraction and processing of subsurface resources, which is stored at depots of approved design, inclusive of metallurgical slag, cinder and ash from thermal power stations, phosphogypsum, pyrite dross, ablations, slurries, etc.
- In Romania, where mining wastes were defined as "residuals of mining exploitation and mineral processing".
- In Poland, where mining waste is defined for the payment of waste fees, and excludes the overburden of brown coal mining.

***Table 4.2***
*Comments on absolute and mirror entries under 01 03 and 01 04 in the EWC (UK Environment Agency, 2005c). For explanation of the H-hazards, refer to Appendix 2 or Appendix 7..*

Absolute and Mirror Entry Wastes

| 01 | Wastes Resulting from Exploration, Mining, Quarrying, and Physical and Chemical Treatment of Minerals | |
|---|---|---|
| 01 03 | wastes from physical and chemical processing of metalliferous minerals | |
| 01 03 04* | acid-generating tailings from processing of sulphide ore | A |
| | Acid-generating wastes of this type are not normally corrosive, despite their ability to produce acidic leachates. They are likely to comprise irritant (H4), harmful (H5), and/or ecotoxic (H14) sulphates of the heavy metals. There may also be potential hazards (H5, H6, H7, H10, H11, or H14) from the presence of a wide range of the metals and their compounds including: nickel; copper; zinc; antimony; tellurium; arsenic; cadmium; mercury; thorium; lead. | |
| 01 03 05* | other tailings containing dangerous substances | M |
| 01 03 07* | other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals | M |
| | 01 03 05 primarily relates to non-sulphide ores which may or may not contain heavy metals. 01 03 07 however could relate to a broader spectrum of ore processing wastes. Unless acid generating, the wastes are unlikely to be irritant (H4), but there are other possible hazards (H5, H6, H7, H10, H11, or H14) from the presence of a wide range of the metals and their compounds including: nickel; copper; zinc; arsenic; cadmium; antimony; tellurium; mercury; thorium; lead. | |
| 01 04 | wastes from physical and chemical processing of non-metalliferous minerals | |
| 01 04 07* | wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals | M |
| | These wastes may arise from processing of minerals including gypsum, salt, potash, asbestos, graphite, fluorite, calcite, clay, sand and gravel. They might contain potentially hazardous minerals from other 01 04 processes (e.g. asbestos) or potentially hazardous metals such as nickel; copper; zinc; arsenic; cadmium; antimony; tellurium; mercury; thorium; lead or their compounds and should be considered under the following hazards: H5 to H7, H10, H11, or H14. | |

## 4.3 Classification of mining waste facilities

### 4.3.1 The European Union

**EU legislation**

On December 19, 2002 the EU adopted a Council Decision with an Annex (2003/33/EC) establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 and Annex II of the Landfill Directive 1999/31/EC. This Decision established:

- Procedures to determine the acceptability of waste at landfills;
- Limit / threshold values and other criteria for waste acceptance in the different classes of landfills;
- Test methods to be used to determine the acceptability of waste at landfills.

Waste generated by the extractive industry that is deposited on site is exempted from the acceptance criteria and procedures set out in the Annex of this decision. In the absence of specific Community legislation, Member States shall apply national criteria and procedures. The Decision was published on January 2003 with effect on July 2004, with a transition period until 16 July 2005. This procedure led to a vacuum while waiting for the MWD (2006/21/EC).

Formally (even if not enforced) the landfill directive, which provides for a classification system, has applied to extractive industry waste facilities until the MWD is implemented in national law, Tailings dams are often classified according to dam classification systems, often through voluntary approaches such as (Mining)RIDAS in Sweden and Finland. Spain has developed a specific decree formalising how tailings management facilities should be classified.

European countries generally require the development of an Environmental Impact Statement (EIS) for proposed mining activities. There are commonly provisions in each countries EIS regulations that exclude small operations/minimal impact projects for performing and EIS.

**EU Member States without mining waste facility classification systems**

In the above mentioned report (section 4.2.1) prepared by JRC at Ispra, Italy, in 2002 (JRC, 2002), the authorities in the then accession and pre-accession countries Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia were also asked if there were separate regulation on mining waste management in their countries. The responses showed that there were no regulations as separate pieces in the countries studied at that time. Since then, Hungary has produced draft legislation on classification of mining waste facilities based on Annex III in the MWD (Madai, 2007), and Slovakia also has developed a risk classification system that applies to mining waste facilities.

The following Member States have confirmed that they do not have mining waste facility classification systems or separate regulation on (operating or planned) mining waste facilities: Ireland (Motherway, 2007), Poland (Naworyta, 2007), Denmark (Christensen, 2007), Germany (Juroszek, 2007), Belgium (Vanbelle, 2007), Italy (Fanfani, 2007) and the Netherlands (Artherberger, 2007). See also table 4.1.

**EU Member states with mining waste classification systems**

***Sweden and Finland***

The Swedish RIDAS system (Swedenergy AB, 2002), which has also been applied in Finland, uses a classification scheme for classifying consequences of tailings dam failures. The system has been adapted for mining dam failures by the Swedish Mining Industry (i.e. MiningRIDAS) with a few supplements to better apply to tailings facilities. The classification scheme takes into consideration consequences both upstream and downstream the actual dam. In the MiningRIDAS system (GRUVRIDAS, 2006) consequences (including both loss of lives and environmental impact) of transport of tailings and leaching of hazardous substances are also considered.

Dam safety work is consequence driven in Sweden and dams are classified according to the consequences in case of a dam failure. The consequence classification is carried out by the individual dam owner on his own initiative – a voluntary system. The consequence class of a dam decides which dam safety requirements should be applied.

The cost for remediation, in case of a failure, is used for classification of the environmental damage. The classification should be based on a thorough analysis and documentation of the characteristics and chemical properties of the tailings and other relevant information, including geographical position, type of dam, dam height, and hydraulic installations. The consequences of dam failure should be analysed with respect to:

- loss of human lives or injury
- damage to important infrastructure, important structures, or significant environmental or economical values

The classification scheme is presented in and table 5.1 and table 5.2.:

- The table resulting in the most serious consequence classification is deciding which consequence class a dam should belong to

Further, a guiding document gives instructions on how the verbal probabilities and the short descriptions of consequences in the tables should be interpreted, see Appendix 3. For example, the classification of consequence-to-life can be based on the specific water depth and water flow velocity, which is expected due to a dam failure, and on whether this water will be in contact with houses or other places where people are permanently staying. As guidance, the consequence class is then expressed as the number of houses affected. Similar guidance is given for consequences in terms of damage to infrastructure and the environment. Guidance on how to classify several dams in series, i.e. the risk of a domino effect, is also given.

- The classification is based on the marginal consequences. (The increase of damage caused by the dam failure beside the damage that e.g. a high flood would have caused even if there had been no dam failure)
- The effect of the dam failure on other dams downstream should be taken into account
- The guidelines apply to classification of existing as well as new dams

***Spain***

The Spanish legislation on tailings management facilities was strengthened as a direct consequence of the Aznalcóllar accident in 1998 by complementing the existing regulations on “safety requirements in relation to mining activities” (Real Decreto 863/1985) with the ITC 08.02.01 (Complementary Technical Instruction) on “management facilities for tailings from the extractive industry”. The ITC 08.02.01 regulates in detail all issues related to tailings management facilities, and uses two ways of classifying tailings management facilities:

1. as a function of their size (class 1-4); and
2. as a function of the potential consequence of a possible failure or from incorrect management of the facility (Category A-D).

The classification is a combination of the Class and the Category, e.g., 1B.

The criteria for the different Classes are as follow:

Class1. Large tailings facility >15 m high, or 10-15 m high if the dam crest is more then 500 m long, or it has more than 1000.000 $m^3$ storage capacity, or if it has a discharge capacity of more than 2000 $m^3/s$.

Class 2. Medium tailings facility if it is between 5-15 m high and not included in Class 1.

Class 3. Tailings facility < 5 m high.

Class 4. Tailings facility that is lower than the surrounding groundlevel e.g., a mined out open pit.

The criteria for the different Categories are as follows:

Category A. A tailings facility which could seriously affect settlements or the environment (understood as economical and environmental environment, including infrastructure, flora and fauna) if it would fail.

Category B. A tailings facility which could cause significant damage to the environment or cause a number of deaths if it would fail.

Category C. A tailings facility which could cause only moderate damage to the environment and only exceptionally cause deaths if it would fail.

Category D. A tailings facility which could only cause minor damage to the environment if it would fail.

The classification determines, amongst other things, which investigations are required for permitting and design and to what detail, what safety factors that apply, which level of emergency preparedness and plans are required and the insurance level required (60 000 000 € for a Class A facility, 6 000 000 $ for a Class B facility,3 000 000 € for a Class C facility and 600 000 € for a Class D facility).

***Portugal and Slovakia***
Portugal (Da Silva, 2002) and Slovakia (Janová, 2007) both have a risk classification system for mine sites (including the waste facilities) which are scoring systems based on a number of parameters (such as drainage quality, dam height and status, etc) and depending on the total score the site get classified in different groups. These initiatives are primarily directed towards closed and abandoned mine sites as a way of prioritising reclamation/remediation work, however it also applies to operating sites.

***United Kingdom***
In Britain legislation is enacted by Acts of Parliament, which set out the general areas addressed by the legislation. These are further refined by Regulations, which explain, extend or amend the parameters to which the relevant Act will apply. Futhermore, president applies, which makes the law develop with time and in this way somewhat reflect current best practice. Interest in the subject of waste management grew in Britain after the Aberfan disaster of 1966 (a failure of a coal waste tip located on a hillside killing 144 persons in the village of Aberfan), which led to the passing of The Mines and Quarries (Tips) Act 1969. This states that it is *“An Act to make further provision in relation to tips associated with mines and quarries; to prevent disused tips constituting a danger to members of the public; and for purposes connected with those matters”.*

The detailed requirements to implement and comply with the 1969 Act are laid out in The Mines and Quarries (Tips) Regulations, 1971. Subsequently The Quarries Regulations 1999 state that tips must be designed, constructed, operated and maintained so that instability or movement likely to cause risk to the health and safety of any person, is avoided.

Under the Quarries Regulations 1999, the operator has a general duty to ensure the safety of excavations and tips (tips to be understood as equivalent to mining waste facility). They are required to be designed, constructed, operated and maintained so as to ensure that instability or movement, which is likely to give risk to the health and safety of any person, is avoided. Requirements for inspection of working places and faces and for action in the event of perceived danger are specified in the Regulations. Reporting of accidents and dangerous occurrences is explained in the Approved Code of Practice *Health and safety at quarries.* All proposed and existing excavations or tips need to be appraised at appropriate intervals to determine whether they constitute a significant hazard. Where a significant hazard exists, the Regulations require that a geotechnical assessment be carried out, at least every two years, to identify and assess all the factors liable to affect the stability and safety of a proposed or existing excavation or tip (full risk assessment). The Regulations also require that the operator shall ensure that in the event of abandonment of or ceasing of operations at a quarry, it is left in a safe condition. For tips associated with underground mines, similar duties are imposed on mine owners under the Mines and Quarries (Tips) Act 1969. The Mines and Quarries (Tips) Regulations 1971 specify the requirements for design of tips, supervision of tipping operations, inspection of tips and the reporting of defects and dangerous occurrences.

Consequently, a risk assessment is done under the Quarries Regulations 1999 and the tips are “classified” according to risk, even though this is not explicitly called “classification system”.

Tailings ponds are formally classified according to the UK Reservoirs act, 1975. The Reservoirs Act 1975 provides the legal framework to ensure the safety of UK reservoirs that hold at least 25 000 $m^3$ of water above natural ground level. Dams are classified into 4 categories, A, B, C and D according to Guidelines – “Floods and Reservoir Safety – 3rd edition” published by Institution of Civil Engineers (RESCDAM, http://www.environment.fi). Residence has been set according to the Mines and Quarries (Tips) act that lower the threshold to tailings facilities > 4 m above the surrounding ground surface or containing > 10000 $m^3$ (Cambridge, 2007). 1975 Reservoir Act requires dam construction, design, etc to be supervised by panel engineers. Secretary of State appoints engineers to panels on recommendations of Institution of Civil Engineers. Sources: Cadden (2007), Cambridge (2007).

***Austria***

In Austria no specific classification system exists for waste facilities from the extractive industry. However, the requirements from regulations regarding dams are applied to tailings ponds (Water act 1959 with amendment from 1999, Impounding basin commission – decree from 1985). There is no risk classification, but there are special requirements regarding expert opinions and inspections for dams higher that 15 m or if the reservoir capacity is > 500 000 $m^3$. This is implicitly a risk classification. Source: Bernhart (2007).

### 4.2.1 Other European countries

Greenland (Kjær, 2007.) and Norway (Braastad, 2007) have no specific mine waste acts or regulations. The permit requirements given by regulating authorities are commonly given based on an Environmental Impact Assessment. There are regulations on performance of an EIS which is not specific for mining and mineral industry.

### 4.2.2 Major mining countries outside Europe

At federal level both USA and Canada have mining acts that only to a limited extent are dealing directly with the environmental issues associated with the mining, while other acts  indirectly are dealing with mining issues (Clean water act, Clean Air act etc). However, each of the states in USA and the provinces in Canada has developed rigorous mining environmental laws and regulations. These laws and regulations are not attempting to classify the waste, they rather set the framework in characterisation, closure/closeout requirements and bonding requirements.

***USA***

The extractive industry in USA has been regulated by Federal level primarily by the Clean Water Act and the Clean Air Act.  If a proposed mineral exploitation is proposed on Federal land there are extensive regulations for performing Environmental Impact Assessment (EIS). This regulation is controlling the content of the EIS depends upon which Federal Agency that controls the land (Bureau of Land Management, US Forest Service). However, none of these EIS regulations/guidelines include any classification system on waste to be generated.

US EPA has regulations on hazardous waste. In this regulation the waste is classified based on its leaching behaviour, which again regulates the type of landfill the waste have to be stored at. This regulation is similar to the EU Landfill Directive, however, the waste from the extractive industry is excluded from this regulation.

The coal mining and the mining of radioactive elements (Uranium) have their separate Federal legislation. The coal mining is governed by the Surface Mining Reclamation Act and the uranium mining is governed by the Uranium Mill Tailings Reclamation Act.

All the States in USA have established Mining laws. The last state implemented its law about six years ago. Some of the states have very simple classification system for the potential environmental affect of a proposed operation. For example: the New Mexico Mining Act divides the operations into two categories Minimal Impact and Impact operation (NM Mining Act, 1996). This division is based on the disturbance area. If the operation is classified as Minimal Impact the reclamation bond is set and no further reclamation costing of the reclamation is necessary.

There is no separate legislation on physical stability of tailings dams, however this is covered under regulation on earth structure and dams.

***Canada***

The mining acts and regulations in Canada are state dependent. The act and regulations are developed to reduce the impact of mining activities on water and soil resources. Guidelines developed under the act specifies characterisation requirements, reclamation requirements, bonding requirements for closure plans etc., however, there are no classification system for waste to be generated in the extractive industry.

There are different acts for different type of extraction products, extraction of radioactive material, oil shale, coal, hard rock mining e.g.

### 4.2.3 Overview of mining waste facility classification systems

Table 4.3 presents an overview of the information collected on the existence of mining waste facility classification systems in the EU Member States, other European countries and selected major mining countries outside of Europe.

Out of the 32 countries surveyed, of which 27 are EU member states, only 8 countries have a system for classification of mining waste facilities in place. Most of the existing classification systems are based on schemes derived directly or slightly modified from systems aimed at classifying water retaining dams (e.g., UK, Sweden, Finland, and Austria). These systems apply mainly to tailings ponds. The Spanish system is specific for tailings ponds, and resembles the other systems derived for water retaining dams. The other methodology used is a type of scoring system (e.g., Portugal and Slovakia) where site-specific information is evaluated and assigned a weight and a score. The total score determines the classification This system is mostly applicable to existing facilities (originally developed for abandoned facilities) as it could give a priority listing of facilities to be attended to. Due to the amount of information required these systems do not seem to be optimal for classification of new (planned) facilities in a permitting procedure.

***Table 4.3***
*Summary of mining waste facility classification systems in EU 27, Norway, Greenland, Australia, Canada and USA.*

| **Country** | **Is there a mining waste facility classification system?** | | | **Comments** | **Source of information** |
|---|---|---|---|---|---|
| | **Yes** | **No** | **No info** | | |
| Austria | x | | | | Bernhart (2007) |
| Belgium | | x | | | Vanbelle (2007) |
| Bulgaria | | | | | Bulgarian Ministry of Environment (2007)/ JRC (2002) |
| Czech Republic | | x | | | JRC (2002) |
| Denmark | | x | | | Christensen (2007) |
| Estonia | x | | | | Adamson (2007) |
| Finland | x | | | Based on Mining RIDAS | |
| France | | X | | | Billaud (2007) |
| Germany | | x | | | Juroszek (2007) |
| Greenland | | x | | | Kjær (2007) |
| Greece | | X | | | Kassaris (2007) and Nicoletopoulos (2007) |
| Hungary | | x | | A draft system for Category A classification has been developed | Madai (2007) |
| Ireland | | x | | | Motherway (2007) |
| Italy | | x | | | Fanfani (2007) |
| Latvia | | x | | | Latvian Environment Agency/JRC, 2002 |
| Lithuania | | x | | | Environmental Protection Ministry/JRC (2002) |
| Luxemburg | | X | | | |
| Norway | | x | | | Braastad (2007) |
| Poland | | x | | | Naworyta (2007) |
| Portugal | x | | | Old and operating mines | Da Silva (2002) |
| Romania | | x | | | Vlad (2007) |
| Slovakia | x | | | Risk classification system | Janová (2007) |
| Slovenia | | x | | | JRC (2002) |
| Spain | x | | | | Golder & Associates |
| Sweden | x | | | Based on Mining RIDAS | Fällman (2007) |
| Netherlands | | x | | | Artherberger (2007) |
| United Kingdom | x | | | | Cambridge (2007) |
| USA | | x | | State dependent regulations | USEPA, State environ. Commissions etc. |
| Australia | | x | | | |
| Canada | | x | | Province dependent regulations | |

# 5. Review of risk assessment methodologies

## 5.1 Risk analysis - general principles and terminology

### 5.1.1 Introduction

The risk assessment methodology is used in a wide range of professions and disciplines. This is reflected in a somewhat unclear and ambiguous risk terminology and there are many different definitions of *risk*. In a technical risk-based discipline, *risk* is often defined as the combined effect of the likelihood of a harmful event to occur (caused by a hazard), and the magnitude of the caused harm. Two fundamental phases are involved: risk assessment and risk management. The terminology and wordings used in this report rely heavily on the EEA report *Environmental risk assessment – approaches, experiences and information sources* (EEA, 1998) and the framework formulated by the National Academy of Sciences (NAS/NRC, 1983) for use in the U.S. federal agencies. Originally, this framework was written specifically for hazards to humans, but the same principles are being used in environmental risk assessment.

The objective of this chapter is to review the general principles of risk assessment and provide the reader with examples from other areas where risk assessment methodologies has been applied. Although the focus in this section is much wider than risk assessment of mining waste facilities, the intent is to present and compile information relevant for the task of developing a classification system for mining waste facilities. To avoid misunderstanding, the risk terminology used is listed below.

### 5.1.2 Terminology (EEA, 1998)

**Consequence assessment:** The examination of the release or production of the hazards, to the receptor and the quantification of the relationship between specified exposures to the hazard and the health and environmental consequences of those exposures.

**Dose-response assessment:** The estimation of the relationship between dose, or level of exposure to a substance, and the incidence and severity of an effect.

**Ecological risk assessment:** The assessment of the risks posed by the presence of substances released to the environment by man, in theory, on all living organisms in a variety of environmental compartments.

**Engineering risk assessment:** The assessment of the risks associated with the construction and the use of plant and structures including component, material and operator failure/error and the consequences.

**Environmental risk assessment:** The examination of risks resulting from technology that threatens ecosystems, animals and man.

**Exposure assessment:** Describing and quantifying the relevant conditions and characteristics of human and environmental exposures to hazards produced or released by a particular risk source or: The determination of the emissions/release, pathways and rates of transport and fate of a substance in order to estimate the concentration/doses to which human populations or environmental compartments are or may be exposed.

**Failure mode:** The ways in which equipment, plant and structures can fail or be incorrectly operated.

**Hazard identification:** Establishing those agents that or failure modes that can cause harm to man, environment or economical values.

**Health risk assessment:** The assessment of the risks to human health posed by exposure to substances released by man into environment.

**Release assessment:** The identification of the potential of the risk source to introduce hazardous agents into the environment.

**Risk:** The combination of the probability, or frequency, of occurence of a defined hazard and the magnitude of the consequences of the occurence

**Risk analysis:** The systematic use of information to identify sources of risk and estimate the risk by covering several phases in a risk chain. However several definitions exist, see section 5.1.3.

**Risk assessment:** The procedure in which the risks posed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively.

**Risk characterisation:** The integration of risk evaluation and risk estimation.

**Risk estimation:** The integration of the results from the release assessment, exposure assessment and the consequence assessment to produce measures of environmental and health risks.

**Risk management:** The decision-making process through which choices can be made between a range of options to satisfy specified criteria.

### 5.1.3 Risk analysis

The main objective of performing risk analysis is to support decision-making processes and provide a basis for comparing alternative concepts, actions or system configurations under uncertainty (Nilsen and Aven, 2003). *Risk* is defined in different ways for specific purposes and in the context of engineering decision-making, and it is important to be precise and consistent in our understanding of risk. Typically, risk is defined as the expected consequences of a given activity. In its simplest form, risk ($R$) is then defined as the probability ($P$) of an activity that is associated with only one event, multiplied by its consequences ($C$) given that this event occurs.[4] If $C$ is expressed as a cost or utility, the risk is thus the expected cost or utility of a given event:

$$R = P \times C$$

The National Research Council (NRC, 1996) identifies two fundamental phases of risk analysis, namely risk assessment and risk management. Covello and Merkhofer (1993) on the other hand, separate risk analysis and risk management and hold that risk analysis provides key information for the risk management process, see Figure 5.1. Whether risk management is placed within or outside risk analysis, it considers the social, economic and political factors involved in the decision-making process and determines the acceptability of damage and what, if any, action should be taken.

Risk assessment on the other hand, is a set of analytical techniques for answering the question: How much damage or injury can be expected as a result of a specific event? A committee of the National Academy of Sciences devised a formulation of risk assessment as a four-step process: (1) hazard identification, (2) dose-response assessment, (3) exposure assessment, and (4) risk characterisation, see figure 5.1. Covello and Merkhofer (1993) define risk assessment slightly differently, placing hazard identification outside of risk assessment, which instead consists of: (1) release assessment, (2) exposure assessment, (3) consequence assessment, and (4) risk estimation (figure 5.1). In both definitions, the fourth step - risk characterisation or risk estimation - aims at integrating the results from the previous steps.

Possibly, the suggested definition of risk analysis by Covello and Merkhofer (1993) is more useful if risk is, as is usually the case, seen as the sum of the links in a risk chain consisting of 1) risk source release

[4] In its extreme, the simplest definition of risk is the probability of an unwanted event.

processes, 2) exposure processes, and 3) consequence processes. For a risk to exist, this chain must remain unbroken.

l

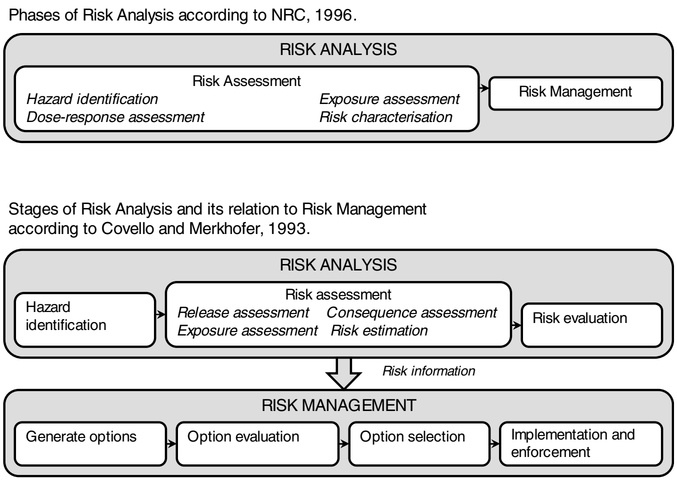


***Figure 5.1***
*Frameworks for risk analysis.*

### 5.1.4 Risk assessment

Risk assessment is the procedure in which the risks posed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively. Risk assessment can help identify existing hazardous situations or problems, anticipate potential problems, provide a basis for regulatory control and corrective actions and may also help gauge the effectiveness of corrective measures or remedial actions Asante-Duah, 1998).

Here a distinction is made between environmental risk assessment (the examination of risks resulting from technology that threatens ecosystems, animals and man) and engineering risk assessment (the assessment of the risks associated with the construction and the use of plant and structures including component, material and operator failure/error and the consequences). Environmental risk assessment acknowledges potential risks to both health and ecology.

**Human health risk assessment**

The pathways for exposure of toxic substances to humans are generally categorised as: inhalation of fugitive dust and volatile compounds, ingestion of water, soil, crops, dairy produce and beef products, ingestion of soil and sediment by accident or by pica behaviour[5], and dermal contact with soil and water (Asante-Duah, 1998). Equations to compute the exposure of each pathway can be found in literature (e.g. Asante-Duah (1998). The effects are measured in toxicity parameters for non-carcinogenic and carcinogenic effects. The cancer risk is usually expressed as an additional lifetime probability to develop cancer. In Europe, the theoretical tolerable excess lifetime cancer risk typically used in the context of genotoxic carcinogens at contaminated sites ranges from $10^{-6}$ to $10^{-4}$ per substance (Ferguson et al., 1998).

[5] Pica behaviour (eating of non-food items, including soil) is common in many toddlers and children.

The non-cancer risk is usually expressed by the hazard quotient (HQ) and/or the hazard index (HI). The HQ is defined as the ratio between the estimated chemical exposure level and the route-specific reference dose. The HI is used for the aggregate non-cancer risk for all exposure pathways and all contaminants associated with a potential environmental contamination problem. If the HI exceeds unity (1) there may be potential for adverse health effects (Asante-Duah, 1998).

**Ecological risk assessment**
The ecological risk assessment evaluates the probability or likelihood that adverse ecological effects will occur (or have occurred or are occurring) as a result of exposure to stressors from various human activities (Smrchek and Zeeman, 1998). The authors define the term stressor as a description of something chemical, physical or biological in nature, which can cause adverse effects on non-human ecological components ranging from organisms, populations and communities to ecosystems. The ecological risk assessment process is slightly modified from that of human health risk assessment (Smrchek and Zeeman, 1998; Asante-Duah, 1998).

There are in principle two approaches: top-down and bottom-up. Although the top-down approach, which evaluates toxic effects in an ecosystem perspective, is preferred, it is difficult to carry out. In the bottom-up approach, hazards and risks identified are extrapolated from laboratory tests in organisms to populations, communities and even ecosystems. Ecotoxicology tries to combine the two approaches (Smrchek and Zeeman, 1998; Asante-Duah, 1998).

**Models for risk assessment**
The human health risk assessment model most referred to is that outlined by the National Research Council of the Academy of Sciences, also called the "Red Book" (Felter et al., 1998; Asante-Duah, 1998; Covello and Merkhofer, 1993; NRC, 1996; Davies, 1993). The model has been widely used by government agencies in the USA for assessing the risks of cancer and other health risks that result from exposure to chemicals. Four steps are proposed in a complete risk assessment, hazard identification, dose-response assessment, exposure assessment, and risk characterisation.

***Step 1: Hazard identification***
Hazard identification involves a qualitative assessment of the presence of, and the degree of hazard an agent could have on potential receptors. It involves an evaluation of the appropriateness, nature, quality and relevance of scientific data on the specific chemical; the characteristics and relevance of the experimental routes of exposure; and the nature and significance to human health of the effects observed. A quantification of the concentration at which the chemical is present in the environment should also be conducted.

Hazard identification of non-cancer end-points and carcinogens differs slightly. Hazard identification for non-cancer end-points depends much on professional judgement of whether to judge a response as adverse or not, since toxic chemicals often elicit more than one adverse effect. Many types of information can be used to determine whether or not a compound has the potential to elicit a carcinogenic response: epidemiological information, chronic animal bioassays, etc. Classification schemes for carcinogenicity has been developed for this purpose (Felter et al., 1998).

***Step 2: Dose-response assessment***
A dose-response assessment is a further evaluation with specific emphasis on the quantitative relation between the dose and the toxic response. Information for doing this assessment can be derived from different studies on human exposures, epidemiology etc. Most important is that the dose-response assessment is based on data of sufficient quality, as judged by experts.

***Step 3: Exposure assessment***
The exposure assessment estimates the magnitude of actual and/or potential receptor exposures to environmental contaminants, the frequency and duration of these exposures, the nature and size of the populations potentially at risk, and the pathways by which the risk group may be exposed. To complete a typical exposure analysis for an environmental contamination problem, populations at risk are identified, and concentrations of the chemicals of concern are determined in each medium (air, water, soil etc.) to which potential receptors may be exposed (Asante-Duah, 1998).

***Step 4: Risk characterisation***
Risk characterisation involves integration of information from the first three steps to develop a qualitative or quantitative estimate of the likelihood that any of the hazards associated with the agent of concern will be realised in exposed people (Felter et al., 1998). It should also include an elaboration of uncertainties associated with the risk estimates. It includes a discussion of the assumptions made and the overall quality of data. It is here the risk assessment results are expressed.

### 5.1.5 Risk as a chain of events

The probabilistic part of the risk, i.e. the probability of an unwanted event, can be conceptually described as a chain of events, figure 5.2. The chain consists of the identified potential contamination source(s) and receptor(s), as well as the potential migration pathways in between. It contains the processes that form the total probability of a given event, although the risk only materializes if (1) the chain remains unbroken, and (2) there is a negative effect at the receptor.


***Figure 5.2***
*The concept of risk illustrated as a chain of events. For a risk to occur, the chain must remain unbroken, and an undesired effect must take place at the receptor.*

The conceptualisation of risk as a chain can be seen as a descriptive tool, although the chain of events can be much more formalised with event-oriented models, e.g. fault trees, event trees, or Bayesian networks (see 5.1.7). Event-oriented, or logical, models describe conditions under which events occur and are composed of conditions and logical terms, usually with a binary outcome space (Nilsen and Aven, 2003).

The conceptualisation of any given risk as a chain is well-suited for identifying the risk reducing alternative actions, since these can be applied at different points of the source – transport – receptor chain. Figure 5.3 summarises four types of risk reducing measures: (1) prevention, (2) measures at the source, (3) measures to prevent spreading and transport, and (4) measures to protect the receptor. The distinction between the source itself, the transport media and the receptor is by no means straightforward. Humans and the environment can be exposed through different media, some of which may be the actual source, e.g. the soil. Furthermore, groundwater may be both a transport medium and a receptor. The collapse of a dam will result in a momentary release of water and sediment creating an overland flow pathway to the receptor. However, the general idea is illustrated below, and one should identify source, transport medium, and receptor for each individual analysis. The examples given here are applicable to mining waste facilities but the idea can equally well be applied to other environmental problems.

In many cases, for example in geotechnical engineering, risk reduction measures of the first type is most effective and start by analysing existing information such as topographical and geological maps (Clayton, 2001). In other situations, risk reduction measures of the first type (preventive measures) are not an option, since the risk source is already present. However, for policy planning problems related to mining waste facilities, prevention is a possible option in e.g. the planning of mining activities and management of waste. The preventive risk reducing measures can take the form of administrative restrictions in e.g. land use design of the facility and waste management. When the risk source is already present, an obvious option is to remove the source. For example, removal of contaminants from soil or groundwater can be done *in-situ* or *ex-situ*, and *on-site* or *off-site*. The other type of risk reduction measure at the source is immobilisation or containment, such as different types of cover or landfill caps for mining waste heaps.

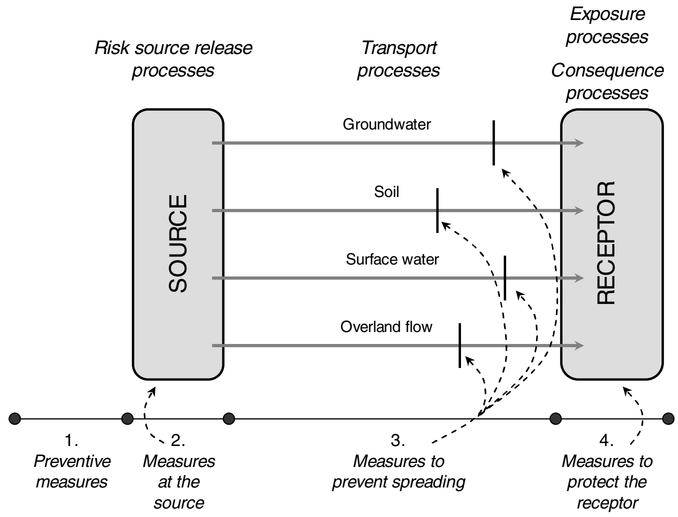


**Figure 5.3**
*The conceptualisation of risk as a chain. Points at which different types of risk reducing measures (risk management) can be applied are indicated (Rosén and Hammar, 2004).*

### 5.1.6 Uncertainty

Sources of uncertainty may vary, and some authors argue that it is important to distinguish between the sources, since the uncertain quantities should be treated differently when included in risk and policy analysis, (e.g. NRC, 1996). A typical distinction is that between aleatory and epistemic uncertainty. Aleatory uncertainty arises because of fundamental or inherent variability or randomness in natural phenomena, sometimes referred to as type 1 uncertainty. Epistemic uncertainty (epistemological or type 2 uncertainty), on the other hand, refers to the lack of knowledge about natural phenomena and can be related to statistical and modelling uncertainty. Statistical uncertainty arises because of a lack of data. Modelling uncertainty is due to: (1) uncertainty as to whether all factors that influence the model have been included, (2) uncertainty as to how the model describes the relationship between these factors Faber and Stewart (2003) and (3) deliberate simplifications introduced by the analyst, e.g. as a trade-off between project economy and level of detail in modelling, or when the model is considered to serve its purpose sufficiently well for the problem to which it is applied (Nilsen and Aven, 2003).

However, some different standpoints exist in relation to what the probabilities actually describe: the classical view versus the Bayesian view. Classical thinking defines probability and risk as true properties of nature, i.e. randomness is an objectively measurable phenomenon. The Bayesian approach considers probability as a subjective measure of uncertainty; it is a knowledge phenomenon and probability is an epistemological issue. According to Aven and Kvaløy (2002), the concept of probability in the Bayesian approach is used as the *analyst's* measure of uncertainty or degree of belief. The choice of approach determines what the probabilities in the analysis input and output express and also, as argued by (Nilsen and Aven, 2003), the definition of models and how to understand and deal with model uncertainty.

### 5.1.7 Bayesian decision analysis

Many authors refer to Bayesian decision analysis (e.g. Davis et al. (1972), Grosser and Goodman (1985), Korving and Clemens (2002), Marin et al. (1989) and Varis (1997)) although Aven and Kvaløy (2002) argue that the understanding of Bayesian analysis varies a great deal among risk analysts.

Hansson (1991) defines Bayesianism or Bayesian decision theory as expected utility theory with both subjective utilities and subjective probabilities and presents four principles that summarise the ideas of Bayesianism:

1. The Bayesian subject has a *coherent* set of probabilistic beliefs, i.e. in compliance with the mathematical laws of probability.
2. The Bayesian subject has a *complete* set of probabilistic beliefs, meaning that the subject is able to assign a probability to each proposition, often subjective probabilities. This means that Bayesian decision-making is *always* decision-making under risk, never under uncertainty or ignorance.
3. When faced with new evidence, the Bayesian subject changes her/his beliefs in accordance with her/his conditional probabilities, following Bayes' rule. We may differentiate between subjective and objective Bayesianism. Subjective Bayesianism states that as long as the updating of the subjective probabilities follows Bayes' rule, there are no further requirements on how to choose the initial subjective probabilities. Objective Bayesianism, on the other hand, states that, given the available information, there is a unique admissible probability assignment, i.e. it states a subject-independent probability function.
4. Bayesianism states that the rational agent chooses the option with the highest expected utility.

Bayesian statistics differs from classical statistics in that it includes all kinds of data, i.e. both objective (hard data) and subjective (soft data) information for making a prior estimate of the probability of a certain event. In fact, it *requires* a prior belief. By using Bayes' theorem, the prior estimate is updated to posterior probabilities. The more hard data that are used to update the prior estimate, the more the updated information will reflect the collected hard data. The prior estimate may be solely based on subjective information, i.e. expert judgement. Decision analysis using the prior estimates of the probabilities of an event (or outcome) is called prior analysis. Updating the prior estimates and repeating the decision analysis is called posterior analysis (Freeze et al., 1992).

## 5.2 Examples of risk assessment models

### 5.2.1 The TAC-model

The criteria and limit values for acceptance of waste at landfills for inert, non-hazardous and hazardous waste landfills was set based on a risk assessment procedure developed by the TAC Subcommittee on the Landfill Directive. This section describes the stepwise procedure used by the TAC Subcommittee (Gronow, 2007; Hjelmar et al., 2005; Hjelmar et al., 2001).

The procedure that was used to set acceptance criteria for landfilling of granular waste consisted of a series of consecutive steps. Only the impact on groundwater quality is considered. First, a decision was made concerning the primary target(s) or point(s) of compliance (POC), here the downstream point(s) where the groundwater quality criteria must be fulfilled. Quality criteria are then selected for the groundwater and the physical characteristics of the landfill scenario and the environment scenario are selected and described. The environment scenario includes the net rate of infiltration and a hydrogeological description of the unsaturated and saturated (aquifer) zones upstream, below and downstream of the landfill. The source of the various contaminants is subsequently described in terms of the flux of contaminants as a function of time based on leaching data and the hydraulic scenario defined. Then the migration of the contaminants through the unsaturated zone into the groundwater and through the aquifer to the POC(s) is described with particular reference to the applicable $K_d$-values for each contaminant, which are used to calculate the retardation factors. The next step is to select and fit one or more models that can be used to describe the water flow and transport of contaminants from the base of the landfill through the unsaturated and saturated zones to the POC(s). The model calculations are carried out and "attenuation factors" (for granular waste the ratio between the source peak concentration and the peak concentration as modelled at the groundwater POC) are determined for each contaminant and POC. The attenuation factors are then used for a "backwards" calculation of the values of the source term corresponding to the selected groundwater quality criteria for each contaminant at a particular POC.

The final step consists of transforming the resulting source term criteria to a limit value for a specific leaching test. The step-wise procedure is summarised below:

- Choice of primary target(s) and principles
- Choice of critical parameters and primary criteria values
- Description of the waste application scenario
- Description of the environment scenario
- Description of the source of potential contamination
- Description and modelling of the migration of the contaminants from the application to the POC(s)
- Determination of attenuation factors
- Application of the results to criteria setting ("backwards" calculation)
- Transformation of the source term criteria to limit values at different L/S values

The impact calculation was carried out using three coupled source and transport models in series: one (model 1) describing the source of contamination (the production of leachate from the landfill), one (model 2) describing the transport of contaminants in the unsaturated zone and one (model 3) describing the transport of contaminants through the saturated zone to the POC. The principle of the three connected models is illustrated in figure 5.4.

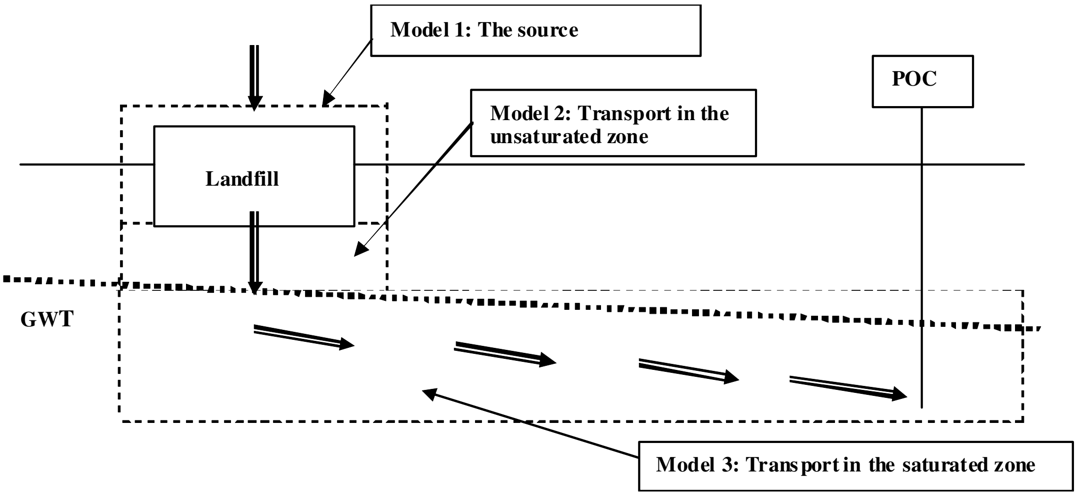


***Figure 5.4***
*Cross-section showing the principle of three coupled source and transport models used for the forward calculation at a landfill scenario (Hjelmar et al., 2005).*

It should be kept in mind that this procedure is aiming at the development of general (European) acceptance criteria and that it therefore necessarily includes generalisations that, from a local point of view, often may seem ill fitting and unrealistic. The same methodology may, however, be used for site-specific impact assessments if a number of the generalised parameters are substituted by parameters that better fit the local situation.

### 5.2.2 US EPA and Superfund risk assessment

***Human Health risk assessment***

The US EPA issued an initial set of five risk assessment guidelines for human health in 1986, relating to cancer, mutagenic effects, developmental effects, exposure assessment, and chemical mixtures., Two new guidelines for neurotoxicity (1998) and reproductive toxicity (1996) have been issued since, and the guideline for carcinogenic risk assessment was revised in 2005. The updated guideline for carcinogen risk assessment (US EPA, 2005) follows the general principles of risk assessment as outlined by (NRC, 1996): Hazard assessment, dose-response assessment, exposure assessment, and risk characterisation.

The primary regulation issued by U.S. EPA's Superfund Program is the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The NCP calls for the identification and mitigation of environmental impacts (such as toxicity, bioaccumulation, death, reproductive impairment, growth impairment, and loss of critical habitat) at hazardous waste sites, and for the selection of remedial actions to protect the environment. This document is accompanied by guidance documents for risk assessment, RAGS – Risk Assessment Guidance for Superfund. Volume I is the Human Health Evaluation Manual, divided into three parts: A (Base-line risk assessment), B (Development of risk-based preliminary remediation goals), and C (Risk evaluation of remedial alternatives) (US EPA. 1989; 1991a and 1991b). The human health risk assessment for superfund follows in principle the already described elements of the general risk assessment procedure. However, the RAGS documents are older and therefore it differs slightly (mostly in terminology) from NRC (1996). The baseline risk assessment is described as: (1) data collection and evaluation, (2) exposure assessment, (3) toxicity assessment, and (4) risk characterisation.

In the report “Superfund Exposure Assessment Manual” guidance is provided on the development of exposure assessments using monitoring data, as well as modelling techniques to predict exposure over time (US EPA, 1988). The exposure assessment proceeds through the following stages: (1) contaminant release analysis, (2) contaminant transport and fate analysis, (3) exposed populations analysis, (4) integrated exposure analysis, and (5) uncertainty analysis.

The base-line risk assessment, as described by RAGS, forms the basis for establishing preliminary remediation goals (PRGs). There are two general sources of chemical-specific PRGs: (i) concentrations based on ARARs (Applicable or Relevant and Appropriate Requirements), and (ii) concentrations based on risk assessment (US EPA, 1991a). Soil Screening Levels (SSLs) can be used as PRGs based on risk assessment provided appropriate conditions are met. SSLs are risk-based concentrations derived from standardised equations combining exposure information assumptions with EPA toxicity data (US EPA, 1996a). The generic SSLs considers a residential setting, assuming the following potential pathways of exposure to contaminants in soil: direct ingestion, inhalation of volatiles and fugitive dusts, ingestion of contaminated groundwater caused by migration of chemicals through soil to an underlying potable aquifer, dermal adsorption, ingestion of home-grown produce that has been contaminated via plant uptake. There are three options for using SSLs: (1) applying generic SSLs (as described above), (2) developing simple, site-specific SSLs, and (3) developing site-specific SSLs based on more detailed modelling. The User’s Guide (US EPA, 1996c) focuses on the application of (2) and the Technical Background Document (US EPA: 1996b) provides more information about the approaches (1) and (3) above.

Finally, Part C of RAGS (US EPA, 1991b) assists in both evaluating the remedial alternatives and to evaluate the human health risk associated with the selected remedial alternative during and after its implementation. It provides general guidance to assist in site-specific risk evaluations and to maintain flexibility in the decision-making process.

***Ecological risk assessment (ERA)***

There are two documents from the US EPA that provide guidance on conducting ecological risk assessment: 1) Guidelines for Ecological Risk Assessment (US EPA, 1998), and 2) Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (US EPA, 1997). They differ slightly in their definition of ecological risk assessment (hereafter referred to as ERA). The first report, the US EPA Guidance (US EPA, 1998) defines ERA as a process that evaluates the likelihood (although not always quantitatively) that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. The second, the Superfund program (US EPA, 1997), refers to ERA as a qualitative and/or quantitative appraisal of the actual or potential impacts of contaminants from a hazardous waste site on plants and animals other than humans and domesticated species.

The US EPA Guidance (US EPA, 1998) describes ERA as consisting of three phases: Problem Formulation, Analysis, and Risk Characterisation. The analysis phase is divided into two parallel parts which form the two major elements of ERA: Characterisation of Exposure and Characterisation of Ecological Effects.[6] In the phase Problem Formulation, the purpose of the assessment is articulated and a plan is worked out. Two main products result from this phase: assessment endpoints and conceptual models. The Analysis phase is directed by the products of the previous phase, and data are evaluated to determine how exposure to stressors are likely to occur and, given this exposure, the potential and type of ecological effects that can be expected. The products are two profiles: one for exposure and one for stressor-response, which, in turn, provide the basis for the risk characterisation. During this last phase, the exposure and stressor-response profiles are integrated through the risk estimation process. It includes a summary of assumptions, scientific uncertainties, and strengths and limitations of the analyses. The final product is a risk description in which the results of the integration are presented, including an interpretation of ecological adversity and descriptions of uncertainty and lines of evidence. It is an iterative process, requiring input from and communication with several interested parties. Further, ERAs are designed and conducted to provide information to risk managers about the potential adverse effects of different management decisions. Finally, ERAs provides a unique scientific evaluation in that it explicitly addresses uncertainty.

In the Superfund program (US EPA, 1997), the goal of an ERA process is to provide risk information necessary to assist managers at Superfund sites in making informed decisions regarding substances designated as hazardous under CERCLA (Comprehensive Environmental Response, Compensation and Liability Act). The specific objectives of the process are: (1) to identify and characterise the current and potential threats to the environment from a hazardous substance release and (2) to identify cleanup levels that would protect those natural resources from risk. The Superfund program divides the ERA process in eight steps[7]: (1) Screening level – problem formulation and ecological effects evaluation, (2) Screening level – preliminary exposure estimate and risk calculation, (3) Problem formulation, (4) Study design and data quality objective process, (5) Verification of field sampling design, (6) Site investigation and data analysis, (7) Risk characterisation, and (8) Risk management. The ecological risk management decisions at Superfund sites should be driven by six principles according to US EPA (1999).

In the mentioned descriptions of ERA, the problem formulation and the identification of assessment endpoints play important roles. According to US EPA (1998), an assessment endpoint is "an explicit expression of the environmental value that is to be protected". In human health risk assessment, only one species is evaluated, and cancer and non-cancer effects are the usual assessment endpoints. ERA, on the other hand, involves multiple species that are likely to be exposed to differing degrees and to respond differently to the same contaminant. Nonetheless, it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site. Instead, assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site.

***Cumulative risk assessment***

The US EPA completed a final document entitled "Framework for Cumulative Risk Assessment" in 2003. As a response to the increasing focus on cumulative risk, i.e. the combined risks from aggregate exposures to multiple agents or stressors, the US EPA began to explore cumulative risk assessment approaches. The document US EPA (2003) is an information document, focused on describing various aspects of cumulative risks. US EPA intends to use this as a basis for developing future guidance.

The framework itself is conceptually similar to the approach used in both human health and ecological risk assessments, but it is distinctive in several areas: (i) Its focus on the combined effects of more than

[6] Thus, it follows the principal elements outlined in NRC, 1996: Understanding Risk. Informing Decisions in a Democratic Society. National Academy Press, Washington D.C., namely hazard identification, dose-response assessment (here stressor-response), exposure assessment, and finally, risk characterisation.

[7] All of those eight steps can be combined into the three phases of ERA according to US EPA Guidance US EPA, 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F, April 1998, US EPA, Washington, DC., including a fourth preceding phase: Planning and Scoping.

one agent or stressor makes it different from many assessments conducted today, in which multiple stressors, if they are evaluated, usually are evaluated individually and presented as if the others were not present; (ii) There is increased focus on the specific populations potentially affected rather than on hypothetical receptors since multiple stressors are affecting the same population; (iii) The consideration of cumulative risk may generate interest in a wider variety of non-chemical stressors than traditional risk assessments do. This can be summarised as a cumulative assessment being a population-focused assessment instead of a chemical-focused assessment, as the traditional risk assessments typically are. The framework outlined is divided into the same three phases as the ERA: (1) Planning, scoping, and problem formulation, (2) Analysis, and (3) Risk characterisation.

### 5.2.3 VROM (The Dutch Directorate General for the Environment)

Dutch soil remediation policy (VROM, 1994) uses soil remediation intervention values, indicative levels for serious contamination and target values.

- The soil remediation intervention values are generic soil quality standards used to classify historically contaminated soils as seriously contaminated in the framework of the Dutch soil protection. The intervention values indicate when the functional properties of the soil for humans, plant and animal life, is seriously impaired or threatened. The soil remediation intervention values are based on studies by the National Institute for Public Health and Environmental Protection (RIVM) of both human and ecotoxicological effects of soil contaminants. Intervention values are related to a spatial scale: The average concentration of a minimum of 25 $m^3$ of the soil volume in the case of earth or sediment contamination, or 100 $m^3$ of pore saturation soil volume in the case of groundwater contamination.
- Indicative values are used instead of intervention values for substances where no standardised measurement and analysis regulations exist or when ecotoxicological data are missing.
- The target values indicate the levels which represent a sustainable soil quality. In terms of curative policy this means that the target values indicate the level that has to be achieved to fully recover the functional properties of the soil for humans and plant and animal life.

The Intervention Value is a generic value and is applied to soils with various uses. Historically, the choice has been made to base the Intervention Value for soil/sediment upon the scenario “residential with garden”. This scenario is worked out in the human exposure model CSOIL (Van den Berg, 1995), and includes several exposure routes:
.
- ingestion of soil
- dermal contact with soil and dust
- inhalation of dust
- inhalation of vapours
- intake of contaminated drinking water
- inhalation during showering
- intake of vegetables grown on the site

The exposure routes included modelling exposure of humans to sediment, via the model SEDISOIL (Otte el al., 2000), which includes the exposure routes:

- ingestion of sediment, surface water and suspended matter
- dermal uptake via sediment and surface water
- intake of fish from nearby surface water

The human toxicological definition of “serious soil contamination” is taken as the soil quality resulting in transgression of the Maximum Permissible Risk for intake. Together with the exposure modelling, the MPR-human forms basis for the definition of intervention values. For non-carcinogenic substances this corresponds to the Tolerable Daily Intake (TDI). For carcinogenic substances this is based on an additional risk of tumour incidence of 10 000 for lifetime exposure.

In the case of serious soil contamination the site must, in principle, be remediated. The remediation urgency is determined on the basis of actual, site-specific risks for humans, the ecosystem and contaminant migration.

### 5.2.4 SEPA (The Swedish Environmental Protection Agency)

According to the Swedish EPA (SEPA, 1999), a contaminated site is defined as any site, landfill, area, groundwater or sediment that is contaminated from one or more local point sources to the extent that the concentrations substantially exceed the local or regional background concentrations. The high number of contaminated sites has a historical background in the industrial revolution, where new techniques and processes were developed without any knowledge regarding the health and environmental impact of various substances. The substances present at sites that are classified as contaminated, can typically be of a wide variety.

Humans and eco-systems are exposed to contaminants in several ways. The potential exposure pathways are considered when developing national generic guideline values for concentration of substances in soil. These are based on the principles for deriving SSLs (Soil Screening Levels) as described by the US EPA (US EPA, 1996b). In Sweden, seven exposure pathways have been included in the human exposure model (SEPA, 1996), figure 5.5:

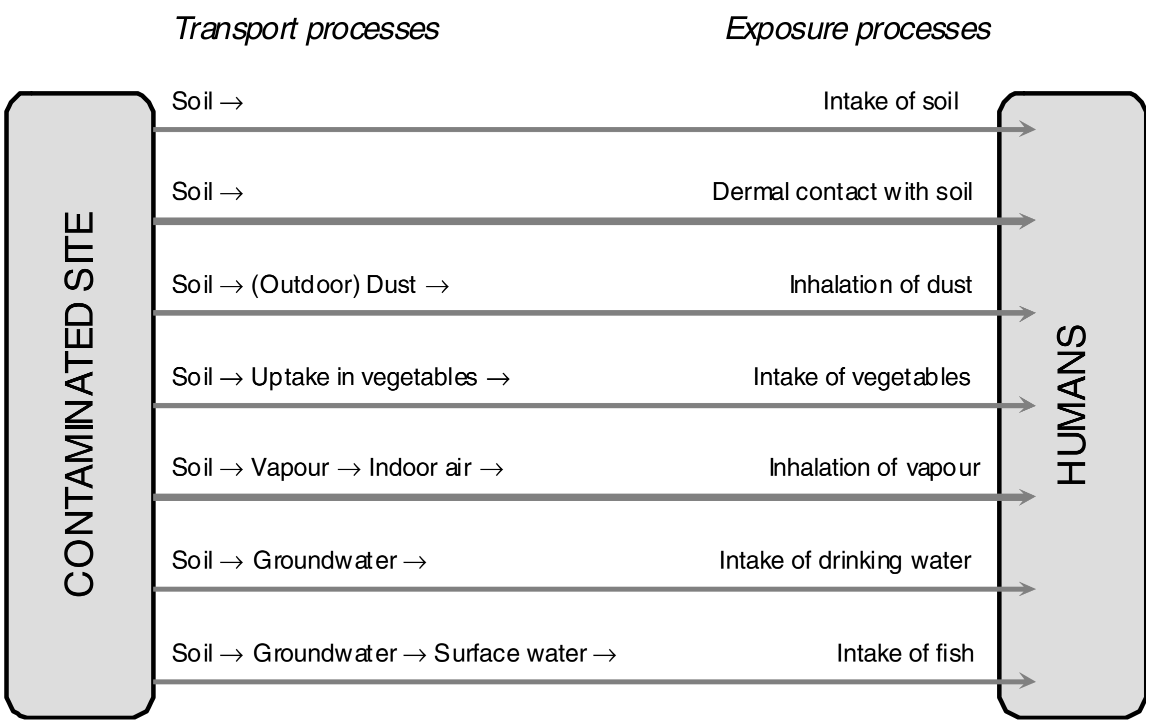


***Figure 5.5***
*Transport and exposure pathways included in the human exposure model, which together with an eco-system exposure model, is used for deriving the Swedish generic guideline values (SEPA).*

- ingestion of soil
- dermal contact with soil and dust
- inhalation of dust
- inhalation of vapours
- intake of contaminated drinking water
- intake of vegetables grown on the site
- intake of fish from nearby surface water

However, e.g. swimming in contaminated surface water or intake of products from grazing animals could also be included. In Sweden, exposure to eco-systems are considered both as *on-site* and *off-site* effects (SEPA, 1996). The *on-site* effects are associated with the soil function, while the *off-site* effects are concerned with the protection of freshwater aquatic life and the aquatic life cycles in nearby surface water.

The human health or ecological risk assessment as being outlined by the US EPA, are typically not being conducted in the Swedish framework. Instead, site-specific guideline values are derived as a step forward for a better decision basis for remediation. Also in Sweden, the site has in principle to be remediated in case of serious contamination.

### 5.2.5 Probabilistic risk assessment

The importance of adequately characterising variability (Type 1 uncertainty as described in section 5.1.6 and uncertainty (or Type 2 uncertainty as described in section 5.1.6) in risk assessments has been emphasised in several documents. Typically, the above described risk assessment processes are point estimate approaches and the output is therefore a point estimate of risk. Such point estimates could be e.g. a central tendency exposure estimate of risk (e.g. the average expected risk) or a reasonable maximum exposure (RME) estimate risk (e.g. the risk expected if the RME was to occur). Probabilistic risk assessment (PRA) uses probability distributions for one or more variables in a risk equation in order to quantitatively characterise uncertainty and/or variability. The output of PRA is a probability distribution of risks that reflects the combination of the input probability distribution.

Probabilistic methods such as e.g. Monte Carlo analysis (probably the most widely used method in PRA), are techniques to characterise uncertainty and variability. The US EPA has published a guidance for conducting PRA (volume III in RAGS), which provide guidance on applying probabilistic analysis to both human health and environmental risk assessment. It contains information on policies and guidance, an introduction to PRA, a chapter on communicating methods and results of PRA with the public, a chapter on the role of PRA in decision making, and discussion and examples of Monte Carlo modelling techniques for estimating exposure and risk.

The potential value of PRA to support risk-based decisions has become increasingly apparent over the last several years. However, a point estimate approach is conducted for every risk assessment, but a probabilistic analysis may not always be needed. A PRA will demand more effort but may offer the following advantages, especially when the decision whether or not to take action is not completely clear:

- It makes more complete use of data
- It provides a more comprehensive characterisation of variability and uncertainty
- By making a sensitivity analysis, it helps identify variables, models and model parameters that influences the estimates of risk
- It may place the risk assessment in a Value-of-Information framework and identify data gaps for further evaluation/data collection.

However, the US EPA recommends a tiered approach to PRA, since there is a balance between the benefits of conducting a more complex analysis, and the cost in terms of additional time, resources, and challenges for risk communication.

### 5.2.6 Performance assessment of nuclear waste facilities

Where the probabilistic risk assessment (PRA) denotes a risk assessment that specifically evaluates the uncertainty in the assessment, the performance assessment is an analysis of the performance of a system (or subsystem) followed by a comparison with appropriate standards and criteria (test of compliance with a set of standards). A PRA displays the entire distribution function and avoids the problem in which events of low probability and high consequence are compared to events with high probability and low consequences (Rechard, 1999).

In assessing the safety of a geological disposal system for nuclear waste in the mid 1970s, a new challenge was to understand the long-term behaviour of engineered system components (waste containers and their interaction with the host rock environment) and natural components over geological time scales. Performance assessment (PA) methodologies were developed to determine whether the selected risk management technique, deep geological disposal of nuclear waste, is likely to meet the selected risk limits for scenarios selected by the regulator. The PA is by definition designed to test compliance with a set of standards.

In 1974 the first scenario development and deterministic analysis for a possible repository system was performed. The Waste Management Systems Division of Sandia National Laboratories developed three scenario categories which became the foundation for later PAs. The first probabilistic assessment of the potential Yucca Mountain disposal system was reported in 1992 (Barnard et al, 1992). The probability of events such as human intrusion, volcanism, seismicity and processes such as climate change were included. An important part of the performance methodology developed at Sandia National Laboratories is a procedure for selecting scenarios for use in evaluating disposal sites and facilities (assessing the performance of a potential disposal site). The scenarios define naturally occurring and/or human-induced conditions that represent realistic future states of the repository, geological systems and ground-water flow systems that could affect the release and transport of radionuclides from the repository to humans.

A systematic procedure for arriving at a set of scenarios for use in the analysis of a potential disposal site could consist of the following steps (Cranwell et al, 1990):

- An initial comprehensive identification of those events and processes felt to be important to the long-term isolation of radioactive waste in deep geological formations.
- A classification of these events and processes to aid in completeness arguments.
- A screening of these events and processes based on well-defined criteria.
- The formation of scenarios by taking specific combinations of those events and processes remaining after the screening process.
- Initial screening of these scenarios.
- The selection of a final set of scenarios for use in evaluating a potential disposal site.

.

USA, Canada and UK support probabilistic based assessment of nuclear waste facilities, whereas most international PAs are deterministic. One example of the latter is the incremental process of developing a final nuclear waste storage facility in Sweden. The Swedish nuclear fuel and waste management company SKB developed a PA to support the following steps (Höglund, 2007):

- Selection of disposal principles and repository concept
- Development of design (evaluation of alternative barrier materials, design and rock types)
- Definition of system design, and safety strategy for the selected barriers
- Site characterisation (surface based), site comparison, system adaptation to site, design optimisation
- Detailed site investigations, shaft/tunnel construction, adaptation of layout and barriers to site, design of encapsulation facility
- System design and site utilisation
- Re-evaluation of experience
- Design for repository closure (sealing).

## 5.3 Assessing low frequency high amplitude events

### 5.3.1 Introduction

Typically in risk analysis, the consequence (e.g. expressed in monetary terms or as utilities) of an event is weighted with the probability of that event. This implies that a one-in-ten probability that 10 person will die corresponds to the same risk as a one-in-a-hundred probability that 100 people will die. Further, the risk (the expected consequence) is typically compared with the benefits when choosing between alternative actions in order to maximise the expected utility, since it is a fairly safe method to maximise the outcome in the long run. For example, if decisions are to be made concerning a group of events, then it is a rather safe principle, since random effects are levelled out in the long run. However, the principle of maximising the expected utility is not valid for a case-by-case decision on a unique or very rare event. Here, random effects will not be levelled out, and we do not know what will lead to fewer deaths: an event with the probability of 0.001 that will kill 50 persons or an event that will kill 1 person with a probability of 0.1. If, however, such a decision is included in a sufficiently large group of decisions for which a meta-decision has been made to maximise the expected utility, then it would be reasonable to choose the first of the two options (with the lowest number of expected deaths). In principle, the larger group of decisions, the larger catastrophic consequences can be levelled out. This should be valid up to some *practical* limit, which has to do with the fact that decisions have to be based on a manageable amount of information, or to some *absolute* limit, which has to do with extreme effects (Hansson, 1993 and 1996).

In this perspective, in the context of assessing low frequency high amplitude events, it seems fully reasonable to focus on the consequences when classifying or comparing different human activities that constitute a hazard to man or environment. In the following section, different consequence classification schemes have been reviewed.

### 5.3.2 Examples of consequence classification systems

**RIDAS and MiningRIDAS (Sweden)**

The Swedish RIDAS system (Swedenergy AB, 2002) uses a classification scheme for classifying consequences of dam failures. The same system will be adapted and used for mining dam failures by the Swedish Mining Industry (i.e. MiningRIDAS) with a few supplements. The classification scheme takes into consideration consequences both upstream and downstream the actual dam. In the MiningRIDAS system (GRUVRIDAS, 2006) consequences (including both loss of lives and environmental impact) of transport of tailings and leaching of hazardous substances is also considered. The cost for remediation is used for classification of the environmental damage. The classification should be based on a thorough analysis and documentation of the characteristics and chemical properties of the tailings and other relevant information, including geographical position, type of dam, dam height, and hydraulic installations. The consequences of dam failure should be analysed with respect to:

- loss of human lives or injury
- damage to important infrastructure, important structures, or significant environmental or economical values

The classification scheme is presented in and table 5.1 and table 5.2. Further, the guiding document gives instructions on how the verbal probabilities and the short descriptions of consequences in the tables should be interpreted. For example, the classification of consequence-to-life can be based on the specific water depth and water flow velocity, which is expected due to a dam failure, and on whether this water will be in contact with houses or other places where people are permanently staying. As guidance, the consequence class is then expressed as the number of houses. Similar guidance is given for consequences in terms of damage to infrastructure and the environment. Guidance on how to classify several dams in series, i.e. the risk of a domino effect, is also given.

***Table 5.1***
*Classification of consequence-to-life according to GRUVRIDAS (2006) in principal identical to RIDAS (Swedenergy, 2002).*

| **Consequence class** | **Consequence** |
|---|---|
| 1A | **High probability** for loss of many lives. |
| 1B *) | **Non-negligible risk/non-negligible probability** for loss of human life or serious injury. |
| 2-3 | **Negligible risk** for loss of human life or injury |

*) Class 1B corresponds to the probability levels in 1B and 2, table 2 below.

***Table 5.2***
*Classification of consequences to infrastructure and the environment according to RIDAS (Swedenergy AB, 2002).*

| **Consequence class** | **Consequence** |
|---|---|
| 1A | **Obvious risk/evident risk/high probability for:**<br>Severe/serious/very severe damage<br>• on important infrastructure, important structures, or<br>• to significant environmental values<br>or<br>• serious economical damage/major damage to economic values/very large economical damage. |
| 1B | **Considerable risk/considerable probability for:**<br>severe/serious damage<br>• on important infrastructure, important structures, or<br>• to significant environmental values<br>or<br><br>**evident risk/high probability for**<br>• serious economical damage/major damage to economic values/large economical damage. |
| 2 | **Non-negligible risk/non-negligible probability for:**<br>considerable damage<br>• on infrastructure structures, or<br>• to environmental values<br>or<br>• economical damage/damage to economic values. |
| 3 | Negligible risk for considerable damage |

**Downstream Consequence Classification with regard to dam safety (Canada)**

Another example of consequence classification is given by the Ministry of Environment in British Colombia, Canada (ME BCC, 2007) with regard to dam safety. The regulation applies to all of the following:

(a) a dam 1 metre or more in height that is capable of impounding a volume of water greater than 1 000 000 m3;

(b) a dam 2.5 metres or more in height that is capable of impounding a volume of water greater than 30 000 m3;

(c) a dam 7.5 metres or more in height;

(d) a dam that does not meet the criteria under paragraph (a), (b) or (c) *but has a downstream consequence classification under Schedule 1 of low, high or very high*.

The downstream consequence classification is given below in table 5.3.

***Table 5.3***
*Downstream Consequence Classification Guide.*

| Rating | Loss of Life | Economic and Social Loss | Environmental and Cultural Losses |
|---|---|---|---|
| VERY HIGH | Large potential for multiple loss of life involving residents and working, travelling and/or recreating public. Development within inundation area (the area that could be flooded if the dam fails) typically includes communities, extensive commercial and work areas, main highways, railways, and locations of concentrated recreational activity. Estimated fatalities could exceed 100. | Very high economic losses affecting infrastructure, public and commercial facilities in and beyond inundation area. Typically includes destruction of or extensive damage to large residential areas, concentrated commercial land uses, highways, railways, power lines, pipelines and other utilities. Estimated direct and indirect (interruption of service) costs could exceed $100 million. | Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and/or practicality of restoration and/or compensation is low. |
| HIGH | Some potential for multiple loss of life involving residents, and working, travelling and/or recreating public. Development within inundation area typically includes highways and railways, commercial and work areas, locations of concentrated recreational activity and scattered residences. Estimated fatalities less than 100. | Substantial economic losses affecting infrastructure, public and commercial facilities in and beyond inundation area. Typically includes destruction of or extensive damage to concentrated commercial land uses, highways, railways, power lines, pipelines and other utilities. Scattered residences may be destroyed or severely damaged. Estimated direct and indirect (interruption of service) costs could exceed $1 million. | Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high. |
| LOW | Low potential for multiple loss of life. Inundation area is typically undeveloped except for minor roads, temporarily inhabited or non- residential farms and rural activities. There must be a reliable element of natural warning if larger development exists. | Low economic losses to limited infrastructure, public and commercial activities. Estimated direct and indirect (interruption of service) costs could exceed $100 000. | Loss or significant deterioration of regionally important fisheries habitat (including water quality), wildlife habitat, rare and endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high. Includes situations where recovery would occur with time without restoration. |
| VERY LOW | Minimal potential for any loss of life. The inundation area is typically undeveloped. | Minimal economic losses typically limited to owner's property not to exceed $100 000. Virtually no potential exists for future development of other land uses within the foreseeable future. | No significant loss or deterioration of fisheries habitat, wildlife habitat, rare or endangered species, unique landscapes or sites of cultural significance. |

**Slope risk analysis (Sweden)**

The Swedish Geotechnical Institute has developed a methodology for slope (landslide) risk analysis (Alén et al. 2000) where the consequences are classified into four different groups: Consequence class 1: Minor damages, Consequence class 2: Large damages, Consequence class 3: Very large/major damages, Consequence class 4: Catastrophic damages (NB – Class 4 is here the worst consequence class). Each class is defined by a verbal description of the extent of the damages, divided into the extent of the landslide, damages in the water area, and damages on land, accompanied by comparable examples of landslides that have occurred. The verbal description is based upon an analysis of the different possible consequences of a landslide. The description of Consequence class 4: Catastrophic damages, is given in table 5.4.

***Table 5.4***
*Consequence class 4: Catastrophic damages (from Alén et al. (2000)).*

| **Consequence class 4: Catastrophic damages** | |
|---|---|
| Extent of the landslide | Very large water and land area is affected. |
| Damages in the water area | The Göta Älv River is completely blocked. Long term break in the sea fare.<br>Water intake of the communities must be shut down until contaminants and suspended material has reached an acceptable level.<br>Break in the power production until a new, provisional, channel has been dug. |
| Damages on land | Private houses: > 10 Collapsed buildings. Possibly loss of many lives or many injured people.<br>Large material destruction.<br>Industries with potential for severe environmental damage<br>Collapsed buildings. Possibly loss of many lives or many injured people.<br>Large material destruction.<br>Industrial buildings, more than 5 private houses and National Road 45 are destroyed in the slope failure, leading to long-term breaks in traffic. Possibly loss of many lives or many injured people. |
| Comparable examples | The Tuve slope failure considering the number of deaths, injured and material damage. The Surte and Göta slope failures considering the amount of soil and stopping up the Göta Älv River. |

The different consequence classes are also schematically pictured in a figure to give an idea of the extent of the landslide, 0.

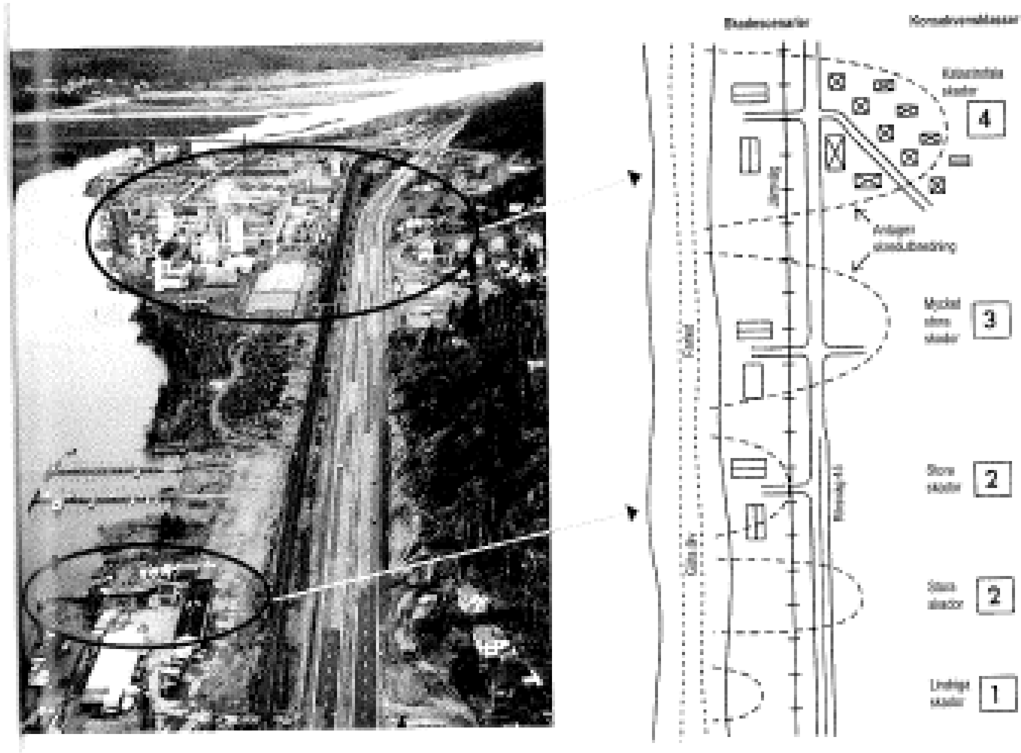


***Figure 5.6***
*Schematic picture of the consequence classes (from Alén et al. (2000).*

**Others**
The Geotechnical Engineering Office in Hong Kong gives a consequence classification system used for slopes and retaining walls in an information note from 2004 (GEO HK, 2004). The classification system is grouped into two categories consequence-to-life and economic consequence, and is based upon the type of facilities that can be affected by landslides/slope failures.

The Swedish Rescue Agency (Räddningsverket, 2003) uses a risk matrix with probability on the y-scale and consequence on the x-scale, see figure 5.7. The consequences are divided into three categories: Health (or loss-of-lives), Environment and Property.

| Probability | | | | | |
|---|---|---|---|---|---|
| > 1 time per year | | | | | Extremely high risk |
| 1 time per 1-10 year | | | | | |
| 1 time per 10-100 year | | | | | |
| 1 time per 100-1,000 year | | | | | |
| < 1 time per 1,000 year | Negligible risk | | | | |
| Health | Passing, minor discomfort | Few injured persons, long-term discomfort | Few severely injured persons, severe discomfort | Loss of lives and several severely injured | Loss of several lives and 10ths of severely injured |
| Environment | No remediation, small extent | Simple remediation, small extent | Simple remediation, large extent | Difficult remediation, small extent | Difficult remediation, large extent |
| Property | < 0.1 million SEK | 0.1-1 million SEK | 1-5 million SEK | 5-20 million SEK | >20 million SEK |

***Figure 5.7***
*Risk matrix (Räddningsverket, 2003).*

**Concluding remarks on the consequence classification systems**
In general, the classification of consequences is divided into a consequence-to-life (or loss of life) category and other categories, such as e.g. economical, infrastructural (and other important structures/buildings), social, environmental and cultural losses.

## 5.4 Concluding remarks on risk assessment methodologies

Risk assessment can be made with different degree of complexity, e.g. by using a "forward" or "backward" approach or to include uncertainties explicitly by probabilistic modelling. A forward approach to risk assessment, i.e. to assess/calculate the actual risk in the form of e.g. *x* additional cases of cancer in a certain population, is in general more complex and is typically made as an in-depth risk assessment. The forward approach is also in general used in occupational and environmental medicine for making health based risk assessments. The backward approach is typically used for developing general guideline values, preliminary remediation goals, setting criteria for leaching properties or performance of engineered system component. Using the backward approach, calculations are made based on a defined acceptable risk level at the point of compliance, and the material or the soil is compared to a certain threshold value or compliance limit (see for example the TAC-model, section 5.2.1). Probabilistic risk assessments, where uncertainties are explicitly estimated and used in the calculations are argued to provide a better basis for decisions.

They are, on the other hand, more time consuming and should therefore be used only when there is balance between the additional costs and the magnitude of the risk (or the experienced risk!).

The risk chain concept forms a good basis for comparing environmental risk assessment methodologies. The chain consists of the identified potential contamination source(s) and receptor(s), as well as the potential migration pathways in between. It contains the processes that form the total probability of a given event, although the risk only materializes if the chain remains unbroken and there is a negative effect at the receptor. The risk chain concept is also useful for identifying the risk reducing alternative actions, since these can be applied at different points of the source – transport – receptor chain. However, the distinction between the source itself, the transport media and the receptor is by no means straightforward: for example both soil and groundwater may be both transport mediums and receptors. National soil clean-up standards, derived with a backward approach, all have as a goal to protect health and environment, including subsequent effect on ground and surface water, but the standards show a large variation. This is due to a variation in their intended use, whether they include both human health, ecological effects, exposure routes, mass transfer between different environmental compartments, the selected toxicological and ecotoxicological criteria, the level of regional natural background exposure and political considerations (Provoost et al., 2006). Although exposure of humans to contaminated soil, sediment or groundwater can occur via various routes, generic risk assessment and modelling risks are widely used and accepted approaches.

For assessment of low frequency – high amplitude events such as the collapse of a dam it seems fully reasonable to focus on the consequences for classification of risk objects, e.g. mining waste facilities. In dam safety regulations it is normal to consider the risk of loss of human life or serious injury to persons as well as damage to the environment and infrastructure. In general, the systems studied for classification of consequences are divided into a consequence-to-life (or loss of life) category and other categories, typically e.g. economical, infrastructural, social, environmental and cultural losses. In environmental risk assessments of industrial operations a distinction is made between routinely and non-routinely release of a harmful agent. The same distinction ought to be made between the catastrophic consequences of a physical collapse of a mining waste facility with a low probability to occur, and the consequences of leaching of metals from waste rock, without potential catastrophic consequences, but with a higher probability of occurring.

In doing this, and taking into account expert advice (DHI, 2007, Appendix 1), it is important:

- to ensure consistency in the assessment of criteria for a tolerable environmental and human health impact as a result of a momentary release due to a physical failure *versus* continuous leaching of contaminants followed by transport in soil and groundwater and surface water;

- that the classification system should clearly define the **type of** impact that may force a facility to be classified as category A. In this way the key forward-looking features of the directive, to create an incentive for risk reduction and to encourage operators to minimize risk related to disposal facilities, is met;

- to acknowledge that tailing dams are unique compared to ordinary dams, because they are there forever. A risk analysis should include the possibility that the surrounding conditions may change, for example land use, and demographic changes or climate changes may occur (Campbell, 2007); and

- that the risk analysis and classification should be reviewed and updated regularly to take any changes in the surroundings (including extreme hydrological or seismic events) into account.

# 6. Major types of mining waste facilities in Europe

## 6.1 Introduction

The purpose of this task is to give a short overview of current waste management options and methodologies within the extractive industry and the types of waste facilities used. Based on current knowledge it is outlined in which directions new practices are developing. The purpose is also to highlight issues that are relevant for classifying the facilities from a risk assessment point of view as well as principal differences, if any, between the different sectors within the extractive industry. It is not the purpose to repeat or extend the results obtained in recently completed projects, such as the development of the European BAT-document on the management of tailings and waste-rock (EU, 2004), the BRGM-report (BRGM, 2001) the TAILSAFE project (www.tailsafe.com), the PECOMINES project (http://viso.jrc.it/pecomines_ext/main.html, e.g., Jordan and Alessandro, 2004) or various UNEP/ICOLD bulletins (e.g., 106 and 121).

The European BAT-document on the management of tailings and waste-rock (EU, 2004) compiles a large number of detailed specific examples on various types of facilities within the extractive industry in Europe, however, it is not complete and does, e.g. not include the aggregates industry. Therefore a section on each mining sector has been included outlining waste management practice within each sector, including the aggregates industry. It has not been the intention in this project to compile more detailed examples of facilities, but rather to give the overview of existing management methods and types of facilities.

## 6.2 Overriding principles – life-cycle management

Leading practice in the management of waste from the extractive industry requires that a waste facility is designed, operated, closed and rehabilitated to ensure performance that meets or exceeds the criteria agreed to through consultation with key stakeholders (Australian Government, 2007). This is typically called applying a life-cycle approach (EU, 2004). Several very good guidelines are available that describe the elements of waste management systems (e.g., MAC, 1998; Australian Government, 2007). Even though most guides focus on tailings management these guidelines provide a sound foundation for the development of customised waste-rock and tailings management systems. They include a framework of management principles and policies, and checklists for implementing the framework through a waste facility's life cycle. A risk based management approach applied to all stages of the life-cycle is required. Even though it may seem obvious to plan for closure already at the planning stage of a mine site, many of the extractive sites operating today have been planned and operated with no real closure planning in mind. This makes closure and rehabilitation of these sites more expensive and less effective than it could have been.

## 6.3 General description

The extraction of ore, minerals or aggregates (called mining and sometimes quarrying), subsequent mineral processing and the management of waste are in most cases considered to be a single operation. The waste management applied depends on, amongst other parameters, the mineral, the geology, the local settings and conditions at the site, ore extraction technique, the subsequent mineral processing techniques.

Throughout this report waste originating from accessing the ore, minerals or aggregates will be called **waste-rock** (including over burden) and waste origination from processing the extracted ore, mineral or aggregate will be called **tailings**. Furthermore, the extracted ore, mineral or aggregate will be called **ore** if not specified. This nomenclature will be used to avoid misunderstandings, as the waste types have different nomination between sectors, commodity and between countries, often also within countries the nomination can vary for the same commodities.

### 6.3.1 Extraction and waste-rock generation

For the mining of solids, there are five basic mining concepts:

- strip mine
- open pit mine
- underground mine
- quarry
- solution mining

A sixth method, underwater mining or dredging for ore is also practiced, mainly by the European aggregates industry. This is often called for as the natural deposits of aggregates have high permeability and are difficult to drain or it might not be desirable to drain the deposits due to the high permeability.
The choice between these five alternatives depends on many factors, such as:

- value of the desired mineral(s)
- grade of the ore
- size, form and depth of the orebody
- environmental conditions of the surrounding area
- geological, hydrogeological and geomechanical conditions of the rock mass
- seismic conditions of the area
- site location of the orebody
- solubility of the orebody
- environmental impact of the operation
- surface constraints
- land availability

(modified from EU (2004)

The different mining methods are related to different cost structures, e.g., up to 2 €/ton for open pit mining and above 15 €/ton in underground mining (Rutqvist, 2007), and are suitable for different types of deposits. The different mining methods also generate different amounts of waste-rock to be deposited on the surface.

Open pit mining, where mining is primarily done in the vertical direction, often generates the largest amount of waste-rock to be deposited on the surface as the open pit very rarely can be backfilled during operation. Strip mining over large areas, e.g., in brown coal fields, allows for continuous backfilling of mined out areas since the depth of the pit is relatively small and the production front moves on in a mainly horizontal direction as the minerals are extracted. In underground mining, the mining costs are high and therefore mining very selective. Thus very little waste-rock is mined and brought to the surface. Only if it is not possible to leave the waste-rock in a mined out area of the mine or use it as back-fill the waste-rock is brought to the surface, e.g., when constructing a new shaft or ramp. Due to the high mining costs for underground mining (normally above 15 €/ton) this method can only be used for relatively rich deposits, where the value of the mined ore can carry the high cost.

Quarrying is normally done into a hillside, resulting in a pit open at the top and in the front. This mining method, which is normally used for stone, such as slate, aggregates, limestone, marble etc., normally generates only small amounts of waste-rock, which is often left in the quarry and used for the decommissioning of the quarry. In solution mining and dredging almost no waste-rock is generated.

In the mining process, except in solution mining and in-situ leaching where a leach solution is introduced into the ground, no process chemicals are used which may report the waste-rock. However, if explosives are used, the waste-rock and ore will contain traces of undetonated explosives, reporting into the site drainage as increased nitrogen concentrations.

#### 6.3.2 Mineralogy

Basically it is possible to differentiate between the major mineral types such as oxide, sulphide, silicate and carbonate minerals, which, through weathering and other alterations, can undergo fundamental chemical changes (e.g. weathering of sulphides to oxides). The mineralogy is set by nature and determines, in many ways, the subsequent recovery processes of the desired minerals and the subsequent tailings and waste-rock management. Having a good knowledge of the mineralogy is an important precursor for:

- environmentally sound management (e.g. selective management of acid-generating and non-acid generating tailings or waste-rock)
- a reduced need for end-of-pipe treatments (such as the lime treatment of acidified seepage water from a facility)
- more possibilities for utilizing tailings and/or waste-rock as aggregates.

(modified from EU, 2004)

### 6.3.3 Processing and tailings generation

The purpose of mineral processing is to turn the raw ore from the mine into a marketable product. This is usually carried out on the extraction site, in the plant being referred to as a mineral processing plant (mill or concentrator). Within the ornamental stone industry and bauxite mining, however, further processing of the extracted ore is often done off-site.

In the aggregates industry the essential purpose of the processing is to create the specific products required by the local market. Primary the techniques applied are crushing (size reduction or comminution), screening (classification) and in some cases washing. Normally no additives are used in the processing of aggregates, however, some flocculants may be used for clarifying suspended solids before discharge of water.

In metal or mineral mining the essential purpose of the processing is often to reduce the bulk of the ore and increase the concentration of the desired mineral, which can be sold as a product or must be transported to and processed by subsequent processes (e.g. smelting), by using methods to separate the valuable (desired) mineral(s) from the gangue. The marketable product of this is called concentrate, and the remaining material (the waste) is called tailings. Within the industrial minerals industry it may also be an objective to create different qualities (purity, grain size etc) of the produced mineral for different segments of the market as the same mineral may have several different applications.
Mineral processing includes various procedures that rely on the mineral's own physical characteristics (i.e. particle size, density, magnetic properties, colour) or physico-chemical properties (surface tension, hydrophobicity, wetability). Typical techniques applied in mineral processing are:

- comminution
- screening and hydro-cycloning
- gravity concentration
- flotation
- sorting
- magnetic separation
- electrostatic separation
- leaching
- thickening
- filtration.

(modified from EU, 2004)

Some of these techniques require the use of reagents. In the case of flotation frothers, collectors and modifiers (e.g., lime or acids for pH adjustments) are necessary to achieve the desired separation. Leaching may involve, for example, acids or cyanide. The techniques used in mineral processing have an effect on the characteristics of the tailings, at least in the short-term (e.g., high or low pH). The processing as such may result in the generation of dissolved components, e.g., thiosalts, which may influence the tailings characteristics in the short-term

### 6.3.4 Waste management

Within the extractive industry waste is mainly generated either when accessing the desired ore or when processing the ore. The waste generated at these two principally different stages of the extractive process are called differently and to a certain degree managed differently depending on industry sector, mining and processing methods, as described above. From a disposal point of view both physical (e.g., grain size distribution) and geochemical characteristics (e.g., metal content or ARD characteristics) may or may not be different for the two types of waste generated even at one specific site and may vary in time for the specific category at a specific site. There is also a large variability in the amount of waste generated at different sites and the relation between the types of waste.

However, despite of these differences at the different sites and between sites, as well as between industry sectors, in practice, there is only a limited number of management practices used for the various waste types[8]. The main management practices are listed below:

- Deposition of waste on the surface in heaps
- Deposition of waste on the surface in ponds
- Backfilling of old excavation voids
- Backfilling of operating strip mines or operating underground mines
- Deposition in rivers, lakes, or sea
- Use of waste for construction purposes at the site (roads, dams, industrial areas, banks, filling material, noise reduction protection, etc.)
- Commercialization of waste for use outside of the mine site, e.g., as aggregates, soil amendment, etc.

Of the above mentioned management methods surface disposal in heaps and ponds and disposal in old excavation voids are the methods of main interest for the purpose of classification of facilities.

## 6.4 Waste-rock management

### 6.4.1 Waste-rock heaps

Waste-rock is, unless used as backfill or for construction purpose on- or off-site, deposited as close to the mine as possible. This is normally done in heaps or, if there exist old excavation voids close to the operating mine, into old excavation voids. Transport and dumping is normally done using conventional truck and shovel operations as permanent installations such as conveyor belts are inconvenient as the pit shape and depth varies with time as does the dumping location. A permanent installation would consequently need to be adapted almost constantly. Furthermore permanent installations could easily be damaged when blasting.

The waste-rock is dumped in layers and lifts or by using end-dumping methodology. End-dumping is often used when extending a dump over an edge, resulting in one, often very high, continuous dump edge at the angle of repose of the waste-rock (normally close to 1:1). This is an economical method for

[8] Depending on how the material is used it might or might not be waste from a legal or semantic point of view.

constructing the dump, however, it leads to a difficult and costly decommissioning of the dump face where a lot of waste-rock needs to be relocated to create an acceptable slope angle for reclamation. End-dumping is also used if depositing waste-rock into old excavation voids. In this case, the void will be filled and the high slope formed is of less concern. Safety aspects may arise as old void often is partly filled with water resulting in slope stability issues. This is normally solved by alternating the point of dumping and allowing for a settling period before returning to a specific dumping position.

Dumps on flat terrain are normally built depositing the waste-rock layers in approximately 10-20 m high lifts. The face of the dump is normally constructed with an overall slope angle of 1:3 and the individual lifts at 1:1. A terrace, with a width of approximately twice the lift height, is left at the toe of each lift to allow for re-sloping of the following lift and the construction of surface water collection ditches. In this way, minimal re-sloping is required when decommissioning the dump.

Waste-rock, which normally does not undergo any crushing before disposal, normally has a large variability in particle size distribution and normally a relatively high permeability as placed in the dump. This leads to a high permeability and to stable constructions as they very rarely become water saturated. However, if the dump contains reactive waste-rock, such as potentially ARD generating waste-rock, the high permeability may also lead to convective air transport in the heap which increases the overall reaction rate. In coal waste-heaps the individual layers are compacted to minimise air transport within the heap and in this way minimise sulphide oxidation (EU, 2004).

From a risk assessment point of view, waste-rock heaps are physically relatively stable constructions, even though failures do happen. These failures are often related to inadequate foundations. As little free water is stored in the waste-rock heap the waste-rock is not transported very far if a failure would happen. If the waste-rock heap is located close to a structure (creek, pit, road, railway, house, etc) significant risk could exist of causing fatalities or any major environmental damage at a failure. From a chemical stability point of view, waste-rock heap leachate composition will depend on the geochemical characteristics and the leaching behavior of the waste-rock. Of particular interest is the ARD generation potential of the waste-rock and the waste-rock leaching characteristics. Selective waste-rock management of potentially ARD generating waste is recommended as BAT (EU, 2004). Suspended solids may be mobilised by surface run-off from heaps, why sediment traps are normally used. Waste-rock heaps are normally surrounded by cut-off ditches to minimise surface water inflow under the heap and seepage collection ditches at the toe of the heap. Waste-rock heaps are rarely equipped with artificial liners.

There is no standard size or height of waste-rock heaps. They span from a few accumulated boulders to waste-rock heap areas covering several hundred hectars (e.g., Aitik copper mine in Northern Sweden with waste-rock heaps currently covering approximately 400 ha containing approximately 400 Mton of waste-rock).

### 6.4.2 Monitoring of waste-rock heaps

Normal environmental monitoring practice applies to waste-rock heaps. Surface- and groundwater monitoring up-streams and down-streams the heap or heap areas is normally performed. Monitoring of noise and dust emissions is done at many sites.

Topographic surveying is done of the heaps as they are built to assure they are built according to design. It is not very common to measure movements or groundwater levels inside or under heaps unless they are located close enough to the pit to pose a risk.

The waste-rock management methodology and the heaps are normally submitted to audits in connection to environmental audits at the mine sites. The BAT-document suggest auditing of waste-rock heaps are done according to the schedule presented in table 6.1.

***Table 6.1***
*Heaps assessment regime during operation and in the after-care phase (from EU ( 2004)).*

| Assessment type | Frequency | | Personnel |
|---|---|---|---|
| | Operational phase | After-care phase | |
| Visual inspection | Daily | Half-yearly | Heap operators, after closure possibly follow-up staff |
| Geotechnical review | Yearly | Every 2 years | Engineer |
| Independent geotechnical audit | Every 2 years | Every 5 - 10 years | Independent expert |

### 6.4.3 Closure of waste-rock heaps

Typically, closure of waste-rock heaps involves assuring safety, landscape integration and assuring physical and chemical stability of the facility. Specific cover requirements may be necessary depending on the ARD characteristics and leaching characteristics of the waste. For heaps containing potentially ARD generation waste qualified covers designed to minimise oxygen flux through the cover are normally applied (EU, 2004). A comprehensive control program assuring the performance of the implemented closure measures needs to be implemented. Figure 6.1 shows the closure of a waste-rock heaps containing potentially ARD generating waste-rock at the Aitik mine in Northern Sweden.

***Figure 6.1.***
*Photos illustrating the closure of a waste-rock heap at the Aitik mine in Northern Sweden.*

## 6.5 Tailings management

### 6.5.1 Backfilling of tailings into operating underground mines

In underground mines tailings are often used as backfill material to provide geotechnical support or to facilitate ore extraction. Increased safety and ore recoveries can thereby be obtained. As the porosity of tailings is approximately double that of the original ore forming rock it is normally not possible to backfill all the generated tailings. In base metal mines approximately 40 % of the generated tailings can be backfilled (EU, 2004). Backfilling is normally done using hydraulic backfill or paste backfill prepared on the surface and pumped into the filling areas in the mine. The backfill may or may not need an addition of binders, such as cement.

### 6.5.2 Tailings ponds

Tailings that is not used for backfilling operating underground mines are normally managed on the surface in ponds or heaps, backfilled into old excavation voids or, in rare occasions in Europe deposited into the sea (e.g., Cleveland Potash, England). Salt brine can in some cases be re-injected into the ground in deep wells (EU, 2004). Of the above mentioned methods, disposal of tailings as a slurry into engineered ponds or old excavation voids is the most common method where wet processing methods are applied and disposal in heaps or into old excavation voids when dry processing methods are used.

There are numerous ways to deposit the slurry tailings into the facility where the most common method is sub-aerial (Cambridge, 2003) single point or multiple point discharge (spigotting). Subaqueous discharge is practiced at a few sites to minimise sulphide oxidation (e.g., Neves Corvo Mine, Portugal). There are also many ways to construct the embankments containing the facility. The facility may or may not be lined (synthetic liner, clay liner, natural liner or a combination) depending on the tailings to be deposited into the facility and the specific hydro-geological setting. Lining can, if it is used, be covering the interior of the entire facility (e.g., Aguablanca Mine, Spain, Figure 6.2) or just in relation to the embankments (e.g., El Valle Mine, Spain).


***Figure 6.2.***
*Disposal of thickened tailings into the fully lined tailing pond at the Aguablanca mine in Southern Spain.*

A conventional tailings pond is a facility designed to store both the solid part of the tailings and the water. Depending on how the pond is located the pond type is called; valley facility (embankment built across a valley); hill side or off-valley facility (embankment built to contain the tailings towards a hill side); or paddock (built on flat land with an embankment surrounding the facility). Some common location types are illustrated in Figure 6.3. The primary function is to allow for the settlement of the solids in the pond. Secondary functions can be to allow for recovery of process water and some times for storage of water. The tailings pond can be a single structure from which the water is either recycled to the processing plant or discharged to the recipient (e.g., Neves Corvo, Portugal) or it can be a combined structure of two or more ponds where the solids settle in the first pond and the water is clarified (polished) and if required stored in the following pond (clarification pond or polishing pond) before it is either recycled to the processing plant or discharged to the recipient (e.g., Aitik Mine, Sweden). If water treatment, in addition to clarification, is necessary it is either done at the processing plant before pumping the tailings to the tailings pond (e.g., Svartliden Gold mine, Sweden), between the tailings pond and the clarification pond or in a separate water treatment facility before discharge. There are often additional processes that take place in tailings ponds (e.g., natural degradation of trace concentrations of cyanide and oxidation of thiosalts) apart from settling of solids and therefore the pond can form an important part of the water treatment scheme at the site.

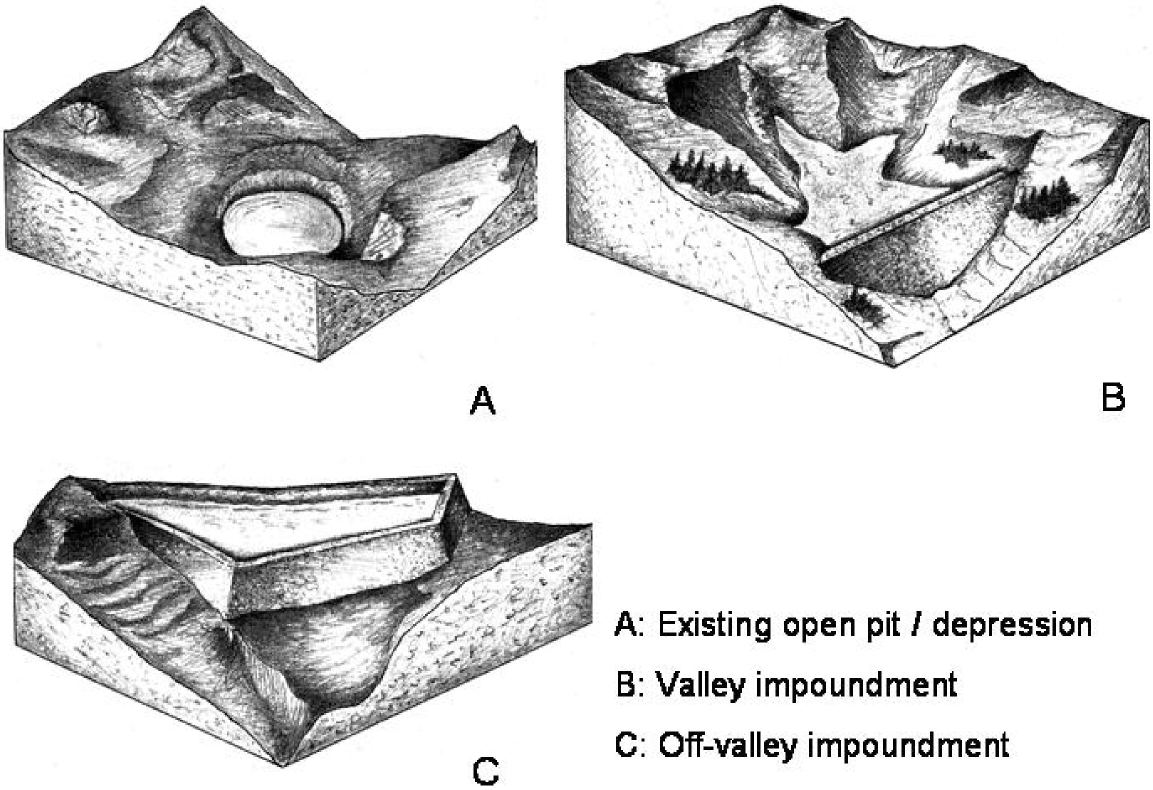


***Figure 6.3.***
*Illustration of common location alternatives for tailings facilities. (From EU, 2004).*

Tailings ponds are often raised and built higher at the same rate as the tailings are generated, so called staged construction or sequentially raised construction. There are many ways to design and raise a tailings pond embankment over time and it is not uncommon to change dam construction method over time. The embankment can either be built as a conventional dam, a staged conventional dam (where borrow materials are used in the construction of the embankment) or by using tailings as the main construction material for the embankment (Figure 6.4). The common methods are listed below and described in detail in UNEP/ICOLD, 1996 and in EU, 2004 and a compilation can be found at www.tailingsinfo.com:

- Upstream – the embankment is raised inwards on top of the deposited tailings using mainly the coarse fraction of the tailings. The design relies on maintaining a wide beach, i.e., a large distance from the dam crest to the free water stored in the pond, and the draining properties of the coarse tailings. The closer the free water is to the dam crest, the higher the phreatic surface of the embankment and thus the greater the risk of failure. The filter under-drain system of the embankments is a key component in reducing the phreatic surface of an upstream designed embankment (tailingsinfo.com).
- Downstream – the embankment is raised expanding downstream (away from the previously deposited tailings).
- Centreline dams – the embankment is raised vertically, which is a middle ground between the upstream and the downstream methods.

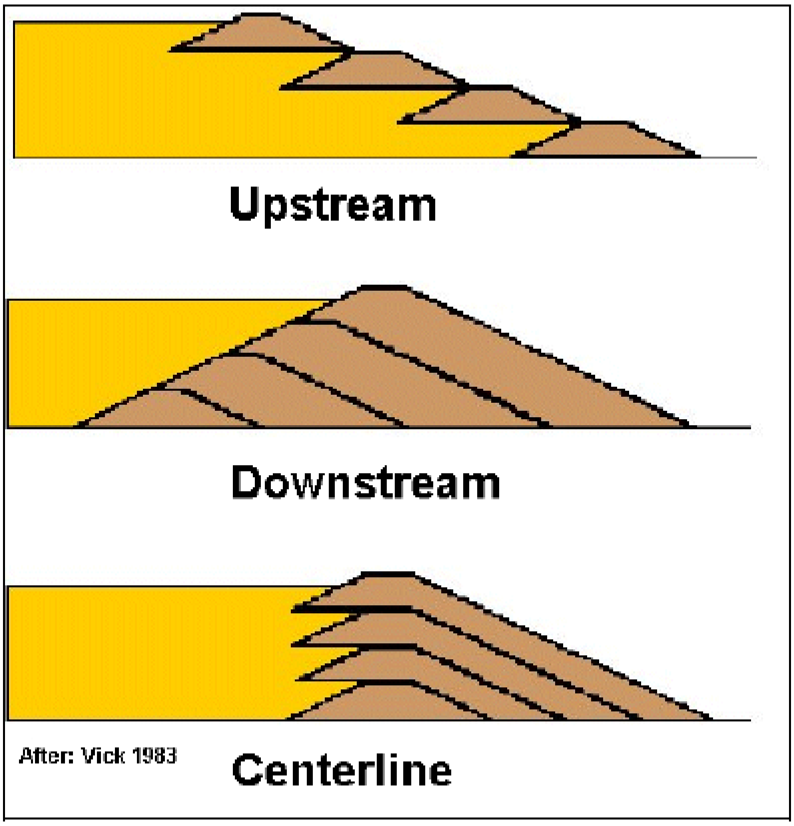


***Figure 6.4***
*Types of sequentially raised dams with tailings in the structural zone (From EU, 2004)*

For the three construction methods either tailings or borrow material can be used. The BAT-document (EU, 2004) gives a summary of different dam construction techniques and when they are suitable, table 6.2.

The International Commission on Large Dams Bulletin 121 (UNEP/ICOLD, 2001) provided a comprehensive report of lessons learnt from past accidents, drawing from the global experience from a range of tailings storage facility failures and incidents. The main causes of failures and incidents identified were (as summarized by Australian Government, 2007):

- lack of control of the water balance
- lack of control of construction
- a general lack of understanding of the features that control safe operations.

***Table 6.2***
*Different dam construction techniques and when they are suitable (from EU, 2004).*

| Dam type | Applicability | Discharge suitability | Water storage suitability | Raising rate restrictions | Construction material | Seismic resistance | Dam cost |
|---|---|---|---|---|---|---|---|
| Conventional dam or water retention type | Suitable for any type of tailings | Any discharge procedure suitable | Good | Not dependent on tailings material properties | Natural soil borrow | Good | High |
| Upstream | If tailings are used: at least 40 - 60 % sand (0.075 - 4 mm) in whole tailings[1)]. Low pulp density desirable to promote grain size segre-gation | Peripheral discharge and well controlled beach necessary, centre discharge for thickened tailings | Suitable under certain conditions | Less than 5 m/yr most desirable, to avoid insufficient consolidation and pore pressure build-up | Natural soil, sand tailings or waste-rock or sand tailings in combination with natural soil or waste-rock | Poor in high seismic areas | Low |
| Downstream | Suitable for any type of tailings | Varies according to design details | Good | None | Sand tailings or mine wastes if production rates are sufficient. Otherwise natural soil. | Good | High |
| Centreline | Sands or low plasticity fines | Peripheral discharge necessary | Not recommended for permanent storage. Temporary flood storage acceptable with proper design details | Height restrictions for individual raises may apply | Sand tailings or waste-rock if production rates are sufficient, otherwise natural soil | Acceptable | Medium |
| 1.) does not apply to thickened tailings | | | | | | | |

Tailings embankment failures were (in order of prevalence):

- slope instability
- earthquake loading
- overtopping
- inadequate foundations
- seepage.

Tailings incidents appeared to be more common where upstream construction was employed, compared with downstream construction. UNEP/ICOLD Bulletin 121 (2001) also concluded that successful planning and management of tailings storage facilities could benefit greatly from:

- the involvement of stakeholders
- thorough investigations and risk assessments
- comprehensive documentation
- tailings management integrated into mine planning, operations and closure.

From the above compilation of the UNEP/ICOLD (2001) findings it can be concluded that poor water management is one of the main reasons for embankment failures. The water stored in the facility may constitute a significant risk to the downstream area if released and it may mobilize and transport significant amounts of tailings out of the facility (e.g., Eriksson and Adamek, 1999).

### 6.5.3 Tailings disposal into old voids

Tailings disposal into old voids or in-pit tailings disposal (Figure 6.5), is simply the process of backfilling abandoned open pit surface mines with tailings. The main advantage to in-pit disposal is that the tailings do not require retaining walls, thus the risks associated with embankment instability are eliminated. However, in pit disposal may also result in serious accidents if a proper risk assessment is not conducted also considering underground workings (e.g., Marcopper accident in the Philippines 1996 when 1.6 million $m^3$ of tailings was lost from storage pit through old drainage tunnel). In pit disposal may appear attractive as worked out voids can be filled at a fraction of the costs associated with designing, constructing and operating a conventional, thickened, paste or dry stack facility. However, water management costs may be significant and the potential for groundwater contamination below and around the void has to be considered.

***Figure 6.5.***
In pit disposal of slurry tailings. (From EU, 2004).

### 6.5.4 Co-disposal of tailings and waste-rock

Tailings and waste-rock co-disposal is worldwide viewed as a novel concept for the containment and disposal of tailings within waste-rock heaps. However, it has been used for some time in Europe, e.g., in Austrian iron mine and German coal heaps. The method utilizes the void space in mine waste rock for the disposal of the fine grained tailings. Because waste rock is commonly a coarse, run-of-mine product created from blasting of hard rock, there are large voids created when the waste is placed in a waste dump. When applied to competent waste, these large void spaces make a good place for the placement of tailings. Clayey and sandy wastes may not be suitable for this technology, depending on the gradation, ratio of waste-to-tailings and, ultimately, the available void ratio (Leduc and Smith, 2007).

### 6.5.5 Thickened and Paste tailings and Dry stacking of tailings

Thickening tailings reduces the quantity of water delivered to the tailings storage facility. This in turn reduces the risks of overtopping, and reduces seepage and evaporation losses. Thicker tailings discharge also enables better control of the decant pond and return water system. Where tailings are discharged into surface storage facilities, depositional beach angles will steepen as the tailings are discharged at a thicker consistency, and the reduced water content will, in turn, reduce the containment requirements (Australian Government, 2007).

Past limitations to successful thickened tailings disposal were either cost or the lack of suitable thickener technology. Today, thickener technology has developed well beyond the conventional thickener to produce high underflow densities, close to the filtration limit, and costs have reduced. These thickeners range from deep bed thickeners (typically used for red mud) through to paste or deep tank thickeners developed for the production of cemented paste tailings backfill for underground application (Potvin et al. 2005).

At the recently constructed Aguablanca Mine in southern Spain thickened tailings disposal into a drained and lined pond is practiced. The experience is after almost 2 years of operation very positive with a high degree of consolidation of the deposited tailings and a high degree of water recovery (Castro, 2007).

### 6.5.6 Monitoring of tailings management facilities

Normal environmental monitoring practice applies to tailings management facilities. Surface- and groundwater monitoring up-streams and down-streams the facility is normally performed. Monitoring of dust emissions is done at many sites.

***Figure 6.6.***
*Collection and monitoring of drainage flow rate from the toe of the Enemossen tailings pond.*

Of special interest is the monitoring of parameters that might give an early warning of any kind of problems with the facility, such as the drainage flow rate, Figure 6.6. A list of parameters, monitoring instrumentation and frequency is given in table 6.3 for such parameters.

***Table 6.3***
*Typical measurements and their frequency and instrumentation for tailings dams monitoring (from EU (2004)).*

| Measurement | Instrumentation | Frequency |
|---|---|---|
| Water level in pond | Level scale, doppler | Weekly, daily or online |
| Seepage discharge through:<br>▪ the dam itself<br>▪ the foundation<br>▪ the abutments | ▪ weirs or containers<br>▪ pore water pressure gauges<br>▪ groundwater wells | Weekly, daily or online |
| Seepage samples | Taking of samples and measurement of turbidity | Monthly or weekly |
| Position of phreatic surface | Piezometer (typically open standpipe) | Monthly or weekly |
| Pore pressure | Piezometer or bourdon tube pressure gauge | Monthly or weekly |
| Movement of dam crest and tailings | Geodetic datum points on beach (completed dam) and crest of the dam, aerial photography, GPS | Yearly or half-yearly |
| Seismicity | Strong motion accelerographs | Events (not done on site) |
| Dynamic pore pressure and liquefaction | Vibrating wire piezometers | Yearly |
| Soil mechanics | Penetrometers for density and shear strength | Yearly (only during design phase) |
| Tailings placement procedures | Shear strength, compressibility, consolidation, grain size and density samples, width of the non-submerged beach as indication of phreatic surface via aerial or satellite photography | Yearly (only during design phase) |

The tailings management facility is normally submitted to periodical audits The BAT-document suggest auditing of tailings management facilities are done according to the schedule presented in table 4.

***Table 6.4***
*Tailings dam assessment regime during operation and in the after-care phase (from EU, 2004).*

| Assessment type | Frequency | | Personnel |
|---|---|---|---|
| | Operational phase | After-care phase | |
| Visual inspection | Daily | Half-yearly | Dam operators, after the closure possibly follow-up staff |
| Annual review | Yearly | Yearly | Engineer |
| Independent audit | Bi-annually | Every 5 - 10 years | Independent expert |
| Safety evaluation of existing dams (SEED) | 15 - 20 years | 15 - 20 years | Team of independent experts |

### 6.5.7 Seepage flow to surface water and groundwater

Seepage to surface water and groundwater may lead to surface water and groundwater contamination in the short- medium- and long-term. The facility needs to be adequately located and designed and the relevant seepage control measures need to be in place according to the characteristics of the managed tailings in order to minimise contamination of surface and groundwater. Figure 6.7 illustrates schematic seepage flow scenarios for different types of tailings facilities.

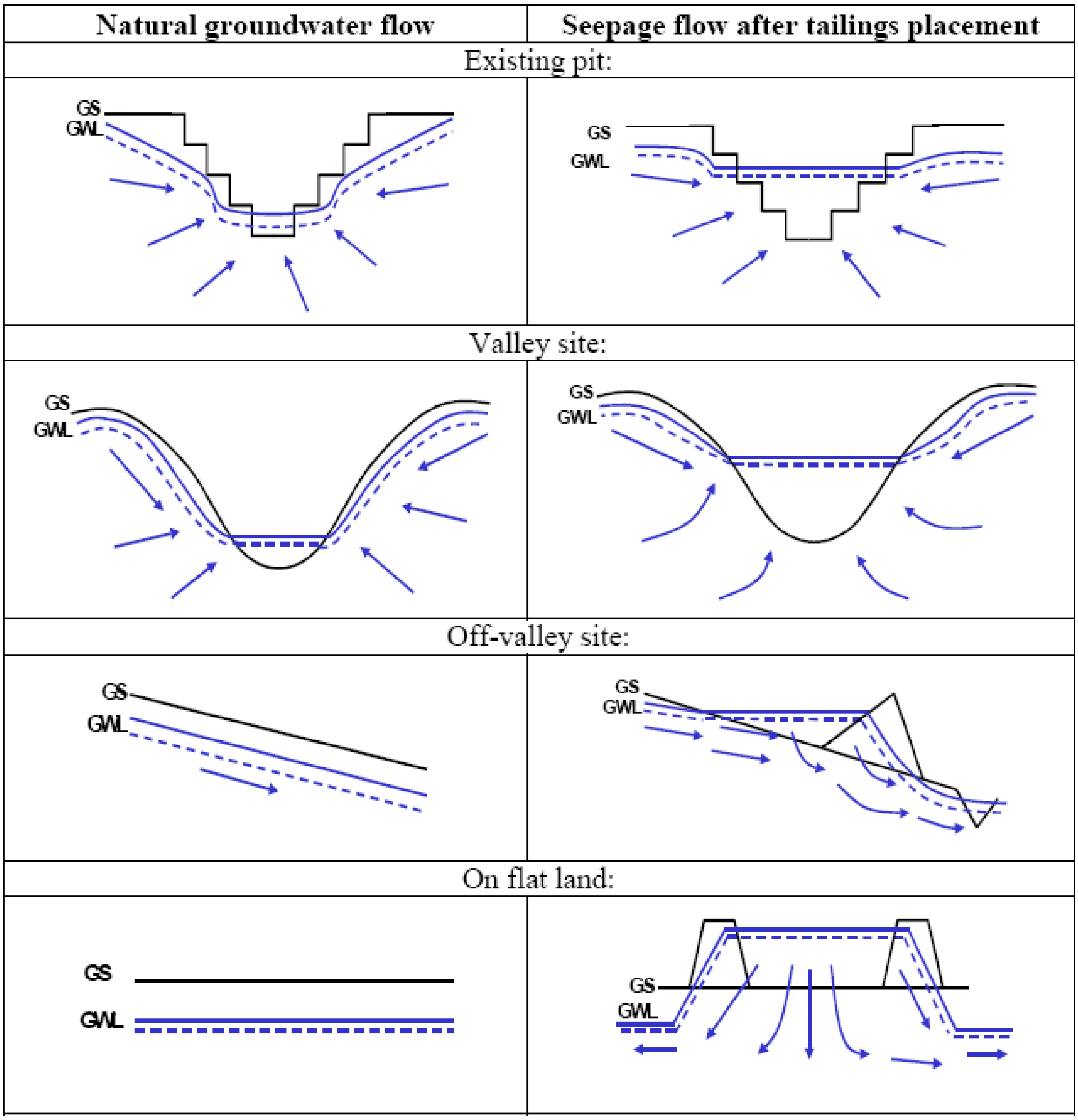


***Figure 6.7.***
*Schematic seepage scenarios for different types of tailings pond (from EU, 2004).*

### 6.5.8 Closure of tailings management facilities

Typically closure of tailings ponds involve assuring safety, landscape integration and assuring physical and chemical stability of the facility. A significant risk reduction is normally obtained after closure when the pond is drained. Specific cover requirements may be required depending on the ARD characteristics and leaching characteristics of the waste. For tailings ponds containing potentially ARD generating waste various methods have been developed to minimise oxygen flux to the deposited tailings, including qualified covers and flooding (EU, 2004). Figure 6.8 illustrates shows the Aznalcóllar tailings pond after failure in 1998, during closure 1998-2000 and after closure was completed in year 2000. Figure 6.9 is a view of the closed Aznalcóllar tailings pond in 2000, 3 years after the failure occurred.

***Figure 6.8.***
*The160 ha Aznalcóllar tailings pond after failure, during closure and after closure.*

***Figure 6.9.***
*View of the160 ha Aznalcóllar tailings pond after closure had been completed in year 2000, 3 years after the failure occurred.*

## 6.6 Future Tailings Management

Tailings management, based on the principles of sustainable development and good business practice are driving the design, operation, closure and rehabilitation of tailings storage facilities towards (Australian Government 2007):

- thickened and paste tailings disposal, to reduce water use and the seepage, and to produce a more stable tailings deposit
- dewatering of tailings to a filter cake for wet or dry stacking, with obvious benefits
- co-disposal and integrated tailings disposal with coarse-grained wastes, to make better use of the available storage volume and produce a more stable deposit
- paste rock for use as a cover seal
- secure tailings storage as underground and pit backfilling
- tailings landforms aligned with natural analogues and community expectations
- tailings minimisation, recycling and reuse.

The European trends (e.g., Cambridge, 2003) coincide to a large extent with the development observed in Australia. Dry disposal of filtered tailings in cells (e.g., Cobre las Cruses project under construction in southern Spain) and paste tailings disposal in surface impoundments (e.g., Agua Teñidas project under construction in Southern Spain) is now being applied even for tailings with a high ARD potential. Paste tailings backfill is becoming more commonly used for backfilling of underground operations (e.g., Garpenberg mine and Zinkgruvan mine, both in central Sweden) optimising the amount of tailings that can be backfilled. Paste backfill allows for the entire size distribution in the tailings to be used in the backfill and not only the coarse fraction implying that more coarse particles are deposited to the tailings pond, changing the tailings deposited tailings characteristics and increasing the possibility to use tailings for the construction of embankments.

In Northern Europe there is also a trend towards further developing the design and construction of long-term stable dams, in order to allow for permanent water covers on potentially ARD generating tailings in areas where an overall positive water-balance can be guaranteed for the facility (e.g., the Lisheen Mine in Ireland and the Svartliden Mine in Northern Sweden). To minimise the depth of the water cover, and thereby the amount of water stored in the facility, wetland covers are under development (Höglund et al., 2003). There is also a trend towards modifying the geochemical characteristics (ARD potential and metal content) of the tailings by, e.g., de-pyritisation (e.g., at the Aitik mine in Northern Sweden and the Klirou Copper-Zinc Project on Cyprus). There is a large interest in developing and implementing co-disposal techniques for tailings and waste-rock in order to minimise the footprint and height of separate tailings disposal facilities. Large scale tests have been performed for all climate zones in Europe (e.g., LKAB in northern Sweden and Rio Narcea in southern Spain).

## 6.7 European mining

A compilation of mined commodities in the EU 27 countries as well as for Norway and Greenland is given in Appendix 4. The compilation is based on information made available by USGS (www.usgs.com).

### 6.7.1 Metal mining sector

The EU metal mining sector is composed of around 250 enterprises, which includes some major multinational mining companies, which have their headquarters in the EU. European companies compete in a global market and most metallic ores are imported to supply the European metallic industry. EU metal mining accounts for up to 10% of world production of silver and zinc, table 6.5. EU is also large in copper and lead. Norway provides a significant part of the world production of titanium. The metals mining sub-sector is located in many of the EU countries, and in particular in some of the more Northern and Southern countries, such as Sweden, Finland, Poland, Ireland, Greece, Spain and Portugal. New mines continue to be developed, and provide employment and economic growth. As metals and their ores and concentrates are traded on international markets European metal mines face strong competition from large-scale, high-grade overseas operations capable of producing metal ores and concentrates under low cost conditions. The industry has over the last 10 years made large efforts to reduce overall cost levels through rationalisations and increasing capital intensity.

***Table 6.5***
*EU production of selected metallic minerals in % of world production 2004 (From Euromines annual report 2005).*

| EU production of selected metallic minerals in % of world production | | |
|---|---|---|
| Metal | % world | EU30 countries with >1% of world output in 2004 |
| Silver | 10.5 | Poland (6.9%), Sweden |
| Zinc | 9.6 | Ireland (4.6%), Sweden, Poland |
| Titanium | 8.3 | Norway (8.2%) |
| Lead | 7.3 | Poland (1.8%), Sweden, Ireland |
| Copper | 6.1 | Poland (3.7%) |
| Chromium | 4.7 | Finland (3.3%), Turkey |
| Tungsten | 4.6 | Austria (3%), Portugal |
| Iron | 2.3 | Sweden (1.7%) |
| Aluminium (bauxite) | 2.3 | Greece (1.6%) |
| Nickel | 1.8 | Greece (1.6%) |
| Gold | 1 | - |
| Manganese | 0.7 | - |
| Tin | 0.1 | - |

Both open pit mining and underground mining is used in Europe. Mineral processing techniques often involve a combination of dry and wet methods such as flotation. Waste-rock and coarse tailings are managed on heaps if not backfilled or used as construction material at the site or sold off-site. Tailings are normally managed in tailings ponds if not backfilled. There are examples of very large tailings ponds within the metal mining industry (e.g., the 1150 ha Aitik tailings pond, Sweden).

From a risk assessment point of view, physical stability of tailings ponds, and to a lesser extent heaps, is of importance. Chemical stability of the deposited tailings and waste-rock is normally related to the ARD generation potential and leaching behaviour of the waste and the additives used in the mineral processing.

### 6.7.2 Industrial minerals

The industrial minerals sub-sector provides a wide range of minerals which can be loosely classified as either ‘physical’ minerals (that is, minerals valued for their physical properties, for example, calcium carbonates, diatomite, kaolin, plastic clays, bentonite, feldspar, silica, and talc) or ‘chemical’ minerals (minerals valued for their chemical properties, for example, borates, salt, potash and sulphur).

Extraction of one more industrial mineral is undertaken in all of the EU Member States, although some countries are more important than others for producing particular minerals. There is much international trade of some industrial minerals. The sub-sector in the EU is mainly composed of small and medium-sized enterprises. However, it also includes the world's leading international production companies, operating on a global basis (e.g. in talc).

Processing of the minerals before sale can be simple (mainly crushing, grinding and classifying) but may also be more sophisticated for some mineral types (e.g. mineral sorting using flotation, laser optics, magnetic separation, or calcination) (www.euromines.org).

Waste-rock and coarse tailings are managed in heaps if not backfilled, used as construction material at the site or sold off-site. Fine tailings are managed in tailings ponds or dewatered and managed on heaps. There are examples of large tailings ponds within the industrial minerals industry (e.g., the 800 ha Musti tailings pond at Finnish Siilinjärvi phosphate mine or the 55 ha and 92 m high Kernick mica tailings pond in England).

From a risk assessment point of view, physical stability of tailings ponds, and to a lesser extent heaps, is of importance. Chemical stability of the deposited tailings and waste-rock is normally related to the leaching behaviour of the waste and the additives used in the mineral processing.

### 6.7.3 Energy minerals extraction

At the moment, approximately 30% of the electricity generation in the EU is coal based. In many EU Member States, coal accounts for over 50% of the total power supply. The economic importance of coal as a fuel has further increased after enlargement, now that the EU includes countries, such as Poland, where indigenous coal production plays a leading role in the domestic energy market. Coal, even though production is in decline, contributes to a large extent to the creation of employment, added value and wealth in the EU. In 2004, the industry provided more than 330,000 jobs in the EU. (http://euracoal.be).

Two main types of coal is extracted, hard coal and brown coal. In underground hard coal mining, which dominates in Europe, and processing the main waste stream is tailings as very little waste-rock is extracted. Any waste-rock produced is managed on heaps or backfilled. When separating the coal from the gangue coarse tailings is produced (using jigs or dense media separation) as well as fine tailings using flotation or hydro-cyclones (EU, 2004). The coarse tailings is managed in heaps and the fine tailings (as a slurry) is managed in ponds or further dewatered and co-deposited into the coarse tailings heaps. Waste from hard coal processing is often sold off-side the site as construction material. (EU, 2004 and Jordan and Alessandro, 2004). The size of coal tailings heaps and ponds can be significant (e.g., Prosper Haniel heap 108 ha and 100 m high and the Schöttelheide tailings pond is planned to become 66 ha and 62 m high).

In brown coal mining the main waste stream is the waste-rock. Normally strip mining is used. Strip mining over large areas, allows for continuous backfilling of mined out areas since the depth of the pit is relatively small and the production front moves on in a mainly horizontal direction as the brown coal is extracted. In this way the use of heaps can be minimised even though relatively high ratios between ore and waste are common. In Poland 60 Mton of lignite was mined generating 260 Mton of waste-rock in 2001. The waste-rock was backfilled into the strip mine and formally not recognized as waste according to Polish legislation (Jordan and Alessandro, 2004).

From a risk assessment point of view, physical stability of tailings ponds, and to a lesser extent heaps, is of importance. Chemical stability is related to the ARD generation potential and leaching behaviour of the coal tailings and waste-rock.

### 6.7.4 Aggregates industry

In Europe about 2.800 Mton of aggregates are produced on an annual basis. The European aggregates industry is the largest non-energy extractive sector in the EU with 3 billion tons produced every year. It consists of more than 30,000 extraction sites across Europe and a majority of operators in the sector are small and medium sized enterprises. The average annual aggregates production represents 7 tons per EU citizen. The produced materials are approximately 47% sand and gravel and 46% crushed rocks. Over the last couple of years recycled aggregates have started to become produced, mainly in

Great Britain, Germany and Belgium, and they currently constitute about 5 % of the total aggregates production in Europe.

Aggregates production is mainly a dry process. The main process steps are extraction, either in a gravel pit or in a rock quarry, crushing and classification (screening). For some specific applications washing of the aggregates is necessary, e.g., for aggregates used in railway construction where dust particles could jeopardize safety and durability of the trains.

I general little waste materials are produced within the aggregates industry, only about 1-2% of the production according to in inventory made by UEPG. Topsoil and overburden are generated when uncovering a quarry or a natural deposit are temporarily stored in heaps at site and used for the reclamation of the site, often in the form of continuous reclamation which minimizes the need to store topsoil and overburden. Top soil and overburden are therefore important resources used for the reclamation of the site and not regarded as waste even if they are sometimes stored temporarily in heaps until they are needed. Waste generation is mainly related to an over-production of fines (0-2 mm or 0-4 mm fraction) from crushing rock. Normally, this fraction can be used in concrete and in asphalt, alternatively used in the reclamation of the site. However, this material might need to be stored "temporarily" in heaps and, in rare occasions when the distance to any asphalt or cement plant is too large, permanently disposed of in heaps.

In some quarries there are parts of the extracted rock that do not fullfil the quality requirements for aggregates and is therefore rejected, so called waste-rock (also called side-rock or bad rock). This waste-rock is then extracted and deposited in heaps close to the quarry. The waste-rock could theoretically constitute an environmental risk, e.g., if it is ARD generating.

Washing of aggregates, which is a wet process, produces particles in suspension which are often passed through a hydraulic cyclone to recover the coarser fraction of these particles. The fine end of the particles in suspension, often called slimes but also pond fines, settling pond fines, pond screenings, pond slime or pond tailings. These slimes are discharged into a series of sequential settling ponds where they settle out via gravity, so called slimes ponds. In some cases flocculants are added to improve sedimentation rate and to reduce suspended solids content in the discharge water quality. The most common type of slimes pond is the use of an excavation void, however, examples exist where ponds are created by building dams to contain the slimes. Slimes ponds are typically small, less than 5 ha and with heights/depth of typically less than 5 m (Bida, 2007). Slimes ponds could constitute a risk in case of a failure.

Often recycling materials brought to site for treatment generate various waste fractions, however this type of waste is not covered by Directive (2006/21/EG) and thus do not enter under the scope of this report.

## 6.8 Discussion

All sectors within the European extractive industry (Metal Mining Sector, Industrial Minerals Sector, Energy Extractive Sector and the Aggregates Industry) use similar waste management methods:

- Waste-rock and tailings are to a large extent backfilled where possible.
- Waste-rock and tailings are used as building material where suitable and possible.
- Coarse waste-rock and coarse tailings are managed on heaps or in old excavation voids, if not backfilled into the operating mine or used as construction materials on or off-site.
- Tailings from dry processing are managed on heaps or in old excavation voids, if not backfilled into the operating mine or used as construction materials on or off-site.
- Tailings from wet processing are managed in tailings ponds or in old excavation voids, if not backfilled into the operating mine or used as construction materials on- or off-site.

Tailings ponds are often built in stages at the rate of increasing need for disposal volume in the facility. Numerous methods for construction tailings pond embankments exist as well as for tailings placement into the pond. It is not unusual that methodology for raising the embankments, tailings placement methodology and tailings characteristics change during the operational period of a tailings pond.

For tailings ponds physical stability is of critical importance as a failure could lead to significant consequences due to out flowing water and tailings. In Europe, and in the world, there is a development towards tailings facilities with less free water stored in the pond, use of separate clarification ponds, thickened or paste tailings disposal. An exception is potentially ARD generating tailings where there is also a trend towards permanent underwater disposal. A failure of a heap is likely to result in smaller consequences as heaps contain little water that could be released at a failure resulting in a more local impact of a failure.

Short- medium- and long-term risk of surface and groundwater contamination by contaminated drainage from the facility is related to the characteristics deposited waste. ARD generation potential, leaching characteristics, possible mineral processing additives in the tailings water as well as possible compounds generated in the mineral processing affects drainage water quality.

Backfilling of waste-rock and tailings into operating mines or old excavation voids may eliminate the risk of a physical failure involving release of solids and water. However, the chemical stability of the waste may still be an issue for release of contaminants into surface water and groundwater (Jordan and Alessandro, 2004; Younger et al., 2002).

An assessment of the performance of a waste facility needs to consider physical and chemical stability over the entire life-cycle of the facility. A decreasing risk with time, especially after closure has been completed, is desired. For potentially ARD generating waste from the extractive industry the closed facilities need to be physically and chemically stable and provide the adequate protection of the waste for hundreds or even thousands of years.

# 7. The amended Seveso II Directive applied to mining waste facilities

## 7.1 Background

The so-called Seveso accident in 1976 (accident at chemical plant in Seveso, Italy, where the dioxin TCDD was released to the environment) called for the adoption of legislation aimed at the prevention and control of major industrial accidents. In 1982, *the first EU Directive 82/501/EEC (CEC, 1982)* – the so-called Seveso Directive – was adopted. In December 1996, *the Seveso Directive* was replaced by *Council Directive 96/82/EC (CEC, 1996) - the* so-called Seveso II Directive. The Seveso II Directive applies to industrial establishments where dangerous substances are present in quantities exceeding the thresholds given in the directive.

The aim of the Seveso II Directive is two-fold. Firstly, the Directive aims at the *prevention* of major-accident hazards involving dangerous substances. Secondly, as accidents do continue to occur, the Directive aims at the *limitation of the consequences* of such accidents not only for man (*safety and health aspects*) but also for the environment (*environmental aspect*). Both aims should be pursued with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.

In 2003, the Seveso II Directive 96/82/EC was amended by the Directive 2003/105/EC (CEC, 2003). The most important amendments of the scope of that Directive were to include risks arising from storage and processing activities in mining, from pyrotechnic and explosive substances and from the storage of ammonium nitrate and ammonium nitrate based fertilizers. The extension to cover mining activities was at least partly triggered by the Aznalcóllar accident in Spain in 1998 and the Baia Mare accident in Romania in 2000 (CEC, 2000).

The following activities are excluded from the scope of Directive 2003/105/EC:

- "the exploitation (exploration, extraction and processing) of minerals in mines, quarries, or by means of boreholes, with the exception of chemical and thermal processing operations and storage related to those operations which involve dangerous substances, as defined in Annex I" (Art 4 e).
- "waste landfill sites, with the exception of operational tailings disposal facilities including tailing ponds or dams, containing dangerous substances as defined in Annex I, in particular when used in connection with the chemical and thermal processing of minerals" (Art 4 g).

Generally, the amended Seveso II Directive is considered to cover **all** tailings ponds associated with mineral processing **using dangerous substances above certain threshold** regardless of the processing method with which they are associated.

If, based on lists of quantities present at any one time of named dangerous substances, an activity is falling under the Directive 2003/101/EC, the operator will be required to provide specified information on the company, the process and any dangerous substances present, to draw up a major-accident prevention policy and to provide the competent authorities with a safety report, which must be periodically updated. Operators of activities not falling under Directive 2003/105/EC do not have to provide this information, unless it constitutes parts of other requirements.

The Directive is addressed to the Member States, and they were required to bring into force the laws, regulations and administrative provisions necessary to comply with the Directive before 1 July 2005. For countries that have become members of the EU shortly before or after 1 July 2005, the deadline for compliance may possibly be later.

## 7.2 Mining waste facilities falling under the amended Seveso II Directive

One of the objectives of this study has been to identify the mining waste facilities in the EU Member States that are covered by the amendment to the Seveso II directive, and to provide information on substances/categories and quantities involved.

In order to obtain information on mining waste facilities falling under the scope of Directive 2003/103/EC, a multitude of sources associated with the extractive industry have been approached. These sources include:

- Representatives of mining and environmental authorities in EU Member States;
- Representatives of European mining organizations (e.g. Euromines, Eurocoal);
- Representatives of international mining consortiums (e.g. Cleveland Potash);
- Representatives of NGOs involved in legal issues in connection with the amendment of Seveso II Directive (e.g. WWF);
- Representatives of International EU Projects connected to mining in Europe (European Network Mining Regions, ReRegions);
- Several individual mining waste experts (e.g. during the project workshop on 5 March 2007);
- Major Accident Hazards Bureau at JRC, Ispra, and
- Internet sources (e.g. www.tailings.info/minesineurope.htm).

All information obtained from these sources indicates that **no European mining waste facilities have been classified as SEVESO II facilities according to the amended Seveso II Directive**. Many European mine sites are classified as Seveso II sites, but this is generally due to the amount of dangerous substances (e.g. explosives or NaCN) stored for use in the processes, and in no (observed) case because of their waste (tailings) disposal facilities.

However there are some doubts related to the above statement which should be emphasised:

- In the Seveso Plants Reports of each Member State waste facilities covered by Seveso II, most Member States reported their Seveso II plants to Seveso Plants Information Retrieval System (SPIRS by MAHB at JRC, Ispra, Italy) before the amendment, and in the near future they have to update their data. As a consequence, SPIRS, which is accessible for EU Commission, is not the best source of information for identification of mining waste facilities covered by the (amended) Seveso II Directive.
- The amended Seveso II Directive was implemented into Member State law as late as in the middle of 2006. It is possible that actual reports do not include all sites covered by amended Directive.

It should be noted that in the Seveso Plants Reports of the Member States waste facilities covered by the Seveso II Directive are reported simply as “waste treatment” without specific reference to the type of activity or operation with which they are associated. This indicates that the forms to be filled out by the Member States may need to be adjusted to the purpose if the Commission wish to obtain this information specifically for mining waste facilities in the future.

## 7.3 Likely reasons why no mining waste facilities are classified as Seveso II sites

In the Communication on Safe operation of mining activities (Com 2000/664) it was concluded that in terms of industrial risk management, the Seveso II Directive seemed to be the most appropriate legislative tool to prevent major accidents involving **dangerous substances**. It was envisaged to amend the Seveso II Directive to unequivocally include the mineral processing of ores and, in particular, tailings ponds or dams used in connection with such mineral processing of ores. It was pointed out that any such activity would only be covered by the Directive if **dangerous substances** are involved and if they are present in quantities beyond the threshold levels set out in the Directive.

In the amended Seveso II Directive (2003/105/EC) the following statements occur in the recitals:

(3) The cyanide spill that polluted the Danube following the accident at Baia Mare in Romania in January 2000 has demonstrated that certain storage and processing activities in mining, especially tailings disposal facilities, including tailing ponds or dams, have potential to produce very serious consequences. The Commission communications on the safe operation of mining activities and on the sixth environment action programme of the European Community have therefore highlighted the need for an extension of the scope of Directive 96/82/EC. In its resolution of 5 July 2001(5) on the Commission Communication on the safe operation of mining activities, the European Parliament also welcomed the extension of the scope of that Directive to cover risks arising from storage and processing activities in mining.

(4) The proposal for a directive on the management of waste from the extractive industries may be a relevant framework for measures relating to those waste management facilities which present an accident risk but which are not covered by the present Directive.

This means that facilities that are not covered by the Seveso II Directive (i.e. facilities which do not contain dangerous substances above the thresholds but still pose an accident risk) are handled under the MWD. It should be noted that there is an inconsistency between the two directives due to the two tiers as described in Annex I of the Seveso II Directive leading to lower requirements for facilities in the lower tier than for any other types of facilities. This is not easily resolved and further discussion of this exceeds the scope of this study; however, it should be noticed and possibly addressed in any future amendments of either of the directives.

Looking at cyanide, or rather sodium cyanide (NaCN, risk phrase R26, R27, R28), it can be referred to Part II, Annex I of the directive as “Very Toxic”. The threshold values are 5 tonnes (article 6 and 7) and 20 tonnes (article 9). Normally, a mine site where cyanide leaching is performed would classify as a Seveso II site because of the storage of > 5 ton NaCN at the site.

Following recent accidents involving cyanide, there have been a number of international initiatives aiming to improve cyanide management in a global perspective. The most widely known initiative is the International Cyanide Management Code (www.cyanidecode.org) developed in a multi-stakeholder consortium including the mining industry, UNEP etc. The Cyanide Code recommends cyanide concentrations to be limited to < 50 ppm in tailings ponds. After the Baia Mare accident, there are no European mine sites that discharge cyanide leach solutions directly to the tailings ponds. All operating sites in Europe use cyanide destruction plants, reducing the CN concentration in the discharge to the tailings pond to very low concentrations, in the range of 1 ppm. In the tailings pond the remaining CN concentrations are further reduced by natural processes (degradation, dilution, etc).

The MWD (Directive 2004/35/EC) regulates the maximum allowed cyanide (weak acid dissociable cyanide) concentration in tailings ponds (article 13(6)) to the lowest possible level using best available techniques and, in any case, not exceeding 50 ppm as from 1 May 2008, 25 ppm as from 1 May 2013, 10 ppm as from 1 May 2018, and 10 ppm at waste facilities which are granted a permit after 1 May 2008.

Assuming a concentration of 1 ppm CN, this means that a volume of at least 5 $Mm^3$ of free water is required in the tailings pond to meet the lower threshold. This is a considerable water volume which is not stored at any of the sites where cyanide leaching is used in Europe. This is assuming that the 1 ppm solution is regarded as “very toxic”. It is a question whether a substance that is present in concentrations far below the lowest concentration which would cause a classification as a dangerous substance (for CN this concentration is 0.1 %) would actually have to be considered under the amended Seveso II Directive.

If heap leaching (with cyanide) was to be used somewhere in Europe, the heap leach and related ponds would most likely exceed the threshold for a SEVESO II site. However, during operation such facilities would not necessarily be classified as waste facilities.

There are possibly other dangerous substances present in some tailings ponds, such as $CuSO_4$. This means that an evaluation needs to be done using the summation rule:

$q_1/Q+q_2/Q+q_3/Q+q_4/Q+q_5/Q+....<1$

where

$q_x$ = the quantity of dangerous substances x (or category of dangerous substances) falling within Parts 1 or 2 of Annex I,

Q = the relevant threshold quantity from Parts 1 or 2 related to the specific substance.

Where this calculation has been performed in detail, e.g., the proposed 220 ha tailings pond "Hötjärnsmagasinet" in the Skellefteå area in Northern Sweden, there is no tailings pond that according to the knowledge of the project team has reached the threshold adding the contributions for the various dangerous substances contained in the pond.

It thus seems that the amendments of the Seveso II Directive and the increased international awareness have already achieved the desired results – the extractive industries have changed their management procedures. Apparently, the initiatives have resulted in even better results than anticipated.

# 8. Proposed methodology

## 8.1 Introduction

A mining waste facility shall be classified as Category A or not Category A in relation to:

a) Failure - due to loss of structural integrity or incorrect operation – that could give rise to a major accident[9]
b) The content of hazardous waste
c) The content of dangerous substances

When classifying a mining waste facility, all three issues should be considered. If a facility is classified under Category A according to any one of the above listed issues, then the overall classification of the facility is Category A, and it is not necessary to consider the other two issues further. If none of the issues lead to a Category A classification, then the overall classification of the facility is not Category A. The procedure for classification of mining waste facilities according to each issue is described in the following.

The procedure is aiming only to establish the classification of the facility – it is not the intention to explore the potential consequences in great detail nor to perform any detailed Environmental Impact Assessments. The procedure should be based on realistic conditions and/or scenarios.

For facilities containing only inert waste or unpolluted soil, only the first part of the first indent (failure due to loss of structural integrity) is relevant. For facilities containing predominantly hazardous waste the second indent will directly lead to the classification of the facility as "Category A".

The potential hazard constituted by a mining waste facility may change significantly between operation and closure. Therefore, a review of the classification should be undertaken, if not before, at the end of the operational period of a facility.

## 8.2 a): Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation

If a failure, due to loss of structural integrity[10], of a waste facility, regardless of the type of facility, can in the short- or long-term lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A.

Similarly, if incorrect operation of a facility could in the short- or long-term lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A.

The consideration of **loss of structural integrity** is intended to include all possible failure mechanisms relevant to the structures covered in the short or the long-term. This may for example be malfunction of decanting system, over-topping, internal erosion, settlements, slides, liquefaction, construction weakness, failure in the underground, seismic activity, etc.

[9] **Major accident** means an occurrence on site in the course of an operation involving the management of extractive waste in any waste facility, leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site.

[10] Structural integrity: The ability of the facility to contain the waste within the boundaries of the facility in the manner for which it was designed.

In the same way, the consideration of **incorrect operation** is intended to include all possible mechanisms that could give rise to a major accident, including malfunction of environmental protection measures and faulty or insufficient design. Incorrect operation could occur during the entire life-cycle of the facility and is likely to pose a significant hazard potential also in the after-closure phase, when e.g. back-pumping, water treatment etc. are likely not to function, bathtub effects may occur, acid and alkaline drainage may develop, covers or liners may not have the intended effect or may become deficient, etc. Examples of environmental protection measures that may fail and lead to incorrect operation are shown in table 8,1. Incorrect operation could, of course, also lead to a failure due to loss of structural integrity, but that has been covered above.

***Table 8.1***

*Some examples of the most common environmental protection measures, their purpose and potential effects caused by incorrect operation.*

| Environmental protection measure | Purpose of measure | Potential effect of incorrect operation |
|---|---|---|
| Bottom liners, drainage and leachate collection (ditches or wells) and treatment systems<br><br>Most relevant to the operation period | Leachate collected and treated before discharged | All leachate leaks to the environment – or the leachate is not treated before discharge (long-term situation) |
| Dry top cover to reduce the rate of infiltration<br><br>Most relevant to the after-closure period | Reduces the flux of contaminants but prolongs the leaching period | Does not function and allows up to 100 % of general infiltration, depending on the conditions |
| Dry top cover to minimise influx of oxygen<br><br>Most relevant to the after-closure period | Prevents/reduces oxidation of potentially ARD generating waste and other reactive waste (also used to prevent self-ignition) | Does not function/is disrupted and allows oxidation of potentially ARD generating waste and other reactive waste |
| Wet covers (under water storage) to prevent oxidation<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces oxidation of potentially ARD generating waste and other reactive waste | Does not function – dries out or is diverted and allows oxidation of potentially ARD generating waste and other reactive waste |
| Selective management (e.g. segregation of different (incompatible) types of waste)<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces undesired waste/waste interactions (e.g. acidification of non-acidic waste from ARD producing waste) | Incompatible types of waste are mixed/landfilled together an causes an increased level of contamination |
| Compaction<br><br>Relevant both to the operation and the aftercare period | Minimise oxygen transport into potentially ARD generating waste or self-igniting waste | Compaction does not have the intended effect and does not reduce oxygen transport to the desired levels |
| Treatment of leachate or waste<br><br>Most relevant to the operation period | Minimise contaminant release in discharged water from the facility | Treatment is interrupted and discharge contain elevated levels of contaminants |
| Back-pumping<br><br>Most relevant to the operation period | Leakage/drainage from the facility is back-pumped to the facility to minimise contaminant transport to the environment | Back-pumping is in-effective or interrupted |

A facility is classified as a Category A facility if the consequences (in terms of impact on human health and impact on the environment) of a failure due to loss of its structural integrity or due to incorrect operation exceed the criteria listed in table 8.2 and table 8.3, respectively. The procedure applies to all facilities.

***Table 8.2***
*Classification with regard to loss-of-life or danger to human health.*

| Category | Consequence |
|---|---|
| A | Non-negligible potential for loss-of-lives or serious danger to human health |
| Not A | Negligible potential for loss-of-lives or serious danger to human health |

***Table 8.3***
*Classification with regard to potential for environmental impact.*

| Category | Consequence |
|---|---|
| A | Non-negligible potential for serious environmental impact |
| Not A | Negligible potential for serious environmental impact |

The potential for loss-of-lives or serious danger to human health is considered non-negligible if people that might be affected are staying permanently or for prolonged periods in the potentially affected area. It does not refer to workers in the extractive industry operating the facility in question as their safety is covered by other Community legislation, in particular Directives 92/91/EEC and 92/104/EEC.

In the case of **loss of structural integrity** for tailings dams, it is assumed that human lives are threatened at water/slurry levels of 0.7 m above ground and water/slurry velocities exceeding 0.5 m/s. In assessing the potential for loss-of-lives and serious danger to human health, the following factors should be considered and, if relevant, accounted for:

- The size and properties of the facility
- The quantity and quality of the waste in the facility
- The topography, including damping features such as, e.g., lakes
- The travel time of the flood-wave to areas where people stay
- The propagation velocity of the flood-wave
- The water or slurry level
- The rising rate of water or slurry levels

Please note that the list is not exhaustive – any relevant, site-specific factors that may influence the potential for loss-of-lives or serious danger to human health must also be taken into account.

For waste heap slides it is assumed that any waste-mass in movement is likely to threaten human lives if people are staying within range of the moving waste-mass. The following factors may be relevant (list not exhaustive):

- The size and properties of the facility
- The quantity and quality of the waste in the facility
- Slope angle of heap
- Potential to build up internal groundwater within the heap

- Underground stability
- Topography
- Proximity to water courses, constructions, buildings, etc
- Mine workings

Injuries leading to disability or prolonged states of ill-health count as serious dangers to human health.

The classification procedure related to loss of the structural integrity shall consider both the immediate impact of any materials transported out of the facility as a consequence of the failure (e.g., tailings slurry, rock, contaminated and/or uncontaminated water) and the resulting short, medium and long-term effects (e.g., contamination of soil and water bodies, loss of animal life, destruction of habitats, etc). The entire life-cycle of the facility needs to be considered in the evaluation of the hazard potential of the facility.

The potential for serious environmental impact of a failure due to loss of structural integrity or incorrect operation is considered negligible if:

- the potential contaminant source strength is decreasing significantly with time,
- if the affected environment can be restored with limited clean-up and restoration efforts[11], and
- if the environment does not suffer any permanent or long-lasting damage.

Examples of permanent or long-lasting damage to the environment are:

- residual soil contamination leading to restrictions in land-use, risk to human health or ecological risk;
- permanent (more than 10 years) restrictions in the use of surface water or groundwater;
- lasting period of chronically toxic concentrations of contaminants in surface water;
- short period of acutely toxic concentrations of contaminants in surface water if there is risk for irreversible damage to the affected ecosystem.

An assessment of the release of contaminants with regard to incorrect operation shall take into account both the effects of short-term pulses and long-term release of contaminants and shall be carried out for two periods of time, namely:

a): The operational period of the facility;
b): The long-term period following closure.

In this assessment special consideration should be given to the potential hazards constituted by facilities containing reactive waste, regardless of the classification of the waste as hazardous or non-hazardous under Directive 91/689/EEC, e.g. waste the may produce acid drainage (ARD), waste that may produce neutral or alkaline drainage with high contents of potential contaminants, and waste that may self-ignite if exposed to air.

In establishing the potential for loss-of-life or serious danger to human health and serious environmental impact, specific evaluations of the extent of the potential impacts shall be considered in the context of the source – pathway - receptor chain. If there is no pathway between the source and the receptor, then the facility cannot be classified under Category A due to failure caused by loss of structural integrity or incorrect operation.

[11] In the assessment, clean-up efforts can be assumed to take place during the operational period of the facility, however, after closure of the facility clean-up can not be taken for granted and should therefore not be included in the assessment for the long-term phase.

## 8.3 b): Classification based on the content of hazardous waste

A mining waste facility is classified as a Category A facility if it contains more than a certain percentage of **hazardous waste**. The classification according to the content of hazardous waste proceeds in two steps.

In **step 1** it shall be determined if any of the waste streams discharged into the facility are hazardous according to the European Waste Catalogue[12] (EWC) and the associated procedures. A waste stream is classified as hazardous:

- If it has an "absolute entry" in the EWC (only entry 01 03 04: acid-generating tailings from processing of sulphide ore). Such tailings are considered acid generating if the ratio NP/AP between the neutralisation potential (NP) and the acidity production potential (AP) as determined by the procedure to be developed by CEN/TC 292/WG8 is < 1. For 1< NP/AP < 3, further evaluation, e.g. using a kinetic test may be necessary to determine if the waste should be considered ARD producing or not. For NP/AP > 3, the waste is considered non- acid generating.

- If it has a mirror entry (this is the case for 01 03 05, 01 03 07 and 01 04 07), and dangerous substances are present above threshold concentrations. Whether or not this is the case is determined using the results of the waste characterisation carried out according to Annex II to the MWD and checking the content of various substances against the thresholds defined by the hazard properties (H1-H14) in Annex III to Directive )1/689/EEC and the risk phases defined in Directive 2001/59/EC). Some guidance concerning relevant H-properties is available, e.g. from the UK Environment Agency.

- If a national authority has determined that it should be classified as hazardous waste.

If none of the waste streams received by the facility consist of hazardous waste, then the facility shall not be classified as a Category A facility based on its content of hazardous waste, and step 2 shall not be carried out.

If one or more waste streams have been identified as hazardous, then step 2 shall be carried out.

In **step 2** the total amount (as weight) of hazardous waste expected to be present in the facility at the end of the planned period of operation (A) shall be determined (on a dry matter basis).

The total amount (as weight) of waste expected to be present in the facility at the end of the planned period of operation (B) shall be determined (on a dry matter basis).

The ratio A/B shall be determined and compared to the limit value for the total content of hazardous waste.

Three alternatives could be considered for this comparison:[13]

**Alternative 1:**

If the weight percentage (A/B) of waste in a mining waste facility classified as hazardous exceeds X % (e.g. 5 %) (including ARD producing tailings from the processing of sulphide ore), then that facility shall be classified as a Category A facility.

**Alternative 2:**

- If more than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste then the facility is classified as Category A.

[12] Directive 91/689/EEC and subsequent amendments.

[13] These alternatives are meant as inspiration for the Commission and/or the TAC to choose only one of them to be included in the final methodology. Similarly values for "X" and (in alternatives 2 and 3) "Y" must be chosen.

- If less than Y % (e.g. 50%) but more than X % (e.g. 5 %) of the deposited waste streams to the facility is hazardous waste then a site specific risk assessment with specific focus on the effects of the hazardous waste shall be performed (as part of the classification based on the consequences of failure due loss of integrity or incorrect operation).

- If less than X % (e.g. 5%) of the deposited waste stream to the facility is hazardous waste then the facility is classified as not Category A based on content of hazardous waste.

**Alternative 3:**

- If more than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste then the facility is classified as Category A.

- If less than Y % (e.g. 50 %) of the deposited waste streams to the facility is classified as hazardous waste, then the facility is not classified as Category A based on content of hazardous waste. A content of hazardous waste must be taken into account in the classification based on the consequences of failure due loss of integrity or incorrect operation.

## 8.4 c): Classification based on the content of dangerous substances/preparations

A mining waste facility shall be classified as a Category A facility if it contains substances or preparations (i.e. additives or reaction products) in sufficient quantities for them to be classified as **dangerous** according to Directives 67/548/EC and 199/45/EC and subsequent amendments.

**Planned facilities (tailings ponds):**

The following stepwise procedure shall be followed for planned facilities (tailings ponds):

6. Produce an inventory of the substances and preparations used in the processing and subsequently discharged with the tailings slurry to the tailings pond (identity and mass/year). The inventory shall be based on the maximum amounts of each substance used during one year.

7. Calculate the average yearly increase in stored water within the tailings pond under steady state conditions, $\Delta Q$. This is assumed to correspond to the pore water present in the tailings deposited during one year, and shall be calculated from the mass of tailings (tonnes dry weight/year) discharged to pond, the average dry bulk density of the deposited tailings (tonnes/$m^3$) and the pore volume of the sedimented tailings ($m^3/m^3$). If exact data are not available, default values of 1.4 t/$m^3$ for the dry bulk density and 0.5 for the pore volume may be used.

8. For each substance in the inventory produced under point 1, determine whether or not it is a dangerous substance according to Annex I in Directive 67/548/EC (or, if necessary, Annex VI). Determine the limit values associated with each danger (R) category.

9. Using the information obtained under point 3, the mass/year of each substance discharged into the pond determined under point 1 and the yearly increase in pore water volume calculated under point 2, use the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous substance.

10. If the aqueous phase is a dangerous preparation as determined under point 4, then the facility should be classified as a Category A facility. If it is not classified as a dangerous preparation, then the facility is not classified as a Category A facility based on content of dangerous substances/preparations.

This procedure is relatively conservative and does not account for reactions that may reduce the level of concentration of dangerous substances/preparations in the water phase (degradation, adsorption to the solid phase) nor does it account for treatment/destruction processes that may be applied before discharging the tailings into the facility (e.g., CN destruction, neutralisation, oxidation). Dilution in the facility is also neglected. If necessary, this may be taken into account in a more sophisticated estimation using, e.g., normal treatment results, water balance calculations and/or compartmentation and degradation modelling and including the solid phase in the calculation of concentrations. Also, if with time, the concentrations fall below the threshold, the facility could be reclassified.

**Operating facilities (tailings ponds):**
For operating facilities, the classification may be based upon the described calculations, or it may be based on direct chemical analysis of the water (and solids) contained in the facility followed by use of the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous preparation. If it does, the facility shall be classified as a Category A facility.

**Heaps and heap leaching:**
Classification according to content of dangerous preparations has little or no relevance for waste heaps. Heap leach facilities are not regarded as waste heaps during operation. At closure they are normally washed out to minimise the content of any remaining leach solution. A screening for dangerous substances can be made based on an inventory of used leach chemicals and the residual concentrations of these leach chemicals in the drainage after washing has been finalised.

## 8.5 Examples

In Appendix 6 the proposed methodology has been applied to a number of mining waste facilities.

# 9. Literature

## 9.1 Literature referenced

Adamson, 2007: Personal communication with Mihkel Adamson, Ministry of the Environment Estonia, March, 2007.

Alén, C., Bengtsson, P.-E., Berggren, B., Johansson, L. and Johansson, Å., 2000. Skredriskanalys i Göta älvdalen - Metodbeskrivning. Rapport 58, Swedish Geotechnical Institute, Linköping, Sweden.

Artherbeger, M., 2007. Personal communication with Ms. Maria Artherbeger, Ministry of Housing, Spatial Planning and Environment, Hague, the Netherlands.

Asante-Duah, K., 1998. Risk Assessment in Environmental Management. A Guide for Managing Chemical Contamination Problems. John Wiley & Sons, Chichester.

Aven, T. and Kvaløy, J.T., 2002. Implementing the Bayesian paradigm in risk analysis. Reliability Engineering & System Safety, 78(2): 195-201.

Australian Government, Department of Tourism Industry and Resources, 2007. Leading Practice Sustainable Development Program for the Mining Industry: Tailings Management, February 2007.

Barnard, R.W, M.L. Wilson, H.A. Dockery, J.H. Gauthier, P.G. Kaplan, R.R. Eaton, F.W. Bingham and T.H. Robey, 1992. TSPA 1991: An initial total system performance assessment for Yucca Mountain, SAND91-2795, Sandia National Laboratories, Albuquerque, New Mexico.

Bernhart, 2007. Personal communication with Wolfram Bernhart, Austria.

Bida J., 2007. UEPG. Personal communication.

Billaud, 2007: Personal communication with Pier Billaud, BRGM, France, December 2007.

Braastad, 2007, Personal communication, with Grethe Braastad, Norwegian Environmental Pollution Agency, April 2007.

BRGM, 2001. Management of mining, quarrying and ore-processing waste in the European union. BRGM/RP-50319-FR.

Bulgarian Ministry of Environment, 2007: Personal communication with Svetlana Zhekova, Ministry of Environment, Bulgaria, March 2007.

Cadden, 2007. Personal communication with Alister Cadden, Golder Associates UK,Personal communication, 2007).

Cambridge M., 2003. The future of tailings disposal in Europe. Minerals & Energy 2003, 4: 16-24.

Cambridge, 2007: Personal communication with Mike Cambridge, Cantab Consulting, UK, April, 2007.

Cambridge M.,2007. Risk assessment and classification of dams, Presentation at the Workshop on the development of a system for classfication of mining waste facilities, Brussels, March 5

Castro M., 2007. Environmental Manager at the Rio Narcea Aguablanca mine. Personal communication.

Christensen, 2007: Personal communication with Ditte Christensen, Skov- og Naturstyrelsen, Denmark, April 2007.

Clayton, C.R.I., 2001. Managing geotechnical risk. Improving productivity in UK building and construction. Thomas Telford Publishing, London, 80 pp.

Covello, V.T. and Merkhofer, M.W., 1993. Risk Assessment Methods: Approaches for Assessing Health and Environmental Risks. Plenum Press, New York.

Cranwell, R.M., R.W. Guzowski, J.E. Campbell, N.R. Ortiz, 1990. Risk Methodology for geologic disposal of radioactive waste – scenario selection procedure, NUREG/CR-1667, SAND80-1429, Sandia National Laboratories, Albuquerque, New Mexico.

Davies, J.C. (Editor), 1996. Comparing Environmental Risks: Tools for Setting the Government Priorities. Resources for the future, Washington D.C.

Davis, D.R., Kisiel, C.C. and Duckstein, L., 1972. Bayesian Decision Theory Applied to Design in Hydrology. Water Resources Research, 8(1): 33-41.

EEA, 1998. Environmental risk assessment - approaches, experiences and information sources. Environmental Issues Series No 4, European Environmental Agency, Copenhagen.

Eriksson N. and Adamek P., 2000. The tailings pond failure at the Aznalcóllar mine, Spain. Proceedings to Sixth International Symposium in Environmental Issues and Waste Management in Energy and Mineral Production, Calgary, Alberta, Canada, 30 May – June 2.

EU, 2004. BAT Reference document on the management of tailings and waste-rock.

Faber, M.H. and Stewart, M.G., 2003. Risk assessment for civil engineering facilities: critical overview and discussion. Reliability Engineering & System Safety, 80(2): 173-184.

Fanfani, 2007: Personal Communication with Prof. Luca Fanfani, Università di Cagliari, Italy, March 2007.

Felter, S.P., Dourson, M.L. and Patterson, J., 1998. Assessing Risks to Human Health from Chemicals in the Environment. In: P. Calow (Editor), Handbook of Environmental Risk Assessment and Management. Blackwell Science, Great Britain, pp. 9-23.

Ferguson, C. et al. (Editors), 1998. Risk Assessment for Contaminated Sites in Europe. Volume 1. Scientific Basis. LQM Press, Nottingham, 165 pp.

Freeze, R.A., Bruce, J., Massman, J., Sperling, T. and Smith, L., 1992. Hydrogeological Decision Analysis: 4. The Concept of Data Worth and Its Use in the Development of Site Investigation Strategies. Ground Water, 30(4): 574-588.

Fällman, 2007: Personal communication with Ann-Marie Fällman, Swedish Environmental Pollution Agency, April, 2007

GEO HK, 2004. http://www.cedd.gov.hk/eng/publications/information_notes/doc/in_2004_09e.pdf, (access date 2006-12-07).

Gronow J., 2007. The development of waste acceptance criteria for the landfill directive. Presentation at the Workshop on the development of a system for classfication of mining waste facilities, Brussels, March 5.

Grosser, P.W. and Goodman, A.S., 1985. Determination of groundwater sampling frequencies through Bayesian decision theory. Civil Engineering Systems, 2(4): 186-194.

GRUVRIDAS, 2006 Gruvföretagens riktlinjer för dammsäkerhet, (in Swedish) preliminary document 2006-09-11 provided by Lindahl L-Å.

Gutiérrez del Olmo, 2007. Personal communication, with Arturo Gutiérrez del Olmo, Golder Associates, Spain, April 2007

Gutiérrez del Olmo, A., 2007. Risk assessment for the mining industry. Presentation at the Workshop on the development of a system for classfication of mining waste facilities, Brussels, March 5.

Hansson, S.-O., 1991. An Overview of Decision Theory. SKN Report 41, Statens Kärnbränslenämnd, Stockholm, Sweden.

Hansson, S.-O., 1993. The False Promises of Risk Analysis. Ratio (New Series), 6(1): 16-26.

Hansson, S.-O., 1996. What is philosophy of risk? Theoria, 62: 169-186.

Hjelmar, O., Holm, J., Hansen, J.G. and Dahlstrøm, K., 2005. The European criteria for acceptance of waste at landfills: Implementation of Council Decision 2003/33/EC in Denmark, The 1st International on Engineering for Waste Treatment, WasteEng 05, May 17-19, 2005, Albi, France.

Hjelmar, O. et al., 2001. Development of acceptance criteria for landfilling of waste: An approach based on impact modelling and scenario calculations. . In: T.H. Christensen, R. Cossu and R. Stegmann (Editors), Sardinia 2001, The Eight International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, CISA, pp. 712-721.

Höglund L. O. and Herbert R. (Editors), Lövgren L., Öhlander B., Neretnieks I., Moreno L., Malmström M., Elander P., Lindvall M., Lindström B. (2004): MiMi – Performance Assessment – Main report. MiMi Report 2003:3. ISSN 1403-9478, ISBN 91-89350-27-8.

Höglund L. O., 2007. Risk assessment in the nuclear industry - focus on waste management and classification, Presentation at the Workshop on the development of a system for classfication of mining waste facilities, Brussels, March 5.

Jordan G. and Alessandro M. D'., (eds), 2004: Mining, mining waste and related environmental issues: problems and solutions in Central and Eastern European Candidate Countries – Joint Research Centre of the European Commission, Ispra,EUR 20868 EN, ISBN 92-894-4935-7, 208 p.

Juroszek, 2007: Personal communication, with Theodor Juroszek, Federal Ministry of Economics and Technology, Germany, April 2007

Kassaris 2007. Personal communication with Costas Kassaris, Environmental Manager at S&B Industrial Minerals, Kiffisia, Greece, December 2007.

Korving, H. and Clemens, F., 2002. Bayesian decision analysis as a tool for defining monitoring needs in the field of effects of CSOs on receiving waters. Water Science and Technology, 45(3): 175-184.

Kjær, 2007: Personal communication, with Ole Fjordgaard Kjær, Natural Resource Com., Greenland, April 2007,

Marin, C.M., Medina, M.A., Jr. and Butcher, J.B., 1989. Monte Carlo analysis and Bayesian decision theory for assessing the effects of waste sites on groundwater, I: Theory. Journal of Contaminant Hydrology(5): 1-13.

Leduc M. and Smith E., 2007. Tailings Co –Disposal Innovations for Cost Savings and Liability Reduction. (published at www.vectoreng.com).

JRC, 2002: Legislation on mining waste management in central and eastern European candidate countries. A report of the JRC Enlargement project. European Commission, EUR 20545 EN.

Madai, 2007: Personal communication, with Dr. Ferenc Madai,, University of Miskolc, Hungary, March 2007.

ME BCC, 2007. http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/downstream_guide.html, (access date 2006-12-07).

(The) Mining Association of Canada (MAC), 1998. A Guide to the Management of Tailings Facilities.

Motherway, 2007: Personal communication with Kevin Motherway, Environmental Protection Agency, Cork, Ireland , April 2007.

Naworyta, 2007: Personal communication, with Wojciech Naworyta, AGH University of Science and Technology, Krakow, Poland , April 2007.

Nilsen, T. and Aven, T., 2003. Models and model uncertainty in the context of risk analysis. Reliability Engineering & System Safety, 79(3): 309-317.

Nicoletopoulos (2007). Personal communication, with Vasili Nicoletopoulos, Natural Resources GP, Athens, Greece , December 2007.

NM Mining Act, 1996: New Mexico Mining Act of April 2006.

NRC, 1996. Understanding Risk. Informing Decisions in a Democratic Society. National Academy Press, Washington D.C.

Otte, P.F, M. van Elswijk, M. Bleijenberg, F. Swartjes en C. van de Guchte (2000). Calculation of human risk limits voor sediments; Discussion report (in Dutch) (RIZA-werkdocument 2000.084). Bilthoven/Lelystad, NL.

Potvin, Y, Thomas, EG & Fourie, AB (eds.) 2005, Handbook on Mine Fill, Australian Centre for Geomechanics, Perth, Australia.

Provoost J., C. Cornelis, F. Swartjes (2006) Comparison of soil clean-up standards for trace elements between countries: Why do they differ?, J. Soils Sediments, 6(3), 173-181.

Rosén, L. and Hammar, T., 2004. Risk reducing measures. Chalmers University of Technology and Kalmar läns county administration, pp. Personal communication.

Räddningsverket, 2003. Handbok för riskanalys, Swedish Rescue Agency, Karlstad, Sweden.

Rutqvist J., 2007. Boliden Aitik Mine, Personal communication.

SEPA, 1996. Development of Generic Guideline Values. Model and Data Used for Generic Guideline Values for Contaminated Soils in Sweden. Report 4639, Swedish Environmental Protection Agency, Stockholm, Sweden.

SEPA, 1999. Methodology for Inventory of Contaminated Sites. Basis for Assessment of Contaminated Sites. Guidance for Collections of Data. Report 4918 (*In Swedish*), Swedish Environmental Protection Agency, Stockholm, Sweden.

Smrchek, J.C. and Zeeman, M.G., 1998. Assessing risks to exological systems from chemicals. In: P. Calow (Editor), Handbook of environmental risk assessment and management. Blackwell Science, Great Britain, pp. 24-90.

Swedenergy AB, 2002. RIDAS - Kraftföretagens riktlinjer för dammsäkerhet, Svensk Energi - Swedenergy - AB, Stockholm, Sweden.

UNEP/ International Committee on Large Dams (ICOLD), 1996. Bulletin 106, A Guide to Tailings Dams and Impoundments-design, construction, use and rehabilitation, ISBN: 92-807-1590-7.

UNEP/ International Committee on Large Dams (ICOLD), 2001. Bulletin 121, TAILINGS DAMS: RISK OF DANGEROUS OCCURRENCES - Lessons learnt from practical experiences, ISBN: 92-807-2053-8.

Vanbelle, 2007. Personal communication with Jean-Marc Vanbelle, Gralex, Bruxelles, Belgium.

UK Environment Agency, 2005a. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix A: Consolidated European Waste Catalogue. Environment Agency, Bristol, UK.

UK Environment Agency, 2005b. What is a Hazardous Waste? HWR01. Environment Agency, Bristol, UK.

UK Environment Agency, 2005c. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix B: Wases and Potential Hazards for Absolute and Mirror Entries in the European Waste Catalogue. Environment Agency, Bristol, UK.

US EPA, 1988. Superfund Exposure Assessment Manual. EPA/540/1-881001, OSWER Directive 9285.5-1, April 1988, Office of Remedial Response, US EPA, Washington, DC.

US EPA, 1989. Risk Assessment for Superfund. Volume I: Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002, December 1989, Office of Emergency and Remedial Response, US EPA, Washington, DC.

US EPA, 1991a. Risk Assessment for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). Interim EPA/540/R-92/003, Publication 9285.7-01 B, December 1991, Office of Research and Development, US EPA, Washington, DC.

US EPA, 1991b. Risk Assessment for Superfund: Volume I - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives). Interim EPA/540/R-92/003, Publication 9285.7-01 C, December 1991, Office of Research and Development, US EPA, Washington, DC.

US EPA, 1996a. Soil Screening Guidance: Fact Sheet. EPA/540/F-95/041, July 1996, Office of Emergency and Remedial Response, US EPA, Washington, DC.

US EPA, 1996b. Soil Screening Guidance: Technical Background Document. EPA/540/R95/128, Publication 9355.4-17A, May 1996, Office of Solid Waste and Emergency Response, US EPA, Washington, DC.

US EPA, 1996c. Soil Screening Guidance: User's Guide. EPA/540/R-96/018, Publication 9355.4-23, July 1996, Office of Solid Waste and Emergency Response, US EPA, Washington, DC.

US EPA, 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. EPA 540-R-97-006, OSWER 9285.7-25, PB97-963211, June 1997, Solid Waste and Emergency Response, US EPA, Washington, DC.

US EPA, 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F, April 1998, US EPA, Washington, DC.

US EPA, 1999. Issuance of Final Guidance: Ecological Risk Assessment and Risk management Principles for Superfund Sites. OSWER Directive 9285.7-28 P, October 1999, Solid Waste and Emergency Response, US EPA, Washington, DC.

US EPA, 2003. Framework for Cumulative Risk Assessment. EPA/630/P-02/001F, May 2003, Risk Assessment Forum, US EPA, Washington, DC.

US EPA, 2005. Guidelines for Carcinogen Risk Assessment. EPA/630/P-03/001F, March 2005, Risk Assessment Forum, US EPA, Washington, DC.

Van den Berg, R. (1995). Exposure of man to soil contamination. A qualitative and quantitative analysis, resulting in proposals for human-toxicological C values. RIVM, Bilthoven, Revised version of RIVM report 725201011.

Varis, O., 1997. Bayesian decision analysis for environmental and resource management. Environmental Modelling & Software, 12(2-3): 177-185.

Vlad, 2007: Personal Communication with Professor Serban Vlad, Universitatea Ecologica Bucuresti, Romania, March, 2007.

VROM, 1994. Ministerial Circular on second phase remediation paragraph, Soil Protection. Act. Reference DBO/16d94001.

Younger, P.L., Banwart S.A. and Hedin, R.S, 2002. Mine Water; Hydrology, Pollution, Remediation. Kluwer Academic Publishers, Dordrecht.

## 9.2 EU Directives and other EU/Commission documents

Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative procedures relating to classification, packaging and labelling of dangerous substances.

Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (the Seveso II Directive).

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

Directive 1999/45/EC of the European Parliament and of the Council of 31 May 1999 concerning the approximation of laws, regulations and administrative provisions of the Member States relating to classification, packaging and labelling of dangerous preparations.

European Waste Catalogue EWC, Commission Decision 2000/532/EC of 3 May 2000 with amendments).

Commission Directive 2001/59/EC adapting to technical progress for the 28th time Council Directive 67/548/ EEC on the approximation of laws, regulations and administrative procedures relating to classification, packaging and labelling of dangerous substances.

Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC.

Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances.

Directive 2006/21/EC of the European Parliament and of the Council of 15 march 2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC (the Mining Waste Directive).

## 9.3 Relevant web-sites

http://euracoal.be

www.euromines.org

www.tailingsinfo.com

www.tailsafe.com

http://www.usgs.gov

http://viso.jrc.it/pecomines_ext/main.html

# Appendix 1

## Notes from the workshop with experts held in Brussels on 5 March 2007

# Notes from workshop on the development of a system for classification of mining waste facilities held on March 5th, 2007, in Brussels

Welcome and introduction by **Fotios Papoulias**, DG Environment.

**Ole Hjelmar**, DHI Water·Environment·Health, presented the project and outlined the work of the project team. The general method for classification was described and summarised in a flowchart.

The discussion that followed focused on whether potential for (acid rock drainage) ARD production is a category A criteria. And the following questions were asked:

- How to handle the situation if only a small portion of the waste in a facility is ARD producing?
- Should ARD production be considered an ”accident” or a result of bad management?
- Shouldn't the focus be on the facility/scenario and not on the waste characteristics such as ARD?

**Lars-Olof Höglund**, Kemakta Konsult AB, presented the work done in Sweden to assess the risk of final storage of nuclear waste.

Nuclear waste may be classified into three categories (low, medium and high radioactivity) and different options exist for the final storage of the different waste categories. The basic strategy to assess the risk of final storage includes:

- Identification of important properties for classification: Origin, criticality, radiological, physical, chemical and biological characteristics.
- A break down of the system into subsystems: Waste, near field, geo sphere
- Incremental process of developing final storage facility (a ten step performance analysis (PA), safety analysis (SA)) (SKB, 1996) including:

- Basic safety functions:
    - Canister
    - Buffer (favourable chemical, mechanical environment for the canister, limit transport)
    - Rock (favourable environment for the canister and buffer, limit advective transport)
- Definition of safety functions indicators.
- Safety assessment scenarios reflecting changes in external conditions
- Selection of scenarios:
    - Main scenario: expected evolution of the repository system
    - Less probable scenario: includes alternative sequence of events to the main scenario and also the effects of additional events
    - Residual scenarios

**George J. Stalter**, Concawe, presented the work by CONCAWE on risk assessment in the petroleum industry.

Report 3/03 available at www.concawe.org

General problem: So many facilities that it is difficult to manage them in the same way.

Oil industry approach to manage ground water contamination:

- Proc-active
- Site specific
- Risk based, first check if a risk exists and if there is a link: Source – transport & exposure pathways – receptor.

- Sites prioritised based on vulnerable receptors. Sensitivity category based on:
  - Aquifer type
  - Source protection zones
  - Groundwater sensitivity
  - Surface water sensitivity
  - Ecological sensitivity

GIS based screening system has been developed that allow superposition of sites, hydrogeology, source protection zones, surface water sensitivity, ecological sensitivity.

Methodology will be published.

**Arturo Gutierrez del Olmo**, Golder Associates, presented a general scheme for risk assessment in the mining industry. It is clear that risk assessment is different for the different phases in the life cycle of a mining operation.

Arturo Gutierrez stressed that:

- Tailings are very different if comparing different sites/plants – and often also within the same mine.
- Risk assessment is only used for downstream effects.
- Risk communication is important.
- The suggested flow scheme for classification will imply that all facilities at metal mines will be classified as category A.

**Mike Cambridge**, Cantab Consulting (Kent) Ltd., presented information on and experiences with risk assessment and classification of dams and reservoirs.

Risk assessment:

- Hazard identified at each stage
- Failure identification
- Identification of failure consequences

Risk assessment should be a continuous process – not static! Important that the risk assessment is reviewed and updated to take changes in extreme event analyses, catchment characteristics, etc into account.

Risk categorisation: Natural (seismic event, flood), external (war, sabotage), internal (instability, operational fault). The highest hazard potential for a dam is likely to result from an extreme hydrological or seismic event outside the control of the designer or operator.

International Commission On Large Dams ICOLD (www.cold-cigb.org): International body responsible for communication of design standards and best practice. Guidelines are written up nationally.

Internationally, the dams are classified in accordance with the consequence of failure. There are several systems for defining a severe consequence, but commonly the assessment is related to loss of lives.

Reference: Interim guide to quantitative risk assessment for UK reservoirs.

**Lars Olof Höglund**, Kemakta Konsult AB, presented the Swedish project: Mitigation of environmental impact from mining waste (MiMi).

Objectives of MiMi:

- Safe methods for remediation of mining waste.
- Reliable assessment of the long term performance.
- Input to policy making.

General strategy for management of mining waste: Looking for front-end solutions and using a Performance Assessment Methodology.

A systematic approach is necessary and systematic solutions possible where components work together. For example, favourable geotechnical properties may also be favourable for limiting the diffusion of oxygen.

The final report is available at www.mistra.org/mimi

**John Hillenbrand**, Region 9, Superfund Division, USEPA, presented relevant USEPA regulation.

About 90% of the US mining activities are concentrated in the western part of the USA. The sites show a large variation in terms of climate. The mining law from 1872 is still in use –which is remarkable, since it is solely intended to promote the exploitation of natural resources. It allows miners to buy land for practically nothing. In Nevada, 90 % of the land is federal. Federal law does not regulate groundwater; this is done at state level.

John Hillenbrand referred to a study where a large number of old permit applications/predictions/environmental assessments (EAs) had been reviewed. The result was somewhat discouraging showing that:

- In 73 % of the cases surface water quality exceed environmental criteria, where the EA predicted that they would not.
- In 89% of the cases ARD occurred, where the EA predicted no risk for ARD.

Relevant US regulation:

National Environmental Policy Act (NEPA)

- Clean Water act:
  - Surface water
  - Discharge limits for site
  - Load based for watershed
  - Type of liquid from mine: Storm water, **m**ine drainage, **p**rocess solutions

- Resource Conservation and Recovery Act:
  - Solid hazardous waste 1976
  - Large volume, low hazard
  - Exclusion for specific mineral processing and all other mining activities

- SUPERFUND (1980, 1986):
  - Cleanup of hazardous material
  - Ranking based on toxicity and exposure pathway
  - 52 mining sites
  - post-mining

- State Regulations California**:**
  - Group A: Hazardous mine waste
  - Group B: Two types: (i) waste that may have an effect (acid mine drainage) (ii) Non-hazardous
  - Group C: Waste that will not affect water quality

US Mine dam safety, national body: Mine safety health administration (MSHA)

**Jan Gronow**, Imperial College, London, presented the work done to develop waste acceptance criteria for the Landfill Directive.

In the Landfill Directive sites were classified in accordance with the type of waste that they were allowed to accept (inert, non-hazardous and hazardous). Leaching properties is the basic criteria in the directive using transport scenarios and a defined point of compliance (POC), where the impact is evaluated.

The procedure used to set acceptance criteria for landfilling of granular waste consisted of a series of consecutive steps. Only the impact on groundwater quality is considered. EU drinking water directive and WHO criteria were used as quality criteria at the point of compliance (in some cases after adjustment). One scenario was used for the calculation of limit values. Waste characterisation is performed using CEN methods.

The step-wise procedure is summarised below:

- Choice of primary target(s) and principles
- Choice of critical parameters and primary criteria values
- Description of the waste application scenario
- Description of the environment scenario
- Description of the source of potential contamination
- Description and modeling of the migration of the contaminants from the application to the POC(s)
- Determination of attenuation factors
- Application of the results to criteria setting ("backwards" calculation)
- Transformation of the source term criteria to limit values at different L/S values

The final step consists of transforming the resulting source term criteria into a limit value for a specific leaching test.

Problem with a definition of hazardous waste and another definition for waste that can be accepted at landfill

**Discussion**

- General:
  - It is important to recognize that the work cover metal mines, mineral mines and aggregates.
  - Is the process driven by regulators or industry?
  - It is important to clarify what we mean by risk (perceived risk?)
  - How to assess low frequency/high impact events vs. the opposite in a consistent way? That is, release taking place over different time scales.
  - There are some concerns over having to repeat the characterisation of the mining waste (not the intention).
  - Mine tailings are unique compared to ordinary dams, because they are there forever. Therefore a risk analysis should include the possibility that the surrounding conditions may change. For example, land use may change and people may settle nearby.

- Comments on the suggested flow scheme for classification:
  - Category A wastes should be split into several sub-categories. It is not a good idea to put them in the same category.
  - Is it the residual risk that we should address when deciding if a facility falls into category A?

- Defining a facility as category A is not the endpoint, the RA-procedure starts here.
- Is the choice between category A and *not* category A really an actual choice?
- It should be acknowledged that the work should focus on facilities that can be excluded from category A.

**Conclusions**

- The classification process should not be oversimplified
- Review of classification over time is important.
- Need for differentiation of category A facilities (this would, however, require amendments to the MWD).
- Consequence analysis is ok for low frequency/high risk events (physical stability).
- Wording is important: Clarify the risk terminology.
- Important how the threshold are set – a high degree of transparency is necessary.

The presentations may be downloaded from the site: ftp.dhigroup.com (do not write www in the browser). You will be prompted for a username (worldwide) and a password (water). Click on the folder “pub” and find the subfolder “Workshop on mining waste facilities” in which you will find the presentations as pdf files.

**Notes prepared by the project team in March 2007**

**List of participants in the workshop**

Lars Olof Höglund, Kemakta Konsult, Sweden
George J. Stalter, Concawe, Belgium
Arturo Gutierrez del Olmo, Golder Associates, Spain
Mike Cambridge, Cantab Consulting (Kent) Ltd., UK
John Hillenbrand, Superfund Division, USEPA, California, USA
Jan Gronow, Imperial College, London, UK
Johannes Drilsma, Euromines, Belgium
Roger Doome, IMA Europe, Belgium
Mira Tayah, IMA Europe, Belgium
Jean-Marc Vanbelle, Gralex, Belgium
Lars-Åke Lindahl, SveMin, Sweden
Helena Byrdziak, KGHM Polska Miedz SA, Poland
Serban Vlad, Universitatea Ecologica Bucuresti, Romania
Ferenc Madai, University of Miskolc, Hungary
Dag Ygland, Sweco VBB, Sweden
Pasi Vahanne, VTT Technical Research Centre of Finland, Finland
Kevin Motherway, EPA Regional Inspectorate, Inniscarra, Cork, Ireland

Fotios Papoulias, DG Environment, European Commission, Belgium

Project team:
Nils Eriksson, DHI, Spain
Ole Hjelmar, DHI, Denmark
Ingar Walder, DHI, Norway
David Bendz, SGI, Sweden
Wojciech Naworyta, AGH University of Science and Technology, Krakow, Poland

# Appendix 2

## List of properties of wastes which render them hazardous

## List of properties of wastes which render them hazardous (Directive 91/689/EEC)

| H No | Property | Relevant to mining waste? |
|---|---|---|
| **H1** | **"Explosive":** substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene. | Not relevant |
| **H2** | **"Oxidizing":** substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances. | Not relevant |
| **H3-A** | **"Highly flammable":**<br>• liquid substances and preparations having a flash point below 21 ºC (including extremely flammable liquids), or<br>• substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or<br>• solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or<br>• gaseous substances and preparations which are flammable in air at normal pressure<br>• substances and preparations which, in contact with water or damp air, evolve highly flammable gasses in dangerous quantities. | Not relevant<br>**Coal waste?**<br>**Coal waste?**<br>Not relevant<br>Not relevant |
| **H3-B** | "**Flammable":** liquid substances and preparations having a flash point equal to or greater than 21 ºC and less than or equal to 55 ºC. | Not relevant |
| **H4** | **"Irritant":** non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation. | **Yes** |
| **H5** | **"Harmful":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks. | **Yes** |
| **H6** | **"Toxic":** substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involove serous, acute or chronic health risks and even death. | **Yes** |
| **H7** | **"Carcinogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence. | **Yes** |
| **H8** | **"Corrosive":** substances and preparations which may destroy living tissue on contact. | **Yes (may be covered by H13)** |
| **H9** | **"Infectious":** substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms. | **Not relevant** |
| **H10** | **"Teratogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary genetic defects or increase their incidence. | **Yes** |
| **H11** | **"Mutagenic"**: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence. | **Yes** |
| **H12** | Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid. | (Maybe? – non-destructed CN) |
| **H13** | Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above. | **Yes** |
| **H14** | **"Ecotoxic"**: substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment. | **Yes** |

**Notes**

1. Attribution of the hazard properties "toxic" (and "very toxic"), "harmful", "corrosive" and "irritant" is made on the basis of the criteria laid down by Annex VI, part I A and part II B, of Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to classification, packaging and labelling of dangerous substances in the version amended by Council Directive 79/831/EEC (or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress).

2. With regard to attribution of the properties "carcinogenic", "teratogenic" and "mutagenic" and reflecting the most recent findings, additional criteria are contained in the Guide to the classification and labelling of dangerous substances and preparations of Annex VI (part II D) to Directive 67/548/EEC in the version as amended by Commission Directive 83/467/EEC (or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress).

# Appendix 3

## RIDAS: Dam Safety Guidelines of the Swedish Hydropower Industry

# RIDAS

**Dam Safety Guidelines of the Swedish Hydropower Industry**

**Section 2**
**Starting-points**
**Application guidance**

**October 25th, 2006**

This version translated into English (February 19th 2007) is not checked by Svensk Energi

## Contents

**2.1 Dam safety policy of the Swedish Hydropower Industry**

See Revised guidelines of 2002

**2.2 Quality assurance**

See Revised guidelines of 2002

**2.3 Consequence classification**

**2.3.1 Conditions**

**Dam safety work should have a consequence-based approach. Dams should therefore be classified according to the consequences following a dam failure. Consequences of a dam failure should be evaluated as to the probability of:**

- **Loss of human life or serious injury to person**
- **Damage to the environment, societal installations and other economic interests**

**Purpose**

The purpose of this **application guidance** is to develop and describe criteria for the classification of dams in accordance with RIDAS, and in an orientating manner propose methods and minimum requirements on information and documentation in a classification.

**Scope**

RIDAS states, like the Swedish Committee for Design Flood Determination, that dams should be classified according to the consequences that could follow a dam failure. The classification is based on the **margin consequence**, i.e. the added damage after a dam failure. The damage in this context is the increase of damage to the surroundings caused by the dam failure, beside the damage that e.g. a high flow would have caused, even if there had been no dam failure. It should be noted that a classification according to the Swedish Committee for Design Flood Determination guidelines is a special case according to RIDAS. The Design Flood guidelines only apply to dam failures caused by flows, with RIDAS also including dam failures caused by other factors.

All dams should be classified. The classification should comprise consequences upstream (for example slope slides) as well as downstream of the dam. When there are several dams at the same facility, each dam should be classified individually. Classification of parts of the same dam is however only required as an exception.

When classifying a dam the nature of the dam failure should be taken into account. 4 (11)
Factors like the time-lapse of the dam failure and the size of the dam breach opening should be studied. The dam failure implying the largest consequences should decide the classification.

The effect of the dam failure on other dams downstream and the risk of continuing dam failures (a domino effect, see 2.3.5) should also be taken into account when classifying a dam.

The guidelines apply to classification of existing as well as new dams. When constructing new dams, other dams upstream should also be taken into account. A consultation between the dam owners is expected at a classification.

The consequence classification is carried our by the individual dam owner on his own initiative. The classification is ratified by the person in charge of dam safety and reported to the Dam Register of the Swedish Hydropower Industry, Svensk Energi.

**Requirements on investigation and documentation**

A classification should in each case be documented and motivated. The requirements on the investigation and the contents of the documentation will vary from case to case, depending on the nature of the damage following a possible dam failure. The complete classification documentation could include information on physical conditions like geographical location, type of dam, dam height, water discharge installations etc. at the dam. An alternative is to refer to the operation, condition monitoring and maintenance manual (the DTU manual) of the facility.

### 2.3.2 Classification

**The consequences of a dam failure are evaluated as to the probability of:**

- **Loss of human life or serious injury to person**
- **Damage to the environment, societal installations and other economic interests**

**The classification system is made up of consequence classes 1A, 1B, 2 and 3, where 1A corresponds to the most serious consequences.**

The consequence classification system is described in two tables. Table 2.1 comprises the probability of loss of life or serious injury to person. Table 2.2 is completing Table 2.1, taking damage to the environment, societal installations and other economic values probably lost after a dam failure into consideration. The Table resulting in the most serious consequence classification is also deciding which consequence class the dam should be included in.

| Consequence class | Consequence | 5 (11) |
|---|---|---|
| 1A | High probability of loss of many lives | |
| 1B */ | The probability of loss of life or serious injury to person is not negligible | |
| 2-3 **/ | (The probability of loss of life or serious injury to person is negligible) | |

*Table 2.1 Classification as to the probability of loss of life or serious injury to person*

*/ Class 1B comprises both probability levels "Not negligible" and "Noteworthy" according to 2.3.3 below.
**/ Class 2 and 3 are established according to an evaluation in accordance with 2.3.4 below.

| Consequence class | Consequence |
|---|---|
| 1A | High probability of:<br>very serious damage to<br>-important societal installations<br>-important environmental values<br>or very extensive economic damage |
| 1B | Considerable probability of:<br>serious damage to<br>-important societal installations<br>-major environmental values<br>or high probability of<br>-extensive economic damage |
| 2 | Not negligible probability of:<br>considerable damage to<br>-societal installations<br>-environmental values<br>or economic damage |
| 3<br>(Other dams) | (The probability of damage as previously described is negligible) |

*Table 2.2 Classification as to the probability of damage to the environment, societal installations and other economic values.*

Besides this application guidance for consequence classification, separate methodological descriptions will be available through Svensk Energi. 6 (11)

### 2.3.2 Probability levels

According to **Table 2.1** the probability of loss of human life or serious injury to person following a dam failure is divided into the levels of **high probability – affecting many, not negligible probability – affecting someone**, and **negligible**. Correspondingly the probability of damage to the environment, societal installations and other economic assets following a dam failure according to Table 2.2 is divided into four levels: **high, noteworthy, not negligible** and **negligible**. The probability values as expressed in everyday language are set forth in the RIDAS guidelines (see also the Flow Committee guidelines). The probability of loss of life or serious injury to person occuring following a dam failure and some person/persons incidentally being on the dam or very close to it (passers-by, berry pickers etc.) may be regarded as **negligible**.

To illustrate the distribution of probability between the levels and provide guidance when **evaluating** possible damage this table could be applied:

| **Probability level** | **Damage and/or loss occuring in X % of cases** |
|---|---|
| High | >90% |
| Noteworthy | 10-90% |
| Not negligible | 1-10% |
| Negligible | <1% |

For practical application of defined probability levels is referred to section 2.3.4 below.

### 2.3.4 Evaluation of damage and loss

**Loss of life or serious injury to person**

The probability of loss of life or serious injury to person should be evaluated in accordance with the following conditions:

- Houses washed away
- The water level exceeds living quarters or spaces where people usually dwell at a certain height combined with a certain water velocity
- County or national road washed over (and away) or inundated

The probability of loss of life is dependant on the water depth and water velocity. Studies indicate that there is a risk of loss of life at a water depth of 0.7 metres and a water velocity of 0.5 metres/second. Other factors like the terrain, the speed of water level increase, possible alert time etc. should also be taken into consideration.

**Serious injury** to a person is an injury resulting in disablement or prolonged illness.

In practical use the classification could be based on the conditions arising after 7 (11)
a dam failure if water of a depth and velocity as previously described reaches houses where people live or stay permanently. Houses, blocks of flats and terrace houses are defined as places where people live. Schools, playgrounds, companies, military camps and the like, as well as places where many people stay from time to time, therefore must be re-counted to enable a comparison with houses/flats etc. This re-counting must take into consideration the number of people staying there and for how long. The same thing applies to holiday cottages. The number of houses/flats etc. is counted and then the table below is applied for a guidance when evaluating consequence class.

| **Consequence in number of houses etc.** | **Consequence acc. to the guidelines** | **Consequence class** |
|---|---|---|
| >20 | High probability of loss of many lives | 1A |
| 1-20 | Probability of loss of life or serious injury to person not negligible | 1B |
| <1 | (Probability negligible of loss of life or serious injury to person) | 2-3 |

*Table 2.3 Evaluation of expected loss of life or serious injury to person.*

When classifying, the evaluation should be based on a dam failure in the part of the facility which presumably will have the gravest consequences with regard to water level and flow. A prerequisite for the application of the Table is access to relevant maps and a visit to the area to count the number of houses/flats.

The possibility that a dam failure could damage infrastructure and other societal functions thereby indirectly jeopardizing human life should be taken into special consideration. A dam failure causing such damage to roads with intense traffic or important passenger train railways could in some cases cause a not negligible probability that people travelling would die. In these cases traffic intensity must be studied and the classification of the dam be adapted to the local conditions in each individual case. If a road of a traffic intensity of 3,000 vehicles or more per 24 hours is affected by a dam failure, then this dam should normally be referred to consequence class 1B. If local conditions are non-favourable, as for example because of poor visibility in an area where a dam failure would affect the road, then the dam would perhaps be referred to consequence class 1B, even if the traffic intensity is less than 3,000 vehicles per 24 hours. If the time of the water running from the dam to the road is >8 hours and there is a preparedness to shut the road, then the dam could be classified in a lower consequence class even if the traffic intensity is >3,000 vehicles per 24 hours.

The number of houses/flats that could be affected, used in the classification, 8 (11)
could be reduced if the time needed for the water to reach the first major accumulation of houses is more than four hours. This possibility requires that this time must be utilized for extensive alert measures. The utilization of this time to alert people could however only diminish the probability of loss of lives if the reliability of the warning system is observed in all its parts:

- Dam failure registration through transmission of signals
- Sounding the alert
- The alert noticed by the public
- Evacuation possibilities

Great caution is recommended when estimating warning-time and time to evacuate people, considering insecurities regarding the reliability of the warning system and the propagation velocity of the flood wave. To establish the scope of the reduction, the basic material must be further elaborated as to the wave´s travelling time, among other things. The results of a flood wave study should be applied to establish this time. As a rule of thumb 10 km/h could be used as a measure of the velocity of the floodl wave, even if this velocity could be higher close downstream of the dam and in more steep parts of the river.

If the conditions for a diminished probability of loss of human lives are met through a functioning warning system, combined with an evacuation system, then the **following general values could be applied on a reduction of the number of houses/flats**:
15% 4-8 hours after the dam failure
30% 8-12 hours after the dam failure
50% 12-16 hours after the dam failure
80% >16 hours after the dam failure
If the number of houses/flats affected is very limited and the possibility of carrying out a complete evacuation is secured, a higher reduction could also be applied. It should be noted in this context that a tidal wave is not a wall of water, but a wave more resulting in a gradual increase of the water level.

**Damage to the environment, societal installations and other economic interests**

Environmental value applies to both natural environment and living environment, including sanitary conditions. Also historic, artistic and cultural values are taken into consideration. Environmental values awarded a legal protection on national and county level (cultural memorials, national parks, nature preservations etc) are especially considered.

Only damage that is quite distinct from natural flow conditions is regarded as damage to the environment. Historic, artistic and cultural values are considered regarding the possibility that they are destroyed or damaged and not possible to restore to their original condition. Damage that could cause emissions of substances harmful to people and/or the environment should be considered, as for example waste facilities, petrol stations etc.

To decide what the difference is between **very serious damage to important environmental value** (Class 1A) and **serious damage to important environmental value** (Class 1B), factors like the scope of the damage, the protection value of the environmental asset and the possibilities of restoring it with an acceptable result after a dam failure should be taken into consideration. Damages of less scope that could give an acceptable result with limited efforts are classified as a **considerable** (less serious) **damage to environmental value** (Class 2). Damages of a very small scope that could give an acceptable result with very limited efforts are classified as **insignificant damage to environmental value** (Class 3). 9 (11)

**Damage to societal installations** refers to stoppages in installations like:

- Water supply installations
- Energy supply installations
- Sewer systems
- Communication systems (telephone, radio, TV etc.)
- Roads, railways and airports

If these criteria are to be decisive when a dam is classified as to the consequences for these installations, it is required that more than one type of installation or several installations of the same type are affected by a dam failure.

If these installations are to be considered **important to society** they must be installations that are vital to uphold normal human and economic activities of a population totalling at least 1,000 persons.

**Very serious damage** (Class 1A) refers to damage that results in several installations of this type being completely unusable and causing problems without any alternatives during at least one week.

**Serious damage** (Class 1B) refers to damage that results in such installations functioning with a reduced capacity and not being repairable right away, causing problems without alternatives during at least one week.

If these installations are to be considered **significant to society** they must be installations that are important to uphold normal human and economic activities of a population totalling at least 100 persons.

**Considerable** (less serious) **damage** (Class 2) is damage resulting in such installations working with a reduced capacity, without being repairable right away, causing problems without alternatives during at least a week.

**Non-serious damage** (Class 3) is damage resulting in such installations working with a somewhat reduced capacity and being repairable forthwith without affecting their operation. 10 (11)

**Economic damage** refers to both direct damages with objects destroyed and indirect damages as for example reduced production capacity. The dam owner´s losses as a result of a dam failure are not considered.

**Very large economic damage** (Class 1A) refers to damages the total value of which exceeds 30,000 Swedish basic amounts.

**Large economic damage** (Class 1B) refers to damages the total value of which exceeds 3,000 Swedish basic amounts.

**Considerable** (lesser) **economic damage** (Class 2) refers to damages the total value of which exceeds 100 Swedish basic amounts.

Other **economic damage** (Class 3) refers to damages the value of which fall below 100 Swedish basic amounts.

### 2.3.5 Dam failure and flows

#### General

The consequences of a dam failure are evaluated both for **normal situations** and **high-flow situations**. The classification is based on the **margin consequence**, i.e. the added damage of a dam failure. A dam failure at a flow that produces the major added damage is deciding the consequence class.

#### Cascading dam failure along a river (domino effect)

When several dams are situated along the same river a cascading dam failure could occur because of the flow starting at a dam failure upstream. This could lead to dam failures in downstream dams as well (the domino effect). There is a connection between upstream and downstream dams, and potential damages. This makes it necessary to study in a coherent way the propagation and effects of the flow or combinations of flows that could result after the dam failures.

When classifying a downstream dam it is presumed to collapse if the water level surpasses the crest of the dam core. The possible ability of concrete dams to withstand overflowing should however be taken into consideration.

When classifying the individual dams along the same river the solution below could be applied to two dams. It could also be extended and applied to more dams in a series. The propagation of the flow is estimated down to the next downstream dam. The effects on the downstream dam could be divided into two scenarios:

1. The downstream reservoir could take in and/or discharge the flow from the failure. In this case there will be no cascading dam failure in the downstream dams, so each dam is classified individually. 11 (11)

2. The downstream reservoir cannot take in and/or discharge the flow from the upstream dam and the dam will presumably fail. This could produce a new scenario with a dam failure, with the flow from the upstream failure adding to the situation. In this case the accumulated effect of cascading dam failures should be taken into consideration when classifying.

Several dam failure situations could occur along a river with several dams. Each dam failure case should be examined, case by case, deciding possible effects for each stretch of the river. Conservative criteria should always be used. **Generally an upstream dam which could cause failures in other, downstream dams should always be referred to at least the same consequence class as the downstream dam causing the gravest consequences in case of a dam failure**.

When there is a risk of cascading dam failures a common evaluation of all dams along the river must be carried out, which in practice presupposes a coordination and exchange of information between the various dam owners.

Two dams, situated in different river arms converging downstream should not be expected to fail at the same time and so the dams could be classified independent of one another.

**2.3.6 Methods of analysis regarding course of dam failure and consequences of a dam failure**

In many cases the classification of consequences is fairly uncomplicated and the dams could be classified according to a reasonable evaluation. This above all applies to dams in the 1A and 3 consequence classes.
In more dubious cases, where the dams obviously are to be classified in consequence classes 1B or 3, the evaluation of possible damage should be based on the the dam failure assumption and inundation studies. The detail of the study should be guided by the difficulty of assessing potential failure consequences and the conservativeness chosen in the evaluations. In simpler cases the calculation methods and the establishing of calculation parametres could be simplified.

Detailed descriptions of how to make a tidal wave calculation are found in "Downstream Hazard Classification Guidlines, Acer Technical Memorandum No. 11, United States Department of the Interior, Bureau of Reclamation, Dec. 1988".

The influence is a function of rising velocity, water level and water velocity from the inundation study and the flood wave calculation.

# Appendix 4

## Mined commodities in the EU Member States, Norway and Greenland

### Austria (year 2004)

**METALS**

Iron ore
Tungsten

**INDUSTRIAL MINERALS**

Clays:
Ilite
Kaolin
Graphite
Gypsum and anhydrite
Magnesite
Pumice
Salt, rock
Sand and gravel
Stone:
Dolomite
Quartz and quartzite
Limestone and marble
Basalt
Marl
Crushed stone
Talc and soapstone
Crushed stone
Talc and soapstone

**MINERAL FUELS AND RELATED MATERIALS**

Coal, brown and lignite
Oil shale

Source: http://www.usgs.gov

### Belgium (year 2004)

**METALS**

**INDUSTRIAL MINERALS**

Barite
Clay, kaolin
Stone
Calcareous:
Alabaster
Dolomite
Limestone
Marble
Petit granite, Belgian bluestone
Porphyry, all types
Quartz and quartzite
Sandstone
Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

### Bulgaria (year 2004)

**METALS**

Copper
Iron ore
Lead
Manganese
Silver
Zinc

**INDUSTRIAL MINERALS**

Asbestos
Barite
Clays:
Bentonite
Kaolin
Feldspar
Fluorspar
Gypsum and anhydrite
Limestone and dolomite
Perlite
Sand and gravel
Silica, quartz sand

**MINERAL FUELS AND RELATED MATERIALS**

Coal:
Anthracite
Bituminous
Brown
Lignite

Source: http://www.usgs.gov

## Czech Republic (year 2004)

**METALS**
Iron ore
Uranium

**INDUSTRIAL MINERALS**
Clays:
Bentonite
Kaolin

Other

Diatomite
Feldspar
Gemstones, crude, pyrope-bearing rock
Graphite
Gypsum and anhydrite, crude
Sand and gravel
Stone:
Basalt
Dimension stone
Limestone and other calcerous stones
Building stone

**MINERAL FUELS AND RELATED MATERIALS**
Coal, brown and lignite

Source: http://www.usgs.gov

## Cyprus (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Bentonite
Gypsum
Limestone

Marl

Sand and gravel
Umber

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

## Denmark (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Clays:
Fire clay
Kaolin

Moler

Sand and gravel
Stone:
Dimension (mostly granite)
Limestone

Source: http://www.usgs.gov

### Estonia (year 2004)

**METALS**

**INDUSTRIAL MINERALS**

Clay

Limestone
Sand and gravel
Silica sand

**MINERAL FUELS AND RELATED MATERIALS**
Oil shale

Peat

Source: http://www.usgs.gov

### Finland (year 2004)

**METALS**
Chromite
Copper
Gold
Nickel
Zinc

**INDUSTRIAL MINERALS**

Feldspar

Stone:
Limestone and dolomite
Quartz silica sand
Talc
Wollastonite

**MINERAL FUELS AND RELATED MATERIALS**
Peat:

Source: http://www.usgs.gov

### France (year 2004)

**METALS**
Bauxite
Copper
Gold
Silver
Tungsten

**INDUSTRIAL MINERALS**

Barite

Bromite
Clays:
Kaolin and kaolinitic clay
Refractory clay
Diatomite
Feldspar
Fluorspar
Gypsum and anhydrite
Mica
Potash
Pozzolan and lapilli
Rock salt

Limestone

Slate
Sand and gravel
Talc

**MINERAL FUELS AND RELATED MATERIALS**
Hard coal

Lignite

Uranium

Source: http://www.usgs.gov

## Germany (year 2004)

**METALS**
Iron ore

**INDUSTRIAL MINERALS**
Pumice (abrasive)
Barite
Clays:
Bentonite
Ceramic clay
Fuller's earth
Kaolin
Other, including brick clay
Diatomite
Feldspar
Fluorspar
Graphite
Potash
Stone:
Dolomite and limestone
Quartz and quartzite
Slate
Sand and gravel
Talc and steatite

**MINERAL FUELS AND RELATED MATERIALS**
Coal:
Anthracite and bituminous
Lignite
Peat

Source: http://www.usgs.gov

## Greece (year 2004)

**METALS**
Bauxite
Iron ore
Lead
Manganese
Nickel
Silver
Zinc

**INDUSTRIAL MINERALS**
Abrasives, natural emery
Barite
Clays:
Bentonite
Kaolin
Feldspar
Gypsum and anhydrite
Magnesite
Huntite
Perlite
Pozzolan, Santorin earth
Pumice
Salt
Stone
Dolomite
Marble
Flysch
Quartz
Sand and gravel
Talc and steatite

**MINERAL FUELS AND RELATED MATERIALS**
Lignite

Source: http://www.usgs.gov

## Hungary (year 2004)

**METALS**
Bauxite
Manganese ore

**INDUSTRIAL MINERALS**
Clays:
Bentonite
Kaolin
Perlite
Sand and gravel
Stone:
Dimension, all types
Dolomite
Limestone
Talc

**MINERAL FUELS AND RELATED MATERIALS**
Coal:
Brown
Lignite
Peat

Source: http://www.usgs.gov

### Ireland (year 2004)

**METALS**
Lead
Silver
Zinc

**INDUSTRIAL MINERALS**
Sand and gravel

Stone:
Limestone

**MINERAL FUELS AND RELATED MATERIALS**
Peat

Source: http://www.usgs.gov

### Italy (year 2004)

**METALS**
Bauxite
Gold
Lead
Manganese
Silver

**INDUSTRIAL MINERALS**
Barite

Clays:
Bentonite
Refractory excluding kaolinitic earth
Fuller's earth
Kaolin
Kaolinitic earth
Diatomite
Feldspar
Fluorspar
Gypsum
Perlite
Pumice and pumiceous lapilli

Pozzolan

Salt:
Rock and brine
Sand and gravel
Stone:

Calcareous:

Alabaster

Marble:

White

Colored

Travertine

Other:
Granite
Sandstone

Slate

Dolomite
Limestone
Marl
Serpentine
Quartz and quartzite
Talc and related materials

**MINERAL FUELS AND RELATED MATERIALS**
Lignite

Source: http://www.usgs.gov

### Latvia (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Limestone

Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**
Peat

Source: http://www.usgs.gov

### Lithuania (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Limestone
Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**
Peat

Source: http://www.usgs.gov

### Luxembourg (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

### Malta (year 2004)

**METALS**

**INDUSTRIAL MINERALS**
Limestone
Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

## Netherlands (year 2004)

**METALS**

**INDUSTRIAL MINERALS**

Sand and gravel

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

## Poland (year 2004)

**METALS**

Copper
Gold
Lead
Silver
Zinc

**INDUSTRIAL MINERALS**

Clays:

Bentonite
Fuller's earth
Fire clay
Kaolin
Diatomite
Feldspar
Gypsum and anhydrite
Magnesite
Salt:
Rock
Stone:
Crushed and dimension stone

Dolomite

Limestone

**MINERAL FUELS AND RELATED MATERIALS**

Carbon black
Coal:
Lignite and brown
Peat

Source: http://www.usgs.gov

## Portugal (year 2004)

**METALS**

Copper
Iron ore
Silver
Tin
Tungsten

**INDUSTRIAL MINERALS**

Calcium carbonate

Clays:
Kaolin
Refractory
Diatomite
Feldspar
Gypsum and anhydrite
Lithium minerals, lepidolite
Salt, rock
Sand
Stone:
Basalt
Calcareous:

Dolomite

Limestone, marl, calcite
Marble
Gabbro
Granite

Graywacke

Ophite

Quartz

Quartzite

Schist

Slate

Syenite
Talc

**MINERAL FUELS AND RELATED MATERIALS**

Source: http://www.usgs.gov

### Romania (year 2004)

**METALS**

Bismuth
Copper
Gold
Iron ore
Lead
Manganese
Silver
Zinc

**INDUSTRIAL MINERALS**

Barite
Clays:
Bentonite
Kaolin
Diatomite
Feldspar
Fluorspar
Graphite
Gypsum
Lime
Salt, rock
Sand and gravel
Talc

**MINERAL FUELS AND RELATED MATERIALS**

Carbon black
Brown
Lignite

Source: http://www.usgs.gov

### Slovakia (year 2004)

**METALS**

Copper
Iron ore

**INDUSTRIAL MINERALS**

Barite
Clays:
Bentonite
Kaolin
Refractory
Ceramic
Dolomite
Gypsum and anhydrite
Magnesite
Perlite
Salt
Sand and gravel
Stone:
Limestone
Talc
Zeolites

**MINERAL FUELS AND RELATED MATERIALS**

Coal, brown and lignite

Source: http://www.usgs.gov

### Slovenia (year 2004)

**METALS**

**INDUSTRIAL MINERALS**

Clays:
Bentonite
Ceramic clay
Kaolin
Pumice and related materials, volcanic tuff[e]
Quartz, quartzite, glass sand
Salt
Sand and gravel
Stone:
Dimension

**MINERAL FUELS AND RELATED MATERIALS**

Coal:
Brown
Lignite

Source: http://www.usgs.gov

### Spain (year 2004)

**METALS**
Copper
Gold
Lead
Mercury
Nickel
Silver
Tin
Uranium
Zinc

**INDUSTRIAL MINERALS**
Barite
Calcium cabonate
Clays:
Attapulgite
Bentonite
Kaolin
Diatomite and tripoli
Feldspar
Fluorspar
Gypsum and anhydrite
Magnesite
Mica
Potash
Pumice
Sand and gravel
Sepiolite, meerschaum
Stone:
Chalk
Dolomite
Limestone
Marble
Marl
Basalt
Granite
Ophite
Phonolite
Porphyry
Quartz
Quartzite
Sandstone
Other
Slate
Strontium minerals
Talc and steatite

**MINERAL FUELS AND RELATED MATERIALS**
Coal
Anthracite
Bituminous
Lignite, black and brown

Source: http://www.usgs.gov

### Sweden (year 2004)

**METALS**
Copper
Gold
Iron ore
Lead
Silver
Zinc

**INDUSTRIAL MINERALS**
Feldspar
Graphite
Quartz and quartzite
Stone:
Chalk
Dolomite
Granite
Limestone
Slate
Sandstone
Talc, soapstone

**MINERAL FUELS AND RELATED MATERIALS**
Peat

Source: http://www.usgs.gov

### United Kingdom (year 2004)

**METALS**
Iron ore
Lead

**INDUSTRIAL MINERALS**
Barite
Bromite
Clays:
Fire clay
Fuller's earth
Kaolin, china clay
Ball clay and pottery clay
Feldspar, china stone
Fluorspar
Gypsum and anhydrite
Potash
Sand and gravel
Stone:
Calcite
Chalk
Dolomite
Igneous rock
Limestone
Sandstone
Slate
Talc, soapstone, pyrophyllite

**MINERAL FUELS AND RELATED MATERIALS**
Coal
Anthracite
Bituminous including slurries, fines, etc.
Peat

Source: http://www.usgs.gov

### Greenland (year 2004)

No significant mining

Source: http://www.usgs.gov

### Norway (year 2004)

**METALS**
Titanium
Cobalt
Nickel

**INDUSTRIAL MINERALS**
Feldspar
Graphite

Mica

Nepheline, syenite
Olivine sand
Sand and gravel
Stone:
Dolomite
Limestone
Quartz and quartzite
Talc, soapstone, steatite

**MINERAL FUELS AND RELATED MATERIALS**
Peat

Source: http://www.usgs.gov

# Appendix 5

## Memo on Directives 67/548/EEC and 1999/45/EC
## June 2007

**Memorandum on**

**Substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC**
June 2006

**Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification , packaging and labeling of dangerous substances – "The Classification Directive" - and amendments**

The classification directive gives criteria for classifying chemical substances as dangerous.

The following categories exist:

Explosive
Oxidizing
Extremely flammable
Highly flammable
Flammable
Very toxic
Toxic
Harmful
Corrosive
Irritant
Sensitizing
Carcinogenic
Mutagenic
Toxic for reproduction
Dangerous for the environment

Substances are classified on the basis of their intrinsic properties, i.e. their inherent possibility of exerting harm. In principle, a classification does not take into account the actual use situation, or exposure scenario. Classification is solely a hazard assessment or dose-effect assessment, the first step in a risk assessment.

However, it has been seen, that physical properties determining the availability for absorption or the like, has been taken into account, and consensus of a lower classification of such substances has been attained.

Annex I, the published list of substances with a harmonised classification and labelling at present contains approximately 2700 existing and 1100 new substance entries (covering approximately 8000 substances). If a dangerous substance not yet included in Annex I is put on the market (as such or contained in a preparation), manufacturers/ importers/distributors have to self-classify it according to the criteria in Annex VI. The classification and labelling of preparations subject to Directive 1999/45/EC also uses the criteria set up in Annex VI.

The classification of a substance on annex 1 is binding, i.e. it must be used in all cases, except if you have access to new data, which give rise to a different classification. In such a case you are obliged to notify the competent authorities.

There is no guarantee that substances on annex I are classified taking all toxicological end-points into consideration. Substances may be classified as only Irritant, but they might not have been studied for toxicity to reproduction or carcinogenicity. No knowledge means no classification, and the burden of proof that a substance is hazardous belongs to the authorities. This problem may be resolved for some high volume substances with the upcoming REACH regulation.

The classification system is going to be slightly changed soon, when EU starts using the global harmonization system (GHS). However, the basic classification principles are not going to change much, since GHS is partly based on the EU classification system. GHS is also going to replace the preparations directive (1999/45/EEC).

## Directive 1999/45/EC of the European Parliament and the Council of 31 May 1999 concerning the approximation of the laws , regulations and administrative provisions of the Member States relating to the classification, packaging and labeling of dangerous preparations – "The Preparations Directive"

A preparation is a mixture or solution composed of two or more substances.

Preparations may be classified based on knowledge of the classification of one or more chemical substances in the preparations.

The basic limits for classification are shown on the next page.

There are rules for adding up the classification for several hazardous substances in one preparation. Some substances are exempt from the basic limits for classification of preparations. This is the case for e.g. preparations with certain barium salts, which must be classified as Harmful if the concentration is 1% or more. Normally, a preparation with less than 25% of a Harmful substance would not be classified as Harmful.

The basic limits, given in the table below, mean limits for *consideration*. If, for instance, there are 50 different Harmful substances present in concentrations of 0.5% each in a preparation, the substances should not be taken into consideration, and not be added up to classify the preparation as Harmful.

If, however, synergism or antagonism between substances leads to an under- or overestimation of the health hazard, this must be taken into consideration, and the preparation be classified accordingly. This is also the case, even when the substances causing the synergy or antagonism are not classifiable as hazardous in their own right.

With the implementation of GHS, the classification rules for preparations are also going to be revised.

## Timeline for implementation of REACH and GHS

The implementation of REACH and GHS (Gloabally Harmonised System of Classification and Labelling of chemicals) is expected to happen during 2007. Manufacturers, importers and traders of chemical substances and preparations will have to reclassify and re-label all substances and preparations. Also the substances and preparations not classified today must undergo assessment according to the new rules.

There will be a transition period before all chemicals must be classified according to the new rules. For substances, a transition period of three years has been assigned for reclassification, and for preparations a further 4-5 years. The whole transition period is expected to be 7-8 years, after which GHS should be fully in force. Until then, the present legislation is valid, but the Commission is planning use a "dual system" with both the present EU-system and the GHS running at the same time. However, this calls for new guidelines.

**Latest development**: On 27 June 2007 the Commission submitted a proposal for a Regulation of the European Parliament and of the Council on classification, labeling and packaging of substances and mixtures, and amending Directive 67/548/EEC and Regulation (EC) No. 1907/2006 - (COM(2007) 355 final. Substances are to be classified according to this proposal from 2010 and substances from 2015. Both systems may be applied during a transition period until 2010 and 2015, respectively. The time schedule for classification of substances are in agreement with the first registration date for REACH (1 December 2010). Directives 67/548/EEC and 1999/45/EC will be cancelled in 2015. The proposal implements GHS in EU legislation.

| Category of danger of the substance | Concentration to take into consideration for | |
|---|---|---|
| | gaseous preparations %vol/vol | other preparations %w/w |
| Very toxic | ≥ 0,02 | ≥ 0,1 |
| Toxic | ≥ 0,02 | ≥ 0,1 |
| Carcinogenic Category 1 or 2 | ≥ 0,02 | ≥ 0,1 |
| Mutagenic Category 1 or 2 | ≥ 0,02 | ≥ 0,1 |
| Toxic for reproduction Category 1 or 2 | ≥ 0,02 | ≥ 0,1 |
| Harmful | ≥ 0,2 | ≥ 1 |
| Corrosive | ≥ 0,02 | ≥ 1 |
| Irritant | ≥ 0,2 | ≥ 1 |
| Sensitising | ≥ 0,2 | ≥ 1 |
| Carcinogenic Category 3 | ≥ 0,2 | ≥ 1 |
| Mutagenic Category 3 | ≥ 0,2 | ≥ 1 |
| Toxic for reproduction Category 3 | ≥ 0,2 | ≥ 1 |
| Dangerous for the environment N | | ≥ 0,1 |
| Dangerous for the environment ozone | ≥ 0,1 | ≥ 0,1 |
| Dangerous for the environment | | ≥ 1 |

# Appendix 6

## Intermediate proposals and discussion papers developed by the project team during the study

# Proposal for a methodology for classification of mining waste facilities as Category A facilities or facilities not belonging to Category A

**26 June 2006**

**Prepared for the EU Commission and the TAC for the Mining Waste Directive**

## 1. Background and objective

The European Commission, DG Environment, has retained DHI Water & Environment and its two co-operation partners, Swedish Geotechnical Institute (SGI) and University of Science and Technology in Krakow /AGH) to undertake the study “Classification of Mining Waste Facilities”, study contract no. 07010401/2006/443229/MAR/G4.

The main objective of the project is to provide the Commission with the necessary technical and scientific information that can be used for defining the criteria for the classification of waste facilities in category A in accordance with the provisions in Annex III of Directive 2006/21/EC of 15 March 2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC (“The Mining Waste Directive”).

An Interim Report with background information has been produced and will, after some revision, be made available in July 2007. The team has discussed the classification methodology with the Commission and TAC members (in particular the members of the TAC Steering Committee for the waste facility classification) over the past months. While this procedure has lead to general agreement on several issues related to the methodology, a few questions are still not totally resolved. This proposal is meant to present possible methodology solutions and to highlight issues that may still be subject to discussion or choices. Hopefully, the feedback from the TAC and the Commission will enable the project team to produce a finalised methodology proposal.

## 2. Annex III in the Mining Waste Directive (MWD)

Annex III in the MWD states that:

“A waste facility shall be classified under category A, if:

g) a **failure** or **incorrect operation**, e.g. the collapse of a heap or the bursting of a dam, could give rise to a major accident*, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the facility; or

h) it contains waste **classified as hazardous** under Directive 91/689/EEC **above a certain threshold**; or

i) it contains substances or preparations **classified as dangerous** under Directives 67/548/EEC or 1999/45/EC **above a certain threshold**.”

*: Definition in article 3 of the MWD: **Major accident** means an occurrence on site in the course of an operation involving the management of extractive waste in any establishment covered by this Directive [in this context only waste facilities], leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site.

It is the opinion of the project team that this leads to consideration of the following issues:

**Issues to be considered under indent a):**
- Physical stability (risk of failure)
- Incorrect operation

**Issues to be considered under indent b):**
- The presence of waste classified as hazardous waste above a certain threshold (waste from the extractive industry with hazardous properties)

**Issues to be considered under indent c):**
- The presence of substances or preparations classified as dangerous above a certain threshold (substances/preparations added during the processing of the ore)

Each of the issues and their implications for the classification of mining waste facilities are discussed separately below. In principle, all issues must be considered for all facilities. However, not all issues are relevant for all types of waste. If a facility receives only one type of waste (or more waste types with identical classification properties), it may be evident that some issues are irrelevant for that particular class of waste and hence need not be considered. The possibility and practicability of drawing up simplified procedures for single classes of waste (e.g. inert waste, non-hazardous non-inert waste, hazardous waste, unpolluted soil) will be investigated.

The actual implications of being classified as a Category A facility are presented and discussed in Appendix 1.

## 3. Issues under indent a) in Annex III to the MWD

### 3.1 Physical stability

#### 3.1.1 Discussion of principles

If a failure, due to physical instability, of a waste facility could lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A. The project team proposes to focus on the consequences of a failure rather than on the probability that it will occur (low frequency, high amplitude event). This is coherent with the main principles developed for dam safety classification within the hydropower industry and the approach used in some countries where specific legislation and practice exist on tailings ponds. In dam safety regulations it is normal to consider the risk of loss of human life or serious injury to persons as well as damage to the environment and infrastructure. Membes of the TAC have expressed the opinion that since only human health/life and the environment are referred to in the MWD, the classification should not address infrastructure/economic issues.

In generic terms, a waste facility will then be classified as a Category A facility if the probability that the consequences of a failure will lead to loss of life or serious injury to persons is <u>not negligible</u> and if the probability of considerable damage to the environment is <u>not negligible.</u> In dam safety regulations, more precise definitions of being negligible/not negligible are available (numerically, the probability is defined as negligible if a damage or loss occurs in < 1 % of cases). In establishing the probability, concrete evaluations of the extent of the potential damage are considered in the context of the source – pathway - receptor chain (flood wave calculations are used to determine water depth and wave propagation velocity and criteria exist for maximum water depth and flow velocity when deaths are likely to occur).

The classification procedure related to failure of physical stability should consider both the immediate physical impact of the materials (tailings slurry, rock, contaminated water) and the resulting contamination of soil and water bodies. Assuming that clean-up/remediation will take place and is effective, the effects of a major accident caused by failure of physical stability is likely to have a relatively short-term character.

### 3.1.2 Proposed methodology

The proposed methodology is in line with the methodology outlined in the mining dam classification system under implementation in Sweden (Gruvridas, 2006), the Finnish dam classification system (RIDAS) and has similarities with the Spanish classification system for tailings ponds (ITC 08.02.01).

The classification should focus on the consequences of the failure of the facility and not the consequences due to natural circumstances (for example, the consequences of extreme floods that may exist independently of the facility are not to be incorporated in the consequences classification).

Different parts of a facility should be classified separately and can therefore be classified in separate categories, but the facility as a whole will have the same classification as the most severe part, i.e. if one part of the facility is classified as Category A, the entire facility will be a Category A facility. For each part of the facility all causes that may initiate a failure are to be studied, and the failure that gives the most severe consequence is to be chosen when classifying the facility. All scenarios should, however, be documented and motivated. Nearby natural or man-made structures that can affect the facility or be affected by the failure of the facility, should also be considered in the process (for example dams upstream or downstream of a facility being classified), the so-called domino effect.

The classification is used to determine if the facility is a “Category A” or “not a Category A”. Tables 3.1 and 3.2 below show the classification system with respect to the consequences (loss of lives or environmental impact) of a failure due to physical instability.

***Table 3.1***
*Classification with regard to loss-of-life or risk of human health as a consequence of failure.*

| Category | Consequence |
|---|---|
| A | High, considerable or non-negligible risk of loss-of-lives or serious danger to human health |
| Not A | Negligible risk of loss-of-lives or serious danger to human health |

***Table 3.2***
*Classification with regard to environmental impact as a consequence of failure.*

| Category | Consequence |
|---|---|
| A | High, considerable or non-negligible risk of unacceptable environmental impact |
| Not A | Negligible risk of unacceptable environmental impact |

A failure causing an unacceptable environmental impact may arise if the facility contains waste classified as hazardous or contains substances or preparations classified as dangerous and if the failure creates a link between the heap or dam and a receptor[A] an overland pathway to the receptor (downstream water resource). Alternatively, non-hazardous waste may cause environmental impact due to high levels of suspended materials in the receiving waters at failure.
For example, the collapse of a dam will result in a momentary release of water and sediment creating

[A] It should be noted that a facility containing hazardous waste or dangerous preparations above the limit values would already for that reason (under indents b or c) be classified as a Category A facility.

The table (1 or 2) giving the severest consequence, or highest category, is used for classification. The consequence classification decides the level of safety requirements to be fulfilled at the facility.

Table 3 defines the levels of the consequences in table 1 and table 2. The description in table 3 is meant to be used as guidance when evaluating the probability that a failure will cause loss of life, serious injury to humans or an unacceptable environmental impact. In this way it is estimated whether the consequences of a failure are negligible (not Category A) or not negligible (Category A).

***Table 3***
*Illustration of levels of probability when evaluating possible loss of life, serious injury or environmental impact.*

| **Level of probability** | **Consequence or loss occur in X% of the cases** | **Description** |
|---|---|---|
| High | X > 90% | A qualified person judge the probability to be high for the consequence to take place. |
| Considerable | X = 10-90% | This probability is supposed to cover all the cases in-between high and non-negligible probability, which is from fairly high to fairly small probability. |
| Non-negligible | X = 1-10% | It is here far from certain that the consequence will occur, but it is not possible to ignore it. |
| Negligible | X < 1% | |

Table 3 presents 4 separate levels of consequences. The three first subcategories define Category A. The not-Category A facility represents the probability of less than 1%.

For tailings ponds, the consequences of failure of a facility should be calculated both at normal hydrological situations and at high floods. The most severe consequence of failure of the facility (and not the consequences due to natural circumstances) should be used for the classification.

In estimating the probability for loss-of-lives or the risk of human health as a result of a failure the following conditions should be evaluated:

- Houses getting washed away
- The water level exceeding 0.7 m above ground level where people normally stay and at a water velocity of above 0.5 m/s. Factors like topography, the water levels rate of rise, warning features etc. should also be taken into consideration.
- Important roads getting overtopped (and washed away).

Injuries leading to disability or prolonged states of ill-health count as risks to human health.

If a warning system is in place, the risk of human lives may be decreased. This demands, however, time enough to warn and evacuate people and, even more important, a reliable system to detect a failure at an early state.

Calculation methodologies (computer models) for flood waves of water are developed and frequently used for example for water dams. For the estimation of the flow of solid materials (for example tailings, liquefied tailings, tailings slurry, rock masses etc.) experiences from previous failures of other facilities or simple estimations can be used.

When evaluating the environmental impact, the protection value of the environmental assets, possibilities to restore it and environmental impact (the areas affected and the resulting effect) should be assessed.

## 3.2 Incorrect operation

### 3.2.1 Discussion of principles

If incorrect operation of a facility could lead to serious danger to human health or to serious danger to the environment (in the short or long term), then the facility should be classified as a category A facility. Examples of incorrect operation could be continuous or repeated discharge of contaminated water to surface or groundwater, poor maintenance or monitoring (which may lead to a failure). Incorrect operation is possible in the after-closure phase (maybe even more likely) when e.g. back-pumping, water treatment etc. are likely not to be working, bathtub effects may occur, acid and alkaline drainage may occur, covers may become deficient, etc. Incorrect operation could, of course, also lead to physical failure, but that is covered under the previous item.

Incorrect operation could thus create a risk of unintended immediate or long-term release of leachate into the environment (beyond that foreseen in the general environmental impact assessment for the facility). Following the same principles (consequence analysis) as those suggested for physical stability, a classification procedure based the risks associated with incorrect operation should consider the potential release of contaminants (assuming malfunction of environmental protection systems), the pathway(s) it could take and the vulnerability of the receiving environment over a longer period of time. Criteria based on the composition of the discharge water during the operational phase and the leaching properties of the waste as determined during waste characterisation as prescribed in Annex II could be set using (simplified) scenario calculations. To keep things in the right proportion, this should not merely repeat the environmental impact assessment carried out in preparation of the permit for facility, and it should address the <u>risk of serious potential environmental impacts</u>.

The effects could be evaluated by comparing the potential impact of the facility on the environment without environmental protection systems (or with all systems malfunctioning) to the impact of the same facility with all systems in working order. This would reflect the degree to which the environmental protection depends on the environmental protection systems (that may fail) and it is consistent with the consequence analysis proposed in section 3.1.1. The criterion for classification as a Category A facility could be a factor expressing this dependency. The size of the factor should be related to the vulnerability of the impacted environment and the size of the waste facility. The effort involved would be limited to producing a “baseline” impact calculation for selected contaminants during the normal environmental impact assessment for the facility and to compare that to the result of the assessment upon which the permit will be or has been issued. The resulting factor (which could be graduated according to the vulnerability of the environment) will then determine the classification of the facility.

One particular issue to be addressed is waste consisting of waste rock (or soil, for that matter) producing acid rock drainage (ARD). It is the opinion of the project team that a mining waste facility containing ARD producing rock should be classified as a Category A facility due to the long term risk of acidification and subsequent release of undesired substances under incorrect operation (or even under operational conditions that today are considered adequate).

The potential impact of a facility containing potentially ARD generating waste rock (ARD producing tailings are addressed as hazardous waste under indent b) and facilities containing reactive waste (even if not ARD generating) should be assessed under the assumption that due to incorrect operation, no environmental protection measures are effective, based on information on release potential and release rates (e.g. obtained from kinetic tests) as described in the Guidance concerning characterisation of mining waste being developed by CEN/TC 292 with reference to Annex II. As above, the estimated impact without environmental protection measures should be compared to the result of the general risk assessment.

It would seem reasonable to stipulate that a facility containing only inert waste could not be classified as a category A facility due to incorrect operation (if it leads to physical instability, it is covered under that issue in section 3.1).

### 3.2.2 Proposed methodology

Based on the above considerations, it is proposed to carry out the classification related to incorrect operation of a waste facility by performing an "extra" impact or risk assessment and subsequently comparing the result to the result of the corresponding "normal" assessment. This assessment should be similar to the ("normal") assessment which is or has been carried out as part of the general permitting procedure, but without taking the mitigating effect of any environmental protection measures into account (assuming they would not work due to incorrect operation). Such environmental protective measures could e.g. include: Pre-treatment of waste discharged into a tailings pond, top covers limiting the infiltration of precipitation or diffusion of oxygen, bottom liners preventing or reducing leakage of leachate into the ground below the facility, collection systems for transport water and leachate, recirculation and treatment systems, any other systems aimed at mitigating the short and/or long term impact on the environment.

The result of an impact assessment may be expressed as a flux or load (e.g. measured as unit mass/year) of various critical substances as a function of time released from the facility. It may be evaluated as such or in relation to the pathway (unsaturated zone, aquifer and/or surface water body) and target (downstream point of compliance, POC: soil, groundwater surface water), e.g. as a resulting maximum, annual average concentration or accumulated amount of the substance(s) in question.

It is proposed to base the classification of a mining waste facility on the ratio between the impact of the "extra" environmental impact/risk assessment and the "normal" environmental impact/risk assessment. If the ratio is above a certain value, the facility should be classified as a Category A facility. The numbers to be compared could be expressing flux/load (annual, maximum or accumulated) –emission related - or resulting concentrations (maximum or average) at a specified POC – immission related.

If the permit is based on an impact/risk assessment which has shown that general or site-specific environmental impact criteria are met, then those criteria may be used for comparison with results of the "extra" assessment instead of the result of the "normal" assessment (this would prevent facilities with insignificant environmental impacts from being unintentionally classified as Category A facilities).

When setting the classification ratios, R, it may be useful to distinguish between small, medium and large facilities for waste from the extractive industries, and, if possible and relevant, apply different ratio values to the different size classes of facilities. The size classes of facilities could e.g. be defined as shown i table 4. As a first approximation, the values of R shown in table 4 could be assigned, reflecting that in general, incorrect operation of a large facility would present higher risk to the environment than incorrect operation of a small facility. Further work is ongoing (scenario and model calculations) to justify/adjust these values of R.

*Table 4*
*Proposed distinction between small, medium and large facilities and proposed, preliminary criteria ratios, R.*

| Class of facility | Description of facility | Criterion: Ratio, R, between "extra" and "normal" impact |
|---|---|---|
| Small | area < 1 ha and height < 5 m | 5 |
| Medium | 1 ha < area < 50 ha or 5 m < height < 10 m | 3 |
| Large | area > 50 ha or height > 10 m | 2 |

As described above, special attention must be paid to waste containing or consisting of reactive waste not classified as hazardous (including ARD producing waste rock). It could even be considered to classify all facilities containing potentially ARD generating waste as Category A.

## 4. Issues under indent b) in Annex III to the MWD

## 4.1 Discussion of principles

### 4.1.1 Definition of hazardous waste

Indent b) states that if a facility contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold, that facility should be classified as a Category A facility.

The first task will be to determine whether or not a given type of waste placed in or to be placed in a mining waste facility should be classified as hazardous waste. This is done using the European Waste Catalogue (EWC, Commission Decision 2000/532/EC of 3 May 2000 with amendments). Waste from the extractive industry belongs to class 01 in the EWC: Wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals. In this system, the wastes listed are generally considered non-hazardous unless they are marked as "Absolute Entries" (A), i.e. they are considered hazardous regardless of any threshold concentrations, or as "Mirror Entries" (M), i.e. they are hazardous waste only if they have one or more of the hazardous properties (H1 to H14) defined in Directive 91/689/EEC and subsequent amendments. However, the competent authorities of a Member State has the opportunity to classify a waste listed as non-hazardous in the EWC as a hazardous waste on a national basis if it displays hazardous properties.

The types of waste belonging to class 01 in the EWC are shown in table 4.1. It should be noted that subgroup 05: "Drilling muds and other drilling wastes" is outside the scope of the MWD. The only waste from the extractive industry which is "born" hazardous (i.e. has an "Absolute Entry") in this system is 01 03 04: "Acid-generating tailings from processing of sulphide ore" (also referred to as "Acid Rock Drainage (ARD) producing tailings"). Three other types of waste in group 01 have "Mirror Entries" and may potentially be classified as hazardous:

01 03 05 "Other tailings containing hazardous substances";

01 03 07 "Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals", and

01 04 07 "Wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals".

It should be noted that although waste rock from mineral metalliferous (01 01 01) and non-metalliferous (01 01 02) excavation are listed in the EWC as inherently non-hazardous waste, waste rock with a potential for production of ARD is in many cases at least as environmentally problematic as ARD producing tailings, which is listed as a hazardous waste. However, ARD producing waste rock (and other reactive mining waste not classified as hazardous waste) is addressed under "Incorrect operation" under indent a).

Table 4.2 presents the properties which must be considered to determine whether or not a waste with a Mirror Entry should be classified as hazardous or non-hazardous. The project team has made a first evaluation of which of the properties may be relevant in relation to classification of waste from the extractive industry. Table 4.3 further provides some information on the waste characteristics and associated limit values to be considered in relation to a number of the H characteristics in table 4.2.

The classification may to a large extent be based on the results of the waste characterisation as described in Annex II to MWD:

For waste types with Mirror Entries, the composition (and mineralogical) data may be used as described in Directives 2004/73/EC of 29 April 2004 adapting to technical progress for the 29$^{th}$ time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances to classify the waste as hazardous or non-hazardous based on concentration limit values.

Leaching data and acid/base neutralisation capacity data from the waste characterisation may be used to used to determine if extreme pH conditions can lead to classification of a waste type with Mirror Entry as hazardous waste (H4/H8 Irritant/Corrosive). Some guidance on this issue may be found in UK Environmental Agency (2006b).

It will also be necessary to classify tailings as tailings not producing ARD (01 03 05) or as ARD producing (acid generating) tailings (01 03 04), respectively, since the latter by definition is hazardous waste. The classification procedure for tailings ponds with respect to ARD generation becomes a matter of determining whether or not a particular type of tailings has ARD generating potential. CEN/TC 292 is currently developing a standard test for that purpose. The so-called static procedure will, inter alia, determine the ratio (NP/AP) between the neutralisation potential (NP) and the acidity production potential (AP). If NP/AP < 1, the material is definitely acid generating. If NP/AP > e.g. 3, the material is most likely not acid generating. For 1< NP/AP < 3, further evaluation, e.g. using a kinetic test may be necessary to determine if the waste should be considered ARD producing or not. The application of kinetic tests will be discussed in a guidance document on characterisation of waste from the extractive industries to be developed by CEN/TC 292.

Specific guidance on the assessment of hazardous property H13, in particular whether the disposal of the waste in a waste facility could lead to the production of leachate which exhibits any of the hazards H1 to H12, is limited or non-existent. Environment Agency (2006b) finds it unlikely that this should be relevant. It might be worth noting that Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC sets leaching based criteria for acceptance of waste otherwise classified as hazardous. These criteria are based on a risk assessment taking into account the leaching properties of the waste, a likely landfill scenario including environmental protection measures and a likely pathway and target scenario.

*Table 4.1*
*Waste Group 01 from the European Waste Catalogue (from UK Environment Agency, 2005a).*

*"Absolute Entries"* - Hazardous waste regardless of any threshold concentrations: A
*"Mirror Entries"* - Hazardous waste only if dangerous substances are present above threshold concentrations: M

| 01 | Wastes Resulting from Exploration, Mining, Quarrying, and Physical and Chemical Treatment of Minerals | |
|---|---|---|
| **01 01** | **wastes from mineral excavation** | |
| 01 01 01 | wastes from mineral metalliferous excavation | |
| 01 01 02 | wastes from mineral non-metalliferous excavation | |
| **01 03** | **wastes from physical and chemical processing of metalliferous minerals** | |
| 01 03 04* | acid-generating tailings from processing of sulphide ore | A |
| 01 03 05* | other tailings containing dangerous substances | M |
| 01 03 06 | tailings other than those mentioned in 01 03 04 and 01 03 05 | |
| 01 03 07* | other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals | M |
| 01 03 08 | dusty and powdery wastes other than those mentioned in 01 03 07 | |
| 01 03 09 | red mud from alumina production other than the wastes mentioned in 01 03 07 | |
| 01 03 99 | wastes not otherwise specified | |
| **01 04** | **wastes from physical and chemical processing of non-metalliferous minerals** | |
| 01 04 07* | wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals | M |
| 01 04 08 | waste gravel and crushed rocks other than those mentioned in 01 04 07 | |
| 01 04 09 | waste sand and clays | |
| 01 04 10 | dusty and powdery wastes other than those mentioned in 01 04 07 | |
| 01 04 11 | wastes from potash and rock salt processing other than those mentioned in 01 04 07 | |
| 01 04 12 | tailings and other wastes from washing and cleaning of minerals other than those mentioned in 01 04 07 and 01 04 11 | |
| 01 04 13 | wastes from stone cutting and sawing other than those mentioned in 01 04 07 | |
| 01 04 99 | wastes not otherwise specified | |
| **01 05** | **drilling muds and other drilling wastes** | |
| 01 05 04 | freshwater drilling muds and wastes | |
| 01 05 05* | oil-containing drilling muds and wastes | M |
| 01 05 06* | drilling muds and other drilling wastes containing dangerous substances | M |
| 01 05 07 | barite-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 08 | chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 99 | wastes not otherwise specified | |

***Table 4.2***

*List of properties of wastes which render them hazardous (Council Directive 91/689/EEC) and the project team's evaluation of the relevance of each property to the classification of mining waste facilities.*

| H No | Property | Relevant to mining waste? |
|---|---|---|
| **H1** | **"Explosive":** substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene. | Not relevant |
| **H2** | **"Oxidizing":** substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances. | Not relevant |
| **H3-A** | **"Highly flammable":**<br>• liquid substances and preparations having a flash point below 21 ºC (including extremely flammable liquids), or<br>• substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or<br>• solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or<br>• gaseous substances and preparations which are flammable in air at normal pressure<br>• substances and preparations which, in contact with water or damp air, evolve highly flammable gasses in dangerous quantities. | Not relevant<br><br>**Coal waste?**<br><br>**Coal waste?**<br><br>Not relevant<br><br>Not relevant |
| **H3-B** | "**Flammable":** liquid substances and preparations having a flash point equal to or greater than 21 ºC and less than or equal to 55 ºC. | Not relevant |
| **H4** | **"Irritant":** non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation. | **Yes** |
| **H5** | **"Harmful":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks. | **Yes** |
| **H6** | **"Toxic":** substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involove serous, acute or chronic health risks and even death. | **Yes** |
| **H7** | **"Carcinogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence. | **Yes** |
| **H8** | **"Corrosive":** substances and preparations which may destroy living tissue on contact. | **Yes (may be covered by H13)** |
| **H9** | **"Infectious":** substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms. | **Not relevant** |
| **H10** | **"Teratogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary genetic defects or increase their incidence. | **Yes** |
| **H11** | **"Mutagenic**": substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence. | **Yes** |
| **H12** | Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid. | (Maybe? – non-destructed CN) |
| **H13** | Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above. | **Yes** |
| **H14** | **"Ecotoxic**": substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment. | **Yes** |

**Notes**

1. Attribution of the hazard properties "toxic" (and "very toxic"), "harmful", "corrosive" and "irritant" is made on the basis of the criteria laid down by Annex VI, part I A and part II B, of Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to classification, packaging and labelling of dangerous substances in the version amended by Council Directive 79/831/EEC (*or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress).*

2. With regard to attribution of the properties "carcinogenic", "teratogenic" and "mutagenic" and reflecting the most recent findings, additional criteria are contained in the Guide to the classification and labelling of dangerous substances and preparations of Annex VI (part II D) to Directive 67/548/EEC in the version as amended by Commission Directive 83/467/EEC (*or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress*).

***Table 4.3***
*Wastes characteristics considered when classifying waste as hazardous or non-hazardous according to properties H3, H4, H5, H6, H7, H8, H10 and H11.*

Wastes classified as hazardous are considered to display one or more of the properties listed in Annex III to Directive 91/689/EEC and, as regards H3 to H8, H10[B] and H11 of that Annex, one or more of the following characteristics:

- flash point ≤ 55 ºC,
- one or more substance(s) classified[C] as very toxic at a total concentration ≥ 0.1 %,
- one or more substances classified as toxic at a total concentration ≥ 3 %,
- one or more substances classified as harmful at a total concentration ≥ 25 %,
- one or more corrosive substances classified as R35 at a total concentration ≥ 1 %,
- one or more corrosive substances classified as R34 at a total concentration ≥ 5 %,
- one or more irritant substances classified as R41 at a total concentration ≥ 10 %,
- one or more irritant substances classified as R36, R37, R38 at a total concentration ≥ 20 %,
- one or more substances known to be carcinogenic of category 1 or 2 at a total concentration ≥ 0.1 %,
- one or more substances toxic for reproduction of category 1 or 2 classified as R60, R61 at a total concentration ≥ 0.5 %,
- one or more substances toxic for reproduction of category 3 classified as R62, R63 at a total concentration ≥ 5 %,
- one or more mutagenic substances of category 1 or 2 classified as R46 at a total concentration ≥ 0.1 %,
- one or more mutagenic substances of category 3 classified as R40 at a total concentration ≥1 %.

**Risk phrases referred to above (defined in Commission Directive 2001/59/EC):**

R34: Causes burns
R35: Causes severe burns
R36: Irritating to the eyes
R37: Irritating to the respiratory system
R38: Irritating to the skin
R40: Limited evidence of a carcinogenic effect
R41: Risk of serious damage to the eyes
R46: May cause heritable genetic damage
R60: May impair fertility
R61: May cause harm to the unborn child
R62: Possible risk of impaired fertility
R63: Possible risk of harm to the unborn child

### 4.1.2 "Certain thresholds"

The discussions with the TAC Steering Committee and the Commission indicate that the original intention behind the use of the phrase "above a certain threshold" in indent b) in Annex III to the MWD was to define a limit for the content of hazardous waste (as a fraction or percentage of the total amount of waste) in a waste facility above which the facility would be classified as a Category A facility.

It is difficult to set such general limit values in a meaningful way. The waste in e.g. a tailings pond is not likely to be homogeneous throughout the facility due to variations in ore and tailings quality (in many cases ore from more than one mine will be co-processed and ore quality will also vary within the same mine) and due to stratification and horizontal differences caused by the sedimentation process and the movement of inlet points. The exact distribution of different types of wastes within the waste facility will

[B] In Council Directive 92/32/EEC amending for the seventh time Directive 67/548/EEC the term "toxic for reproduction" was introduced. This replaced the term "teratogenic" and has a more precise definition, without changing the concept. It is therefore the equivalent of H10 in Annex III to Directive 91/689/EEC.

[C] The classification as well as the R numbers refer to Council Directive 67/548/EEC and its subsequent amendments. The concentration limits refer to those laid down in Council Directive 88/379/EEC and its subsequent amendments.

generally not be known in detail and a local separation of some types of hazardous waste from non-hazardous could partly occur as a result of the sedimentation/distribution processes in the tailings pond. It is likely that a concentrated amount of hazardous waste, in particular ARD producing waste, placed near the downstream boundary of a tailings pond would be more environmentally critical than a similar amount of hazardous waste placed near the upstream boundary, at least in the short and medium term, provided the vulnerability of the downstream environment is the same. This has been used in practice as a protective measure in the construction of mining waste facilities.

It is not possible to predict in a general way whether an even distribution throughout the site of the same amount of hazardous waste/ARD producing waste in the short and long term would be more or less critical than a more segregated distribution. This would depend on the interaction with the other types of waste and the local environmental conditions. The only way to produce a true rationale for the setting of appropriate limit values for the allowable content and distribution of hazardous waste within a mining waste facility would be to perform an impact/risk assessment based on characterisation data on the waste types in the waste facility combined with data on quantities and distribution of the waste and information/assumptions about the pathways and environmental targets, either on a site-specific basis or based on scenario modelling. To the extent this would include a prediction of the expected (leaching) behaviour of ARD producing waste materials, this exercise would be far from trivial and inter alia require incorporation of a model that can account for leaching kinetics and the propagation of the acidification processes (as well as input data for such a model).

### 4.2 Proposed methodology

Each stream of waste to be placed or which has been placed in the waste facility shall be classified as hazardous or non-hazardous according to the procedures discussed in section 4.1.1, and the annual quantity during operation/the quantity in place at the time of determination and total quantity at the end of the planned operation period shall also be determined. The classification may be based on characterisation of exploration or test production samples of mining waste for planned facilities and on historical data and, to the extent necessary, characterisation of field samples of waste for existing facilities. Guidance on the characterisation methods will be given by CEN/TC 292 pursuant to Annex II to the MWD.

For facilities containing sulphide minerals or minerals with similar properties, the potential for ARD production shall be determined and evaluated as described above in section 4.1.1, using the procedures being developed by CEN/TC 292 (which are not very different from the well-established procedures already being applied routinely within the extractive industry).

The quantities of non-hazardous waste and hazardous waste (divided into ARD-producing hazardous waste and hazardous waste without a potential for ARD production) present or expected to be present in the facility e.g. at the completion of the operation period are calculated.

As a first approximation (at this stage somewhat pragmatically without an actual risk assessment based rationale), limit values in terms of maximum weight percentages of waste classified as hazardous could be suggested. The project team would find it reasonable to have two sets of limit values, one for ARD-producing tailings, and one (possibly less strict) for waste classified as hazardous for other reasons, e.g. because of high contents of various metals such as As, Cd, Cu, Hg, Sb, Th, Tl and Zn and their compounds. ARD production may have severe long-term (and increasing) consequences, whereas a waste may have high total contents of various metals and metalloids, which are not necessarily released to the environment even over a long period of time.

As proposed in section 3.2.2 for the considerations pursuant to incorrect operation under indent a), it may also here be useful to distinguish between small, medium size and large mining waste facilities. Using the same size classes as in 3.2.2, the very pragmatic and preliminary weight percentages presented in table 4.4 may be proposed and subjected to discussion and revision.

*Table 4.4*
*Preliminary examples of limit values for content of hazardous waste in mining waste facilities.*

| Class of facility | Description of facility | Limit value for content of ARD producing tailings* | Limit value for content of other hazardous waste |
|---|---|---|---|
| | | % by weight | % by weight |
| Small | area < 1 ha and height < 5 m | 5 | 10 |
| Medium | 1 ha < area < 50 ha or 5 m < height < 10 m | 2 | 5 |
| Large | area > 50 ha or height > 10 m | 1 | 2 |

*: Additional criteria concerning location of the ARD producing waste inside the waste facility and the vulnerability of the environment should be developed.

## 5. Issues under indent c) in Annex III to the MWD

### 5.1 Discussion

#### 5.1.1 Assumption and legal setting

It is assumed that waste management facilities within the extractive industry only contain ”preparations” as a result of mineral processing and not ”pure” substances. Disposal of “pure” substances would be considered “dumping” and would be prohibited by law.

Directive 67/548/EEC, Annex I, is an index of dangerous substances for which harmonised classification and labelling have been agreed at Community level in accordance with the procedure laid down in Article 4(3) of the Directive. The list contains the following information on each substance:

A. Classification - the process of classification consists of placing a substance in one or more categories of danger (as defined in Article 2(2) of Directive 92/32/EEC) and assigning the qualifying risk phrase or phrases. The classification has consequences not only for labelling but also for other legislation and regulatory measures on dangerous substances.

B. The label.

C. The concentration limits and associated classifications necessary to classify dangerous preparations containing the substance in accordance with Directive 1999/45/EC. Unless otherwise shown, a concentration limit is a percentages by weight of the substance calculated with reference to the total weight of the preparation. Where no concentration limits are given, the concentration limits to be used when applying the conventional method of assessing health hazards are those in Annex II, and when applying the conventional method of assessing environmental hazards are those in Annex III of Directive 1999/45/EC.

Directive 1999/45/EC article 3 (3) outlines the general concentration limits of the substance at which the preparation containing the substance is classified as dangerous on the basis of their health and/or environmental effects, whether the substances are present as impurities or additives. For non gaseous preparations (other preparations), which would be the expected type of preparation in a waste facility within the extractive industry, the lowest concentrations to consider is 0.1 % (e.g., very toxic substances). In real terms this means that a substance (or a combination of substances) has to be present in a total concentration of at least 1000 mg/l in the aqueous phase or 1 g/kg (1 kg/ton) in the solid phase.

#### 5.1.2 The use of additives in the extractive industry

In wet mineral processing additives are used for various purposes, which include but are not limited to:

- Separate desired minerals from gangue (e.g., bulk flotation of sulphide minerals) or separate different fractions or types of desired minerals (e.g., Zn/Pb separation).
- Leaching of desired components from gangue (e.g., Cu or Au leaching).
- Enhancing processes like sedimentation, flotation, dissolution etc.
- Water treatment (e.g. CN destruction).

Typically additives are used in low or moderate concentrations, normally expressed as g/ton ore processed. Some of the additives react (e.g., acids neutralize) or adsorb (e.g., xanthates adsorb on concentrates). Some additives are added to obtain a desired equilibrium concentration (or pH) in the dissolved phase (e.g. $CN^-$ in gold leaching, acid or alkaline leach) where the added amount will depend on specific conditions related to the treated ore.

Additives are, if possible, recycled to the process (e.g. caustic soda in alumina production) due to economical and environmental reasons. Some adsorb to the products (e.g. xanthates) and some are treated before the waste stream is deposited in the waste management facility (e.g. cyanide) due to environmental and legislative requirements.

Consequently, it is unlikely that waste management facilities within the extractive industry would contain substances or preparations classified as dangerous according to Directives 67/548/EEC or 1999/45/EC. This conclusion is illustrated by a number of examples below.

### 5.1.3 Cyanide leaching

Cyanide is used mainly within gold extraction as a leaching substance. The cyanide ion ($CN^-$) concentration in the leachate is normally around 150-200 mg/l, but there are examples of both higher and lower concentrations having been found optimal (EU, 2004). However, as $CN^-$ forms complexes with other competing metals (Fe, Cu, Zn, etc.) it is often necessary to add more cyanide to the process. A normal addition is typically 1 to 1.5 kg of NaCN per ton ore. The ore is normally leached in a slurry with approximately 1.2 to 1.4 $m^3$ water per ton ore.

Following leaching and adsorption to activated coal, the leach slurry undergoes cyanide recovery and/or destruction. The most common cyanide destruction method is the $SO^2$/air-process. The treated slurry normally contains less than 1 mg/l of free cyanide when discharged to the tailings pond[B], which is well below the threshold (1000 mg/l) referred to in directive 1999/45/EC. As a matter of fact, not even the actual leach-solution would normally reach the threshold.

### 5.1.4 Flotation

Froth flotation is a selective process for separating minerals from gangue by using surfactants and wetting agents. The flotation process is used for the separation of a large range of sulphides, carbonates and oxides prior to further refinement. Phosphate and coal as well as some industrial minerals are also processed by flotation technology.

Froth flotation commences by comminution (crushing/grinding), which is used to increase the surface area of the ore for subsequent processing and break the rocks into the desired mineral and gangue. The desired mineral is rendered hydrophobic by the addition of a surfactant or collector chemical; the particular chemical depends on the mineral that is being refined - as an example, pine oil can be used to float copper. This slurry (normally about 1.4 to 2 $m^3$ water per ton ore, (EU, 2004)) of hydrophobic mineral-bearing ore and hydrophilic gangue is then aerated, creating bubbles. The hydrophobic grains of mineral-bearing ore escape the water by attaching to the air bubbles, which rises to the surface, forming a froth. The froth is removed and the concentrated mineral may be further refined.

[B] Directive 2004/35/EC calls for the use of BAT $CN^-$ destruction methods and in any case limits the $CN_{WAD}$ concentration to less than 10 ppm (article 13), which can be met without any problems by a modern $CN^-$ destruction plant.

In flotation, different classes of additives may be used. Normally collectors (makes the desired mineral hydrophobic), frothers (create the bubbles that bring the hydrophobic minerals to the surface) and modifiers (make the collectors attach to the correct minerals) are used. Sometimes it is necessary to add substances that suppress certain minerals in order to float other similar minerals (selective flotation) - they can be included under the modifiers.

Examples of collectors are xanthates and dithiophosphates. Examples of frothers are pine oil, alcohols, polyglycols, polyoxyparafins, cresylic acid. Examples of modifiers are lime, acids, soda ash, metal salts, cyanide, NaHS and starch.

An example (Pyhäsalmi Cu/Zn mine in Finland) of reagents added at a mine is given below (EU, 2004):

- grinding: lime, ZnSO4, Sodium isobutyl xanthate (SIBX), frother
- Cu-flotation: lime, ZnSO4, SIBX, frother, NaCN
- Zn-flotation: lime, CuSO4, SIBX, frother, NaCN (cleaning)
- Pyrite-flotation: H2SO4, SIBX
- dewatering: flocculant (thickeners), HNO3, CH3COOH (filters)
- tailings: lime (neutralisation).

Normally, the additives are used in low concentrations. Typical added quantities are 5-150 g/ton ore of collectors, 10-50 g/ton of frothers. The added quantities of modifiers vary to a larger extent and it is difficult to give any specific range of addition.

The classification of the additives used in flotation varies, from being not dangerous to very toxic. Regardless of classification, it is unlikely that any waste stream resulting from flotation processes would contain concentrations of substances or preparations (or mixtures of substances) classified as dangerous above the thresholds referred to in directive 1999/45/EC.

## 5.2 Proposed methodology

The additives are likely to be distributed relatively evenly throughout a tailings pond, and it seems reasonable to consider only the average concentrations of dangerous substances and preparations for the entire facility.

**Planned facilities (tailings ponds):**
A procedure consisting of the following steps could therefore be proposed for tailings ponds:

1. Produce an inventory of the substances and preparations used in the processing and subsequently discharged with the tailings slurry to the tailings pond (identity and mass/day). The inventory should be based on the maximum amounts of each substance used during one day.

2. Calculated the average daily increase in stored water within the tailings pond under steady state conditions, ΔQ. This would in principle be the pore water present in the tailings sedimented during a day, and could be calculated from the mass of tailings (tonnes dry weight/day) discharged to pond, the average dry bulk density of the sedimented tailings (tonnes/$m^3$) and the pore volume of the sedimented tailings ($m^3/m^3$). In a first estimate, default values of 1.4 t/$m^3$ for the dry bulk density and 0.5 for the pore volume may be used.

3. For each substance in the inventory produced under point 1, determine whether or not it is a dangerous substance according to Annex I in Directive 67/548/EC (or, if necessary, Annex VI). Determine the limit values associated with each danger (R) category.

4. Using the information obtained under point 3, the mass/day of each substance discharged into the pond determined under point 1 and the daily increase in pore water volume calculated under point 2, use the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous substance.

5. If the aqueous phase is a dangerous preparation as determined under point 4, then the facility should be classified as a Category A facility.

This procedure is relatively conservative and does not account for reactions that may reduce the level of concentration of dangerous substances/preparations in the water phase (degradation, adsorption to the solid phase) nor does it account for treatment/destruction processes that may be applied before discharging the tailings into the facility (e.g., CN destruction, neutralisation, oxidation). Dilution in the facility is also neglected. If necessary, this could be taken into account in a more sophisticated estimation using, e.g., normal treatment results, water balance calculations and/or compartmentation and degradation modelling and including the solid phase in the calculation of concentrations.

**Operating facilities (tailings ponds):**
For operating facilities it could be possible to either do the above described calculation or based on chemical analysis of the water (and solids) contained in the facility directly determine if it should be classified as dangerous substances or not.

**Heaps and heap leaching:**
Indent c) of Annex III to the MWD has little or no relevance for waste heaps. Heap leach facilities are not regarded as waste heaps during operation. At closure they are normally washed out to minimise the content of any remaining leach solution. A screening for dangerous substances can be made based on an inventory of used leach chemicals and the residual concentrations of these leach chemicals in the drainage after washing has been finalised.

## 6. References

EU, 2004. BAT Reference document on the management of tailings and waste-rock.

GRUVRIDAS, 2006. Gruvföretagens riktlinjer för dammsäkerhet, (in Swedish) preliminary document 2006-09-11 provided by Lindahl L-Å.

UK Environment Agency, 2006a. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix A: Consolidated European Waste Catalogue. Environment Agency, Bristol, UK.

UK Environment Agency, 2006b. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix C: Hazardous Property Assessment. Environment Agency, Bristol, UK.

# Annex 1

## Classification of a mining waste facility in Category A

**The implications of being classified as a Category A facility**
If a facility is classified as a Category A facility, it implies that the operator must adapt major accident prevention measures and produce the relevant documentation that this has taken place:

1. The operator shall adopt and apply a major-accident prevention policy for waste (article 6). In terms of preventive measures, this should entail the delivery of a safety management system; emergency plans to be used in the event of accidents; and the dissemination of safety information to persons likely to be affected by a major accident. In the event of an accident, operators are required to provide the competent authorities with all the relevant information necessary to mitigate actual or potential environmental damage (unless the facility falls within the scope of Directive 96/82/EC).

2. A document is required (article 5 (3)) in the waste management plan demonstrating that a major-accident prevention policy, a safety management system for its implementation and an internal emergency plan will be put into effect in accordance with Article 6 (3).

It further implies that various exemptions of or reductions in requirements possible for facilities that are not classified as Category A facilities do not apply:

3. Member States may reduce or waive the requirements of Articles 11(3), 12(5) and (6), 13(6), 14 and 16 for non-hazardous non-inert waste only if it is deposited in a facility not classified as a Category A waste facility (article 2(3)).

4. Inert waste and unpolluted soil resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries and waste resulting from the extraction, treatment and storage of peat shall be subject to Articles 7, 8, 11(1) and (3), 12, 13(6), 14 and 16 of the directive only if deposited in a Category A waste facility (article 2(3)).

5. There is no minimum time for temporary storage of waste in the facility until it is defined as a "waste facility" if it is a Category A facility (article 3(15)).

In addition, some of the requirements applying to facilities not classified as Category A facilities may have to be more demanding for Category A facilities:

6. It is e.g. necessary to establish monitoring procedures during the operation and after-closure for Category A facilities and they should be laid down proportionate to the risk posed by the individual waste facility, in a way similar to that required by Directive 1999/31/EC (recital 22).

**The significance of being classified as a Category A facility**
Some of the above mentioned requirements for **Category A** facilities have mainly administrative and organisational consequences (points 1, 2, 5 as well as partly points 3 and 4). Others, such as points 3, 4 and 6, have direct economical impacts on the operation.

Point 3 refers to reduced or waived requirements that Member States may apply to facilities containing non-hazardous non-inert waste[C], unless the deposit is classified as a Category A facility. Of these requirements 11(3) *"notification without undue delay in case of an incident"* and 16 *"transboundary infor-*

[C] This may constitute a large part of the waste produced within the base metal mining industry and coal mining industry depending on how "inert waste" is defined in relation to the sulphide content.

*mation"* are mainly of administrative nature, whilst article 12(5) *"monitoring and maintenance after closure"*, 12 (6) *"reporting and economical responsibility for closed facility"*, article 13(6) *"minimized cyanide concentration in facility"* and article 14 *"financial security for closure and post-closure"* have significant economical impact.

Point 6 is already partly captured by point 3. However, point 6 should not primarily be regarded as an additional cost, as it is in the interest of the operator to monitor the facility and make sure it performs as intended.

Point 4 refers to inert waste and unpolluted soil[D] which are materials with reduced requirements unless they are deposited in a Category A facility. Of these requirements some are of administrative nature, such as article 7 *"permitting requirements"*, article 8 *"public participation"*, article 11(1) *"competent person"* and article 11(3) *"notification without undue delay in case of an accident"* and article 16 *"transboundary information"*. Others have direct economical impacts on the operation, such as article 12 *"closure and after-closure procedures"*, article 13(6) *"minimized cyanide concentration in facility"*, article 14 *"financial security for closure and post-closure"*.

**Discussion**

Facilities containing waste classified as hazardous or waste containing dangerous substances above a certain threshold will all be classified as Category A facilities.

For unpolluted soil, non-hazardous inert waste and non-hazardous non-inert waste there are significant implications depending on how the disposal facilities are classified. The implications of classifying a facility as a Category A facility are both administrative and economical. Requirements of administrative nature, such as permitting and development as well as maintenance of various management plans, are significantly more comprehensive for Category A facilities. Economical consequences may be significant, especially regarding monitoring, reporting, maintenance after closure and financial security for closure and post-closure.

For non-hazardous inert waste and non-hazardous non-inert waste the Directive is formulated in such a way that it encourages mining companies to design, locate and operate the disposal facilities in such a way that it is not classified as a Category A facility, i.e., minimise risk over the life-cycle of the facilities.

This important aspect of the Mining Waste Directive, creating an incentive for risk reduction by simplified administration and lower costs for low risk facilities, is a key forward-looking feature of the Directive. For this reason, any methodology developed for the classification of waste disposal facilities should be carefully formulated in order to encourage operators to minimise risk related to the disposal facilities. The developed methodology should therefore, to the extent possible, provide possibilities for the operator to design, locate, operate and close facilities in such a way that when risk is minimised to certain levels (to be defined in the methodology) the facilities are not classified as Category A facilities.

[D] This may constitute a large part of the waste produced within quarrying, industrial mineral sector and the aggregates industry and it may constitute a large part of the waste produced within the metal mining industry and the coal mining industry – depending on how "inert waste" is defined in relation to the sulphide content. Within the aggregates industry mineral sources with elevated sulphide contents can in most cases be avoided by initial site investigations (Vanbelle, 2007).

# Proposal for a methodology for classification of mining waste facilities as Category A facilities or facilities not belonging to Category A

**29 October 2007**

**Prepared for the EU Commission and the TAC for the Mining Waste Directive**

## 1. Background and objective

The European Commission, DG Environment, has retained DHI Water & Environment and its two co-operation partners, Swedish Geotechnical Institute (SGI) and University of Science and Technology in Krakow /AGH) to undertake the study "Classification of Mining Waste Facilities", study contract no. 07010401/2006/443229/MAR/G4.

The main objective of the project is to provide the Commission with the necessary technical and scientific information that can be used for defining the criteria for the classification of waste facilities in category A in accordance with the provisions in Annex III of Directive 2006/21/EC of 15 March 2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC ("The Mining Waste Directive").

An Interim Report with background information has been produced and made available to the TAC in July 2007 along with a first draft of the methodology proposal. The team has discussed the classification methodology with the Commission and TAC members (in particular the members of the TAC Steering Committee for the waste facility classification) over the past months. While this procedure has lead to general agreement on several issues related to the methodology, a few questions are still not totally resolved. This is particularly true for the criteria listed in table 3.3, 3.4 and 4.4. As described in Annexes 2 and 3, it has not been possible to develop a full rationale for the setting of these criteria. It would therefore be useful to test (and if necessary adjust) the proposed criteria by applying the methodology to a large number of different mining waste facilities.

This proposal is meant to present possible methodology solutions and to highlight issues that may still be subject to discussion or choices.

## 2. Annex III in the Mining Waste Directive (MWD)

Annex III in the MWD states that:

"A waste facility shall be classified under category A, if:

j) a **failure** or **incorrect operation**, e.g. the collapse of a heap or the bursting of a dam, could give rise to a major accident*, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the facility; or

k) it contains waste **classified as hazardous** under Directive 91/689/EEC **above a certain threshold**; or

l) it contains substances or preparations **classified as dangerous** under Directives 67/548/EEC or 1999/45/EC **above a certain threshold**."

*: Definition in article 3 of the MWD: **Major accident** means an occurrence on site in the course of an operation involving the management of extractive waste in any establishment covered by this Directive [in this context only waste facilities], leading to a serious danger to human health and/or the environment, whether immediately or over time, on-site or off-site.

It is the opinion of the project team that this leads to consideration of the following issues:

**Issues to be considered under indent a) concerning the hazard potential of the facility related to:**

- **Structural integrity** (effect of a failure)
- Incorrect operation of the facility (effect of incorrect operation)

**Issues to be considered under indent b):**
- The presence of waste classified as hazardous waste above a certain threshold (waste from the extractive industry with hazardous properties)

**Issues to be considered under indent c):**
- The presence of substances or preparations classified as dangerous above a certain threshold (substances/preparations added during the processing of the ore)

Each of the issues and their implications for the classification of mining waste facilities are discussed separately below. In principle, all issues must be considered for all facilities. However, not all issues are relevant for all types of waste. If a facility receives only one type of waste (or more waste types with identical classification properties), it may be evident that some issues are irrelevant for that particular class of waste and hence need not be considered. The possibility and practicability of drawing up simplified procedures for single classes of waste (e.g. inert waste, non-hazardous non-inert waste, hazardous waste, unpolluted soil) could be investigated.

The actual implications of being classified as a Category A facility are presented and discussed in Annex 1.

# 3. Issues under indent a) in Annex III to the MWD

## 3.2 Structural integrity

### 3.1.1 Discussion of principles

If a failure, due to loss of structural integrity, of a waste facility, regardless of the type of facility, could lead to serious danger to human health or to serious danger to the environment, then the facility should be classified as category A.

The consideration of structural integrity is intended to include all failure mechanisms relevant to the structures covered. This may for example be meteorological conditions, over-topping, internal erosion, settlements, earthquakes, liquefaction, construction weakness, failure in the underground, etc. However, due to the classification principles proposed below, the cause of failure is not discussed further in this context.

The project team proposes that each facility shall be classified on the basis of the reasonably foreseeable hazard potential in the event of a failure. This is coherent with the main principles developed for dam safety classification within the hydropower industry and the approach used in some countries where specific legislation and practice exist on tailings ponds. In dam safety regulations it is normal to consider the risk of loss of human life or serious injury to persons as well as the potential environmental impact of a failure. Members of the TAC have expressed the opinion that since Article 1 in the MWD calls for "…measures, procedures and guidance to prevent or reduce as far as possible any adverse effects on the environment, in particular water, air, soil, fauna and flora and landscape, and any resultant risks to human health…", the classification should not address infrastructure/economic issues. The project team suggests applying the definition of "environmental impact" given in Council Directive 85/337/EEC as amended by Council Directive 97/11/EC. This definition is consistent with the general understanding of the term "environmental impact". Directive 97/11/EC states that the assessment should consider:

- human beings, fauna and flora,
- soil, water, air, climate and the landscape,
- material assets and the cultural heritage,
- the interaction between the factors mentioned in the first, second and third indents

In generic terms, a waste facility will then be classified as a Category A facility if the probability that a failure will lead to:

- loss of life or serious injury to persons and/or
- serious damage to the environment (environmental impact)

is not negligible.

In existing dam safety regulations, a more precise definition of being negligible/not negligible is available (numerically, if the probability of serious damage or loss of one life or more occurring is less than 1%, it is considered negligible). In establishing the probability, specific evaluations of the extent of the potential damage are considered in the context of the source – pathway - receptor chain. Flood wave calculations can be used to determine water depth and wave propagation velocity. Criteria exist for maximum water depth and maximum flow velocity allowed (see section 3.1.2).

The classification procedure related to loss of the structural integrity should consider both the immediate impact of any materials transported out of the facility as a consequence of the failure (e.g., tailings slurry, rock, contaminated and/or uncontaminated water) and the resulting short, medium and long-term effects (e.g., contamination of soil and water bodies, loss of life, destruction of habitats, etc). Assuming that clean-up/remediation will take place and is effective, the effects of a failure of structural integrity may have a relatively short-term character, which should be considered in the evaluation of the environmental impacts.

The entire life-cycle of the facility needs to be considered in the considered in the evaluation of the hazard potential of the facility.

### 3.1.2 Proposed methodology

The proposed methodology is in line with the methodology outlined in the mining dam classification system under implementation in Sweden (GruvRIDAS, 2007), the Finnish dam classification system (RIDAS) and has similarities with the Spanish classification system for tailings ponds (ITC 08.02.01).

The classification should focus on the consequences of the failure of the facility itself and not on the consequences of extreme natural events that may occur at the same time. An extreme storm event/flood may, for example, cause severe impacts on the receptor and at the same time give raise to a failure of a mining waste facility. The consequences of the failure of the facility to be considered in the classification procedure should then be the incremental impact over and above the impact that would occur had the facility not failed. Similar considerations may apply to other extreme natural conditions such as earthquakes, droughts, land- and rockslides and high winds.

Different parts of a facility should be classified separately and can therefore be classified in separate categories, but the facility as a whole will have the same classification as the most severe part, i.e. if one part of the facility is classified as Category A, the entire facility will be a Category A facility. For each part of the facility all causes that may initiate a failure are to be studied, and the failure that gives the most severe consequence is to be chosen when classifying the facility. All scenarios should, however, be documented and motivated. Nearby natural or man-made structures that can affect the facility or be affected by the failure of the facility (the so-called cascade effect), should also be considered in the process (for example dams upstream or downstream of a facility being classified).

The classification is used to determine if the facility is a “Category A” or “not a Category A”. Tables 3.1 and 3.2 below show the classification system with respect to the consequences (loss of lives or environmental impact) of a failure due loss of structural integrity.

When classifying dams (water storage dams for water supply and/or hydropower production) it is usual to have more than two classes based on the hazard potential of a failure. The levels of probability when evaluating possible loss of life, serious injury or environmental impact can then be divided into “High” (> 90 % probability of loss of life, serious injury or environmental impact), “Considerable” (< 90 % but > 10 %), “Non-negligible” (< 10 % but > 1 %) and “Negligible” (< 1%). The wording in article 3 of the MWD is, however, clear and sets a very low level of acceptable risk for non - Category A facilities as it sets the limit at “serious danger to human health”. A failure where the associated probability of loss of life is more than negligible should therefore lead to a classification as a Category A facility. Similar considerations could be made concerning the potential hazard to the environment caused by a failure.

***Table 3.1***
*Classification with regard to loss-of-life or danger to human health as a consequence of loss of structural integrity..*

| Category | Consequence |
|---|---|
| A | Non-negligible potential for loss-of-lives or serious danger to human health |
| Not A | Negligible potential for loss-of-lives or serious danger to human health |

***Table 3.2***
*Classification with regard to potential for environmental impact as a consequence of loss of structural integrity.*

| Category | Consequence |
|---|---|
| A | Non-negligible potential for serious environmental impact |
| Not A | Negligible potential for serious environmental impact |

A failure causing a serious environmental impact may arise if the facility contains waste classified as hazardous or contains substances or preparations classified as dangerous[A]. The same may be true for facilities containing waste that is not classified as hazardous but still exhibits undesirable environmental properties. This requires a potential migration pathway between the facility (source) and a receptor. For example, the collapse of a dam will result in a momentary release of water and sediment and may create an overland pathway to a receptor (e.g. a downstream water resource). Any waste, including inert waste, may cause an environmental impact due to the formation of high levels of suspended materials in the receiving waters or by forming a layer on top of downstream land due to a failure.

The table (3.1 or 3.2) giving the most severe consequence, or highest category, is used for classification.

[A] It should be noted that a facility containing hazardous waste or dangerous preparations above the limit values would already for that reason (under indents b or c) be classified as a Category A facility.

In the classification of a mining waste facility (a tailings pond or a heap) with regard to the potential for to loss-of-life or danger to human health and environmental impact as a consequence of loss of structural integrity, the facility is classified as a Category A facility, if the probability of the manifestation of the hazards in question exceeds “negligible” (i.e. > 1 %).

In estimating the probability for loss of lives or the risk of human health as a result of a failure, the following conditions should be evaluated:

- Houses being washed away.
- The water level exceeds the ground level where people normally stay by a certain height in combination with a certain water velocity.
- Populated infrastructure getting overtopped (and possibly washed away) causing loss of lives or risk of human health (the damage to the infrastructure it self is not considered, but the risk to people using the infrastructure is).

The definition of a house is a building where people live or a building where people spend time (for example schools, playgrounds, companies, military camps etc.). In buildings that are not residential it is necessary to take into account how many people and at how long time they spend time at the location in question.

The probability that human lives are threatened due to a water flow is dependent of water level and water velocity. There is a risk for human lives at a water level of 0.7 m above ground level and a water velocity of 0.5 m/s. Factors like topography, the rising rate of water levels etc. should also be taken into consideration.

Injuries leading to disability or prolonged states of ill-health count as risks to human health.

Calculation methodologies (including computer models) for flood waves of water are developed and frequently used for example for water dams. For the estimation of the flow of solid materials (for example tailings, liquefied tailings, tailings slurry, rock masses etc.) experiences from previous failures of other facilities or simple estimations have to be used. Computer models are also available for the description of flood waves of a tailings slurry.

Evaluating the impact on the environment includes both the natural and the human environment. The natural environment is the nature, like forest, fields, meadows, streams, lakes etc., while the human environment is residential areas etc. In human environment historical, artistic and cultural values are included. In the evaluation of these the possibility for restoration may be included. Environments of special interests like national parks, nature reserves, vulnerable areas etc., should be subject to particular consideration.

Long-term environmental effects of a failure should also be considered. Long-term effects could, e.g., be residual soil contamination after clean-up, permanent damage to habitats etc.

## 3.2 Incorrect operation

### 3.2.2 Discussion of principles

If incorrect operation of a facility could lead to serious danger to human health or to serious danger to the environment in the short or long term, then the facility should be classified as a category A facility. Examples of incorrect operation are e.g. poor maintenance or monitoring that could lead to continuous or repeated discharge of contaminated water to surface water or groundwater. Incorrect operation could occur during the entire life-cycle of the facility and is likely to pose a significant hazard potential particularly in the after-closure phase when e.g. back-pumping, water treatment etc. are likely not to be working, bathtub effects may occur, acid and alkaline drainage may occur, covers or liners may become deficient, etc. Incorrect operation could, of course, also lead to a failure due to loss of structural integrity, but that is covered under the previous item.

Incorrect operation could thus create a risk of unintended immediate or future/long-term release of contaminants to the environment. Following the same principles of evaluating the hazard potential as suggested for structural integrity, a classification procedure based on the effects (consequences) associated with incorrect operation should consider the potential release of contaminants (assuming malfunction of environmental protection systems), the pathway(s) it could take and the vulnerability of the receiving environment over time. Criteria based on the composition of the discharge water during the operational phase and the leaching properties of the waste as determined during waste characterisation as prescribed in Annex II to the MWD (2006/21/EC) could be set using (simplified) scenario calculations. However, to keep things in the right proportion, this should not merely repeat the environmental impact assessment carried out in preparation of the permit for facility, and it should address the risk of serious potential environmental impacts.

The hazard potential could be evaluated by comparing the potential impact of the facility on the environment without environmental protection systems (or with all systems malfunctioning) ("worst case") to the impact of the same facility with all systems in working order ("BAT"). This would reflect the degree to which the environmental protection depends on the environmental protection systems (that may fail) and it is consistent with the evaluation of the hazard potential proposed in section 3.1.1. The criterion for classification as a Category A facility could be a factor expressing this dependency. The size of the factor should be related to the vulnerability of the impacted environment and the size of the waste facility.

The evaluation effort involved would be limited to producing:

- a "BAT" impact calculation for the release of selected contaminants (normally done during the environmental impact assessment for the facility)
- a "worst case" impact calculation for release of selected contaminants (often done implicitly during the normal environmental impact assessment for the facility but not explicitly shown)

and to calculate the ratio, R, between the results of the two assessments (i.e., "worst case"/"BAT"). The resulting factor (which could be graduated according to the accessability and the vulnerability of the environment) will then determine the classification of the facility. As highlighted above, the evaluation should consider the entire life-cycle of the facility with special emphasis on the long-term scenario. It is proposed to account for accessibility (pathway) and vulnerability of the environment (the receptor) in a simplified way using a modifying factor.

The proposed methodology is a simplified way of assessing hazard potential related to incorrect operation developed in order to simplify the classification process as much as possible and at the same time applying the precautionary principle. In order to avoid "unjust" classification of a waste facility as a Category A facility, it could be considered allowing an operator to carry out a more comprehensive, full EIA for the "worst case" situation, taking into account the nature and vulnerability of the environment, even if an initial "worst case"/"BAT" comparison comes out with a high R factor indicating that the facility should be placed in Category A. If the full "worst case" scenario EIA shows that the impact on the environment, both in the short and long term, is acceptable, then the facility should not be classified as a Category A facility on the basis of the potential consequences of incorrect operation.

One particular issue to be addressed is waste with a potential for production of acid rock drainage (ARD) due to the long term risk of acidification and subsequent release of undesired substances under incorrect operation (or even under operational conditions that today are considered adequate). Note that only potentially ARD producing tailings from the processing of sulphide ore is addressed as hazardous waste under indent b of Annex III to Directive 2006/21/EC.

The potential impact of a facility containing potentially ARD generating waste and facilities containing other reactive waste (in this context "reactive" waste is defined as waste which is thermodynamically unstable under present or expected future ambient conditions and hence may react (for example oxidise) and cause the release of significant amounts of contaminants or heat), should be assessed under the assumption that due to incorrect operation, no environmental protection measures are effective, based on information on release potential and release rates (e.g. obtained from kinetic tests) as described in the Guidance concerning characterisation of mining waste being developed by WG8 of CEN/TC 292 with reference to Annex II. As above, the estimated impact without working environmental protection measures should be compared to the ”BAT” assessment. Special emphasis should be placed on the long-term scenario.

It would seem reasonable to stipulate that a facility containing only inert waste could not be classified as a category A facility due to incorrect operation (if it leads to problems with the structural integrity, it is covered under that issue in section 3.1).

### 3.2.2 Proposed methodology

Based on the above considerations, it is proposed to carry out the classification related to incorrect operation of a waste facility by performing a “worst case” impact calculation and subsequently comparing the result to the result of the corresponding “BAT” impact calculation. This “worst case” assessment should be similar to the normal “BAT” impact assessment which is or has been carried out as part of the general permitting procedure, but without taking the mitigating effect of any environmental protection measures into account (assuming they would not work due to incorrect operation). Such environmental protective measures could e.g. include: effluent water treatment, top covers limiting the infiltration of precipitation or diffusion of oxygen to the waste, bottom liners preventing or reducing leakage of leachate into the ground below the facility, collection systems for transport water and leachate, recirculation and treatment systems, any other systems aimed at mitigating the short and long term impact on the environment.

The result of an impact assessment may be expressed as a flux or load (e.g. measured as unit mass/year) of various critical substances as a function of time released from the facility. It may be evaluated as such or in relation to the pathway (unsaturated zone, aquifer and/or surface water body) and target (downstream point of compliance, POC: soil, groundwater surface water), e.g. as a resulting maximum, annual average concentration and/or accumulated amount of the substance(s) in question.

It is proposed to base the classification of a mining waste facility on the ratio, R, between the “worst case” impact calculation and the “BAT” impact calculation. If the ratio is above a certain value, the facility should be classified as a Category A facility. The numbers to be compared could be expressing flux/load (annual, maximum or accumulated) –emission related - or resulting concentrations (maximum or average) at a specified POC – immission related. For the sake of simplicity, it is suggested to calculate $R = R_L$ on the basis of emission, i.e. a load, such as the flux of the contaminants of interest across the boundary of the facility.

To take the existence of a pathway and the vulnerability of the target environment into account in a simplified way, it is proposed that $R_L$ is multiplied by a factor (vulnerability factor, VF) of 0.5, if the target environment is very inaccessible and insensitive to the anticipated impact and by a factor of 2 if the target environment is very accessible and sensitive to the anticipated impact. In the case that the target environment is neither particularly inaccessible/vulnerable nor very accessible/vulnerable, a factor of VF = 1 is used. Indicators of low sensitivity may e.g. be: Deep and well protected groundwater/no groundwater interests, long distance to surface water bodies, no protected species or habitats in surface wasters. Indicators of high sensitivity may e.g. be: Valuable, relatively unprotected groundwater of high quality close to the facility, surface water bodies with limited dilution potential close to the site, protected species or habitats in or close to receiving surface waters. Note that if a vulnerable environment is highly inaccessible, a factor of 0.5 should be used. The values of VF are summarised in table 3.3.

***Table 3.3.***
*Suggested vulnerability factor, VF, according to the sensitivity and accessibility of the recipient.*

| Sensitivity and accessibility of recipient | Vulnerability factor, VF |
|---|---|
| Low | 0.5 |
| Medium | 1 |
| High | 2 |

When setting the classification ratios, $R_L$ x VF, it may be useful to distinguish between small, medium and large facilities for waste from the extractive industries, and, if possible and relevant, apply different ratio values to the different size classes of facilities (as indicated under indent a in Annex III of Directive 2006/21/EC). The size classes of facilities could e.g. be defined as shown in table 3.4. As a first approximation, the values of $R_L$ x VF shown in table 3.4 could be assigned, reflecting that in general, incorrect operation of a large facility would present a higher risk to the environment than incorrect operation of a small facility.

$R_L$ x VF is calculated both for a short term scenario (operation) and a long-term scenario (for 1000 years after closure). The values of BAT and Worst case to be compared are the highest annual loads calculated for each component in question. The calculation giving the highest value of $R_L$ x VF is used for the classification.

In Table 3.4 “area” refers to the total surface area of the facility where waste is deposited and “height” refers to the height of the waste in the facility above the ground. The criteria for “Small” have been set to include most facilities at small scale extractive operations containing, in this context, small amounts of waste. Similar for “Medium” and “Large” facilities, the criteria has been set to reflect the amount of waste deposited in the facility and its exposure to the environment as well as its possibility to attenuate or mitigate release of contaminates released from the waste.

***Table 3.4***
*Proposed distinction between small, medium and large facilities and proposed, preliminary criteria ratios, $R_L$ x VF.*

| **Type of facility** | **Description of facility** | **$R_L$ x VF where $R_L$ is the the ratio between “Worst case” and “BAT” impact and VF the vulnerability factor for the recipient** |
|---|---|---|
| Small | area < 1 ha and height < 5 m | 100 |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 10 |
| Large | area > 50 ha and/or height > 10 m | 5 |

As described above, special attention must be paid to waste containing or consisting of reactive waste not classified as hazardous (including ARD producing waste). Special emphasis should be placed on the long-term scenario as it is in the post-closure phase where environmental protection systems are most likely to fail and the monitoring of the site may be reduced or completely non-existent.

Examples of waste that is thermodynamically unstable if access to atmospheric air (oxygen) is allowed are certain types of coal waste that may self-ignite. To prevent sef-ignition, they are compacted and covered (BAT procedure). However, if these measures fail, self-ignition may occur and cause serious environmental damage. It is suggested that any medium or large size facilities (according to the definitions in table 3.4) containing waste that may self-ignite if exposed to oxygen, are classified as Category A facilities.

The setting of the criteria for incorrect operation is further discussed in Annex 2.

## 4. Issues under indent b) in Annex III to the MWD

## 4.2 Discussion of principles

### 4.1.1 Definition of hazardous waste

Indent b) states that if a facility contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold, that facility should be classified as a Category A facility.

The first task will be to determine whether or not a given type of waste placed in or to be placed in a mining waste facility should be classified as hazardous waste. This is done using the European Waste Catalogue (EWC, Commission Decision 2000/532/EC of 3 May 2000 with amendments). Waste from the extractive industry belongs to class 01 in the EWC: Wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals. In this system, the wastes listed are generally considered non-hazardous unless they are marked as “Absolute Entries” (A), i.e. they are considered hazardous regardless of any threshold concentrations, or as “Mirror Entries” (M), i.e. they are hazardous waste only if they have one or more of the hazardous properties (H1 to H14) defined in Directive 91/689/EEC and subsequent amendments. However, the competent authorities of a Member State has the opportunity to classify a waste listed as non-hazardous in the EWC as a hazardous waste on a national basis if it displays hazardous properties.

The types of waste belonging to class 01 in the EWC are shown in table 4.1. It should be noted that subgroup 05: “Drilling muds and other drilling wastes” is outside the scope of the MWD. The only waste from the extractive industry which is “born” hazardous (i.e. has an “Absolute Entry”) in this system is 01 03 04: “Acid-generating tailings from processing of sulphide ore” (also referred to as “Acid Rock Drainage (ARD) producing tailings”). Three other types of waste in group 01 have “Mirror Entries” and may potentially be classified as hazardous:

01 03 05 “Other tailings containing hazardous substances”;

01 03 07 “Other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals”, and

01 04 07 “Wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals”.

It should be noted that although waste rock from mineral metalliferous (01 01 01) and non-metalliferous (01 01 02) excavation are listed in the EWC as inherently non-hazardous waste, waste rock with a potential for production of ARD, or ARD generating tailings from processing of non-sulphide ore, is in many cases at least as environmentally problematic as ARD producing tailings from processing of sulphide ore, which is listed as a hazardous waste. However, ARD producing waste rock, and other reactive mining waste not classified as hazardous waste, is addressed under “Incorrect operation” under indent a).

Table 4.2 presents the properties which must be considered to determine whether or not a waste with a Mirror Entry should be classified as hazardous or non-hazardous. The project team has made a first evaluation of which of the properties may be relevant in relation to classification of waste from the extractive industry. Table 4.3 further provides some information on the waste characteristics and associated limit values to be considered in relation to a number of the H characteristics in table 4.2.

The classification may to a large extent be based on the results of the waste characterisation as described in Annex II to the MWD.

For waste types with Mirror Entries, the composition (and mineralogical) data may be used as described in Directives 2004/73/EC of 29 April 2004 adapting to technical progress for the 29$^{th}$ time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances to classify the waste as hazardous or non-hazardous based on concentration limit values.

Leaching data and acid/base neutralisation capacity data from the waste characterisation may be used to determine if extreme pH conditions can lead to classification of a waste type with Mirror Entry as hazardous waste (H4/H8 Irritant/Corrosive). Some guidance on this issue may e.g. be found in UK Environmental Agency (2006b).

It will also be necessary to classify tailings from processing of sulphide ore as tailings not producing ARD or as ARD producing tailings (01 03 04), respectively, since the latter by definition is hazardous waste (the project team understands the wording of the catalogue in the light of the MWD as referring to "potentially acid generating tailings - according to testing" - and not to tailings actually producing ARD at the moment it is characterised/evaluate). The classification procedure for tailings ponds with respect to ARD generation becomes a matter of determining whether or not a particular type of tailings has ARD generating potential according to testing. CEN/TC 292 is currently developing a standard test for that purpose. The so-called static procedure will, inter alia, determine the ratio (NP/AP) between the acid neutralisation potential (NP) and the acidity production potential (AP). If $NP/AP < 1$, the material is considered as being acid generating. If $NP/AP >$ e.g. 3, the material is most likely not acid generating. For $1< NP/AP < 3$, further evaluation, e.g. using a kinetic test may be necessary to determine if the waste should be considered ARD producing or not. The application of kinetic tests will be discussed in a guidance document on characterisation of waste from the extractive industries to be developed by WG8 of CEN/TC 292.

Note that ARD producing potential is only one possible property of one type of reactive waste. Neutral rock drainage (NRD) may in some cases be as harmful as ARD due to elements soluble at any pH range e.g. As, Se, Ni and Mo. NRD is covered by section 3.2. The same is true for alkaline rock drainage (which may, in the long term, become carbonated by atmospheric air and move towards neutrality).

***Table 4.1***
*Waste Group 01 from the European Waste Catalogue (from UK Environment Agency, 2005a).*

*"Absolute Entries"* - Hazardous waste regardless of any threshold concentrations: A
*"Mirror Entries"* - Hazardous waste only if dangerous substances are present above threshold concentrations: M

| **01** | **Wastes Resulting from Exploration, Mining, Quarrying, and Physical and Chemical Treatment of Minerals** | |
|---|---|---|
| **01 01** | **wastes from mineral excavation** | |
| 01 01 01 | wastes from mineral metalliferous excavation | |
| 01 01 02 | wastes from mineral non-metalliferous excavation | |
| **01 03** | **wastes from physical and chemical processing of metalliferous minerals** | |
| 01 03 04* | acid-generating tailings from processing of sulphide ore | A |
| 01 03 05* | other tailings containing dangerous substances | M |
| 01 03 06 | tailings other than those mentioned in 01 03 04 and 01 03 05 | |
| 01 03 07* | other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals | M |
| 01 03 08 | dusty and powdery wastes other than those mentioned in 01 03 07 | |
| 01 03 09 | red mud from alumina production other than the wastes mentioned in 01 03 07 | |
| 01 03 99 | wastes not otherwise specified | |
| **01 04** | **wastes from physical and chemical processing of non-metalliferous minerals** | |
| 01 04 07* | wastes containing dangerous substances from physical and chemical processing of non-metalliferous minerals | M |
| 01 04 08 | waste gravel and crushed rocks other than those mentioned in 01 04 07 | |
| 01 04 09 | waste sand and clays | |
| 01 04 10 | dusty and powdery wastes other than those mentioned in 01 04 07 | |
| 01 04 11 | wastes from potash and rock salt processing other than those mentioned in 01 04 07 | |
| 01 04 12 | tailings and other wastes from washing and cleaning of minerals other than those mentioned in 01 04 07 and 01 04 11 | |
| 01 04 13 | wastes from stone cutting and sawing other than those mentioned in 01 04 07 | |
| 01 04 99 | wastes not otherwise specified | |
| **01 05** | **drilling muds and other drilling wastes** | |
| 01 05 04 | freshwater drilling muds and wastes | |
| 01 05 05* | oil-containing drilling muds and wastes | M |
| 01 05 06* | drilling muds and other drilling wastes containing dangerous substances | M |
| 01 05 07 | barite-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 08 | chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06 | |
| 01 05 99 | wastes not otherwise specified | |

***Table 4.2***

*List of properties of wastes which render them hazardous (Council Directive 91/689/EEC) and the project team's evaluation of the relevance of each property to the classification of mining waste facilities.*

| H No | Property | Relevant to mining waste? |
|---|---|---|
| **H1** | **"Explosive":** substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene. | Not relevant |
| **H2** | **"Oxidizing":** substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances. | Not relevant |
| **H3-A** | **"Highly flammable":**<br>• liquid substances and preparations having a flash point below 21 ºC (including extremely flammable liquids), or<br>• substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or<br>• solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or<br>• gaseous substances and preparations which are flammable in air at normal pressure<br>• substances and preparations which, in contact with water or damp air, evolve highly flammable gasses in dangerous quantities. | Not relevant<br>**Yes**<br>**Yes**<br>Not relevant<br>Not relevant |
| **H3-B** | "**Flammable":** liquid substances and preparations having a flash point equal to or greater than 21 ºC and less than or equal to 55 ºC. | Not relevant |
| **H4** | **"Irritant":** non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation. | **Yes** |
| **H5** | **"Harmful":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks. | **Yes** |
| **H6** | **"Toxic":** substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involove serous, acute or chronic health risks and even death. | **Yes** |
| **H7** | **"Carcinogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence. | **Yes** |
| **H8** | **"Corrosive":** substances and preparations which may destroy living tissue on contact. | **Yes (may be covered by H13)** |
| **H9** | **"Infectious":** substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms. | **Not relevant** |
| **H10** | **"Teratogenic":** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary genetic defects or increase their incidence. | **Yes** |
| **H11** | **"Mutagenic"**: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence. | **Yes** |
| **H12** | Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid. | Yes |
| **H13** | Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above. | **Yes** |
| **H14** | **"Ecotoxic"**: substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment. | **Yes** |

**Notes**

1. Attribution of the hazard properties "toxic" (and "very toxic"), "harmful", "corrosive" and "irritant" is made on the basis of the criteria laid down by Annex VI, part I A and part II B, of Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to classification, packaging and labelling of dangerous substances in the version amended by Council Directive 79/831/EEC (*or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress).*
2. With regard to attribution of the properties "carcinogenic", "teratogenic" and "mutagenic" and reflecting the most recent findings, additional criteria are contained in the Guide to the classification and labelling of dangerous substances and preparations of Annex VI (part II D) to Directive 67/548/EEC in the version as amended by Commission Directive 83/467/EEC (*or by subsequent Commission Directives adapting Directive 67/548/EEC to technical progress*).

***Table 4.3***
*Waste characteristics considered when classifying waste as hazardous or non-hazardous according to properties H3, H4, H5, H6, H7, H8, H10 and H11.*

| |
|---|
| Wastes classified as hazardous are considered to display one or more of the properties listed in Annex III to Directive 91/689/EEC and, as regards H3 to H8, H10[E] and H11 of that Annex, one or more of the following characteristics: |
| • flash point ≤ 55 ºC,<br>• one or more substance(s) classified[F] as very toxic at a total concentration ≥ 0.1 %,<br>• one or more substances classified as toxic at a total concentration ≥ 3 %,<br>• one or more substances classified as harmful at a total concentration ≥ 25 %,<br>• one or more corrosive substances classified as R35 at a total concentration ≥ 1 %,<br>• one or more corrosive substances classified as R34 at a total concentration ≥ 5 %,<br>• one or more irritant substances classified as R41 at a total concentration ≥ 10 %,<br>• one or more irritant substances classified as R36, R37, R38 at a total concentration ≥ 20 %,<br>• one or more substances known to be carcinogenic of category 1 or 2 at a total concentration ≥ 0.1 %,<br>• one or more substances toxic for reproduction of category 1 or 2 classified as R60, R61 at a total concentration ≥ 0.5 %,<br>• one or more substances toxic for reproduction of category 3 classified as R62, R63 at a total concentration ≥ 5 %,<br>• one or more mutagenic substances of category 1 or 2 classified as R46 at a total concentration ≥ 0.1 %,<br>• one or more mutagenic substances of category 3 classified as R40 at a total concentration ≥1 %. |
| **Risk phrases referred to above (defined in Commission Directive 2001/59/EC):**<br><br>R34: Causes burns<br>R35: Causes severe burns<br>R36: Irritating to the eyes<br>R37: Irritating to the respiratory system<br>R38: Irritating to the skin<br>R40: Limited evidence of a carcinogenic effect<br>R41: Risk of serious damage to the eyes<br>R46: May cause heritable genetic damage<br>R60: May impair fertility<br>R61: May cause harm to the unborn child<br>R62: Possible risk of impaired fertility<br>R63: Possible risk of harm to the unborn child |

Specific guidance on the assessment of hazardous property H13, in particular whether the disposal of the waste in a waste facility could lead to the production of leachate which exhibits any of the hazards H1 to H12, is limited or non-existent. UK Environment Agency (2006b) finds it unlikely that this should be relevant. It might be worth noting that Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC sets leaching based criteria for acceptance of waste otherwise classified as hazardous. These criteria are based on a risk assessment taking into account the leaching properties of the waste, a likely landfill scenario including environmental protection measures and a likely pathway and target scenario.

[E] In Council Directive 92/32/EEC amending for the seventh time Directive 67/548/EEC the term “toxic for reproduction” was introduced. This replaced the term “teratogenic” and has a more precise definition, without changing the concept. It is therefore the equivalent of H10 in Annex III to Directive 91/689/EEC.

[F] The classification as well as the R numbers refer to Council Directive 67/548/EEC and its subsequent amendments. The concentration limits refer to those laid down in Council Directive 88/379/EEC and its subsequent amendments.

Specific criteria related to the assessment of hazardous property 14 are also lacking at Community level. However, some member states (e.g. the UK and Sweden) have produced guidelines on assessment of the hazardousness of waste based on the content and ecotoxicological properties of various substances and preparations (using Council Directive 67/548/EEC and Council Directive 1999/5/EC and later amendments). In the directives, limit values for content of substances that, if exceeded, will render the waste hazardous, may be found for the following risk phrases (and combinations of these):

R50: Very toxic to aquatic organisms
R51: Toxic to aquatic organisms
R52: Harmful to aquatic organisms
R53: May cause long-term effects in the aquatic environment

Some guidance on the assessment of hazardousness on the basis of H14 ecotoxicity may e.g. be found in UK Environmental Agency (2006b).

#### 4.1.2 "Certain thresholds"

The discussions with the TAC Steering Committee and the Commission indicate that the original intention behind the use of the phrase "above a certain threshold" in indent b) in Annex III to the MWD was to define a limit for the content of hazardous waste (as a fraction or percentage of the total amount of waste) in a waste facility above which the facility would be classified as a Category A facility.

It is difficult to set such general limit values in a meaningful way. The waste in e.g. a tailings pond is not likely to be homogeneous throughout the facility due to variations in ore and tailings quality (in many cases ore from more than one mine will be co-processed or processed in batches in the same concentrator and deposited into the same waste facility and the ore quality may also vary within the same mine over time) and due to stratification and horizontal differences caused by the sedimentation process and the movement of outlet points. The exact distribution of different types of wastes within the waste facility will generally not be known in detail and a local separation of some types of hazardous waste from non-hazardous could partly occur as a result of the sedimentation/distribution processes in the tailings pond. It is likely that a concentrated amount of hazardous waste, in particular ARD producing waste, placed near the downstream boundary of a tailings pond would be more environmentally critical than a similar amount of hazardous waste placed near the upstream boundary, at least in the short and medium term, provided the vulnerability of the downstream environment is the same. This has been used in practice as a protective measure in the construction of mining waste facilities.

It is not possible to predict in a general way whether an even distribution throughout the site of the same amount of hazardous waste/ARD producing waste in the short and long term would be more or less critical than a more segregated distribution. This would depend on the interaction with the other types of waste and the local environmental conditions. The only way to produce a true rationale for the setting of appropriate limit values for the allowable content and distribution of hazardous waste within a mining waste facility would be to perform an impact/risk assessment based on characterisation data on the waste types in the waste facility combined with data on quantities and distribution of the waste and information/assumptions about the pathways and environmental targets, either on a site-specific basis or based on scenario modelling. To the extent this would include a prediction of the expected (leaching) behaviour of ARD producing waste materials, this exercise would be far from trivial and inter alia require incorporation of a model that can account for leaching kinetics and the propagation of the acidification processes (as well as input data for such a model). It is the opinion of the project group that such an extensive assessment is not motivated for the mere sake of classifying the facility.

### 4.2 Proposed methodology

Each stream of waste to be placed or which has been placed in the waste facility shall be classified as hazardous or non-hazardous according to the procedures discussed in section 4.1.1, and the annual quantity during operation/the quantity in place at the time of determination and total quantity at the end of the planned operation period shall also be determined. The classification may be based on characterisation of exploration or test production samples of mining waste for planned facilities and on historical data and, to the extent necessary, characterisation of field samples of waste for existing facilities. Guidance on the characterisation methods will be given by CEN/TC 292 pursuant to Annex II to the MWD.

For facilities containing sulphide minerals or minerals with similar properties, the potential for ARD production shall be determined and evaluated as described above in section 4.1.1, using the procedures being developed by CEN/TC 292 (which are not very different from the well-established procedures already being applied routinely within the extractive industry).

The quantities of non-hazardous waste and hazardous waste (divided into ARD-producing hazardous waste and hazardous waste without a potential for ARD production) present or expected to be present in the facility e.g. at the completion of the operation period are calculated.

As a first approximation, limit values in terms of maximum weight percentages of waste classified as hazardous could be suggested. The project team would find it reasonable to have two sets of limit values, one for ARD-producing tailings, and one (possibly less strict) for waste classified as hazardous for other reasons, e.g. because of high total contents of various elements such as As, Cd, Hg, and Pb. ARD production may have severe long-term (and increasing) consequences, whereas a waste may have high total contents of various metals and metalloids, which are not necessarily released to the environment even over a long period of time.

As proposed in section 3.2.2 for the considerations pursuant to incorrect operation under indent a), it may also here be useful to distinguish between small, medium size and large mining waste facilities. Using the same size classes as in 3.2.2, the very pragmatic and preliminary weight percentages presented in table 4.4 may be proposed and subjected to discussion and revision.

***Table 4.4***
*Preliminary examples of limit values for content of hazardous waste in mining waste facilities.*

| **Class of facility** | **Description of facility** | **Limit value for content of ARD producing tailings*** | **Limit value for content of other hazardous waste** |
|---|---|---|---|
| | | % by weight | % by weight |
| Small | area < 1 ha and height < 5 m | 5 | 10 |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 2 | 7 |
| Large | area > 50 ha and/or height > 10 m | 1 | 5 |

*: As it is impossible to assess the location of the hazardous waste in the facility, the water flow paths and neutralisation capacity and attenuation capacity in a general way, thus the precautionary principle should be applied. The actual values, however, may be set according to a political agreement/decision by the TAC. There exist no criteria on what can be “accepted”.

In the discussion with the Steering Group a methodology it was suggested to base the evaluation of whether or not the waste in a facility should be classified as hazardous waste or not on the average composition of all the waste deposited into the facility. This approach was, however, believed to unintentionally stimulate the dilution hazardous waste and not to capture correctly the intentions of the MWD.

The setting of classification criteria based on “certain thresholds” for content of hazardous waste is further discussed in Annex 3.

# 5. Issues under indent c) in Annex III to the MWD

## 5.1 Discussion

### 5.1.1 Assumption and legal setting

It is assumed that waste management facilities within the extractive industry only contain ”preparations” as a result of mineral processing and not ”pure” substances. Disposal of “pure” substances would be considered “dumping” and would be prohibited by law.

Directive 67/548/EEC, Annex I, is an index of dangerous substances for which harmonised classification and labelling have been agreed at Community level in accordance with the procedure laid down in Article 4(3) of the Directive. The list contains the following information on each substance:

A. Classification - the process of classification consists of placing a substance in one or more categories of danger (as defined in Article 2(2) of Directive 92/32/EEC) and assigning the qualifying risk phrase or phrases. The classification has consequences not only for labelling but also for other legislation and regulatory measures on dangerous substances.

B. The label.

C. The concentration limits and associated classifications necessary to classify dangerous preparations containing the substance in accordance with Directive 1999/45/EC. Unless otherwise shown, a concentration limit is a percentages by weight of the substance calculated with reference to the total weight of the preparation. Where no concentration limits are given, the concentration limits to be used when applying the conventional method of assessing health hazards are those in Annex II, and when applying the conventional method of assessing environmental hazards are those in Annex III of Directive 1999/45/EC.

Directive 1999/45/EC article 3 (3) outlines the general concentration limits of the substance at which the preparation containing the substance is classified as dangerous on the basis of their health and/or environmental effects, whether the substances are present as impurities or additives. For non gaseous preparations (other preparations), which would be the expected type of preparation in a waste facility within the extractive industry, the lowest concentrations to consider is 0.1 % (e.g., very toxic substances). In real terms this means that a substance (or a combination of substances) has to be present in a total concentration of at least 1000 mg/l in the aqueous phase or 1 g/kg (1 kg/ton) in the solid phase.

### 5.1.2 The use of additives in the extractive industry

In wet mineral processing additives are used for various purposes, which include but are not limited to:

- Separation of desired minerals from gangue (e.g., bulk flotation of sulphide minerals) or separation of different fractions or types of desired minerals (e.g., Zn/Pb separation).
- Leaching of desired components from gangue (e.g., Cu or Au leaching).
- Enhancing processes like sedimentation, flotation, dissolution etc.
- Water treatment (e.g. CN destruction).

Typically additives are used in low or moderate concentrations, normally expressed as g/ton ore processed. Some of the additives react (e.g., acids neutralize) or adsorb (e.g., xanthates adsorb on concentrates). Some additives are added to obtain a desired equilibrium concentration (or pH) in the dissolved phase (e.g. $CN^-$ in gold leaching, acid or alkaline leach) where the added amount will depend on specific conditions related to the treated ore.

Additives are, if possible, recycled to the process (e.g. caustic soda in alumina production) due to economical and environmental reasons. Some adsorb to the products (e.g. xanthates) and some are treated before the waste stream is deposited in the waste management facility (e.g. cyanide) due to environmental and legislative requirements.

Consequently, it is unlikely that waste management facilities within the extractive industry would contain substances or preparations classified as dangerous according to Directives 67/548/EEC or 1999/45/EC. This conclusion is illustrated by a number of examples below.

### 5.1.3 Cyanide leaching

Cyanide is used mainly within gold extraction as a leaching substance. The cyanide ion ($CN^-$) concentration in the leachate is normally around 150-200 mg/l, but there are examples of both higher and lower concentrations having been found optimal (EU, 2004). However, as $CN^-$ forms complexes with other competing metals (Fe, Cu, Zn, etc.) it is often necessary to add more cyanide to the process. A normal addition is typically 1 to 1.5 kg of NaCN per ton ore. The ore is normally leached in a slurry with approximately 1.2 to 1.4 $m^3$ water per ton ore.

Following leaching and adsorption to activated coal, the leach slurry undergoes cyanide recovery and/or destruction. The most common cyanide destruction method is the $SO^2$/air-process. The treated slurry normally contains less than 1 mg/l of free cyanide when discharged to the tailings pond[G], which is well below the threshold (1000 mg/l) referred to in directive 1999/45/EC. As a matter of fact, not even the actual leach-solution would normally reach the threshold.

### 5.1.4 Flotation

Froth flotation is a selective process for separating minerals from gangue by using surfactants and wetting agents. The flotation process is used for the separation of a large range of sulphides, carbonates and oxides prior to further refinement. Phosphate and coal as well as some industrial minerals are also processed by flotation technology.

Froth flotation commences by comminution (crushing/grinding), which is used to increase the surface area of the ore for subsequent processing and break the rocks into the desired mineral and gangue. The desired mineral (or the gangue) is rendered hydrophobic by the addition of a surfactant or collector chemical; the particular chemical depends on the mineral that is being refined - as an example, pine oil can be used to float copper. This slurry (normally about 1.4 to 2 $m^3$ water per ton ore, (EU, 2004)) of hydrophobic mineral-bearing ore and hydrophilic gangue is then aerated, creating bubbles. The hydrophobic grains of mineral-bearing ore escape the water by attaching to the air bubbles, which rises to the surface, forming a froth. The froth is removed and the concentrated mineral may be further refined.

In flotation, different classes of additives may be used. Normally collectors (makes the desired mineral hydrophobic), frothers (create the bubbles that bring the hydrophobic minerals to the surface) and modifiers (make the collectors attach to the correct minerals) are used. Sometimes it is necessary to add substances that suppress certain minerals in order to float other similar minerals (selective flotation) - they can be included under the modifiers.

Examples of collectors are xanthates and dithiophosphates. Examples of frothers are pine oil, alcohols, polyglycols, polyoxyparafins, cresylic acid. Examples of modifiers are lime, acids, soda ash, metal salts, cyanide, NaHS and starch.

An example (Pyhäsalmi Cu/Zn mine in Finland) of reagents added at a mine is given below (EU, 2004):

- grinding: lime, ZnSO4, Sodium isobutyl xanthate (SIBX), frother
- Cu-flotation: lime, ZnSO4, SIBX, frother, NaCN
- Zn-flotation: lime, CuSO4, SIBX, frother, NaCN (cleaning)
- Pyrite-flotation: H2SO4, SIBX
- dewatering: flocculant (thickeners), HNO3, CH3COOH (filters)

[G] Directive 2004/35/EC calls for the use of BAT $CN^-$ destruction methods and in any case limits the $CN_{WAD}$ concentration to less than 10 ppm (article 13), which can be met without any problems by a modern $CN^-$ destruction plant.

- tailings: lime (neutralisation).

Normally, the additives are used in low concentrations. Typical added quantities are 5-150 g/ton ore of collectors, 10-50 g/ton of frothers. The added quantities of modifiers vary to a larger extent and it is difficult to give any specific range of addition.

The classification of the additives used in flotation varies, from being not dangerous to very toxic. Regardless of classification, it is unlikely that any waste stream resulting from flotation processes would contain concentrations of substances or preparations (or mixtures of substances) classified as dangerous above the thresholds referred to in directive 1999/45/EC.

## 5.2 Proposed methodology

The additives are likely to be distributed relatively evenly throughout a tailings pond, and it seems reasonable to consider only the average concentrations of dangerous substances and preparations for the entire facility.

**Planned facilities (tailings ponds):**
A procedure consisting of the following steps could therefore be proposed for tailings ponds:

1. Produce an inventory of the substances and preparations used in the processing and subsequently discharged with the tailings slurry to the tailings pond (identity and mass/year). The inventory should be based on the maximum amounts of each substance used during one year.

2. Calculate the average yearly increase in stored water within the tailings pond under steady state conditions, $\Delta Q$. This would in principle be the pore water present in the tailings deposited during one year, and could be calculated from the mass of tailings (tonnes dry weight/year) discharged to pond, the average dry bulk density of the deposited tailings (tonnes/$m^3$) and the pore volume of the sedimented tailings ($m^3/m^3$). In a first estimate, default values of 1.4 t/$m^3$ for the dry bulk density and 0.5 for the pore volume may be used.

3. For each substance in the inventory produced under point 1, determine whether or not it is a dangerous substance according to Annex I in Directive 67/548/EC (or, if necessary, Annex VI). Determine the limit values associated with each danger (R) category.

4. Using the information obtained under point 3, the mass/year of each substance discharged into the pond determined under point 1 and the yearly increase in pore water volume calculated under point 2, use the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous substance.

5. If the aqueous phase is a dangerous preparation as determined under point 4, then the facility should be classified as a Category A facility.

This procedure is relatively conservative and does not account for reactions that may reduce the level of concentration of dangerous substances/preparations in the water phase (degradation, adsorption to the solid phase) nor does it account for treatment/destruction processes that may be applied before discharging the tailings into the facility (e.g., CN destruction, neutralisation, oxidation). Dilution in the facility is also neglected. If necessary, this could be taken into account in a more sophisticated estimation using, e.g., normal treatment results, water balance calculations and/or compartmentation and degradation modelling and including the solid phase in the calculation of concentrations. Also, if with time, the concentrations become below the threshold, the facility could be reclassified.

**Operating facilities (tailings ponds):**
For operating facilities it could be possible to either do the above described calculation or based on chemical analysis of the water (and solids) contained in the facility directly determine if it should be classified as dangerous substances or not.

**Heaps and heap leaching:**
Indent c) of Annex III has little or no relevance for waste heaps. Heap leach facilities are not regarded as waste heaps during operation. At closure they are normally washed out to minimise the content of any remaining leach solution. A screening for dangerous substances can be made based on an inventory of used leach chemicals and the residual concentrations of these leach chemicals in the drainage after washing has been finalised.

## 6. References

EU, 2004. BAT Reference document on the management of tailings and waste-rock.

GRUVRIDAS, 2006. Gruvföretagens riktlinjer för dammsäkerhet, (in Swedish) preliminary document 2006-09-11 provided by Lindahl L-Å.

UK Environment Agency, 2006a. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix A: Consolidated European Waste Catalogue. Environment Agency, Bristol, UK.

UK Environment Agency, 2006b. Hazardous waste. Interpretation of the definition and classification of hazardous waste. Technical Guidance WM2. Second edition, version 2.1. Appendix C: Hazardous Property Assessment. Environment Agency, Bristol, UK.

Vanbelle, 2007. Personal communication with Jean-Marc Vanbelle, Gralex, Belgium.

# Annex 1

## Classification of a mining waste facility in Category A

**The implications of being classified as a Category A facility**
If a facility is classified as a Category A facility, it implies that the operator must adapt major accident prevention measures and produce the relevant documentation that this has taken place:

1. The operator shall adopt and apply a major-accident prevention policy for waste (article 6). In terms of preventive measures, this should entail the delivery of a safety management system; emergency plans to be used in the event of accidents; and the dissemination of safety information to persons likely to be affected by a major accident. In the event of an accident, operators are required to provide the competent authorities with all the relevant information necessary to mitigate actual or potential environmental damage (unless the facility falls within the scope of Directive 96/82/EC).

2. A document is required (article 5 (3)) in the waste management plan demonstrating that a major-accident prevention policy, a safety management system for its implementation and an internal emergency plan will be put into effect in accordance with Article 6 (3).

It further implies that various exemptions of or reductions in requirements possible for facilities that are not classified as Category A facilities do not apply:

3. Member States may reduce or waive the requirements of Articles 11(3), 12(5) and (6), 13(6), 14 and 16 for non-hazardous non-inert waste only if it is deposited in a facility not classified as a Category A waste facility (article 2(3)).

4. Inert waste and unpolluted soil resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries and waste resulting from the extraction, treatment and storage of peat shall be subject to Articles 7, 8, 11(1) and (3), 12, 13(6), 14 and 16 of the directive only if deposited in a Category A waste facility (article 2(3)).

5. There is no minimum time for temporary storage of waste in the facility until it is defined as a "waste facility" if it is a Category A facility (article 3(15)).

In addition, some of the requirements applying to facilities not classified as Category A facilities may have to be more demanding for Category A facilities:

6. It is e.g. necessary to establish monitoring procedures during the operation and after-closure for Category A facilities and they should be laid down proportionate to the risk posed by the individual waste facility, in a way similar to that required by Directive 1999/31/EC (recital 22).

**The significance of being classified as a Category A facility**
Some of the above mentioned requirements for **Category A** facilities have mainly administrative and organisational consequences (1, 2, 5 as well as partly 3 and 4). Others, such as 3, 4 and 6, have direct economical impacts on the operation.

3 refers to reduced or waived requirements that Member States may apply to facilities containing non-hazardous non-inert waste[H], unless the deposit is classified as a Category A facility. Of these requirements 11(3) *"notification without undue delay in case of an incident"* and 16 *"transboundary information"* are mainly of administrative nature, whilst 12(5) *"monitoring and maintenance after closure"*, 12 (6) *"re-*

[H] This may constitute a large part of the waste produced within the base metal mining industry and coal mining industry depending on how "inert waste" is defined in relation to the sulphide content.

*porting and economical responsibility for closed facility"*, 13(6) *"minimized cyanide concentration in facility"* and 14 *"financial security for closure and post-closure"* have significant economical impact.

6 is already partly captured by 3. However, 6 should not primarily be regarded as an additional cost, as it is in the interest of the operator to monitor the facility and make sure it performs as intended.

4 refers to inert waste and unpolluted soil[1] which are materials with reduced requirements unless they are deposited in a Category A facility. Of these requirements some are of administrative nature, such as article 7 *"permitting requirements"*, article 8 *"public participation"*, 11(1) *"competent person"* and 11(3) *"notification without undue delay in case of an accident"* and 16 *"transboundary information"*. Others have direct economical impacts on the operation, such as 12 *"closure and after-closure procedures"*, 13(6) *"minimized cyanide concentration in facility"*, 14 *"financial security for closure and post-closure"*.

**Discussion**

Facilities containing waste classified as hazardous or waste containing dangerous substances above a certain threshold will all be classified as Category A facilities.

For unpolluted soil, non-hazardous inert waste and non-hazardous non-inert waste there are significant implications depending on how the disposal facilities are classified. The implications of classifying a facility as a Category A facility are both administrative and economical. Requirements of administrative nature, such as permitting and development as well as maintenance of various management plans, are significantly more comprehensive for Category A facilities. Economical consequences may be significant, especially regarding monitoring, reporting, maintenance after closure and financial security for closure and post-closure.

For non-hazardous inert waste and non-hazardous non-inert waste the Directive is formulated in such a way that it encourages mining companies to design, locate and operate the disposal facilities in such a way that it is not classified as a Category A facility, i.e., minimise risk over the life-cycle of the facilities.

This important aspect of the Mining Waste Directive, creating an incentive for risk reduction by simplified administration and lower costs for low risk facilities, is a key forward-looking feature of the Directive. For this reason, any methodology developed for the classification of waste disposal facilities should be carefully formulated in order to encourage operators to minimise risk related to the disposal facilities. The developed methodology should therefore, to the extent possible, provide possibilities for the operator to design, locate, operate and close facilities in such a way that when risk is minimised to certain levels (to be defined in the methodology) the facilities are not classified as Category A facilities.

[1] This may constitute a large part of the waste produced within quarrying, industrial mineral sector and the aggregates industry and it may constitute a large part of the waste produced within the metal mining industry and the coal mining industry – depending on how "inert waste" is defined in relation to the sulphide content. Within the aggregates industry mineral sources with elevated sulphide contents can in most cases be avoided by initial site investigations (Vanbelle, 2007).

# Annex 2

## Discussion of the classification of mining waste facilities as Category A according to indent a) in Annex III of the Mining Waste Directive: Incorrect operation

**Background and objectives**

The proposed methodology requires that the ratio between the impact of a “worst case” situation and the impact of a “normal” operation/post-closure situation for the same facility should exceed a certain number for the facility to be classified as a Category A facility. The “normal” situation is represented by an impact assessment for the facility based on the Best Available Technology (BAT) principle, whereas the “worst case” situation is represented by an impact assessment where all the measures taken to protect the environment have been removed or are assumed not to function.

The methodology should identify facilities which may give rise to **major accidents** and, on the one hand, ensure that such facilities are indeed classified as Category A facilities, while, on the other hand, ensuring that facilities which, due to size, the nature of the operation and the impact, location and vulnerability of the environment cannot give rise to a major accident, are **not** classified as Category A facilities. It is further desirable for the procedure to be as transparent and simple as possible.

The purpose of this note is to discuss some of the specific issues involved in the assessment of the ratio of the worst case to the BAT situation and in setting appropriate classification criteria for that ratio.

Initially, the three components of the impact assessment (the source/hazard potential, the pathway/transport and the receptor/environmental vulnerability) are considered separately. All types of facilities are included.

**The source**

Considering the objectives mentioned above, it seems reasonable to distinguish between small, medium sized and large facilities: Under the same external circumstances, the potential impact will generally increase with size for the same type of facility. Size depends both on the area covered and on height. In general, the flux or load of contaminants is roughly proportional to the area covered by the facility and the time during which it may remain above a certain threshold generally increases with increasing height/thickness for a percolation scenario (but depends on the deposition technique). Small, medium and large units are defined as follows:

| | |
|---|---|
| Small: | area < 1 ha and height < 5 m |
| Medium: | 1 ha < area < 50 ha and/or 5 m < height < 10 m |
| Large: | area > 50 ha and/or height > 10 m |

If we compare the total load from a small unit (1 ha), a medium unit (25 ha) and a large unit (50 ha), the relative loads will be: 1:25:50 (assuming that the same waste is deposited in all the facilities and disregarding the influence of different heights that may occur).

This would suggest similar relative differences between the limit values for the load ratio, $R_L$ = Worst case load/BAT load for small:medium:large units of 50:25:1.

Some of the different corresponding BAT and Worst case situations for environmental protection measures at mining waste facilities that should be considered in an impact assessment are shown in table 1. Some estimations of the potential performance of the measures under BAT and Worst case conditions, respectively, are also shown.

The load ratio, $R_L$, is calculated for all contaminants considered critical in the BAT impact assessment (to be determined by the competent authorities in each case).

It is suggested that $R_L$ is calculated for two periods of time:

a): The period of operation of the facility
b): For a period of 1000 years following the closure

***Table 1:***
*Some examples of the most common environmental protection measures and some examples of their possible performance under BAT and Worst case conditions.*

| Environmental protection measure | BAT situation | Worst case situation | Comment |
|---|---|---|---|
| Bottom liners, drainage and leachate collection (ditches or wells) and treatment systems<br><br>Most relevant to the operation period | Leachate collected and treated/discharged (95 %) | All leachate leaks to the environment (100%) – or the leachate is not treated before discharge (long-term situation) | The differences in impact may depend on the rate of release |
| Dry top cover to reduce the rate of infiltration<br><br>Most relevant to the after-closure period | Reduces the flux of contaminants but prolongs the leaching period (10 % of general infiltration) | Does not function and allows up to 100 % of general infiltration, depending on the conditions | The difference in leachate production rate could be100%/10% = 10 based on hydraulics – should be evaluated in combination with bottom liners |
| Dry top cover to minimise influx of oxygen<br><br>Most relevant to the after-closure period | Prevents/reduces oxidation of ARD producing waste and other reactive waste (also used to prevent self-ignition) | Does not function/is disrupted and allows oxidation of ARD producing waste and other reactive waste | The difference in concentration level of certain contaminating substances in the leachate may easily be 1:10 or 1: 100 if acidification occurs |
| Wet covers (under water storage) to prevent oxidation<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces oxidation of ARD producing waste and other reactive waste | Does not function – dries out or is diverted and allows oxidation of ARD producing waste and other reactive waste | The difference in concentration level of certain contaminating substances in the leachate may easily be 1:10 or 1: 100 if acidification occurs |
| Selective management (e.g. segregation of different (incompatible) types of waste)<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces undesired waste/waste interactions (e.g. acidification of non-acidic waste from ARD producing waste) | Incompatible types of waste are mixed/landfilled together an causes an increased level of contamination | It should be evaluated whether an operational error could lead to a worst case situation |
| Compaction<br><br>Relevant both to the operation and the aftercare period | Minimise oxygen transport into potentially ARD generating waste | Compaction does not have the intended effect and does not reduce oxygen transport to the desired levels | The difference in concentration level of certain contaminating substances in the leachate may easily be 1:10 or 1: 100 if acidification occurs |
| Treatment of leachate or waste<br><br>Most relevant to the operation period | Minimise contaminant release in discharged water from the facility | Treatment is interrupted | It should be evaluated whether an operational or technical error could lead to a worst case situation |
| Back-pumping<br><br>Most relevant to the operation period | Leakage/drainage from the facility is back-pumped to the facility to minimise contaminant transport to the environment | Back-pumping is in-effective or interrupted | It should be evaluated whether an operational or technical error could lead to a worst case situation |

For the calculation of $R_L$ for period a), the maximum annual loads (weight unit/year) of the contaminants of interest for the Worst case situation and the BAT situation should be used.

For the calculation of $R_L$ for period b), the maximum annual loads (weight unit/year) of the contaminants of interest for the Worst case situation and the BAT situation should be used.

The highest value of $R_L$ determined either under a) or b) will be used in the classification.

**The pathway/transport**

In order for a risk to exist, the pathway between the source and the receptor (the environment in question) must exist. The pathway may consist of groundwater, surface waste, soil or overland flow. The pathway may in itself have a mitigating effect (dilution, retention) on the contaminants transported, but in the worst case situation this is disregarded.

For a facility to be submitted to classification according to **incorrect operation** under indent a in Annex III to the Mining Waste Directive, it should be established that there is a pathway between the facility and the environment to be protected and considered. It is assumed that this is done as part of the general environmental impact assessment prior to permitting. **If no such (likely) pathway exists, the classification according to incorrect operation should be omitted.**

NB: When establishing the possible pathway, a long term perspective should be applied.

**The receptor/the vulnerability of the environment**

It is also necessary to consider the vulnerability of the environment to the (potential) impact from the mining waste facility. It is suggested to use a very simplified evaluation of the sensitivity of the environment in question, namely a vulnerability factor, VF. This factor will be multiplied by the load ratio, $R_L$, to reach the determining ratio, R. The factor could, to a certain extent, also take the pathway into account.

It is suggested that a factor of VF = 1 is used for a “normal” situation with no special groundwater/drinking water fresh water interests or habitats to protect.

If such interests are present, and/or the environment is sensitive to the anticipated impact, and/or if the source is close to the environment to be protected and/or the access to the environment is easy/fast, a factor of VF = 2 is applied.

If no environmental protection interests exist and contaminant access to the environment is difficult/very slow, a factor VF = 0.5 is applied.

**Overall system**

Even though it is attempted to fulfil the objectives described above to the extent possible, there will still be a certain element of subjectivity and policy involved in the final determination of the criteria to be fulfilled. The numbers suggested here should therefore be subject to further discussion by the TAC and the Commission.

Taking into account the relative impacts of smaller and larger facilities, the fact that more thorough impact assessments will generally be carried out for larger than for smaller facilities, that there are many small facilities, that sensitive and easily accessible environments require protection, that the situation may be different during the operational period and in the longer term, that both of these periods are important, that reactive and ARD-producing wastes pose a special problem, the following criteria are proposed for VF and $R = VF \times R_L$ :

***Table 2***
*Suggested vulnerability factor, VF, according to the sensitivity and accessibility of the recipient.*

| Sensitivity and accessibility of recipient | Vulnerability factor, VF |
|---|---|
| Low | 0,5 |
| Medium | 1 |
| High | 2 |

***Table 3***
*Proposed distinction between small, medium and large facilities and proposed criteria ratios, R x VF.*

| Type of facility | Description of facility | $R = R_L$ x VF where $R_L$ the is the ratio between "Worst case" and "BAT" load and VF the vulnerability factor for the recipient |
|---|---|---|
| Small | area < 1 ha and height < 5 m | 100* |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 10 |
| Large | area > 50 ha and/or height > 10 m | 5 |

*: NB - Changed from 15 compared to the proposal of 2007-10-01

A few more comments on the numbers selected in table 3:

A – the size (area) motivates the relative factors 1:25:50 for R for large:medium:small facilities.

B –for non-reactive waste the height motivates something like 1:2:3 for R for large:medium:small facilities and is maybe less relevant for potentially ARD producing waste assuming worst-case (the release may possibly be delayed in case of significant thickness).

Combined, A and B results in 1:50:150 for R for large:medium:small facilities. Taking into account that we are addressing the risk of **major** accidents, we allow for an increase corresponding to a factor of R = 5 from BAT to Worst case, including the Vulnerability factor, for the large facilities. This would proportionally lead to relative factors of 5:250:750 for large:medium:small facilities. However, we suggest 5:10:100 (discount 1:1/25:1/7,5, note that this means applying relatively stricter criteria for the smaller facilities, especially for the medium size facilities). The reason for this is that the area of the medium size facility may vary over a wide range and it may actually have the same size (50 ha) as that chosen to represent the large facilities in this case.

We suggest that the values are set to a level that ensures that a failure of the protective measures (if required, which we assume that it is, if it is part of the design) would be picked up at least for the large and medium size facilities. A cover failure may cause an increase in load by a factor of 10 (infiltration) and 100 (oxygen flux for e.g. waste with a potential for ARD production), which justifies $R_L$ x VF factors of 10 or less.

For the small facilities, using a factor of 100 can be justified by their, in this context, insignificant size and potential to cause a major accident.

# Annex 3

## Discussion of the classification of mining waste facilities as Category A according to indent b) in Annex III of the Mining Waste Directive: Hazardous waste above a certain threshold

**Background and objectives**
Annex III to the Mining Waste Directive requires under indent b) that a mining waste facility is classified as a Category A facility if it contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold.

The methodology should, on the one hand, identify and classify a facility as a **Category A** facility, if, due to its content of hazardous waste, it constitutes a real hazard, either in the short or the long term, and, on the other hand, ensure that a facility, which due to its size and low (or zero) content of hazardous waste does not constitute a hazard, neither in the short nor in the long term, are **not** classified as Category A facilities. It is further desirable for the procedure to be as transparent and simple as possible.

The purpose of this note is primarily to discuss the difficulties involved in producing a rationale for the setting of the "certain thresholds" referred to in Annex III of the MWD (i.e. the limit values shown in table 1).

**The proposed methodology**
The proposed methodology prescribes a two-step procedure:

**Step 1:**
Determine if any of the streams of waste placed in the facility are hazardous according to the European Waste Catalogue (EWC) and the associated procedures. A waste stream is classified as hazardous:

- If it has an "absolute entry" in the EWC (only entry 01 03 04: acid-generating tailings form processing of sulphide ore).
- If it has a mirror entry (this is the case for 01 03 05, 01 03 07 and 01 04 07), and dangerous substances are present above threshold concentrations. Whether or not this is the case is determined using the results of the waste characterisation carried out according to Annex II to the MWD and checking the content of various substances against the thresholds defined by the hazard properties (H1-H14) in Annex III to Directive )1/689/EEC and the risk phases defined in Directive 2001/59/EC). Some guidance concerning relevant H-properties has been given in the proposed methodology and more is available, e.g. from the UK Environment Agency.
- If a national authority has determined that it should be classified as hazardous waste.

Once a waste stream has been identified as hazardous, the annual quantity of the waste produced during operation/the quantity in place at the time of determination and the total quantity in the facility at the end of the planned period of operation shall be determined.

**Step 2:**
The quantities of non-hazardous waste and hazardous waste (divided into ARD-producing hazardous waste and hazardous waste without a potential for ARD production) present or expected to be present in the facility at the completion of the operation period are calculated.

If the weight percentage of waste in a mining waste facility classified as hazardous exceeds the limit values shown in table 1 for content of ARD producing tailings or total content of hazardous waste (including ARD producing tailings), then that facility shall be classified as a Category A facility.

***Table 1***
*Proposed limit values for content of hazardous waste in mining waste facilities.*

| Class of facility | Description of facility | Limit value for content of ARD producing tailings | Limit value for total content of hazardous waste |
|---|---|---|---|
| | | % by weight | % by weight |
| Small | area < 1 ha and height < 5 m | 5 | 10 |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 2 | 7 |
| Large | area > 50 ha and/or height > 10 m | 1 | 5 |

**The "certain thresholds" in step 2 of the proposed methodology**
In the methodology, it has been proposed to distinguish between small, medium and large facilities. This is consistent with the methodology proposed for incorrect operation under indent a), and the same size classification is used. It is intended to provide administrative procedures that are as simple as possible. The hazard exhibited by a certain type of hazardous waste depends both on the absolute amount of the waste (this justifies classification according to size of the facility) and on the potentially mitigating or buffering effect of the non-hazardous waste also present in the facility. The latter, and the fact that larger facilities often are more remotely located with respect to human population than smaller facilities are, could justify allowing larger absolute quantities of hazardous waste in larger facilities before they are classified as Category A facilities.

In the methodology, it has also been proposed to have two sets of limit values, one for potentially ARD producing tailings, and one for the total content of hazardous waste, including potentially ARD producing tailings, the first being substantially lower than the latter. This is justified by the fact that the hazard, e.g. in terms of release of dangerous substances such as toxic elements (for example certain heavy metals), particularly in the longer term, may increase by a factor of 10 to 1000 if the waste and leachate become acidic due to the production of ARD.

The actual numbers (the limit values) proposed in table 1 are, however, not based on a solid, scientific rationale. They are, to a large extent, based on pragmatic considerations, and could therefore be subject to political discussion, possible change and subsequent agreement/decision by the TAC and the Commission. Some of the main causes of the difficulties involved in the setting of these thresholds are:

1. The "hazardousness" of a waste material as determined on the basis of Directive 91/689/EEC (step 1 above) is rather wide-ranging and unspecified, and not necessarily related to the (risk-related) behaviour of a waste material in a mining waste facility. If a material is deemed hazardous e.g. due to its content of lead, but this lead is incorporated into minerals which are likely to remain stable for hundreds or thousands of years under the conditions existing in a mining waste facility, then this waste would most likely not constitute any real risk to humans or the ecosystem. If, on the other hand, the same amount of lead is present in minerals (e.g. sulphides) that are potentially ARD producing, then that waste would indeed present a real risk to humans and the ecosystem. The waste would be deemed hazardous in both cases, but only in one of the cases would it mean that a real risk existed.

2. The potential risk of a certain amount of hazardous waste present in a mining waste facility depends on its specific properties, its distribution and location within the facility and the potentially mitigating effect of the non-hazardous waste also present in the facility (e.g. the capacity of the non-hazardous waste to neutralise acid rock drainage produced by the hazardous waste).

This means that it is virtually impossible to generalise and set meaningful general limit values for the content of hazardous waste in a facility that would ensure a certain level of risk or protection. To achieve this, it would be necessary to consider the actual hazardous properties of the waste and perform a site-specific impact or risk assessment.

In the discussions with the TAC and Steering Group, the project team has understood that the classification according to indent b) should not be based on (site-specific) risk assessment.

From the point of view of safety and environmental protection, the danger involved in a possible wrong classification of a facility a not being a Category A facility (due to the limit values being set too high) even if the content of hazardous waste may actually, under the prevailing site-specific conditions, constitute a real risk, may not be so significant after all. The risk assessments required under indent a): Incorrect operation, should pick up any serious risks to the environment, regardless of the classification of the waste as hazardous or non-hazardous, and ensure proper classification of the facility.

# Classification of mining waste facilities as Category A or not Category A in accordance with Annex III to Directive 2006/21/EC ("The Mining Waste Directive")

## Proposal for a classification procedure

## 12 November 2007

**Introduction**
A mining waste facility shall be classified as Category A or not Category A in relation to:

a1) Structural integrity
a2) Incorrect operation
b) The content of hazardous waste.
c) The content of dangerous substances

When classifying a mining waste facility, all four issues must be considered. If a facility is classified under Category A according to any one of the above listed issues, then the overall classification of that facility is Category A. The procedure for classification of mining waste facilities according to each issue is described in the following.

### a1): Classification based on the consequences of loss of structural integrity

If a failure, due to loss of structural integrity[J], of a waste facility, regardless of the type of facility, can lead to serious danger to human health or to serious danger to the environment, then the facility shall be classified as category A.

The consideration of structural integrity is intended to include all failure mechanisms relevant to the structures covered. This may for example be malfunction of the decanting system, over-topping, internal erosion, settlements, slides, liquefaction, construction weakness, failure in the underground, etc.

A facility is classified as a Category A facility if the consequences (in terms of impact on human health and impact on the environment) of a failure of its structural integrity exceeds the criteria listed in table 1 and table 2, respectively. The procedure applies to all facilities.

***Table 1***
*Classification with regard to loss-of-life or danger to human health as a consequence of loss of structural integrity.*

| **Category** | **Consequence** |
|---|---|
| A | Non-negligible potential for loss-of-lives or serious danger to human health |
| Not A | Negligible potential for loss-of-lives or serious danger to human health |

[J] Structural integrity may be defined as the ability of the facility to contain the waste within the boundaries of the facility.

***Table 2***
*Classification with regard to potential for environmental impact as a consequence of loss of structural integrity.*

| **Category** | **Consequence** |
|---|---|
| A | Non-negligible potential for serious environmental impact |
| Not A | Negligible potential for serious environmental impact |

The potential for loss-of-lives or serious danger to human health is considered negligible if people that might be affected only stay in the potentially affected area in an occasional way (passing by). It is assumed that human lives are threatened at water levels of 0.7 m above ground and water velocities exceeding 0.5 m/s. The following factors should be taken into consideration:

- The water level
- The rising rate of water levels
- The propagation velocity of the flood-wave
- The topography, including damping features such as e.g. lakes
- The travel time of the flood-wave to areas where people live or stay
- Warning systems
- The possibility to evacuate and plans for such evacuation

Injuries leading to disability or prolonged states of ill-health count as serious dangers to human health.

The potential for serious environmental impact is considered negligible if the affected environment can be restored with limited clean-up and restoration efforts and the environment does not suffer any permanent or long-lasting damage or effects.

In establishing the potential for loss-of-life or serious danger to human health and serious environmental impact, specific evaluations of the extent of the potential impacts shall be considered in the context of the source – pathway - receptor chain. If there is no pathway between the source and the receptor, then the facility cannot be classified under Category A due to loss of the structural integrity.

The classification procedure related to loss of the structural integrity shall consider both the immediate impact of any materials transported out of the facility as a consequence of the failure (e.g., tailings slurry, rock, contaminated and/or uncontaminated water) and the resulting short, medium and long-term effects (e.g., contamination of soil and water bodies, loss of life, destruction of habitats, etc). The entire life-cycle of the facility needs to be considered in the evaluation of the hazard potential of the facility.

**a2): Classification based on the consequences of incorrect operation**

If incorrect operation of a facility can lead to serious danger to human health or to serious danger to the environment in the short or long term, then the facility shall be classified as a category A facility. Examples of incorrect operation are e.g. poor maintenance or monitoring that could lead to continuous or repeated discharge of contaminated water to surface water or groundwater. Incorrect operation could occur during the entire life-cycle of the facility and is likely to pose a significant hazard potential particularly in the after-closure phase when e.g. back-pumping, water treatment etc. are likely not to be working, bathtub effects may occur, acid and alkaline drainage may occur, covers or liners may become deficient, etc. Incorrect operation could, of course, also lead to a failure due to loss of structural integrity, but that has been covered under a1).

A mining waste facility shall be classified as a Category A facility if the potential consequences of incorrect operation exceeds the criteria described below. The classification procedure includes a comparison of two assessments of the release of contaminants for the facility in question: one based on a “Worst case” scenario, and one based BAT conditions.

For a facility to be submitted to classification based on incorrect operation, it must be established that there is a pathway between the facility and the environment to be protected and considered. It is assumed that this is done as part of the general environmental impact assessment prior to permitting. If no such (likely) pathway exists, then classification according to incorrect operation should be omitted.

The “BAT” scenario is defined as the conditions existing when the facility is designed and operated in accordance with BAT requirements[K], in particular with respect to environmental protection measures (this would generally correspond to “normal” conditions for a facility).

The “Worst case” scenario is defined as the conditions existing when it is assumed that all environmental protection measures at the facility are failing or non-existing.

Examples of BAT and Worst case situations for environmental protection measures are shown in Appendix 1.

An assessment of the release of contaminants (or the source strength) shall be carried out both for the Worst case scenario and for the BAT scenario. In both cases the maximum annual load or flux, L (weight unit/year), of the relevant contaminants[L] shall be carried out for two periods of time, namely:

a): The period of operation of the facility
b): For a period of 1000 years following the closure

For each period, the ratio, $R_L$, between the maximum value of L determined for the Worst case scenario and the maximum value of L determined for the BAT scenario shall be calculated. The highest value of $R_L$ determined for either of the periods a) or b) shall be used for the classification.

A vulnerability factor, VF, describing the accessibility and sensitivity of the receptor (the environment) shall then be determined. The accessibility is a measure of the ease with which the contamination is transported along the pathway to the receptor. The sensitivity is a measure of how sensitive the receptor is to the potential impact. For a given facility in a given environment, VF is assigned the value 0.5, 1 or 2, based on the ranking of accessibility and sensitivity shown in table 3. The basis for the ranking of the accessibility and sensitivity of the receptor is shown in table 4.

***Table 3***
*Assignment of values to VF depending on the sensitivity and accessibility of the receptor (the environment).*

| **Sensitivity of receptor** | **Accessibility/pathway** | | |
|---|---|---|---|
| | Easy/quick | Normal | Difficult/slow |
| Vulnerable | 2 | 2 | 0.5 |
| Normal | 2 | 1 | 0.5 |
| Non-vulnerable | 0.5 | 0.5 | 0.5 |

[K] BAT is normally evaluated for each specific facility and guidance can be found in the EU BAT Reference document on the management of tailings and waste-rock (2004).

[L] The relevant contaminants are those considered in the impact assessment upon which the permit is based.

***Table 4***
*Basis for ranking of accessibility and sensitivity of the receptor (the environment) to be used in table 3.*

| **Ranking** | **Explanation** |
|---|---|
| **Accessibility of the environment** | |
| Easy/quick | Direct access/short pathway, transport time in the order of weeks or a few months or less |
| Normal | “Normal” access, transport time in the order of a one or a few years |
| Difficult/slow | Difficult access/long pathway, transport time in the order of 10 years or more |
| **Sensitivity of the environment** | |
| Vulnerable | The environment is sensitive to the anticipated impact, groundwater, surface water or habitat interests to be protected |
| Normal | “Normal” level of sensitivity of the environment with no special surface water, groundwater or habitat interests to be protected |
| Non-vulnerable | No environmental interests exists, no surface water body, no or very deeply located aquifer, no habitat to be protected |

The highest value of $R_L$ as determined above and the appropriate value of VF are combined to produce the classification factor $R = VF \times R_L$.

The classification factor, R; is compared to the criteria listed in table 5. The criteria are different for small, medium sized and large facilities (see the table). A facility is classified a Category A facility if R exceeds the limit value corresponding to its size as shown in table 5.

***Table 5***
*Limit values $R = VF \times R_L$ for classification of small, medium size and large mining waste facilities as Category A facilities.*

| **Type of facility** | **Description of facility** | **Limit values for R[M] A facility is Category A if R exceeds the limit value** |
|---|---|---|
| Small | area < 1 ha and height < 5 m | 100 |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 10 |
| Large | area > 50 ha and/or height > 10 m | 5 |

When carrying out the contaminant release assessments, special attention must be paid to waste containing or consisting of reactive waste not classified as hazardous (including ARD producing waste).

Any medium or large size facilities containing waste that may self-ignite if exposed to oxygen, shall be classified as Category A facilities.[N]

**b): Classification based on the content of hazardous waste**

A mining waste facility is classified as a Category A facility if it contains more than a certain percentage of **hazardous waste**. The classification according to the content of hazardous waste proceeds in two steps.

[M] The numbers may be subject to change based on the results of classification of a large number of facilities.

[N] To be discussed by the TAC Steering Group.

In **step 1** it shall be determined if any of the waste streams discharged into the facility are hazardous according to the European Waste Catalogue[O] (EWC) and the associated procedures. A waste stream is classified as hazardous:

- If it has an "absolute entry" in the EWC (only entry 01 03 04: acid-generating tailings from processing of sulphide ore). Such tailings are considered acid generating if the ratio NP/AP between the neutralisation potential (NP) and the acidity production potential (AP) as determined by the procedure to be developed by CEN/TC 292/WG8 is < 1. For 1< NP/AP < 3, further evaluation, e.g. using a kinetic test may be necessary to determine if the waste should be considered ARD producing or not. For NP/AP > 3, the waste is considered non- acid generating.
- If it has a mirror entry (this is the case for 01 03 05, 01 03 07 and 01 04 07), and dangerous substances are present above threshold concentrations. Whether or not this is the case is determined using the results of the waste characterisation carried out according to Annex II to the MWD and checking the content of various substances against the thresholds defined by the hazard properties (H1-H14) in Annex III to Directive )1/689/EEC and the risk phases defined in Directive 2001/59/EC). Some guidance concerning relevant H-properties is available, e.g. from the UK Environment Agency.
- If a national authority has determined that it should be classified as hazardous waste.

If none of the waste streams received by the facility consist of hazardous waste, then the facility shall not be classified as a Category A facility based on its content of hazardous waste, and step 2 shall not be carried out.

If one or more waste streams have been identified as hazardous, then step 2 shall be carried out.

In **step 2** the total quantity of hazardous waste present in the facility at the end of the planned period of operation shall be determined (on a dry matter basis). The quantities of acid-generating tailings from processing of sulphide ore (A) and the quantities of waste classified as hazardous for other reasons (B) shall be determined separately.

The total amount of waste expected to be present in the facility at the end of the planned period of operation (C) shall be determined (on a dry matter basis).

The ratios A/C and (A+B)/C shall be determined and compared to the limit values for acid (ARD) producing waste and the total content of hazardous waste, respectively, shown in table 6. Different limit values exist for small, medium sized and large mining waste facilities, respectively.

If the weight percentage of waste in a mining waste facility classified as hazardous exceeds the limit values shown in table 6 for content of ARD producing tailings or total content of hazardous waste (including ARD producing tailings), then that facility shall be classified as a Category A facility.

[O] Directive 91/689/EEC and subsequent amendments.

*Table 6*
*Proposed limit values for content of hazardous waste in mining waste facilities.*

| Class of facility | Description of facility | Limit value for content of ARD producing tailings[P] (A/C) | Limit value for total content of hazardous waste[Q] (A+B)/C |
|---|---|---|---|
| | | % by weight | % by weight |
| Small | area < 1 ha and height < 5 m | 5 | 10 |
| Medium | 1 ha < area < 50 ha and/or 5 m < height < 10 m | 2 | 7 |
| Large | area > 50 ha and/or height > 10 m | 1 | 5 |

**c): Classification based on the content of dangerous substances/preparations**

A mining waste facility shall be classified as a Category A facility if it contains substances or preparations (i.e. additives or reaction products) in sufficient quantities for them to be classified as **dangerous** according to Directives 67/548/EC and 199/45/EC and subsequent amendments.

**Planned facilities (tailings ponds):**

The following stepwise procedure shall be followed for planned facilities (tailings ponds):

1. Produce an inventory of the substances and preparations used in the processing and subsequently discharged with the tailings slurry to the tailings pond (identity and mass/year). The inventory shall be based on the maximum amounts of each substance used during one year.

2. Calculate the average yearly increase in stored water within the tailings pond under steady state conditions, ΔQ. This is assumed to correspond to the pore water present in the tailings deposited during one year, and shall be calculated from the mass of tailings (tonnes dry weight/year) discharged to pond, the average dry bulk density of the deposited tailings (tonnes/$m^3$) and the pore volume of the sedimented tailings ($m^3/m^3$). If exact data are not available, default values of 1.4 t/$m^3$ for the dry bulk density and 0.5 for the pore volume may be used.

3. For each substance in the inventory produced under point 1, determine whether or not it is a dangerous substance according to Annex I in Directive 67/548/EC (or, if necessary, Annex VI). Determine the limit values associated with each danger (R) category.

4. Using the information obtained under point 3, the mass/year of each substance discharged into the pond determined under point 1 and the yearly increase in pore water volume calculated under point 2, use the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous substance.

5. If the aqueous phase is a dangerous preparation as determined under point 4, then the facility should be classified as a Category A facility. If it is not classified as a dangerous preparation, then the facility is not classified as a Category A facility.

This procedure is relatively conservative and does not account for reactions that may reduce the level of concentration of dangerous substances/preparations in the water phase (degradation, adsorption to the solid phase) nor does it account for treatment/destruction processes that may be applied before discharging the tailings into the facility (e.g., CN destruction, neutralisation, oxidation). Dilution in the facility

[P] The numbers may be subject to change based on the results of classification of a large number of facilities.

[Q] The numbers may be subject to change based on the results of classification of a large number of facilities.

is also neglected. If necessary, this may be taken into account in a more sophisticated estimation using, e.g., normal treatment results, water balance calculations and/or compartmentation and degradation modelling and including the solid phase in the calculation of concentrations. Also, if with time, the concentrations fall below the threshold, the facility could be reclassified.

**Operating facilities (tailings ponds):**
For operating facilities, the classification may be based upon the described calculations, or it may be based on direct chemical analysis of the water (and solids) contained in the facility followed by use of the directions in Annex 1 of Directive 1999/45/EC to determine if the aqueous phase and its contents have to be considered a dangerous preparation. If it does, the facility shall be classified as a Category A facility.

**Heaps and heap leaching:**
Classification according to content of dangerous preparations has little or no relevance for waste heaps. Heap leach facilities are not regarded as waste heaps during operation. At closure they are normally washed out to minimise the content of any remaining leach solution. A screening for dangerous substances can be made based on an inventory of used leach chemicals and the residual concentrations of these leach chemicals in the drainage after washing has been finalised.

# Annex 1

*Some examples of the most common environmental protection measures and some examples of their possible performance under BAT and Worst case conditions.*

| Environmental protection measure | BAT situation | Worst case situation |
|---|---|---|
| Bottom liners, drainage and leachate collection (ditches or wells) and treatment systems<br><br>Most relevant to the operation period | Leachate collected and treated/discharged (95 %) | All leachate leaks to the environment (100%) – or the leachate is not treated before discharge (long-term situation) |
| Dry top cover to reduce the rate of infiltration<br><br>Most relevant to the after-closure period | Reduces the flux of contaminants but prolongs the leaching period (10 % of general infiltration) | Does not function and allows up to 100 % of general infiltration, depending on the conditions |
| Dry top cover to minimise influx of oxygen<br><br>Most relevant to the after-closure period | Prevents/reduces oxidation of ARD producing waste and other reactive waste (also used to prevent self-ignition) | Does not function/is disrupted and allows oxidation of ARD producing waste and other reactive waste |
| Wet covers (under water storage) to prevent oxidation<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces oxidation of ARD producing waste and other reactive waste | Does not function – dries out or is diverted and allows oxidation of ARD producing waste and other reactive waste |
| Selective management (e.g. segregation of different (incompatible) types of waste)<br><br>Relevant both to the operation and the after-closure period | Prevents/reduces undesired waste/waste interactions (e.g. acidification of non-acidic waste from ARD producing waste) | Incompatible types of waste are mixed/landfilled together an causes an increased level of contamination |
| Compaction<br><br>Relevant both to the operation and the aftercare period | Minimise oxygen transport into potentially ARD generating waste | Compaction does not have the intended effect and does not reduce oxygen transport to the desired levels |
| Treatment of leachate or waste<br><br>Most relevant to the operation period | Minimise contaminant release in discharged water from the facility | Treatment is interrupted |
| Back-pumping<br><br>Most relevant to the operation period | Leakage/drainage from the facility is back-pumped to the facility to minimise contaminant transport to the environment | Back-pumping is in-effective or interrupted |

# Appendix 7

## Examples of application of the proposed methodology to mining waste facilities

## Examples of Classification of mining waste facilities

To test the methodology and to illustrate how it may be used, the methodology proposed in chapter 8 has been applied to a number of different mining waste facilities. The facilities have been classified as Category A facilities or not Category A facilities according to the proposed methodology for classification in Annex III in the MWD.

For the sake of illustration, the facilities are classified with regard to all indents even if the facility is classified as Category A in a previous step of the assessment.

| Example no. | Type of facility | Size | Material extracted | Result of classification | Example provided by |
|---|---|---|---|---|---|
| 1 | Waste-rock heap | 226 ha, 45 m high | Base Metals | Not Category A | Project team |
| 2 | Waste-rock heap | 631 ha, > 50 m high | Base Metals | Category A | Project team |
| 3 | Tailings pond | 1100 ha, > 30 m high | Base Metals | Category A | Project team |
| 4 | Waste-rock heap | 60 ha, 21-31 m high | Hard-coal | Not Category A | Project team |
| 5 | Waste-rock heap | 56 ha, 80 m high | Hard-coal | Not Category A | Project team |
| 6 | Waste-rock heap | 57 ha, 75 m high | Gold | Not Category A | Project team |
| 7 | Tailings pond | 500 ha, 40 m high | Gold | Category A | Project team |
| 8 | Waste-rock heap | 27 ha, 40 m high | Aggregates | Not Category A | Gralex/Vanbelle and Project team |
| 9 | Waste-rock heap | 2 ha, max. 60 m high | Aggregates | Not Category A | Gralex/Vanbelle and Project team |

**Example 1**

## Waste-rock dump T6, Aitik, Northern Sweden

**Short description of the facility and its environment**
Waste-rock dump T6 is a 266 ha and approximately 45 m high waste-rock dump for selectively managed non-ARD generating waste-rock at the Aitik Cu mine in Northern Sweden. The dump is situated on 2-30 m low permeable moraine overlying the bedrock. There dump is surrounded by drainage collection ditches and the drainage is collected and used as process-water in the concentrator. There are no buildings, roads, surface water streams nor aquifers in the immediate vicinity of the dump. The Aitik mine is situated in the Kalix and Torne Rivers catchment area which has been declared a Natura 2000 area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The heap slopes are built at an overall slope angle of 1:3 (V:H) which is considered long-term stable. The friction angle of the waste material as well as the underlying moraine is around 45 degrees (1:1). The waste has a relatively high permeability which makes it unlikely that a perched groundwater level would occur within the heap. The area where the heap is located is flat forest land.

According to the reasoning above, it is unlikely that any major structural failure of the heap would occur. If there was a failure it would be a local failure involving movement of a relatively small quantity of waste-rock over a short distance (<100 m horizontally). Such a failure is unlikely to lead to any loss of life or any significant environmental impact due to the absence of buildings, infrastructure or surface water streams close to the heap as well as the characteristics of the waste-rock deposited in the heap.

No environmental protection measures are applied to heap T6. During operation of the concentrator, the drainage is collected and used as process water, however, the drainage is suitable for direct discharge to the recipient posing a neutral pH and low metal concentrations. The drainage water quality is predicted to remain the same in the long-term. Closure measures area limited to a shallow moraine cover in order to enhance the establishment of vegetation and the drainage is planned to be released directly to the recipient. No realistic scenario can be foreseen in which incorrect operation could lead to a major accident and thus the potential for serious environmental impact is neglishable.

This leads to the classification of the heap as “not Category A” with respect to failure due to loss of structural integrity or incorrect operation.

**Classification based on the content of hazardous waste**
All waste-rock deposited on the T6 heap has undergone characterization with respect to ARD generation potential, S and Cu content as well as rock type before it is loaded in the mine and transported to the T6 heap. Only waste-rock complying with certain criteria is allowed to be deposited in the heap, all other waste is deposited in other heaps. The information about the waste characteristics is fed into the mine’s dispatch system and automatically transferred to loaders and trucks which are tracked by GPS. This system makes it almost impossible that waste which does not comply with the strict criteria would end up in heap T6. No other waste-rock or waste types are deposited on heap T6.

According to the waste European Waste Catalogue waste-rock is by definition non-hazardous waste, which leads to the classification of the heap as “not Category A” with respect to the content of Hazardous Waste.

**Classification based on the content of dangerous substances and preparations**
The waste deposited in heap T6 does not contain any substances or preparations classified as dangerous under directives Directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to Dangerous substances and preparations.

**Overall classification**
The overall classification of Heap T6 at the Aitik mine in Northern Sweden is “not Category A”.

**Example 2**

**Waste-rock dump T2-4, Aitik, Northern Sweden**

**Short description of the facility and its environment**
Waste-rock dump T2-T4 is a 631 ha more than 50 m high waste-rock dump for potentially ARD generating waste-rock at the Aitik Cu mine in Northern Sweden. The dump is situated on 2-30 m low permeable moraine overlying the bedrock. The dump is surrounded by drainage collection ditches, and the drainage is collected and used as process-water in the concentrator. There are no buildings, public roads, surface water streams nor aquifers in the immediate closeness of the dump. The Aitik mine is situated in the Kalix and Torne Rivers catchment area which has been declared a Natura 2000 area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The heap slopes are built at an overall slope angle of 1:3 (V:H) which is considered long-term stable. The friction angle of the waste material as well as the underlying moraine is around 45 degrees (1:1). The waste has relatively high permeability which makes it unlikely that a perched groundwater level would occur within the heap, which has also been verified by drilling into the waste-rock dumps. The area where the heap is located is flat forest land.

According to the reasoning above, it is unlikely that any major structural failure of the heap would occur. If there was a failure, it would be a local failure involving movement of a relatively small quantity of waste-rock over a short distance (<100 m horizontally). Such a failure is unlikely to lead to any loss of life or any significant environmental impact. This leads to the Classification of the heap as "not Category A" with respect to failure due to loss of structural integrity.

The drainage for heap T2-T4 is characterized by low pH and high Cu concentrations. The annual copper load from the heap is more than 80 ton/year. During operation, the drainage from the heap is collected in surrounding collection ditches and used as process water in the concentrator or treated with lime before it is released to the tailings pond and clarified. Water of good quality is released from the clarification pond to the environment. The heap is progressively covered with a qualified dry cover in order to limit oxygen transport to the sulphide-containing waste-rock and thereby limit the sulphide oxidation rate and consequent metal release. The drainage water will require treatment before it is released to the environment during at least 50 years after the cover has been completed. The closure objectives aim at a release of less than 100 kg Cu/year to recipient.

Several scenarios can be identified where a failure due to incorrect operation could lead to significant environmental impacts, such as: the design of the qualified dry cover does not comply with design criteria in the long-term due to gradual failure of the cover, pumping of drainage water is interrupted during the operational period or before the water treatment requirements have been made obsolete in the closure phase or any of the drainage collection ditched are obstructed, e.g., due to ice clogging and overtopped. Of the above mentioned failures, permanent and long-lasting damage to the environment could occur especially in the long-term post-closure phase if the dry cover does not perform as designed. Such a failure could lead to annual pollutant loads one or two orders of magnitude higher than acceptable to the recipient. A failure during the operational period is likely to be of short durability and not lead to irreversible damage to the affected ecosystem, however, such damage can not be completely ruled out due to the high conservation value of the recipient. Consequently, the heap is classified as a "Category A" facility with respect to failure due to incorrect operation.

**Classification based on the content of hazardous waste**
According to the waste European Waste Catalogue waste-rock is by definition non-hazardous waste, which leads to the classification of the heap as "not Category A" with respect to Hazardous Waste. Note, however, that the ARD-characteristics of the waste leads to the classification of the facility as a Category A facility based on failure due to incorrect operation.

**Classification based on the content of dangerous substances and preparations**
The waste deposited on heap T6 does not contain any substances or preparations classified as dangerous under directives Directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to Dangerous substances.

**Overall classification**
The overall classification of Heap T2-T4 at the Aitik mine in Northern Sweden is “Category A”.

**Example 3**

**Tailings pond, Aitik, Northern Sweden**

**Short description of the facility and its environment**
The Aitik tailings pond covers a surface area of more than 1100 ha and is more than 30 m high. The tailings pond contains potentially ARD generating tailings from the concentrator at the Aitik Cu mine in Northern Sweden. The pond is situated on 2-30 m low permeable moraine overlying the bedrock. Water, which is of good quality suitable for direct discharge to the recipient, is recycled from the clarification pond to the concentrator and used as process water. The clarification pond is situated at the downstream end of the tailings pond and contains up to 15 million $m^3$ of water. Approximately 7 million $m^3$/year of water is released to the recipient. There is a major public road (E10) and surface water streams just a few hundred meters downstream of the tailings pond, but no aquifers of importance. The Aitik tailings pond is situated in the Kalix and Torne Rivers catchment area which has been declared a Natura 2000 area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
In case of a failure due to structural integrity it can not be ruled out that the road E10, which is located 400 m downstream the tailings and clarification pond, may be flooded and cars on the road washed away. The road has a relatively high traffic intensity which leads to considerable risk for loss of life. This leads to the classification of the facility in "Category A" with respect to failure due to loss of structural integrity.

During operation no water treatment is required, and water of good quality is discharged directly to the recipient. The target value is to release less than 100 kg Cu/year and the limit value is 300 kg Cu/year. Normally the annual discharge from the tailings pond contains less than 80 kg Cu/year and about 7 million $m^3$/y of water. During operation, no environmental protection measures are in place.

However, if production would be stopped, the deposited tailings could start to produce ARD within a few years time and the situation would be completely different. Closure plans incorporate a combination of measures including de-pyritisation of the tailings to produce non-ARD tailings, groundwater saturation of deposited tailings and a qualified dry cover of the dams and the beach area in order to avoid ARD generation. If production would be stopped within the near future a qualified a dry cover on top of the entire tailings pond would be required.

Any scenario leading to ARD generation in the deposited tailings could lead to significant environmental effects. Permanent and long-lasting damage to the environment could occur especially in the long-term post-closure phase if the closure measures do not perform as designed (de-pyritisation and dry cover). The facility is classified as a "Category A" facility with respect to failure due to incorrect operation.

**Classification based on the content of hazardous waste**
Today the tailings pond contains 100 % potentially ARD generating tailings (hazardous waste 01 03 04*). Even if de-pyritisation would be introduced and shown to be successful, the tailings already deposited (400 Mton) would remain in place. In addition, a small percentage of high sulphide tailings, about 3-4 % of the total tailings stream, would also be produced and deposited in a separate part of the tailings pond. Current mine plans are based on more than 600 Mton ore base. This means that the facility would contain about 45 % potentially ARD generating tailings from sulphide ore processing (hazardous waste 01 03 04*), and the facility consequently classified as "Category A" with respect to hazardous waste.

**Classification based on the content of dangerous substances and preparations**
The concentrator at Aitik runs a conventional froth flotation process where 1.4 $m^3$/ton of ore is used together with low concentrations of process chemicals. On an annual basis 18 million tons of ore are processed and 185 tons of xanthates, 150 ton of frothers (polyglycols), 6500 ton of lime and insignificant amounts of flocculants are used. Assuming 50% porosity and a bulk density of the tailings of 1.4

tons/$m^3$, this results in an annual increased amount of water in the pond of 6.5 million $m^3$/y. This in turn results in a maximum calculated concentration of xanthates of 0,028 g/l (significantly below the limit value of 0.1% or 1 g/l). Similarly, the maximum calculated concentrations of the other process chemicals used are calculated to  0.023 g/l for frothers 0.1 g/l for lime.

The facility is consequently classified as “not Category A” with respect to dangerous substances and preparations.

**Overall classification**
The overall classification of the tailings pond at the Aitik mine in Northern Sweden is “Category A”.

**Example 4**

**Waste-rock heap, Skrzyszów hard coal mine, Godów in Poland**

**Short description of the facility and its environment**
The dump of a waste-rock form hard coal mining is located in southern part of Upper Silesia, Poland, about 10 km from the city of Jastrzębie. The dump area is 60 ha and the height is 21 to 31 m. The deposited material is coarse waste-rock and washery refuse consisting of mudstone (82 %) and carbonaceous shale (18 %). About 38 % of the material belongs to the stone fraction (diameter > 20 mm ). The dump is located on top of quaternary materials and the quaternary aquifer is a source of water for local wells. Carbon aquifer is separated from the quaternary one by a layer of impermeable tertiary clays. Presently no material is deposited since the dump was closed in 1999, never-the-less, the heap serves as a good example even though the purpose of the methodology is not to classify closed facilities.

Seepage waters are removed from the dump by a system of drainage collection ditches to settling ponds and from the settling ponds to the local rivers. Nearest houses and roads are 300 m from the dump. The dump has been partially reclaimed, however, in the future there will be a highway going through a part of the dump and therefore the facility will be reconstructed.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The dump has a form of a flat tableland. The slope angle varies from 1:1.25 to 1:2.5. Friction angle is 1:1. In some places, the slopes have been re-contoured to 1:3. In spite of disadvantageous shape the consequence of slides would be small as the slopes are not high and it is unlikely any perched groundwater would build up in the heap. The area where the dump is located is flat and partly afforested. The consequences of limited rock-mass movements are presently small and they would only be local and not dangerous for human life nor would th ey cause any significant environmental impact. Therefore the heap is classified as “not Category A” with respect to failure due to loss of structural integrity.

The area of the heap to be reconstructed, in order to accommodate the highway, will be about 6 ha. The deposited material will be moved towards the center of the heap. Even though the heap will be very close the new highway the consequences of any potential rock mass movements have been assessed to be insignificant also in the future.

No environmental protection measures are applied to the Skrzyszow heap. The only measures include periodical cleaning of the surrounding drainage collection ditches and removal of settled material from the settling ponds. Reclamation of the dump surface does not include any complete cover layer of fertile soil. Seedlings are instead planted to holes filled partly with fertile material.

Leachates have neutral pH, relatively high dissolved salt content and contain low concentrations of heavy metals. The risk related to a failure due to incorrect operation is very limited at present as there are no environmental protection measures in place that could fail nor are any planned for the long-term phase. The dump does not contain “flammable substances” at concentration leading to self-ignition. The surrounding of the dump is agricultural area and there are no special objects under protection. The local municipalities have their own water supply systems and the wells are not used anymore, however, the quaternary aquifer constitute a groundwater resource of local importance. The facility is classified as ”not Category A” with respect to failure due to incorrect operation.

**Classification based on the content of hazardous waste**
According to the waste European Waste Catalogue the waste rock is not dangerous. The washery refuse is classified as “01 04 12 tailing and other wastes from washing and cleaning of minerals other then those mentioned in 01 04 07 and 01 04 11”. The dump does not contain “flammable substances” at concentration leading to self-ignition. Therefore according to this criterion the dump is “not Category A”

**Classification based on the content of dangerous substances and preparations**
The waste deposited on heap does not contain any substances or preparation classified as dangerous under directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to Dangerous substances.

**Overall classification**
The overall classification of the waste-rock heap Skrzyszow in Godów in South Poland is “not Category A”.

**Example 5**

**Waste–rock heap, “Marcel“Hard Coal Mine, Poland**

**Short description of the facility and its environment**
Waste-rock from the hard coal mine “Marcel” is deposited the heap. The heap, which is 80 m high and it covers an area of about 56 ha, is located in the village Radlin, municipality of Wodzisław, in the vicinity of the public national road No. 91, Poland. The area is heavily industrialized without any housing. In the nearest vicinity of the dump there are facilities of the hard coal mine „Marcel”.
The heap is located in the Rybnik Upland. Geologically the area of the Upland is built of carbon, tertiary and quaternary rocks. Carbon rocks occur at the depth of approximately 250 m. They are covered by tertiary materials, mainly clays that form a layer impermeable for quaternary waters. Quaternary soils are represented by loesses, silts and loams. There are three aquifers in the area - carbon, tertiary and quaternary one. The carbon and tertiary aquifers contain salty waters and are therefore not usable.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The heap is formed of the waste rock of the hard coal mine “Marcel”. Its oldest part was form as a group of cones. Presently the heap is under reconstruction. During the reconstruction the old cones will be cut and covered with a new waste-rock. The final shape of the heap will be a truncated cone. The slopes of the heap will be formed into several escarps with inclination 1:3 (V:H) divided by 5 m wide terraces.
The main motive for covering of old heaps with a new material is protection against endogenic fires that might occur as the deposited material contains some flammable substances. The heaps are covered from all sides simultaneously and the material is spread uphill. The material is transported using lorries, spread using bulldozers and compacted using sheepsfoot rollers.

Probability of any major structural failure of the heap is small considering the low slope angle. If there were any landslide it would be only a local failure involving movement of a limited rock mass over a short distance. Such an event would cause no or only negligible danger of loss of life or serious environmental impact.

No additional protective measures, apart from the compaction of the waste as it is placed and the top cover, are applied to the heap. Compaction of the deposited material aims at minimizing the possibility of endogenic fire as does the top cover. The shape of the heap is designed to protect it against erosion and ensures maximal retention of precipitation water in order to enhance growth of plants on the heap surface. Possible excess of precipitation water is collected by the surrounding drainage water ditch. Any toe drainage is discharged directly to the recipient.

There is theoretically a possibility that the heap will become untight. This in turn may cause an increase of oxygen concentration within the heap and lead to self-ignition of the deposited materials. The heap has self ignited in the past and this has not lead to any significant environmental effects and it is unlikely that it would in the future. Final closure of the heap includes spreading of an inert waste-rock layer (1.5 m thick) without compaction, and covering with 10 cm of a fertile soil. The prepared surface will be planted with tree seedlings.

Consequently the heap is classified as “not Category A” with regard to failure due to loss of structural integrity or incorrect operation..

**Classification based on the content of hazardous waste**
According to the European Waste Catalogue waste-rock is non-hazardous waste.. Thus, the heap is classified as “not Category A” with respect to Hazardous Waste.

**Classification based on the content of dangerous substances and preparations**
The waste deposited on heap does not contain any substances or preparation classified as dangerous under directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to Dangerous substances.

**Overall classification**
Overall classification of the waste-rock heap of Hard Coal Mine “Marcel” is “not Category A”.

**Example 6**

**Waste-rock dump, Fäboliden gold mine, Northern Sweden**

**Short description of the facility and its environment**
Fäboliden is a new gold mine not yet in operation located 30 km west of Lycksele in northern Sweden. The ore mined in the planned open pit will be crushed, grinded and leached with cyanide. In the pit selective waste-rock management will be performed and potentially ARD generating waste-rock will be managed separately from non-ARD generating waste-rock. A waste-rock dump is planned for up to 76 Mt of waste-rock covering approximately 57 ha on sloping ground with the difference in height of maximum 75 m between the lowest ground and highest level of the dump. The waste-rock dump is planned for selectively managed non-ARD generating waste-rock. The dump will be situated on up to 10 m low permeable till overlying the bedrock. The dump will be surrounded by drainage collection ditches and the drainage will be collected, pumped to the process water dam and used as process water in the concentrator. There are no buildings or roads in the immediate vicinity of the dump, but a surface water stream, Storbäcken, downstream of the dump. The Fäboliden mine is situated in the Örån River catchment area which has been declared a Natura 2000 area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The heap slopes are built at an overall slope angle of 1:3 (V:H) which is considered long-term stable. The friction angle of the waste material as well as the underlying till is around 45 degrees (1:1). The waste has a relatively high permeability which makes it unlikely that a perched groundwater level would develop within the dump. The dump is located at the side of a hill in forest land.

According to the reasoning above, it is unlikely that any major structural failure of the dump would occur. If there was a failure it, would be a local failure involving movement of a relatively small quantity of waste-rock over a short distance (<100 m horizontally). Such a failure is unlikely to lead to any loss of life or any significant environmental impact. This leads to the classification of the heap as “not Category A” with respect to failure due to loss of structural integrity.

No environmental protection measures will be applied to the waste-rock dump. During operation of the concentrator, the drainage will be collected and used as process water and the drainage system has been designed to prevent any leakage of drainage water into the Natura 2000 classified stream, Storbäcken until it is proven that the drainage water quality is suitable for direct discharge to the recipient. Closure measures area limited to a shallow till cover in order to enhance the establishment of vegetation and the drainage is planned to be released directly to the recipient. No scenario can be identified which could lead to a major accident in the short- or long-term,, which leads to the classification of the heap as “not Category A” with respect to failure due to incorrect operation.

**Classification based on the content of hazardous waste**
All waste-rock deposited on the waste rock heap in Fäboliden will undergo characterization with respect to ARD generation potential and arsenic content as well as rock type before it is loaded in the mine and transported to the waste-rock dump. Only waste-rock complying with certain criteria (so-called low risk, LR, waste rock) will be allowed to be deposited on the heap, all other waste will be deposited in the tailings impoundment. The information about the waste characteristics will be fed into the mine’s dispatch system and automatically transferred to loaders and trucks which at all times will be tracked by GPS. This system makes it almost impossible that waste which does not comply with the strict criteria would end up in the waste rock heap. No other waste rock or waste types are deposited on the heap.

According to the waste European Waste Catalogue waste-rock is by definition non-hazardous waste, which leads to the classification of the heap as “not Category A” with respect to the content of Hazardous Waste.

**Classification based on the content of dangerous substances and preparations**
The waste deposited on the waste-rock dump at Fäboliden does not contain any substances or preparations classified as dangerous under directives Directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to the content of Dangerous substances and preparations.

**Overall classification**
The overall classification of the waste rock heap at the Fäboliden mine in Northern Sweden is “not Category A”.

**Example 7**

**Tailings pond, Fäboliden gold mine, Northern Sweden**

**Short description of the facility and its environment**
Fäboliden is a new gold mine not yet in operation located 30 km west of Lycksele in northern Sweden. The ore mined in the planned open pit will be crushed, grinded and leached with cyanide. The tailings slurry will undergo cyanide destruction before is will be deposited into the tailings pond. Furthermore, the tailings will undergo de-pyritisation in order to produce a large part of non-ARG generating tailings (low risk (LR) tailings) and a small amount of potentially ARD-generating waste (high risk (HR) tailings). The Fäboliden tailings impoundment is planned to store up to 65 Mm3 covering approximately 500 ha. The dam walls are going to be up to 40 m high.

The tailings pond will contain three types of materials:

1. LR (low risk) tailings (non ARD generating tailings with a low content of S and As);
2. HR (high risk) tailings (potentially ARD generating tailings with a high content of S and As); and,
3. HR (high risk) waste-rock (potentially ARD generating tailings with a high content of S).

The tailings pond is situated on, after compaction, 1,5-2 m very low permeable peat overlying 5-10 m low permeable till, which in turn is overlying the bedrock. The HR wastes (both tailings and waste-rock) will be deposited in the center of the impoundment which will be covered by water at all times, including the after closure phase. Drainage and surface water will be recycled to the concentrator from the tailings pond via a process water impoundment (situated downstream of the tailings pond). Treated water, up to 100 000 m3/year, will be released to the recipient, Umeälven (not declared Natura 2000), 20 km north east of the impoundment. There is a public road and surface water streams close to the tailings impoundment. The Fäboliden tailings pond is situated in the Örån River catchment area which has been declared a Natura 2000 area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
In case of a structural failure the road 360, approximately 2 km downstream, will not be seriously affected. This is due to the low water level within the impoundment, approximately 1 m, which result in a slow failure scenario where water and tailings (estimated to be <0,32 $Mm^3$) may flow out of the impoundment in a more or less "controlled" manner and no real flood wave develops. Any out flowing tailings would be LR-tailings as the other types of materials in the pond are located far away from the dikes. The out flowing tailings and water would not be expected to cause any permanent or long-lasting environmental effects. This leads to the classification of the tailings pond in "Not category A" with respect to failure due to loss of structural integrity.

During operation seepage water from the tailings impoundment is collected and used as process water. If process water is discharged to the recipient it is treated in a water treatment plant located at the processing plant before pumping the water to the clarification pond prior to pumping it to the recipient Umeälven. In case of failure of the water treatment plant, untreated process water can be stored within the clarification pond and the process water impoundment. In the tailings impoundment natural degradation of trace concentrations of cyanide and oxidation of thiosalts occur and therefore the impoundment acts as an important part of the water treatment system at the site. The limit value for As is to release less than 150 µg/L As and any arsenic mobilized in the process water will be precipitated by the addition of Fe(III)sulphate.

If production would be stopped, the tailings impoundment would not start to produce ARD due to the HR wastes being deposited under water and surrounded/protected by the net buffering LR tailings. Closure planning is incorporated from the start of deposition and is based on a combination of measures including de-pyritisation of the tailings to produce non-ARD tailings as well as permanent groundwater saturation of deposited HR tailings and waste-rock. The groundwater saturation is not depending on water retention by the surrounding dikes. LR tailings is physically deposited around the HR wastes to act as an additional protective shield introducing oxygen consuming and buffering capacity.

Thus, if production would be stopped at any point in time no qualified dry cover on top of the tailings pond would be required.
No scenario which could lead to a major accident has been identified leading to the classification o the tailings pond as “not Category A” with regard to failure due to incorrect operation and the

**Classification based on the content of hazardous waste**
The tailings impoundment will contain up to 10 % potentially ARD generating tailings (hazardous waste 01 03 04*). Even if de-pyritisation would be successful, the HR tailings deposited in the central part would remain in place (app. 5-10% by weight) as would the 48 - 100 Mton HR waste rock that is planned to be co-disposed of in the tailings pond. This means that the facility would contain approximately 50 % potentially ARD generating waste material of which approximately 10% would be from sulphide ore processing (with the tailings classified as hazardous waste 01 03 04. The facility is consequently classified as “Category A” with respect to hazardous waste (based on its content of tailings classified as hazardous due to ARD potential and its content of As).

**Classification based on the content of dangerous substances and preparations**
The concentrator at Fäboliden runs a conventional froth flotation process with low concentrations of process chemicals. Also a cyanide leaching process for gold extraction is utilized. Maximum calculated concentration of xanthates is significantly below the limit value of 0.1% or 1 g/l.

Cyanide, which will be destroyed in a cyanide destruction plant prior to pumping the tailings to the tailings pond. Conventional cyanide destruction results in residual cyanide concentrations well below the maximum concentration, 10 mg/l, stipulated by article 13(6) in the MWD (2006/21/EC) and consequently the residual cyanide concentration is well below the limit value of 0.1% or 1 g/l.

The facility is consequently classified as “not Category A” with respect to dangerous substances and preparations.

**Overall classification**
The overall classification of the planned tailings pond at the planned Fäboliden mine in Northern Sweden is “Category A”.

**Example 8**

## Waste rock heap at Quenast, Belgium

### Short description of the facility and its environment

The waste rock heap of Quenast is a 27 ha and approximately 40 m high waste rock dump. It is constituted by a mix of microdiorites rocks of various grading, sand, and clays. Those rocks have.the same type and mineral composition as the products certified for use under water according to the Dutch Construction Material Decree. The wastes dumped are non-ARD generating. The dump is located on rather low permeable clay and sand overlying Silurian shales bedrock. There is no building, surface water streams nor aquifers in the immediate vicinity of the dump. The dump is surrounded by pasture or crops field and two small roads which use is restricted to agricultural purpose. The heap is partially (> 50% of the area) covered by trees. There is no specific drainage system. The after closure destination of the heap is a natural area.

### Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation

The heap slope are build with an overall slope angle of 30° which is considered long-term stable. The permeability of the waste makes it unlikely that a perched groundwater level would occur within the heap. Progressive revegetation prevents erosion. The heap is located in a nearly flat agricultural field area.

According to the reasoning above, it is unlikely that any major structural failure of the heap would occur. If there was a failure, it would be a local failure involving movement of a relatively small quantity of waste-rock over a short distance (<100 m horizontally). Such a failure is, in this case, unlikely to lead to any loss of life or any significant environmental impact. This leads to the classification of the heap as “not Category A” with respect to failure due to loss of structural integrity

No environmental protection measures are applied to the heap of Quenast and none are planned to be implemented during or after closure. No scenario that could lead to a major accident have been identified leading to the classification of the heap as “not category A” with respect to failure due to incorrect operation.

### Classification based on the content of hazardous waste

The waste–rock deposited in the heap is similar to those produced by the quarry and regularly tested for consistency with the Dutch Construction Products decree. According to the European Waste Catalogue waste-rock is by definition non-hazardous waste, which leads to the classification of the heap as “not Category A” with respect to the content of Hazardous Waste.

### Classification based on the content of dangerous substances and preparations

The waste deposited on the Quenas heap does not contain any substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to the content of dangerous substances and preparations.

### Overall classification

The overall classification of the waste rocks heap of Quenast Belgium is “not Category A”.

**Example 9**

## Waste rock heap at Lustin, Belgium

**Short description of the facility and its environment**
The waste rock heap of Lustin is located in an old quarry pit. The pit is opened on a hill side in a forest area situated in the Meuse River catchments area. Downhill from the pit is a small public road. There is no building area in the vicinity. The pit is located at the extremity of synclinal of limestone and sandstone levels. An aquifer is located upper to the pit, but no water stream is coming into the pit. At the end of operation, the heap will cover an area of 2 ha with a maximum height of 60m. It is constituted by a mix of limestone and sandstone rocks of various grading, sand, and clays. These wastes are non-ARD generating and regarded as inert according to the present Walloon legislation. There is no specific drainage system. The after closure the destination of the heap is a natural area.

**Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation**
The wastes are dumped in benches in order to build a slope with an overall angle of 35° which is considered long-term stable by the operator. The relatively high permeability of the waste makes it unlikely that a perched groundwater level would occur within the heap. Progressive revegetation prevents erosion. A berm built of hard rock armor stones and mixed with all-in aggregates closes the quarry pit on the side of the public road.

According to the reasoning above, it is unlikely that any major structural failure of the heap would occur that could lead to a major accident. If there was a failure, it would be a minor slide inside the quarry pit and the rock-berm would prevent any environmental impact outside the quarry. No material would reach the small public road. This leads to the classification of the heap as “not Category A” with respect to failure due to loss of structural integrity

No environmental protection measures are applied to the heap of Lustin.
All drainage is is naturally discharged to the recipient due the hill side location of the heap in the catchment area of the Meuse. No scenario that could lead to a major accident as a result of a failure due to incorrect operation has been identified. The heap is classified as “not Category A” with respect to failure due to incorrect operation.

**Classification based on the content of hazardous waste**
Wastes are constituted of waste-rocks similar to these produced by the quarry and used for outdoor construction works. According to the waste European Waste Catalogue waste-rock is by definition non-hazardous waste, which leads to the classification of the heap as “not Category A” with respect to the content of Hazardous Waste.

**Classification based on the content of dangerous substances and preparations**
The waste dumped on the Lustin heap does not contain any substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC, which leads to the classification of the heap as “not Category A” with respect to Dangerous substances

**Overall classification**
The overall classification of the waste rocks heap of Quenast Belgium is “not Category A”.