Report to DG Environment, European Commission

A Study on the Costs of Improving the Management of Mining Waste

Final Report
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Report by Symonds Group, in association with COWI

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1. EXECUTIVE SUMMARY

Context, Scope and Priorities

1.1 This is the Final Report of a study into the costs of improving the management of mining waste. It was not carried out in isolation, but in parallel with a consultation process being run by the Directorate General for the Environment of the European Commission (DG ENV) and a technical review process coordinated by the European Integrated Pollution Prevention and Control Bureau (EIPPCB) in Sevilla. DG ENV's consultation was prompted by their stated intention to introduce a 'Mining Waste Directive', covering current and historic installations. EIPPCB's technical review, although not initiated in direct response to this potential Mining Waste Directive, has been running in parallel with DG ENV's consultation, and closely coordinated with it.

1.2 Throughout this report the term 'potential Mining Waste Directive' is used even though the scope of this initiative is still under discussion, and could include mineral waste from a range of mining and quarrying activities.

1.3 Chapter 2 of this report sets out the background in more detail, and stresses that this study is limited in its scope to considerations of costs, and particularly:

(i) the current costs of managing mining waste; and

(ii) the economic implications for the mining sector of implementing certain additional waste management measures.

1.4 Waste is defined in the same way as in the EU's Waste Framework Directive, which includes some materials not thought of as waste by 'the man in the street'. In the context of mining and non-aggregate quarrying this includes waste rock and overburden, whether inert or not, as well as tailings.

1.5 Establishing which minerals needed to be covered, and with what priority, was not simple. The differences between the three categories of metal mining, coal and lignite mining and industrial minerals mining are very considerable, as are the variations within each category. Chapter 4 seeks to set the different mining activities in context using the most recent available statistics and the results of extensive internet searches. Readers who are familiar with the European mining industry will be able to ignore Chapter 4, but for those with a partial knowledge based on a few minerals or a few countries, it is intended to provide a helpful *tour d'horizon*.

1.6 Given the limitations on time and budget available, this study gave the highest priority to investigating costs at zinc, copper, gold, coal and potash mines. It should be stressed that these priorities refer to this study, and are not intended to influence the coverage of the potential Mining Waste Directive in any way.

Main Findings on Current Costs

1.7 This study found that the costs of managing mining waste vary considerably from mineral to mineral, and for a single mineral they vary significantly from mine to mine. For both zinc and copper mines, waste management typically accounts for about 1.5-2.0% of total cash costs. This includes an allowance for capital expenditure (on items such as raising the height of tailings dams) as well as current costs.

1.8 The cost of managing waste from underground coal mines is estimated at around €1.25 per tonne of coal sold. Because mining costs per tonne of coal produced vary so much (from around € 125 per tonne in France, to € 100 in Germany and Spain and € 36 in the UK), the proportion of mining costs accounted for by the same waste management practices ranges from 1.0% in France to 3.5% in the UK.

1.9 For industrial minerals, the cost of waste management seldom if ever exceeds 2% of the sales value of the mineral being sold.

1.10 These cost estimates have drawn on limited information already in the public domain, plus significant detailed information provided by mining companies. This help and cooperation is readily acknowledged. All individual mine cost details were provided by the mining companies on the basis that they were to be treated as commercially sensitive.

The Implications of Raising the Cost of Waste Management

1.11 In Chapter 6 the implications of raising the costs reported above are considered. The general conclusion is that many European metal mines could until recently almost certainly have absorbed the relatively modest costs of higher waste management standards without becoming uncompetitive on the world market. However, the recent steep fall in metal prices has made many European mines much less profitable than the long-term norm.

1.12 The European coal industry has for some time been under more severe financial pressure than metal mining, but many of its waste management practices are already substantially in line with the thinking behind the potential Mining Waste Directive.

1.13 Some industrial mineral producers generate little or no waste of any sort, and several others produce inert waste only. The economic implications for such companies arising from the potential Mining Waste Directive are therefore very limited. There are, however, some industrial minerals producers for whom this is not true.

1.14 Because the techniques for managing mining waste are closely linked to those for mining and processing the ore, and because the investment cycle in mining is relatively long, any cost impacts associated with implementing the potential Mining Waste Directive would be reduced if they were phased in over a long time period.

How Higher Waste Management Costs Might Come About

1.15 The potential additional measures being considered when this study was commissioned were specified in general terms only. It is expected that in due course the Commission will define and describe such measures more fully in its proposal for a Mining Waste Directive. This is likely to have in common with the Landfill Directive an emphasis on those measures which will guarantee the protection of surface and groundwater from pollution, and the long-term protection of the environment. The preferred mechanisms are likely to be identified through the EIPPCB technical review. Since this is not expected to be complete until mid-2003, it offers an opportunity for interested parties to contribute information and views to the definition of good industry practice.

1.16 Since this study has been carried out in advance of the results of the EIPPCB review being available, it has sought to identify those waste management activities which involve significant costs, and to see which of these might change, or be more widely required. Most of the larger cost items are directly related to the management of tailings, which in many cases are stored in a wet form, at least in the operational phase of the facility. Some tailings are then stored permanently under water. Others are managed wet, with the tailings pond being drained once it is full, before being capped and planted.

1.17 This distinction between the short-to-medium-term storage of tailings (i.e. while a mine and/or its tailings pond is operational), and the long-term/permanent storage/disposal of tailings after the mine is closed has tended to get lost in some of the discussions concerning what represents best practice, and what the potential Mining Waste Directive may require. This is something which should be addressed in the next phase of consultation.

2. INTRODUCTION AND BACKGROUND TO THE STUDY

The Policy Context

2.1 This study has its origins in a communication issued by the Directorate General for the Environment of the European Commission (DG ENV) in October 2000 entitled 'Safe operation of mining activities: a follow-up to recent mining accidents' (COM(2000) 664 final). It also follows a study which DG ENV commissioned from the French consultancy BRGM (Bureau de Recherche Géologique et Minière) covering 'Management of Mining, Quarrying and Ore Processing Waste in the European Union'. The draft final report from the BRGM study was completed in June 2001, and can be downloaded from DG ENV's web page devoted to the mining waste management consultation process, at http://europa.eu.int/comm/environment/waste/facts_en.htm.

2.2 COM(2000) 664 final proposed an action plan with three elements:

(i) an extension to the 'Seveso II' Directive (96/82/EC), which covers industrial risk management, to ensure that certain potentially hazardous mining-related activities, including some tailings dam operations, are covered, thereby requiring the operators to put in place safety management systems;

(ii) the production of a 'Reference Document on BAT (best available technology) for Management of Tailings and Waste-Rock in Mining Activities' (referred to throughout this report as the BAT Reference Document), to be prepared on the basis of the methodology set up in the framework of the IPPC Directive (96/61/EC), whilst acknowledging that mining *per se* will remain outside the scope of the IPPC Directive; and

(iii) the production of a brand new proposal for a Directive on the management of mining and mineral waste (referred to in this report as the potential Mining Waste Directive).

2.3 This study arose from the third of these three elements. Although the focus of the potential Mining Waste Directive is expected to be on reducing risks to the environment from the more hazardous wastes associated with metals mining, it is likely that coal mining and some industrial minerals operations will also be affected by this initiative to some degree.

2.4 An assumption underlying DG ENV's first consultation paper (which was dated 15 June 2001, and was discussed at a meeting of Member States on 3 July 2001, and at an *ad hoc* meeting with representatives from industry and NGOs eight days later), was that certain parts of the Landfill Directive (99/31/EC) might in future be applied to mining waste, with some further provisions specific to mining waste introduced through the potential Mining Waste Directive. Those discussions do not directly affect this study, which is concerned with establishing the costs of managing mining waste, rather than with one particular regulatory model.

The Main Focus of the Potential Mining Waste Directive

2.5 The potential Mining Waste Directive is likely to focus on both hazardous waste and on non-hazardous non-inert waste, thereby affecting the large volumes of materials which are neither hazardous nor inert. The determination of whether and when a particular material is to be considered to be a waste, and (if so) on whether it constitutes a hazardous or an inert waste (or if neither of these, then a non-hazardous non-inert waste), would continue to be based on the criteria and procedures established in the Waste Framework Directive (75/442/EEC as amended, particularly by 91/156/EEC). The relationships between these various categories of materials, and the implications for their management arising from the potential Mining Waste Directive, are illustrated in Figure 2.1. This interpretation is based on DG ENV's first consultation paper and subsequent guidance, and it is recognised that the proposed scope of the potential Mining Waste Directive might be changed following the present consultation phase.

Figure 2.1 Different types of materials

Characteristics of materials	Not waste	Waste		
		← Less hazardous		More hazardous →
Waste classification	Not waste	Inert waste	Non-hazardous non-inert waste	Hazardous waste
Implications of the potential Mining Waste Directive	Could be **excluded** from the provisions of the potential Mining Waste Directive		Likely to be **covered** by the provisions of the potential Mining Waste Directive	

2.6 The most significant impact for some minerals operators could be to end the practice of disposing of wet tailings in future installations and the covering of tailings by water, unless it could be demonstrated that wet waste management would have clear advantages in terms of reduced risks to the environment. Such choices will be directly influenced by the work being carried out for the development of the BAT Reference Document.

2.7 The Landfill Directive contains specific requirements related to the disposal of other sorts of waste, such as the necessity to have a barrier (usually geological) to prevent pollutants from entering the surrounding soil and water environment. Based on the precedents established by the Landfill Directive and its underlying philosophy, it should be expected that the potential Mining Waste Directive will:

(i) lay down minimum requirements to be applied to new and existing facilities; and

(ii) oblige disposal sites to have leachate collection and treatment systems, and monitoring systems to ensure that pollution does not reach sensitive receptors.

2.8 The potential Mining Waste Directive is also likely to contain measures designed to ensure the safe use of certain chemicals, most notably cyanide and xanthates. The usefulness of cyanide in particular is recognised, but its potential dangers, particularly for fish, make it likely that the storage of water with high levels of cyanide, already rare, will no longer be accepted. Measures may also be included to encourage the treatment of mining wastes to enable them to be recycled for use in construction, agriculture, industry etc.

2.9 Although these provisions will primarily apply to new installations developed after the potential Mining Waste Directive is brought in, it is likely that operators will be obliged to adapt and upgrade their existing waste management installations.

The Tasks to be Covered in this Study

2.10 The study brief focussed on two main tasks, one of which was sub-divided. These are summarised in Figure 2.2 below.

Figure 2.2 Tasks included in the Study

1.	Evaluate current costs for the management of mining waste for specific sites, including sites dealing with ferrous metals, non-ferrous metals, coal and non-inert industrial minerals (such as potash).
2.	Assess the economic implications of implementing certain additional measures during the management of mining waste, as follows: (a) the planning and design of all new waste management installations on the basis of state-of-the-art technologies, giving preference to the safe disposal of dry tailings; (b) the installation of minimum geological and/or artificial barriers for disposal sites, in order to protect the surrounding soil and water environment from pollution; (c) the proper characterisation of waste through the whole life of the mining installation; (d) the collection, storage and treatment of contaminated water and leachate, and the avoidance of mixing of contaminated water with clean water; (e) the installation of emergency storage facilities for contaminated water from any tailings facilities (to avoid its discharge in the event of an extreme weather event or similar emergency); (f) the safe closure of disposal sites in order to avoid short, medium and long-term contamination of the environment; (g) the minimisation of the quantities of hazardous additives (such as cyanide and xanthates) that are stored in tailings ponds; (h) the design, management and monitoring of tailings dams to uniformly high safety standards.

Other Background Documents and References

2.11 As well as the documents referred to above, current working documents from DG ENV can be found *via* http://europa.eu.int/comm/environment/waste/facts_en.htm.

2.12 Further information related to the amendments which are being proposed to the Seveso II Directive can be found at http://europa.eu.int/comm/environment/seveso/consultation.htm.

2.13 The status of the BAT Reference Document can be tracked *via* the website of the European Integrated Pollution Prevention and Control Bureau, which forms part of the Institute for Prospective Technological Studies in Sevilla, Spain. Their website can be found at http://eippcb.jrc.es. The membership of the Technical Working Group charged with developing the BAT Reference Document can be found at the same location.

3. DATA COLLECTION

The Consultation Process

3.1 A significant element of the study was to consult with the mining industry in order to obtain cost data which could form the basis for a subsequent evaluation. It was recognised that the issues concerned were being considered by various other parties in a variety of *fora*, including the formal consultation process launched by DG ENV on the potential Mining Waste Directive, the EIPPCB Technical Working Group and a Working Group set up for the purpose by the Raw Materials Supply Group, which includes representatives from Member States, the Commission, industry and NGOs.

3.2 Although there is no single trade association or federation that represents all mining interests, it was agreed with DG ENV that due to the priority to be given to the more hazardous wastes, the main focus for consultation should be Euromines and its members. The draft report was also sent to the Industrial Minerals Association - Europe inviting them to comment.

3.3 Euromines is a federation whose membership includes many of the larger European mining companies and several national European mining associations. Its interests and activities go beyond the boundaries of the EU, though its primary focus is on European issues. Its website can be found at www.euromines.org. Greater in-depth coverage of several industrial minerals (namely silica, kaolin, feldspar, perlite, bentonite, borates, talc and calcium carbonate) is provided by the Industrial Minerals Association - Europe (see www.ima-eu.org for details).

3.4 Other helpful sources of information on metal mines which should be noted here include:

(i) www.mining-technology.com/projects, which provides its own descriptions of many of the world's larger mining projects, including descriptions of their operations and investments;

(ii) www.mining-journal.com, which provides links direct to the websites of major mining companies; and

(iii) www.minesite.com, which also provides links to company sites, but is more geared to gold mining than the other two sites mentioned above.

3.5 Following extensive searches on the internet, backed up by consultation with Euromines, a list of 25 target consultees was drawn up, predominantly in the metal mining and coal and lignite industries. In several cases the companies concerned were known to have interests in more than one mine, sometimes in more than one country. The list included some companies (including, for example, gold mining companies) not covered by Euromines' membership. It also included a relatively few industrial minerals companies, whose interests include phosphates, potash, magnesite, magnesium chloride, talc and bentonite production.

3.6 On 23 May 2001 a consultation letter, accompanied by a short letter of support from Euromines, was sent to these 25 companies. Each letter identified the mines to which the questions referred, and asked for responses by the end of June.

3.7 As can be seen by reference to Annex 1, the consultation letter asked for information about individual mines, under the following headings:

(i) age of facilities;

(ii) production and remaining life;

(iii) status of waste management facilities;

(iv) capital costs of waste management facilities;

(v) running costs;

(vi) chemical additives;

(vii) closure costs;

(viii) environmental monitoring;

(ix) 'best practice' vs lower standards; and

(x) any other information that the consultee might wish to provide.

3.8 A follow-up was sent on 29 June to all those on the original mailing list from whom no response had been received by that point. By that stage Euromines had also provided two further contacts, some industrial minerals companies had requested or offered information at a meeting with DG ENV, and Symonds had found one more company through www.coalportal.com.

3.9 In late July the responses that had been received by that point were evaluated, and a draft Report drawing on the information contained within them was submitted to DG ENV. Once an agreed text was available, copies of the draft Report were sent to the companies who had been consulted, to Euromines and the Industrial Minerals Association - Europe, to the EIPPCB and to a small number of other companies and experts nominated by DG ENV. These copies were sent out on 14-15 August, inviting all recipients to submit whatever further information and comments they wished by 15 September: the same date by which comments were due to DG ENV itself on its Working Document No.1 (DGENV-A.2/AP D(2001)).

3.10 By mid-August the consultation letter had been sent to 31 companies. These companies' mailing addresses were spread between Austria (1), Finland (3), Germany (5), Greece (3), Ireland (3), Poland (2), Portugal (2), Spain (4), Sweden (3), the Netherlands (1) and the UK (4). A further and final reminder was sent on 10 September to those who had not by that stage responded to the consultation letter.

3.11 By Monday 17 September, replies had been received from 22 of the 31 companies covering some or all of their mining activities. These replies came from:

(i) 11 metal mining companies with 14 metal mines (or groups of metal mines) between them;

(ii) three coal and lignite mining companies with in excess of 30 underground and open pit mines between them;

(iii) eight industrial mineral companies, several of them with multiple mines or quarries.

3.12 Three of the companies that responded consider that their mines fall completely outside the scope of the potential Mining Waste Directive, either because (in their view) they produce minimal or no waste (a magnesite mining company which uses the 'room and pillar' extraction technique), or only inert waste (a lignite mining company and a chalk quarrying company). While noting and reporting these responses, this study makes no judgement as to the legal validity of the underlying judgements.

3.13 The information provided (which is reported in Chapter 5) has illustrated how complex this topic is, and how hard it is to disentangle investments linked to waste management from regular mining investments. This emphasises one of the differences between mining waste management and some other waste management: mines generate, treat and dispose of their waste as a seamless part of their on-site activities, whereas much other waste (and most non-inert waste) is managed by a third party contractor with clearly identifiable costs and fees.

Sources of Consolidated Data

Statistics and general information

3.14 This study did not include a significant allowance for the collection of statistical data on mineral production, which had been one of the primary objectives of the BRGM study. That study used two approaches: a questionnaire which was sent to national contacts in each of the Member States, and an alternative estimate generated by the study team.

3.15 That alternative estimate (summarised in Figure 3.1 below) provided a more comprehensive result. It was based on:

(i) mineral production data for a period of 10 years from 1986-95 (except for coal and lignite, for which they used 5-year data from the period 1990-94); and

(ii) standardised waste:mineral ratios.

3.16 BRGM defined mining waste as waste rock plus tailings, which is the same position as was taken for this study (see Annex 1 for the actual guidance provided to consultees).

Figure 3.1 BRGM's estimates for mining waste production 1986-95

Product	Waste: mineral ratio	Tonnes of waste per year	Main Member States (>10% of total at that time)
Iron	5.2:1	71.4 m	Sweden, France, Spain
Zinc and lead	32:1	29.8 m	Spain, Sweden, Ireland
Copper	450:1	94.5 m	Portugal, Sweden
Nickel	560:1	11.4 m	Greece, Finland
Bauxite	3:1	5.8 m	Greece
Gold	950,000:1	16.8 m	Sweden, Spain, France
Other metals	varies	2.8 m	Portugal, Finland, UK
Coal(*)	varies	179.2 m	Germany, Spain, France
Lignite	varies	1,664.8 m	Germany, Greece
Industrial minerals (**)	varies	105.1 m	Sweden (mainly from refractory materials)

(*) Only includes anthracite. Bituminous coal production is roughly 10x anthracite production.

(**) Excludes construction aggregates.

3.17 The view has been expressed to Symonds by mining companies that average ratios of this kind are of strictly limited value, since for each individual mineral they can vary from mine to mine by a factor of 10 or more. Such variation derives from a complex of factors. For one thing some mines are open pit while others involve underground working, and open pit mines produce more waste rock per tonne of ore. This is compounded by the fact that underground mines typically have higher ore grades. The metal content of copper ores, for example, varies within Europe from 0.35% (an open pit mine) to around 5.0% (an underground mine).

3.18 Since the period(s) covered by these estimates, coal production in particular has declined steeply. A recently published 'Proposal for a Council Regulation on State aid to the coal industry' (COM(2001)423 final, which can be downloaded from the Eur-Lex website) discussed this aspect in some detail, though it does not provide detailed statistics.

3.19 The World Coal Institute's website (www.wci-coal.com) gives data for European coal production in terms of oil equivalent rather than in tonnes of coal. Those data show that the combined energy value of EU coal (i.e. anthracite and bituminous coal) and lignite (brown coal) production declined from 226 million tonnes of oil equivalent in 1989 to 106 million in 1999 (a decline of 53%). Within the coal fraction, the ratio between anthracite and bituminous coal is typically 10:90. Anthracite has a very low content of volatile materials, and is much less likely to be washed before sale. It is therefore of less relevance to this study than bituminous coal.

3.20 Another website, www.coalportal.com, confirms that production of bituminous (hard) coal in the EU fell from 211.7 million tones in 1989, to 131.1 million tonnes in 1994, and 98.6 million tonnes in 1999. A more detailed breakdown, together with figures from other major European countries (including Turkey), can be found in the section on coal in Chapter 4.

3.21 The BRGM report estimated potash production in the EU-15 at around 5 million tonnes a year. More detailed data on the output and value of some of the other main industrial minerals is given on www.ima-eu.org, and summarized as follows.

3.22 By volume the main minerals covered by IMA Europe's members are silica (38 million tonnes a year) and calcium carbonate (10 million tonnes a year). Kaolin, feldspar, bentonite, talc, borates and perlite (in declining tonnage order) account for a further 15 million tonnes a year between them. Sales of calcium carbonate are worth around ε 1,000 million a year, with sales of kaolin, feldspar, borates and silica all in the range ε 500-700 million a year. Bentonite, talc and perlite are reported to be worth progressively less.

3.23 For reference, the 'kick-off meeting' of the EIPPCB Technical Working Group held on 20-22 June 2001 decided that their focus would be on the materials listed in Figure 3.2 below.

Figure 3.2 Minerals selected by the EIPPCB Technical Working Group for more detailed study

Metals	Energy Minerals	Industrial Minerals
Aluminium/bauxite, cadmium, chromium, copper, gold, iron, lead, manganese, mercury, nickel, silver, tin, tungsten, zinc.	Coal (if processed with tailings, i.e. including most underground coal, but probably excluding open pit coal and lignite), oil shale.	Baryte, boron, feldspar (if recovered by flotation), fluorspar, limestone (if processed), kaolin, phosphate, potash, strontianite, talc.

Cost data

3.24 Data on industrial metal mining and ore processing costs can be downloaded, on a commercial basis, from www.minecost.com. This organization describes itself as "… a co-operative website using shared information from mining analysts employed by mining companies, stockbrokers, investment banks, commercial banks and government agencies". They have cost models for over 200 individual mines, mainly in North America, Latin America, Australia, Europe and South Africa, with smaller numbers in other African and Asian countries. Of the major mining countries, they do not have data from Russia, China, India or Mexico. The mines are primarily concerned with iron, zinc, lead, copper, nickel and molybdenum, though many by-products including gold, silver and cobalt are also produced.

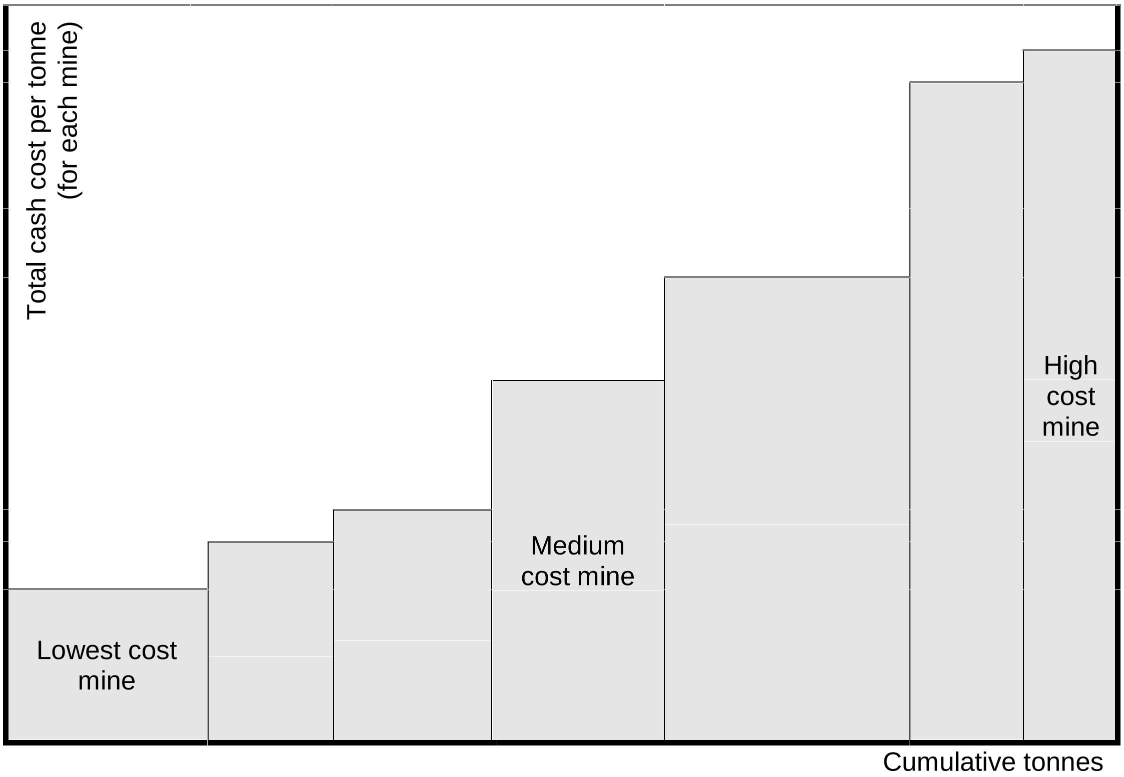
3.25 For iron, zinc, lead, copper, nickel and molybdenum it is possible to obtain industry cost curves from www.minecost.com. These give the tonnages produced and the cost data for each mine on the database, enabling an industry cost curve to be generated in a format which is generically illustrated in Figure 3.3. The costs that are given are 'total cash costs', as defined by the Gold Institute. The relationships between operating costs, total cash costs and total production costs can be summarised as follows.

(i) direct mining expenses + smelting, refining and transport costs + by-product credits + other costs = **cash operating costs;**

(ii) **cash operating costs** + royalties (not-profit based) + production taxes = **total cash costs;** and

(iii) **total cash costs** + depreciation, depletion and amortization + reclamation and mine closure costs = **total production costs.**

Figure 3.3 Generic industry cost curve (total cash costs)



3.26 What this enables the user to do is to identify those mines which are least able to bear additional costs, whether those additional costs are significant or minor. Such extra costs might be associated with a more demanding waste management regime.

3.27 To work out which mines' costs are presently above the metal price, it is necessary to check the current metal price, which can be done through www.lme.co.uk, the website of the London Metal Exchange.

3.28 The proportion of 'western world' coverage claimed by www.minecost.com is 70% for iron ore, 83% for copper, and 74-77% for the other ore types.

3.29 Comparable services, and commodity-based reports, are available through other mining analysts such as, for example, www.brookhunt.com and www.roskill.co.uk.

3.30 No equivalent source of operating cost data for individually identified coal mines or industrial minerals operations was found.

3.31 Another source of standardised costs can be accessed *via* www.westernmine.com, though this is based on US sources, and is very much geared to the capital and operating costs of individual items of equipment.

4. THE MINING INDUSTRY IN EUROPE

Opening Comments

4.1 This Chapter could easily be dismissed as excessively long and detailed, and for those readers who are fully familiar with their own sector of the European mining industry it should be possible to pass direct to Chapter 5. However, for those whose knowledge is limited to a few countries or a few minerals, and who need to take a wider view, it is intended as a *tour d'horizon*.

4.2 It deals in turn with:

(i) mainstream industrial metals (iron, zinc, lead, copper, nickel, tin and bauxite/aluminium);

(ii) precious metals (gold and silver)

(iii) other minor metals (cadmium, chromium, manganese, mercury and tungsten);

(iv) coal and lignite;

(v) the 10 industrial minerals to be covered in the BAT Reference Document (phosphate, potash, feldspar, fluorspar, kaolin, barytes, talc/pyrophyllite, processed limestone, boron and strontianite);

(vi) other selected industrial minerals (salt, soda ash/magnesium compounds, asbestos and others).

4.3 Most sections in this Chapter include a table of statistics, with comment kept to a reasonable minimum. The statistics referring to metals are for metal production, not concentrate or ore. In all cases the intention is to provide basic information about the structure of the mining industry as it is today and the identity of leading industry players. Where possible, comments are also provided on how widespread abandoned mines may be, and on those trends or factors which affect European mines and their international competitiveness. All of the non-statistical information was obtained from publicly available sources, including the USGS, but primarily from mining companies' own websites.

4.4 Chapter 4 illustrates the importance for metal mining of Sweden, Spain, Ireland and Finland and (for certain metals) Portugal and Greece. For coal the general decline in production across the EU is addressed, though production in Germany, the UK and Spain remains significant. Industrial minerals are very widely distributed, with Germany, Italy and the UK major producers of several of the key minerals within the EU. However, Chapter 4 also shows the extent to which the EU's share of world mining is falling, and stresses that Russia, Poland and Turkey provide significant competition for many of the minerals reviewed.

Note on Data Sources

4.5 The main statistical source used in this Chapter, certainly as far as metals and industrial minerals are concerned, is the Commodity Statistics and Information website of the United States Geological Service (USGS). This provides data that are significantly more current than those cited in the BRGM study referred to in Chapter 2. This website can be found at http://minerals.usgs.gov/minerals/pubs/commodity. For each mineral the website gives access to a short 2-page summary of the position in 2000/01 and a more detailed review based on statistics and developments up to and including 1999. This source has the advantage that it provides worldwide data (with some gaps) manipulated, where necessary, to be as close as is reasonably possible to a common format.

4.6 Where statistics are given below they are for EU-15 Member States (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK) and for 'other European countries'. These 'other European countries' include those from north western Europe that remain outside the EU (e.g Norway), all of central and eastern Europe up to and including Russia, and all of south eastern Europe up to and including Cyprus and Turkey. This excludes the countries of the Caucasus region and all those further south and east (other than those parts of Russia that lie east of the Urals).

4.7 At the same time as this report was being drafted, the EIPPCB Technical Working Group has assembled production statistics for 1999 for EU-15 Member States and for the 13 candidate countries (Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia and Turkey). Those statistics are based on data from the Austrian Ministry of the Economy, and although they differ in some details from the figures used in this report, the differences are generally minor.

4.8 The tables given in this report also provide some evidence of reserves, production trends (based on a 5-year spread), and cover all European countries (as defined above), not just the Member States and the candidate countries. This is intended to give a broad indication of how easily supply patterns within Europe might change if output in the EU rose or fell. The definition of reserves used by the USGS is as follows: "That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative". The term reserves as used here therefore excludes marginally economic and inferred reserves as well as sub-economic and hypothetical reserves.

Mainstream Industrial Metals

Iron

Figure 4.1 Iron production 1995-99, and reserves 2000 (million tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	552	577	535	71,000
EU-15, of which:	15	15	13	n/a
Sweden	12	14	12	2,200
Others	3	1	1	n/a
Other European countries, of which:	78	75	77	n/a
Russia	45	41	47	11,000
Turkey	3	3	2	12,000
Ukraine	28	29	26	n/a
Others	2	2	2	n/a

4.9 The only major iron ore mining company in the EU is LKAB of Sweden (see www.lkab.com for further information). They have two very large underground mines in northern Sweden, at Kiruna and Malmberget, which supply several European steel makers. Large investments have recently been put in place at Kiruna to assure its future until at least 2018. All other EU mines are much smaller, and appear to be in long-term decline. Abandoned iron workings are very widespread throughout Europe.

Zinc

Figure 4.2 Zinc production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	7,280	7,540	8,040	190,000
EU-15, of which:	569	579	560	n/a
Finland	16	31	30	n/a
Greece	15	18	19	n/a
Ireland	184	195	226	n/a
Italy	15	8	0	n/a
Spain	172	172	110	n/a
Sweden	167	155	175	n/a
Other European countries, of which:	396	386	363	n/a
Bulgaria	26	20	12	n/a
Macedonia	15	15	20	n/a
Norway	19	16	12	n/a
Poland	155	158	153	n/a
Romania	35	29	25	n/a
Russia	131	121	132	n/a
Serbia and Montenegro	3	13	3	n/a
Turkey	9	13	5	n/a
Others	3	1	1	n/a

4.10 Three of the EU's largest zinc mines are in Ireland: Outokumpu's Tara mine (see www.outokumpu.com), Arcon's mine at Galmoy (see www.arcon.ie), and Anglo Base Metals' Lisheen mine (see www.ivernia.com). Indeed, within the EU, the most notable feature in recent years has been the rise of Ireland as a zinc producer, from both older and brand new mines. The well-established Tara mine is reported (by USGS) to have a potential output capacity of 170,000 tonnes a year of zinc and 42,000 tonnes a year of lead. The much newer Lisheen mine is expected to produce 190,000 tonnes a year of zinc and 33,000 tonnes a year of lead. In international terms, however, these mines are small compared to giant operations such as Cominco's Red Dog mine in Alaska, which in 1999 produced 943,500 tonnes of zinc concentrate containing 521,000 tonnes of metal.

4.11 One of the oldest zinc mines in Europe is in northern Spain: Asturiana de Zinc's Reocin mine (see www.azsa.es). In southern Spain the Iberian pyrites belt (which supports the Neves-Corvo copper mine in Portugal - see below) also hosts Navan Mining's Almagrera mine (see www.navanminingplc.co.uk) and Boliden's Los Frailes mine (see www.boliden.se). Los Frailes is reported to have been put up for sale in September 2001, and to be operating under protection from its creditors (see www.mining-technology.com/projects). In their home country of Sweden, Boliden have several zinc mines around the town of Boliden, and another at Garpenberg. Rio Tinto operate another large Swedish zinc mine at Zinkgruvan (see www.zinkgruvan.com and www.riotinto.com).

4.12 Just as most of these mines produce lead as a by-product, there are several other mines that produce zinc as a by-product, including some of the copper and lead mines referred to elsewhere in this Chapter.

4.13 Demand for zinc is substantially driven by the car industry and its need for galvanized steel. If prices of zinc rise too far, there are acceptable substitutes for most of its uses, which puts a cap on the prospects facing the industry. However, the industry is currently concerned with the effects of low prices rather than high. The world price of zinc has fallen from around

US$ 1,300 per tonne in 1990 (expressed in 1999 dollars) to US$ 1,100 for most of the 1990s to only slightly over US$ 800 in September 2001. This decline has not been linear: after dropping below US$ 1,000 per tonne in late 1998 and early 1999 the price rallied to pass US$ 1,200 as recently as the autumn of 2000. Since then, the fall to its present level has been steep and dramatic, reflecting both the general industrial downturn and the coming on stream of new mines. A price of US$ 1,000 per tonne is equivalent to US¢ 45.36 per lb.

4.14 When the price of zinc recovers, the Aljustrel complex in Portugal appears to have the potential to produce significant tonnages of zinc, copper, lead and silver. To date it has never got into serious commercial production. Other mines might well be developed across southern Portugal and Spain if market conditions provide appropriate price signals. Other companies are also known to be actively investigating the potential for further zinc mines in Ireland. Links available through www.minesite.com are particularly helpful for anyone wanting to identify companies which are primarily active in the business of prospecting rather than mining.

Lead

Figure 4.3 Lead production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	2,830	3,110	3,020	64,000
EU-15, of which:	235	211	201	n/a
Greece	20	19	16	n/a
Ireland	69	45	45	n/a
Italy	14	12	6	n/a
Spain	30	24	18	n/a
Sweden	100	109	115	500
UK	2	2	1	n/a
Other European countries, of which:	179	174	153	n/a
Bulgaria	33	32	18	n/a
Macedonia	25	28	26	n/a
Poland	58	55	61	n/a
Romania	23	17	20	n/a
Russia	23	16	13	n/a
Turkey	10	13	12	n/a
Others	7	13	3	n/a

4.15 Most lead is produced as a by-product of mines which have been developed for other metals, most notably zinc and silver. There are few active mines where lead is the primary mineral. Boliden's Laisvall mine (see www.boliden.se) has been one, but Laisvall is scheduled to close in October 2001. There are many former lead mine sites all over Europe, some of them dating back for many centuries.

4.16 The lead market is mainly determined by the demand for lead-acid batteries for vehicles and industry, much of this market being satisfied by recycled materials. In some other applications (such as solders and additives for plastics and paint) emerging legislation is seeking to encourage the phasing out of lead use. Overall, therefore, demand for lead is unlikely to expand significantly, certainly in Europe and other developed market economies, and it would be a surprise if a new lead mine (as opposed to a mine with lead as a by-product) was to be opened in Europe.

4.17 In central and eastern Europe, lead smelters had a particularly poor record on pollution, and as some of them have been closed down this has made the mines beside which they were originally built substantially less competitive.

Copper

Figure 4.4 Copper production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	10,000	11,400	12,600	340,000
EU-15, of which:	251	240	182	n/a
Finland	10	9	10	n/a
Portugal	134	106	100	n/a
Spain	23	38	2	n/a
Sweden	84	87	70	n/a
Other European countries, of which:	1,143	1,200	1,234	n/a
Bulgaria	76	93	75	n/a
Cyprus	0	4	6	n/a
Macedonia	9	13	9	n/a
Norway	7	7	0	n/a
Poland	384	415	461	20,000
Romania	25	23	20	n/a
Russia	525	505	530	30,000
Serbia and Montenegro	75	74	52	n/a
Turkey	38	65	80	n/a
Others	4	1	1	n/a

4.18 The major EU producer of copper is SOMINCOR of Portugal, whose mine at Neves-Corvo in the Alentejo region of Portugal was one of the most notable European mine developments of the 1980s. The London-based mining company Rio Tinto plc (see www.riotinto.com) has a 49% share in the mine, with the majority owned by Empresa de Desenvolvimento Mineiro SA (see www.edm.pt). A much, much older mine is at Rio Tinto, in the province of Huelva in southern Spain. Since 1995 this property has been owned by its workers, and is not directly linked either to Rio Tinto plc or to the nearby copper smelter and refining business belonging to Atlantic Copper SA, a subsidiary of Freeport-McMoran Copper & Gold Inc (see www.fcx.com/fmcg/atlantic-page.htm).

4.19 Boliden of Sweden operates a number of mines which produce copper. The most important of these is the large open pit mine at Aitik, which is characterised by a very low (0.35%) copper content which is in sharp contrast to, for example, Neves-Corvo in Portugal (see above). See www.boliden.se for information on all of their mines, including Aitik. The other leading producer in northern Europe is Outokumpu of Finland (see www.outokumpu.com for some information on their mine at Pyhäsalmi).

4.20 It is understood that a new mine is being planned in southern Spain at the other end of the Iberian pyrites belt from Neves-Corvo, by Cobre Las Cruces. An article in The Mining Journal in 2000 reviewed the prospects for further copper, nickel, platinum and palladium production in this same area (see www.mining-journal.com/mininginfo/projects/agua.htm).

4.21 By contrast with EU mines, output in some of the applicant countries has been rising rapidly (e.g. Poland, Cyprus and Turkey), or holding up relatively well in economies which have otherwise been in deep recession (e.g. throughout the Balkans). Easily the largest copper mining company from the applicant states, and reportedly the seventh largest in the world, is KGHM Polska Miedz SA with three mines at Lubin, Rudna and Polkowice-Sieroszowice (see www.polishcopper.com for further information). Another notable mine in the applicant countries is Navan Mining's Chelopech, in Bulgaria (see www.navanminingplc.co.uk). The largest copper producer in Russia is Norilsk Nickel (see www.nornik.ru).

4.22 The prospects and returns achievable in the copper mining sector are largely driven by the world price of copper, and by the costs achievable in certain massive mine projects in Chile, Argentina, Peru, Indonesia, Australia and the US. Unit costs in EU mines are significantly higher than those achieved in huge open pit mines such as Chuquicamata and Escondida in Chile, let alone the Grasberg mine in Indonesia. As a consequence, EU production has been falling while world output has been rising.

4.23 Overall, the industry was notably more profitable than other base metals over the past decade, though the price of copper has fallen quite steeply in recent months. In a speech to the Prospectors and Developers Association of Canada in March 2000, Richard Wilson, Managing Director of the mining consultancy Brook Hunt stated that "… based on recent experience, a long-term average price (in constant US dollar terms) of 75¢/lb is unlikely to sustain existing production levels, let alone encourage the development of additional capacity. Likewise, at a long run price of US$ 1.20/lb, the threat of substitution by other materials becomes a very real concern" (see www.brookhunt.com for the full speech). Prices of US¢ 75 and US$ 1.20 per pound are equivalent to US$ 1,635 and US$ 2,646 per tonne, respectively.

4.24 According to price data from Brook Hunt and the London Metal Exchange (see www.lme.co.uk) the price of copper fell within (or slightly above) this band from late 1986 to min-1998, with peaks of around US$ 2,850 in early 1988 and again in early 1995. From early 1995 the price fell to the trigger level of US$ 1,635 per tonne in the autumn of 1998, at which point it continued to fall further, reaching US$ 1,350 per tonne in the spring of 1999. From that low point it recovered to US$ 2,000 per tonne in late 2000, from where it has fallen steeply again, reaching US$ 1,440 per tonne (US¢ 65.4 per pound) in early September 2001. At such levels, EU producers are under considerable pressure.

4.25 There are many former copper mining sites throughout Europe.

Nickel

Figure 4.5 Nickel production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	1,040	1,130	1,120	49,000
EU-15, of which:	23	21	17	n/a
Finland	3	3	1	n/a
Greece	20	18	16	450
Other European countries, of which:	260	270	265	n/a
Russia	251	260	260	6,600
Others	9	10	5	n/a

4.26 Traditionally, most nickel came from underground mines exploiting sulphide ore bodies, quite often in association with cobalt. Such ore bodies are found in Canada, Russia and southern Africa. In recent years the balance has been shifting towards laterite ore bodies much closer to the surface. These are mainly found in south east Asia, Australia and the Caribbean basin, though Greek reserves are also laterite. These two mining types have very different cost structures.

4.27 The main producer of Nickel in the EU is the Greek company Larco SA (see www.larco.gr, though the English translation facility may not be operational). They have four mines in various locations, and their output has been rising gradually over the past 20 years. Outokumpu's Hitura mine in Finland (see www.outokumpu.com) has been put on care and maintenance on several occasions since it opened in 1970 in response to changes in the price of nickel. Outokumpu also own a nickel mine in Norway. Nickel is also produced as a by-product at Mondo Minerals' talc mines in Finland.

4.28 A potential area for future sulphide body nickel production is Aguablanca in south west Spain (see www.mining-journal.com/mininginfo/projects/agua.htm), where nickel is associated with copper, platinum and palladium.

4.29 Dwarfing all other producers is Russia's Norilsk Nickel (see www.nornik.ru). As well as nickel, they produce copper, cobalt, palladium and other minor metals.

4.30 The main use for nickel is in the production of stainless steel. This is a sector which appears likely to continue to show growth in the future, though some of this growth will probably be met from increased recycling of scrap stainless steel. Another significant growth area in recent years has been in the production of batteries. While nickel-cadmium batteries have come under attack because of their cadmium content, much interest has been focussed on nickel-metal hydride batteries for pure electric vehicles and for petrol-electric hybrids.

Tin

Figure 4.6 Tin production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	201	217	198	9,600
EU-15, of which:	7	5	3	n/a
Portugal	5	3	3	70
UK	2	2	0	n/a
Other European countries, of which:	9	8	5	n/a
Russia	9	8	5	300

4.31 Tin is occasionally a by-product of other mines, such as the Neves-Corvo copper mine in Portugal (see above under copper) and Beralt Tin & Wolfram's Panasqueira mine, also in Portugal, but further north, near Covilhã. At one time there were many dedicated tin mines, in areas such as the south west of England, but the last of these (the South Crofty mine) closed a few years ago, and would only re-open if world tin prices experienced a strong and sustained recovery.

4.32 In light of the above, it seems highly unlikely that tin mining will expand in Europe in future. Reserves and production are dominated by mines in South America and Asia.

Bauxite / Aluminium

Figure 4.7 Bauxite production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	112,000	122,000	127,000	n/a
EU-15, of which:	2,200	1,877	1,883	n/a
Greece	2,200	1,877	1,883	n/a
Other European countries, of which:	4,400	4,950	5,410	n/a
Russia	3,100	3,350	3,750	n/a
Others	1,300	1,600	1,660	n/a

4.33 Bauxite mining in the EU is restricted to Greece, the last mine in Italy having closed in the mid-1990s. The main working bauxite mines in Greece belong to Silver & Baryte Ores Mining (see www.sandb.gr) and Aluminium de Grèce/Delphes & Distomon SA, a subsidiary of Pechiney.

4.34 The refining of aluminium from bauxite requires a lot of energy, giving a competitive advantage to bauxite mines located close to sources of cheap energy. The only countries in Europe expected to develop new bauxite mines in the foreseeable future are Hungary and Russia.

4.35 Although outside the scope of this report, it should be noted that processing bauxite into aluminium generates large volumes of 'red mud'. According to research in Australia reported in the Economist magazine (issue of 12 July 2001) it is possible to use a mixture of 'red mud' and sea water to neutralise the acidity of drainage water in other minerals' tailings dams, and to remove heavy metals. The topic of mineral processing waste will be dealt with in the BAT Reference Document.

Precious Metals

Gold

Figure 4.8 Gold production 1995-99, and reserves 2000 (tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	2,230	2,450	2,540	48,000
EU-15, of which:	21	19	19	n/a
Finland	2	3	3	n/a
France	5	4	5	n/a
French Guiana(*)	3	3	3	n/a
Spain	4	2	4	n/a
Sweden	7	7	4	n/a
Other European countries, of which:	144	125	135	n/a
Bulgaria	3	1	2	n/a
Romania	4	4	4	n/a
Russia	132	115	126	3,000
Serbia and Montenegro	3	3	1	n/a
Others	2	2	2	n/a

(*) Part of France, and therefore of the EU

4.36 As can be seen from the production data above, there are several active gold mines in Europe. See, for example:

(i) details of the very significant Rio Narcea gold belt in Spain and the mining company of the same name, described as western Europe's largest current gold producer, at www.mining-journal.com/mininginfo/projects/rionarcea.htm and at www.minesite.com/companies/rio_narcea.htm;

(ii) limited information on various Swedish mines which produce gold as either their primary output or as an important co-product at www.boliden.se;

(iii) detailed technical information on Terra Mining's Pahtavaara dedicated gold mine in northern Finland at www.gsf.fi/explor/gold/pahtavaara.htm, and on two mines in Finland with gold as an important by-product at www.outokumpu.com; and

(iv) a description of the Chelopech copper-gold mine in Bulgaria at www.navanminingplc.co.uk.

4.37 Two EU Member States where gold production is being expanded, but which do not appear in Figure 4.8, are:

(i) Italy, and particularly the island of Sardegna (see www.gmslimited.com for details of the recently opened mines at Furtei and Osilo); and

(ii) Greece: for descriptions of several gold mines in Greece see www.tvxgold.com/greece.

4.38 Historically, France has also been a major producer of gold. By some way the largest French gold mine is at Salsigne in south-central France. During the 20th century Salsigne yielded around 90 tonnes of gold, partly from underground but more recently from an open pit. After changing ownership several times over recent years, the focus at Salsigne (which also produces silver, copper, arsenic, bismuth and sulphur) is now primarily on remediation rather than further production, though some limited mining is still taking place. A detailed report on Salsigne (the 'Rapport Barthélemy-Legrand') can be found *via* www.environnement.gouv.fr by searching for 'Salsigne'. It was produced in June 1998 to see how best to take matters forward.

4.39 The French Chemical Society (Société Francaise de Chimie) has some limited information on the French gold industry in the mid-1990s at www.sfc.fr/donnees/metaux/au/texau.htm. This identifies other gold mines, at Lauriéras and Le Bourneix in central France, and at Rouez, further north, near Le Mans. Various closed mines are also identified.

4.40 During the first six months of 2001 the Finnish government issued calls for tender for five gold prospects (see www.gsf.fi for details, including an assessment of the nature and extent of all gold resources in Finland). Some companies specialise in exploration rather than mining operations (see, for example, www.endomines.fi).

4.41 The Bulgarian government has also issued permits for exploration and development (see, for example, the website of Hereward Ventures plc at www.hereward.com for a description of two districts). Similarly, the Romanian government has a list of potential gold (and silver) mines which can be consulted at www.namr.ro. See also www.mining-journal.com/mininginfo/projects/rosia.htm for a description of the Rosia Montana project in Romania, which is "… believed to be Europe's largest gold deposit".

4.42 By contrast, in the Czech Republic, the government is reported to have withdrawn the exploration licence for the Kasperske Hory project from TVX Gold Inc of Canada after protracted disputes. Kasperske Hory lies in an area of particularly environmental sensitivity close to the Czech-German border.

4.43 As reported in Chapter 3, the website at www.minesite.com (from which details of Rio Narcea can be extracted) provides many links to the gold mining sector. See, for example, the website of Cambridge Mineral Resources plc (www.cambmin.co,uk/spain.htm) for details of another potential gold mine in southern Spain.

4.44 The gold mining sector has always been volatile, with mines closing or being put on a 'care and maintenance' basis when the world price of gold falls, and new finds being developed when the price rises. Expert analysis (c.f. 'Prices and Production Costs: Implications for Gold Mines', a speech to the LBMA Precious Metals Conference 2000 by Paul Smith of Brook Hunt mineral economics consultancy, available from www.brookhunt.com) suggests that gold prices below US$ 280 per ounce put considerable pressure on the less competitive mines to close or suspend operations, while new projects will only start to come on stream at a price of US$ 300 per ounce or more.

4.45 In the recent past prices have been depressed, partly by sales of gold reserves by central banks, and gold mines have indeed been closed down. Prices fell to a low of US$ 256 per ounce in the first week of April 2001. However, instability following the recent terrorist attacks on the US on 11 September 2001 has prompted a strengthening in the demand for gold, with the price recovering to around US$ 285-295 in mid-September. The current gold price, and historical price trends, can be checked through the World Gold Council website (www.gold.org) or through gold traders such as, for example, Kitco (see www.kitco.com for very helpful charts for gold, silver, platinum and palladium).

4.46 The economics of gold production are such that many mines would be uncompetitive without using cyanide. A paper by George Morizot of BRGM ('Environmental Aspects of the Use of Cyanide in Gold and Silver Ore Processing') put forward an estimate of "… more than 60% of the total extracted gold … obtained through a leaching process based on the use of a cyanide reagent".

4.47 Some bacteria can oxidise metal sulphides. The process of bio-oxidation involves using such bacteria as a pre-treatment before cyanide leaching as an alternative to roasting the ore concentrates, to make the metal recovery process more efficient. Bio-oxidation techniques have been available commercially since the 1980s, but do not remove the need for cyanide. No commercial plants have been established in Europe to date.

4.48 In a comparable process known as bio-leaching, a solution containing *thiobacillus* bacteria is percolated through a pile of mineralised material, such that the gold passes into solution. This technique, which may supplant cyanide leaching under certain circumstances, is in its very early stages of development.

Silver

Figure 4.9 Silver production 1995-99, and reserves 2000 (tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	14,900	16,100	17,700	280,000
EU-15, of which:	499	506	453	n/a
Finland	26	32	30	n/a
Greece	33	45	44	n/a
Ireland	14	13	12	n/a
Italy	14	10	10	n/a
Portugal	39	34	30	n/a
Spain	102	66	25	n/a
Sweden	268	304	300	n/a
Others	3	2	2	n/a
Other European countries, of which:	1,807	1,664	1,687	n/a
Bulgaria	35	32	25	n/a
Macedonia	10	10	10	n/a
Poland	1,001	1,029	1,100	n/a
Romania	60	60	60	n/a
Russia	600	400	375	n/a
Serbia and Montenegro	31	43	7	n/a
Turkey	70	90	110	n/a

4.49 One of the main uses of silver is in photography. Although digital imaging poses a challenge to conventional photographic processes, it is by no means certain that the former will displace the latter, and market analysts expect the mined output of silver to continue to grow.

4.50 Silver is generally a by-product from the extraction of another metal. Roughly two thirds is associated with zinc, lead and/or copper, and the remaining third with gold. The trend in recent years has been for recovery efficiency to rise, which has raised the output of silver without increasing the amount of ore produced. Like gold mines, many silver mines use cyanide to maximise the recovery of silver.

Other Minor Metals

4.51 Of the 14 metals for which the BAT Reference Document is to be produced, nine are dealt with above. The other five are cadmium, chromium, manganese, mercury and tungsten.

4.52 Most cadmium is produced as a by-product from the mining, smelting, and refining of sulphide ores of zinc and, to a lesser degree, lead and copper. The persistence of cadmium in the environment has led to strong pressures to reduce its use (e.g. in re-chargeable batteries and other electrical and electronic goods), so demand for cadmium is expected to decline over the next few years.

4.53 Both chromium and manganese are used primarily in steel making. Chromium production is heavily dominated by South Africa, and other significant producers are Kazakhstan, Turkey and India. Of the EU Member States only Finland has chromium mines of any size, notably the Kemi mine operated by AvestaPolarit Chrome (see www.avestapolarit.com).

4.54 Manganese mining is again dominated by South Africa, with large reserves in the Ukraine and substantial production there, in China and in Gabon. Of the EU Member States only Italy and Greece produce any manganese, and both produce around 1,000 tonnes a year.

4.55 Although mercury is increasingly being substituted in new products, and recycled from old ones, it is still produced at one dedicated underground mine in Spain (the Las Cuevas mine in Ciudad Real, owned by Minas de Almadén y Arrayanes SA). Las Cuevas' production in 1999 was 600 tonnes, and falling quite steeply. The same company's open pit mine (El Entredicho) closed in 1997 when its economic resources were worked out. There is also a mine in Finland with an output of 80-90 tonnes a year. World production in 1999 was 1,800 tonnes, making Spain the leading producer in the world, alongside Kyrgystan. Spain also has the world's most extensive reserves.

4.56 Tungsten is used to toughen steels, and in some lighting products. Within the EU it is produced in Austria (by Wolfram Bergbau und Hütten GmbH, from scheelite) and in Portugal (by Beralt Tin & Wolfram, a subsidiary of Avocet Mining plc, see www.avocet.co.uk for information). Elsewhere in Europe it is produced in Russia. The dominant world producer, by a very large margin, is China. Further information on tungsten can be found on the very helpful website of the International Tungsten Industry Association, at www.itia.org.uk.

Coal and Lignite

Introductory comments

4.57 Figure 4.10 draws on data from the US government (see www.eia.doe.gov/emeu/iea/table51.html) to show the balance between anthracite and bituminous coal within the coal fraction, and to show the relative importance of lignite production compared to coal. Some of the data in Figure 4.10 (e.g. coal production in the Czech Republic) are significantly different from data given by other sources.

Figure 4.10 Anthracite, bituminous coal and lignite production 1998 (million short tons)

	Anthracite	Bituminous coal	Lignite
World production	368.8	3,714.1	923.4
EU-15, of which:	11.8	117.3	263.1
France	0.5	5.4	0.8
Germany	4.5	45.5	183.0
Greece	0.0	0.0	67.1
Spain	6.3	11.7	10.7
UK	0.5	45.0	0.0
Others	0.0	0.7	1.5
Other European countries, of which:	33.4	438.7	361.0
Bulgaria	0.0	4.1	30.0
Czech Republic	0.0	82.7	0.7
Hungary	0.0	0.9	15.3
Macedonia	0.0	0.0	9.0
Poland	0.3	127.2	69.2
Romania	0.0	2.0	27.4
Russia	16.5	153.3	86.9
Serbia and Montenegro	0.0	0.1	48.0
Slovakia	0.0	0.0	4.4
Slovenia	0.0	0.9	4.6
Turkey	0.0	2.4	71.9
Ukraine	16.6	65.1	1.6
Others	0.0	0.0	2.0

Coal

Figure 4.11 Bituminous (hard) coal production 1989-99 (million tonnes)

	1989	1994	1999
World production	3,509.9	3,442.2	3,458.3
EU-15, of which:	211.7	131.1	98.6
France	12.2	7.5	5.1
Germany	77.5	57.0	43.8
Spain	19.3	18.0	11.7
UK	99.9	48.0	37.4
Others	2.8	0.6	0.6
Other European countries, of which:	795.3	432.6	429.3
Czech Rep / Slovakia	25.1	19.0	14.2
Poland	177.6	133.6	111.5
Former USSR	576.5	269.0	300.1
Others	16.1	11.0	3.5

4.58 The data in Figure 4.11 are from www.coalportal.com, and although described there as referring to hard coal production, are almost certainly limited to bituminous coal (i.e. excluding anthracite). The largest remaining reserves in the EU are in the German coal fields of the

Ruhr (eight underground mines in 2001, down from 11 in 1999), Saar (two underground mines, down from three) and Ibbenbüren (one underground mine). All 11 remaining mines are operated by Deutsche Steinkohle AG (DSK), a wholly-owned subsidiary of the RAG Group (see www.rag.de). Production in 2000 was 33.3 million tonnes.

4.59 According to www.mining-technology.com/projects/germany, all of DSK's mines have coal washing plants. Between them these plants are reported to have produced around 10-12 million tonnes of waste in 1999 (i.e. around 25% of the output of coal, or 20% of the mined material), some of which is disposed of underground and some in surface dumps.

4.60 German mines have for many years had costs significantly greater than the value of the coal being produced. According to the Commission's Green Paper 'Towards a European Strategy for the Security of Energy Supply' (available *via* http://europa.eu.int/comm/dgs/energy_transport) this is due to a combination of "… structural and geological reasons. (The EU) has many underground mines which are expensive to operate. Drastic cost-reduction programmes have taken place in Germany and the UK which have reduced their cost and raised productivity - the UK now has the highest productivity among EU producers, but levels of production have been slashed. Similar developments are taking place in France and Spain".

4.61 The subsidies which have kept the German coal industry going have been reduced over recent years, and by 2005 production is expected to drop to around 26 million tonnes, from around 40 million tonnes in 1999/2000. A wholesale review of state aid to the coal industry is under way (see COM(2001)423 final for further details).

4.62 The large majority of the remaining UK coal industry is owned and operated by UK Coal plc (formerly RJB Mining: see either www.rjb.co.uk or www.ukcoal.com). In 2001 they have 13 underground mines in northern England with a combined output of 17-18 million tonnes a year. A further four underground mines (two in Wales and one each in England and Scotland) are operated by other companies, with a combined output of 2 million tonnes a year. Most, if not all, UK underground mines operate coal washing plants, very like their counterparts in Germany. Most of the tailings are disposed of in ponds, though some washings are backfilled into closed mines.

4.63 A further 15 million tonnes of coal are produced from 20 open pit mines, just over half in Scotland and most of the rest in northern England. The remaining 10% of open pit coal comes from Wales. It is understood that none of these open pit mines have coal washing facilities, and therefore do not have wet tailings ponds.

4.64 It appears relatively unlikely that any new underground mines will be opened in the EU in the short term, though substantial underground mine reserves are known to exist. Promoters of new open pit mines also face considerable obstacles in areas such as northern England, where the reserves are mainly in countryside areas. It would require a major commitment to win planning approval, even if they could be shown to be commercial. The main objection to new rural mines would be on landscape grounds, given where the reserves of coal are to be found. By contrast, new urban fringe mines may be developed, possibly in combination with clean-up operations on contaminated sites.

4.65 Coal production in Spain is geographically spread out, though the main mining area is in the northern mountains of Asturias and León. Some of the production comes from open pit sites (e.g. Puertollano, in south central Spain), but most is from underground mines.

4.66 French coal production is scheduled to finish in 2005 under the terms of the 'coal pact' signed between the mining organizations and the government. The main mining area still producing coal is Lorraine (3.7 million tonnes in 1999), with smaller production from various fields in Centre and Midi. The Nord-Pas de Calais coal field closed in 1990. The largest single mining company is Charbonnages de France.

4.67 The EU's coal industry is dwarfed by Russia's. The largest producer in Russia is Kuzbassrazrezugol Joint Stock Holding Company, based in the Kuznetsky basin in south western Siberia (see www.kru.ru/english). They operate 110 coal seams with underground and open pit mines producing a wide range of coals.

4.68 Outside the EU and Russia, Poland is the major European producer of coal, with an output of 111.5 million tonnes in 1999. Although output has fallen markedly since the mid-1990s, the industry remains large, and competitive on world markets. The main Polish coal mining company, with six mines, is The Jastrzebie Coal Company plc (details available *via* their parent company's website, at www.polskikoks.pl). According to the profile of Polish coal mining available at www.eia.doe.gov/emeu/cabs, it was decided in March 1999 that 15 coal mines would be closed over the following three years, and another nine partially closed, taking the total industry from 53 mines in 1999 to 20-25.

4.69 The Czech coal industry has also been restructuring in recent years, following privatisation in 1993 into five large and two small companies (including lignite mining). According to COM(2001)423 final, coal mining is in the hands of two large companies: OKD (Ostravo-Karvinske Doly) with almost 80% of the market, and CMS (Ceskomoravske Doly). Limited further information is available at www.eia.doe.gov/emeu/cabs.

4.70 There is only one producer of coal in Turkey: the state-owned Türkiye Taskömürü Kurumu Genel Müdürlügü (TTKGM), whose mines are concentrated on the Black Sea coast, near Zonguldak.

Lignite

4.71 Some data on lignite production were already given in Figure 4.10. However, a level of detail on lignite production equivalent to the information in Figure 4.11 has not been found.

4.72 The leading lignite producer in the EU, and one of the most important in the world, is Germany, with an output of 168 million tonnes in 2000 from five areas. The main lignite field is the Rheinland, with an output of 92 million tonnes, all accounted for by RWE Rheinbraun (see www.rwe.com). RWE Rheinbraun operates three very large mines, with one new site (Garzweiler II) replacing two others that are almost worked out. RWE also has interests in lignite mining in Hungary.

4.73 Of the other lignite fields in Germany, two (Hessen and Bayern) are very small, and a third (Helmstedt) is modest (4 million tonnes a year) compared to the Rheinland (see above). Lausitz (55 million tonnes a year) and Mitteldeutschland (around 15 million tonnes a year) are more significant. More detailed figures can be found on www.kohlenstatistik.de).

4.74 As with most open pit mines, German lignite mines do not wash their output, and it is the view of the German Mining Association (Wirtchaftsvereinigung Bergbau) and the German Lignite Industry Association (Deutsche Braunkohlen-Industrie-Verein) that lignite mines produce no mining waste as discussed in this report. This appears not to be entirely in line with the EU's definition of waste, which would normally include top soil and overburden except where they are re-used in the restoration of the open pit.

4.75 Lignite is mined in Greece by the public sector power company, DEI (see www.dei.gr, though the English translation facility may not be operational). There are also mines in north west Spain (La Coruña), and lignite is produced on a small scale in Austria by GKB Bergbau.

4.76 Production is widespread throughout central and south eastern Europe, and in Turkey, as can be seen by reference back to Figure 4.10.

Phosphate

Figure 4.12 Phosphate rock production 1995-99, and reserves 2000 (million tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	131	143	141	12,000
EU-15, of which:	1	1	1	n/a
Finland	1	1	1	n/a
Other European countries, of which:	9	10	11	n/a
Russia	9	10	11	n/a

4.77 Phosphate rock is an essential raw material for the fertilizer industry, though it has other uses such as in detergents. European production of phosphate rock represents a very small share of world output, and a very small total tonnage. Only Russia (of the countries under consideration) has significant reserves, based on igneous rocks. The dominant producer has for years been the USA, though the USA is likely to move from being a net exporter to a net importer as deposits in Florida are worked out over the next few years.

Potash

Figure 4.13 Potash production 1995-99, and reserves 2000 ('000 tonnes K_2O equivalent)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	24,800	25,200	25,700	8.4 m
EU-15, of which:	5,419	5,353	4,950	753,200
France	799	725	300	1,200
Germany	3,278	3,423	3,600	710,000
Spain	760	640	550	20,000
UK	582	565	500	22,000
Other European countries, of which:	6,121	6,708	7,835	2.6 m
Belarus	3,211	3,248	3,600	800,000
Russia	2,800	3,400	4,200	1.8 m
Ukraine	110	60	35	25,000

4.78 Like phosphate rock, potash is an essential raw material for the fertilizer industry.

4.79 The leading German producer is Kali und Salz (see www.kalisalz.de for information, including a description of their waste recycling and disposal activities, which includes some underground disposal and deep well disposal, alongside large tailings dumps). The Boulby mine in north east England is another major EU producer of potash, and it is located within a National Park. Their proximity to the sea allows them to rely on under-sea discharge rather than tailings dumps. Their mining operations are described at www.clevelandpotash.co.uk. The last French reserves, operated by Mines de Potasses d'Alsace, are expected to be exhausted by 2004.

4.80 Beyond the EU, the main European producers from Russia and Belarus have joined forces as the International Potash Company (see www.ipcmos.com).

Feldspar

Figure 4.14 Feldspar production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	7,910	8,550	8,980	n/a
EU-15, of which:	3,771	4,059	4,363	n/a
Finland	42	40	40	n/a
France	632	621	600	n/a
Germany	330	456	460	n/a
Greece	30	65	65	n/a
Italy	2,199	2,300	2,600	n/a
Portugal	107	121	120	n/a
Spain	379	398	425	n/a
Sweden	45	50	45	n/a
UK	7	8	8	n/a
Other European countries, of which:	987	1,246	1,332	n/a
Macedonia	15	10	10	n/a
Norway	75	75	75	n/a
Poland	46	74	70	n/a
Romania	31	25	30	n/a
Russia	55	45	45	n/a
Serbia and Montenegro	5	5	2	n/a
Turkey	760	1,012	1,100	n/a

4.81 Feldspar is a collective name for several very widely distributed light coloured, glassy minerals consisting of aluminium and silicon, with varying amounts of sodium, potassium and calcium. They occur in veins within granitic igneous rocks. Feldspar is widely used in the manufacture of glass and ceramics (table ware, sanitary ware and tiles).

4.82 Leading EU producers of feldspar include Maffei SpA and Gruppo Minerali of Italy (see www.maffei.it and www.gruppominerali.com respectively) and Denain-Anzin Mineraux of France (see www.dam-mineraux.fr). Details of some other leading producers can be found within the EUROFEL section of the IMA Europe website (see www.ima-eu.org). One of the larger Turkish producers is Toprak Mining Inc (see www.toprak.com.tr).

4.83 No information was found on the extent to which flotation is used by feldspar producers, this being the key factor in the production of tailings for disposal.

Fluorspar

4.84 Fluorspar is the main source of fluorine, which is used in the manufacture of CFCs and HFCs, which in turn are used as refrigerants and in insulating foams. With the decline in manufacture and use of CFCs in response to concerns over global warming, and specifically the Montreal Protocol, the fluorspar market has declined in recent years. By-product fluorosilicic acid production from phosphoric acid producers supplements fluorspar as a source of fluorine.

4.85 Other direct or indirect uses of fluorspar include fuel (petrol) additives, and in the manufacture of aluminum, steel, and uranium fuel.

4.86 China is by some way the dominant player in the world fluorspar market, with a share of over 50%.

Figure 4.15 Fluorspar production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	4,170	4,410	4,460	220,000
EU-15, of which:	467	444	420	n/a
France	130	110	107	10,000
Germany	39	24	28	n/a
Italy	125	126	110	6,000
Spain	118	120	133	6,000
UK	55	64	42	n/a
Other European countries, of which:	274	270	270	n/a
Romania	15	15	15	n/a
Russia	250	250	250	n/a
Turkey	9	5	5	n/a

Kaolin

Figure 4.16 Kaolin production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	39,700	40,300	41,500	n/a
EU-15, of which:	5,792	5,459	5,341	n/a
Austria	57	60	60	n/a
Belgium	300	300	300	n/a
France	345	332	325	n/a
Germany	1,925	1,800	1,800	n/a
Greece	69	60	60	n/a
Portugal	180	180	180	n/a
Spain	316	315	300	n/a
UK	2,586	2,400	2,304	n/a
Others	14	12	12	n/a
Other European countries, of which:	4,489	4,578	6,669	n/a
Czech Republic	2,800	2,982	5,183	n/a
Poland	53	84	80	n/a
Romania	49	29	24	n/a
Russia	50	50	40	n/a
Serbia and Montenegro	62	60	43	n/a
Slovakia	13	24	25	n/a
Slovenia	14	17	14	n/a
Turkey	490	473	400	n/a
Ukraine	950	850	850	n/a
Others	8	9	10	n/a

4.87 Kaolin is used in a wide range of industrial applications, of which the most significant is paper manufacturing. Other uses include refractory applications, agricultural applications (fertilizers and insecticides), filler applications in rubber, paint, plastics, cosmetics and pharmaceuticals, and as a key constituent of ceramic products (i.e. as china clay).

4.88 The European Kaolin Association is part of IMA Europe (see www.ima-eu.org). The largest producer in the world is Imerys, a multinational group based in France (see www.imerys.com). Other leading producers are listed on the IMA Europe website.

4.89 China clay occurs naturally in association with granite, from which it is derived. In the UK, where china clay production is strongly concentrated in Cornwall (in the far south west), each tonne of 'good' china clay generates roughly 900 kg of micaceous residue (very fine sand and mica), 3.7 tonnes of coarse china clay sand (quartz silicate), and 2 tonnes each of waste rock and overburden. Although the ratio between 'good' material and micaceous residue is reasonably constant, the amounts of coarser wastes can vary considerably from pit to pit. Typically, the deeper the pit, the more waste is generated.

4.90 After drilling and blasting, the kaolin is separated from the surrounding granite fraction using powerful hoses. Waste rock is deposited on solid tips, while coarse sand is separated from the slurry wash in the pits by either spiral classifiers or bucket wheels, and stored dry. This dry waste can be screened to produce graded aggregate and sand, and the coarse china clay sand is suitable for use as a fine aggregate, in concrete or in block manufacture. The economics of re-use or recovery are almost entirely dominated by the distance between the quarry and the main markets for aggregates, because the materials which can be produced are of a relatively low value.

4.91 The china clay and micaceous residue are separated during the refining process, and the micaceous residue is pumped as a slurry to a tailings dam where it is dumped onto a 'beach' to separate the solids from the liquid by natural gravity. The supernatant water is either re-used within the quarry, or discharged to a river. All such discharges are controlled, monitored and regulated. The main concern over water quality is the level of suspended solids: there is no acid drainage issue. When the pond is full it dries out relatively quickly, at which point it can be vegetated.

4.92 This system contrasts strongly with the position prior to the early 1970s, when the micaceous residue was simply pumped into rivers.

Barytes

Figure 4.17 Barytes production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	4,870	6,770	5,660	150,000
EU-15, of which:	386	353	317	n/a
Belgium	30	30	30	n/a
France	75	75	60	2,000
Germany	122	119	120	1,000
Greece	1	1	1	n/a
Italy	44	26	25	n/a
Spain	29	28	26	n/a
UK	85	74	55	100
Other European countries, of which:	442	484	310	n/a
Bulgaria	150	120	100	10,000
Poland	25	3	0	n/a
Romania	18	12	5	n/a
Russia	70	60	60	n/a
Slovakia	25	62	15	n/a
Turkey	154	227	130	4,000

4.93 Barytes (or barite, or heavy spar) is barium sulphate. Its principal use is as a weighting fluid in drilling fluids for the petroleum and natural gas industries, so demand for it tends to fluctuate broadly in line with oil and gas exploration activity. Over time the amount of barytes used per well has fallen, as has the number of wells drilled per exploration block. On top of this, Chinese production has grown strongly over recent years, putting western barytes output on a markedly downward trend. Other minor uses of barytes, amounting to around 150,000 tonnes per year, include fillers in paint, plastics, rubber, paper and friction materials, and as aggregates for high-density concrete. Around 400,000 tonnes a year of barium carbonate is used in the manufacture of glass.

4.94 Information on the identity of leading producers has been very hard to find, though the dominant commercial force in the industry is understood to be Solvay Barium Strontium GmbH of Bad Hönningen in Germany (see www.solvayminerals.com).

Talc and Pyrophyllite

Figure 4.18 Talc and pyrophyllite production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	8,490	10,400	9,470	n/a
EU-15, of which:	1,218	1,156	1,153	n/a
Austria	132	156	150	n/a
Finland	464	350	350	n/a
France	322	350	350	n/a
Germany	14	9	15	n/a
Italy	136	142	140	n/a
Portugal	8	8	8	n/a
Spain	112	110	110	n/a
Sweden	25	25	25	n/a
Others	5	6	5	n/a
Other European countries, of which:	145	143	140	n/a
Hungary	1	1	1	n/a
Macedonia	10	10	10	n/a
Norway	20	30	26	n/a
Romania	10	8	8	n/a
Russia	100	90	90	n/a
Turkey	4	4	5	n/a

4.95 Talc (hydrous magnesium silicate) is a chemically inert material valued for its fragrance retention, lustre, purity, softness and whiteness. Pyrophyllite (hydrous aluminium silicate) is similar, and is often grouped together with talc. The main uses for talc are in the manufacture of ceramics, paint, paper and plastics. Talc is obtained from the rock steatite. A less pure source is soapstone. Although talc is chemically inert, it is always found in combination with at least one other mineral, such as chlorite, dolomite or magnesite. In Finland it is found in combination with nickel-bearing ores.

4.96 The leading producers in Europe are Luzenac, a French group with production facilities in several EU Member States and in North America (see www.luzenac.com for details), and Mondo Minerals of Finland (see www.mondominerals.fi). Luzenac operate both underground mines (in Italy and Austria) and open pits (in France, Spain, Italy and Austria). Mondo's mines in Finland are open pits.

Processed limestone

4.97 Limestone is widely produced throughout the EU Member States and the rest of Europe. Its primary use is as an aggregate material.

4.98 Statistics on the proportions of those limestones which are processed (and therefore covered by the proposed BAT Reference Document) have not been found. Among the leading producers of non-aggregate limestone are the OMYA Group (see www.omya.com), with extensive operations throughout western and central Europe.

Boron

4.99 Borates are salts of boron which are mainly recovered from both mines and brines. Turkey is the world's largest producer, with a range of open pit and underground mines producing around 1.4 million tonnes of concentrates a year: around 30% of the world total. All of this production is under the control of Eti Holding AS, a government corporation (see www.etiholding.gov.tr for further information). A further 1 million tonnes a year is mined in Russia, and slightly more in the USA.

4.100 No significant boron production capacity exists in the current EU Member States.

Strontianite

4.101 Strontianite is strontium carbonate. The main use for strontium is in cathode ray tubes for computer monitors and colour televisions. It is also used by the car industry.

4.102 Statistics on strontianite are hard to find, though it is known that Spain is a major producer. Turkey was historically an important producer, but has declined in importance in recent years, as has the UK. The dominant commercial force in the industry is understood to be Solvay Barium Strontium GmbH of Bad Hönningen in Germany (see www.solvayminerals.com).

Other Selected Industrial Minerals

Asbestos

Figure 4.19 Asbestos production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	2,180	2,110	1,930	n/a
EU-15, of which:	76	80	60	n/a
Greece	76	80	60	n/a
Other European countries, of which:	681	711	701	n/a
Russia	680	710	700	n/a
Others	1	1	1	n/a

4.103 The government-owned Asbestos Mines of Northern Greece SA (MAVE) is the sole producer of asbestos in the EU.

Salt

4.104 World resources of salt are practically unlimited. Although there are alternatives for some applications (e.g. de-icing) these are generally more expensive.

4.105 Some salt production is linked to potash mining, examples including Cleveland Potash's Boulby mine in the UK, and Kali und Salz's operations in Germany (see above under Potash for details).

Figure 4.20 Salt production 1995-99, and reserves 2000 ('000 tonnes)

	1995 (P)	1997 (P)	1999 (P)	2000 (R)
World production / reserves	199,000	206,000	209,000	n/a
EU-15, of which:	44,529	43,732	42,050	n/a
Austria (brine salt)	523	400	400	n/a
Denmark (sales)	603	600	600	n/a
France (brine salt)	1,491	1,475	1,500	n/a
(marine salt)	1,473	1,188	1,200	
(rock salt)	165	371	300	
(salt in solution)	4,410	4,051	4,000	
Germany (marine salt)	617	700	700	n/a
(rock salt and other)	14,607	15,087	15,000	
Greece	143	150	150	n/a
Italy (brine/rock salt)	2,952	2,910	3,000	n/a
(marine salt)	600	600	600	
Netherlands	4,976	5,000	5,000	n/a
Portugal (rock salt)	545	600	600	n/a
Spain (marine/evaporated salt)	1,282	1,500	1,200	n/a
(rock salt)	3,494	2,500	2,000	
UK (brine salt)	1,300	1,300	1,300	n/a
(rock salt)	1,800	1,800	1,500	
(other salt)	3,548	3,500	3,000	
Other European countries, of which:	16,255	15,573	15,817	n/a
Bulgaria	1,500	1,600	2,500	n/a
Poland (rock salt)	812	791	750	n/a
(other salt)	3,402	3,068	3,250	
Romania (rock salt)	669	350	70	n/a
(other salt)	1,820	2,300	2,000	
Russia	3,100	2,100	2,000	n/a
Turkey	1,444	2,344	2,200	n/a
Ukraine	3,000	2,500	2,500	n/a
Others	508	520	547	n/a

Soda Ash and Magnesium Compounds

4.106 Like borates (see above), soda ash and magnesium compounds are sometimes mined and sometimes recovered from brines.

4.107 Soda ash is primarily used in glass making, but is also an important chemical feedstock used in the manufacture, among other things, of soaps and detergents. Roughly one third of world supplies are recovered from trona and sodium carbonate-rich brines, with the balance is synthesized. The main brine reserves are in the US, and the only significant European reserves are in Turkey. Most European soda ash is synthetic.

4.108 Magnesite, which is used in the animal feed industry among others, can be mined (as in parts of Europe) or a range of salts of magnesium can be recovered from brine (as in the US and many other countries including, for example, the Netherlands). Mined production of magnesite in 1999 was reported by the USGS to total around 3 million tonnes, including 187,000 tonnes in Austria, 187,000 tonnes in Greece, 144,000 tonnes in Spain, 259,000 tonnes in Russia, 245,000 tonnes in Slovakia and 721,000 tonnes in Turkey.

Other Industrial Minerals

4.109 The remaining industrial minerals are mostly extracted by quarrying / open pit mining, and in a relatively pure form that means that, apart from overburden, there is little waste produced. The principal remaining products are listed in alphabetical order in Figure 4.21.

Figure 4.21 Other industrial minerals

Mineral	Main producing countries in Europe	Comments
Bentonite	Greece 950,000 t, Germany and Italy both 500,000 t, Spain 150,000 t. Russia, Turkey and Ukraine all substantial producers. Several other small producers.	Used in remediation of contaminated land. The main EU supplier is Silver & Baryte Ores Mining Co.
Diatomite	Denmark 185,000 t, France 80,000 t, Spain 36,000 t, Italy 25,000 t. Russia, Romania and Iceland all medium producers.	Used in filtration of liquids (drinks and others).
Fuller's earth	Germany 500,000 t, UK 140,000 t, Spain 90,000 t, Italy 30,000 t. No data for non-EU European producers.	Used in printing industry, among others.
Gypsum	Spain 7.5 million t, France 4.5 million t. Most EU countries have some production. Poland 1.0 million t, plus several small producers.	Mainly used for plaster in construction. The industry is concentrated, and represented by Eurogypsum.
Perlite	Greece 500,000 t (about 30% of world production), Italy 60,000 t. Turkey 130,000 t, Hungary 100,000 t, Slovakia 30,000 t.	Used in horticulture. The main EU supplier is Silver & Baryte Ores Mining Co.
Silica	Germany, France, Austria and Spain all 6-7 million t, UK, Italy and Netherlands all 3-4 million t. Several smaller producers. Several small non-EU producers.	Used in many industries.

5. WASTE MANAGEMENT SYSTEMS AND THEIR COSTS

Opening Comments

5.1 The report on 'Management of Mining, Quarrying and Ore-Processing Waste in the European Union' by BRGM (published in June 2001) describes, characterises and analyses the full range of mining and quarrying techniques as they relate to the generation and management of mining waste.

5.2 This report does not seek to cover the same ground again, but to concentrate on those aspects of waste management which are likely to affect the operator's costs. One of the main objectives of this study is to collect and interpret information on current waste management practices and costs.

5.3 It is acknowledged that mining (and, to a lesser extent, quarrying) is already regulated in many Member States, with the result that good practice can be found on several sites, even if there is no widespread agreement on what constitutes best practice. Several of the companies that responded to the consultation process described in Chapter 3 claimed (unprompted) that their waste management systems already represent either BAT, good practice or similar. If their confidence is justified, the marginal costs of moving from good practice to best practice may well be relatively modest, provided that the phasing-in period allowed for the necessary changes is long enough. However, if the change from good practice to best practice involves a complete change of processes or organization within the mine, this would almost certainly involve a high financial cost.

5.4 The issue of regulatory costs is not covered in this study. No estimate is made of the potential costs to governments and public agencies of a changed regulatory system based on new standards, nor is any estimate made of the administrative costs which might be faced by mining companies in dealing with any new regulatory structure.

Prioritisation

5.5 The complexity of this subject must not be underestimated. As Chapter 4 has shown, there is a very wide range of minerals and extraction processes in an equally wide range of physical locations and settings to be considered. In order to achieve clarity, this study has focussed on those mine and quarry types, and on those extraction techniques, which have the potential to cause the greatest threat to the environment if mis-managed.

5.6 The process of prioritisation was approached by posing a series of questions, as set out in Figure 5.1.

Figure 5.1 Considerations for prioritisation

Q1	Is there overburden to be removed for off-site recovery, recycling or disposal?
Comments	There is a general assumption that immediate backfilling of the void space within open pit mines or quarries with overburden is acceptable (probably desirable). This practice falls outside the scope of this study. Most overburden comprises top soil and clean/inert sub-soil and/or rock. However, where the pit has to be kept open for an extended period, off-site management (i.e. recovery, recycling, long-term storage or disposal) of the discarded overburden material will be involved, and will involve costs.

Q2	Does the void space require de-watering, either during the operational or post-operational phase?
Comments	Where the depth of the water table is such that the void space created by working the mine/quarry floods, this can generate significant contamination of ground and/or surface waters (e.g. acid drainage), particularly where metal ores and coal are concerned. Pumping costs can be considerable, and the obligation potentially lasts for ever if the worked-out mine is not back-filled to prevent flooding. However, the regulation of groundwater and drinking water quality is already covered by Directives 80/68/EEC and 80/778/EEC respectively, even though these Directives only lay down rather general requirements. The potential Mining Waste Directive may reinforce the working of these other Directives by linking the issues of water and waste management.
Q3	Does the exploitation process generate non-inert waste rock (i.e. material which needs to be discarded without undergoing a mining-related process such as crushing or concentrating)?
Comments	If the answer is 'Yes', this is likely to fall under the scope of the potential Mining Waste Directive. The follow-on question is: can any non-inert waste rock be back-filled within the mine/quarry (i.e. in an environment with which it is largely consistent from a physical and chemical standpoint) without posing an unacceptable environmental risk, or does it need to be managed off-site (by recovery, recycling or disposal)? Either option will involve costs, which may be raised by the potential Mining Waste Directive.
Q4	Is the ore (or other product) ready to use without further processing? (NB 'use' in this context includes controlled - and regulated - processing elsewhere).
Comments	If the answer is 'Yes', then there is no obvious reason why the potential Mining Waste Directive should add further costs not already identified above. This conclusion is likely to apply to iron ore, coal from open pit mines (in present EU Member States), and several industrial minerals.
Q5	Is the ore milled and concentrated as part of the mining process, thereby producing tailings? Is some form of wet process involved (either with or without chemicals such as cyanide and xanthates)?
Comments	If the answer to either the first question or to both questions is 'Yes', the potential Mining Waste Directive is likely to introduce obligations, and therefore costs, if suitable measures are not yet implemented on the site in question. This conclusion is likely to apply to non-ferrous metal mines which are not yet in compliance with best practice.
Q6	Are the tailings de-watered prior to disposal?
	Any mine that is already wholly or partially de-watering its tailings may see only a modest increase in costs due to the potential Mining Waste Directive. It may be feasible to back-fill some of the tailings within the mine void space (with or without lining the void space). Tailings for backfilling are generally pumped down the mine in a slurry form, possibly after a suitable process of partial de-watering and/or treatment of the chemical residues. They may be cement-stabilized or backfilled as paste.

Q7	Are the tailings transported and/or disposed of as a slurry?
Comments	If the answer is 'Yes', this implies the classic tailings dam, which involves a series of investments over time, plus costs for management, monitoring, eventual closure and after-care. The potential Mining Waste Directive is expected to impose costs on those operators of tailings dams who are not yet complying with best practice.

5.7 A further consideration concerns the issue of the economics of scale and the genuine scope for new players to enter the minerals market.

5.8 Several of the minerals under consideration are produced by only one or two companies within the existing EU Member States, possibly by one or two mines. In some cases this is because competing ore bodies have been worked out, and no further economically exploitable reserves are believed to exist within Europe. Generally the geology of Europe is well known, and it is relatively unlikely that new reserves will be discovered in unexpected locations.

5.9 Although operators should know their own costs very well, obtaining reliable cost data can raise issues of commercial sensitivity. Costs can be particularly hard to establish where the producer concerned is, or used to be, state owned and the costs are historic.

5.10 A final consideration concerns the fact that many metal mines produce several metals. Under such circumstances it can be difficult to assign common costs sensibly to the different metals.

5.11 With the time and resources available for this study being limited, it was necessary to impose some priorities. For the above reasons, this study has placed the highest priority on establishing the costs of mines located in existing EU Member States, and particularly the following categories:

(i) mines where zinc is the major product (because there are several producers in both actual and applicant countries, and because there are real prospects of new zinc mines being developed in future, and because most if not all mines dispose of wet tailings);

(ii) mines where copper is the major product (for the same reasons as zinc, though there are fewer active copper mines than zinc mines);

(iii) mines where gold is the major product (for the same reasons as zinc, though gold mining companies are typically smaller than industrial metal producers, and less likely to belong to diversified enterprises);

(iv) coal mines with coal washing facilities (because although new mines are unlikely to be developed in future, the volume of tailings produced is so significant); and

(v) potash mines, which were identified in the study brief as a priority.

5.12 The other metals and coal products were not prioritised for a variety of reasons, including one or more of the following:

(i) tailings are not produced (applicable to iron ore, bauxite, open pit coal and lignite);

(ii) the mining sector is very heavily concentrated (applicable to iron ore, nickel, tin, bauxite, chromium, manganese, mercury, tungsten and lignite);

(iii) the economics of the ore concerned is primarily driven by other minerals, because it is usually a by-product (applicable to lead, tin, silver and cadmium); and

(iv) there is a lack of information on the sector concerned, and production is on a relatively small scale within Europe (applicable to cadmium, manganese and mercury, even though the EU produces over 30% of all mined mercury worldwide, mostly in one dedicated mine in Spain).

5.13 Most of the industrial minerals are also excluded from the list of priorities. However, potash waste was specifically mentioned in the study brief (see Figure 2.2), and findings specific to potash are reported at the end of this chapter. However, it should be acknowledged that all conclusions from one potash mine (or group of mines) regarding waste issues cannot always be applied directly to others, due, for instance, to differences in the surrounding geology, or in the water systems adjacent to the mine(s).

5.14 For nine of the 10 industrial minerals to be covered by the BAT Reference Document, the reasons behind their omission from the list of priorities are as follows:

(i) phosphate production has declined to a very low level in the EU, and is highly unlikely to recover;

(ii) waste from feldspar, kaolin, talc, limestone and boron production is substantially inert, and the feldspar, talc and boron industries are heavily concentrated in a small number of units (state-owned in the case of boron); and

(iii) the fluorspar, barytes and strontianite sectors are not well documented, making it very difficult to identify representative operators in the first place.

5.15 A limited amount of information on waste management in the kaolin (china clay) industry is provided in Chapter 4 in support of the argument above. As with the coal industry, china clay producers use tailings ponds to separate solids from liquids, not as a long-term storage solution. Once the water has been drained off, the remaining tips are planted up, with or without the introduction of additional top soil.

Actions that Result in Waste Management Costs for Mines

5.16 The Waste Framework Directive (75/442/EEC as amended, particularly by 91/156/EEC) establishes that it is preferable to re-use a material rather than simply disposing of it. Where direct re-use is not feasible, the Directive prefers recycling to disposal. Recycling is to be achieved by subjecting the waste material to an approved physical, chemical or biological treatment such that it can then be used without undue threat to the environment.

5.17 Mines which divert either overburden or waste rock for use as an aggregate, including general fill, are liable to find themselves regulated under the same national waste management legislation that responds to the demands of the Waste Framework Directive, even if the relevant national legislation pre-dates the Directive.

5.18 The same general point applies to top soil and sub-soil, even where the material is clean and uncontaminated.

5.19 Mines, quarries and their waste management facilities are all assumed to be authorised and monitored by the authorities responsible for local government, whether or not they are also regulated by national authorities. This will certainly apply to all future installations, and to any that started operation later than the introduction of formal environmental impact assessment, and to many much older operations.

5.20 Certainly any new authorisations in the UK include formal approval for restoration plans for pits and tips. This would apply whether those plans are based on back-filling, re-profiling, restoration to productive use, habitat creation or whatever. Directly comparable information on this aspect was not received from other Member States, though it is clear that the position is similar, in several countries.

5.21 All of the above activities are likely to involve the handling and management of waste materials, and to entail costs, though actions such as sorting, screening, crushing, storing and placement of materials all involve costs that are relatively minor. The agreed plan will also impose limitations on the options open to the operator.

5.22 Tailings are generally assumed not to be inert, particularly where chemicals have been used in the flotation process. At a well-run mine, the costs associated with tailings management (prior to their long-term storage or disposal) are tailings pumping, de-watering, neutralisation and the treatment of chemical residues to render the tailings less hazardous. These operations are not always carried out at all mines.

5.23 A tailings management facility is generally developed in phases. The initial construction will normally include:

(i) a containment dam and (possibly) supplementary bunding;

(ii) whatever liner (geological or artificial) is required to prevent contamination (e.g. acid drainage) from infiltrating the underling soil and rock and affecting either groundwater or surface water (or both); and

(iii) the accompanying infrastructure (pumps and presses) needed to operate the tailings management facility.

5.24 Over subsequent years the height of the containment dam is likely to be raised in stages. Thus the capital investment required for the facility is likely to be spread over the life of the facility, if not the mine.

5.25 Sulphidic minerals occur in nature below the water table, and sulphide ore tailings are often deemed to be best stored under water to prevent oxidation. If oxidation occurs, the metal oxides which are produced are generally easily soluble, enabling them to pollute surface or groundwater. Sulphide ore tailings stored in the open air will act as a source of new acid drainage each time it rains or snows. This is the basis of the argument for storing metal mining waste under water in perpetuity. However, this in turn raises the difficult issue of the long-term stability of tailings dams, which are required to remain in place and effective in perpetuity.

5.26 An alternative approach is to store the tailings under water until the tailings management facility is full, but then to drain the water and cover the tailings with rock, soil or other imported materials. This would be engineered to minimize the extent to which rainfall and other water can infiltrate the tailings and wash out any newly formed metal oxides. The eventual landform and function of such a restored tip would normally be subject to official agreement and approval. This closure phase can involve a significant cost.

5.27 Many of the provisions applicable to wet tailings management facilities would also apply if the tailings were de-watered and disposed of dry. A continuous barrier below and around the waste material would be required to protect the surrounding environment from any outgoing contamination, and to protect the tailings from incoming water which might react with, or dissolve, elements within the tailings.

5.28 For some materials, backfilling within the mined-out void space is an option. This will involve some costs to achieve proper separation of materials, expenditure on cement or cement substitutes, and handling costs to place the waste into the void space.

5.29 Whether the waste materials are stored in wet or dry form, a tailings management facility requires management effort, some monitoring equipment, and access to appropriate analytical facilities.

5.30 The scope of the potential Mining Waste Directive is unlikely to seek to determine in detail what (beyond routine monitoring) might be done at tailings management facilities once they have been closed.

Capital Costs, Semi-Capital Costs and Operating Costs

5.31 Mines are generally developed around an operating concept which includes waste management as an integral part of ore concentration and processing. The implication of this is that any enforced change to the preferred waste management system may well have significant knock-on implications, particularly for ore concentration operations. The working life of most capital investments is 10-15 years.

5.32 Some changes (such as, for example, the elimination of the use of certain chemicals such as cyanide or xanthates) may reduce the ore recovery rate if equally effective replacement chemicals are not available.

5.33 The main capital costs relevant to this study are those associated with the design, installation and eventual closure of tailings management facilities, including any dedicated waste water treatment plants needed to treat leachate or contaminated run-off.

5.34 Semi-capital costs are those items of a capital nature which are scheduled to occur regularly over the life of a project, but whose timing is determined by the rate at which existing facilities are being used. The only relevant instances in this context are the extension of tailings dams, and the replacement of large capital items (such as pumps) at the end of their useful lives, though these items are relatively large in the context of this study.

5.35 Operating costs are items such as pumping, neutralisation of hazardous residues, general water treatment processes, materials handling, monitoring and management oversight.

Findings from this Study

General points arising

5.36 Responses with varying levels of detail were received from 22 mining and quarrying companies. Of these, 11 are primarily engaged in mining metal ores, three are involved in coal and lignite mining, and the other eight are primarily engaged in the production of a range of industrial minerals. Of this final group of eight, one also produces metal concentrates as a by-product, so a total of 12 of the respondent companies have an interest in metal ore production.

5.37 These 12 companies provided information from over 30 mines: 18 zinc, lead, copper, nickel, tungsten, tin or gold mines, and 12+ bauxite mines. All 18 of the non-bauxite mines have tailings management facilities, with widely varying characteristics. Seven of the companies reported that they already backfill mined-out void space in some or all of their mines, and others are actively studying the use of backfilling techniques.

5.38 Only three of the mining companies reported that they use cyanide. One of these reported (unprompted) that all traces of cyanide are removed before the tailings reach their tailings pond. By contrast, all nine respondents that produce zinc, lead, copper, nickel, tin or gold as a primary or secondary product reported that they use xanthates. Some use other hazardous chemicals (such as sulphuric acid, nitric acid, phosphoric acid, sodium hydroxide, zinc sulphate, copper sulphate and methyl isobutyl carbinol) as well. Three of these companies (with three mines between them) did not report the probable consequences to their businesses of an end to xanthate use, but of the remaining six, two (with 11 mines between them) were clear that metal production would cease completely as a result, one (with one large mine) was uncertain of the consequences, and three (with one mine each) expressed varying degrees of pessimism over the future of their mines under such circumstances.

Zinc mines

5.39 Developing a new metal mine is a very expensive business. The capital investment can easily run into hundreds of millions of Euros before any income is generated. See, for example, www.ivernia.com/operate/lisheen.htm where it is stated that the recently opened Lisheen mine in Ireland involved a capital cost of US$ 280.5 million. This investment was committed to achieve an intended output of 1.5 million tonnes of material a year for 14 years, of which 340,000 tonnes a year will comprise zinc and lead concentrates at 58%. On this basis, 1.16 million tonnes a year, or 16 million tonnes over 14 years, will be waste. These data are broadly consistent with the estimate from USGS (quoted above in Chapter 4) to the effect that Lisheen will generate up to 190,000 tonnes a year of zinc as metal.

5.40 The Lisheen project is both recent and well documented (see 'The regulation and construction of a new Zinc Mine including a tailings management facility at Lisheen Mine, Co. Tipperary (Ireland)' by Margaret Stokes of Anglo Base Metals (Ireland) Ltd and Dr Jonathan Derham of EPA Ireland in 'Les Techniques de l'Industrie Minérale', March 2001). This article reports that half (51%) of the tailings are to be cemented and back-filled in mined-out areas of the mine, and half (49%) are to be pumped to a lined impoundment near the mine entrance.

5.41 Similarly, at the long-established Zinkgruvan mine in Sweden (see www.zinkgruvan.com for a description) the output of ore is around 830,000 tonnes a year, and over half of the volume of tailings is backfilled within the mine void space, with the balance placed in a tailings pond, as at Lisheen. In the case of Zinkgruvan, a further 200,000 tonnes of waste rock are generated each year.

5.42 Tailings from zinc and lead ore processing typically comprise ground limestone with some trace metal content, mixed with water. Tailings can be used as mine back-fill, in combination with added cement. If waste rock is available, some of this can also be back-filled. However, the reduction in density that occurs when solid rock is milled means that it would never be possible to back-fill all mine waste. Cemented tailings are less prone to generate acid drainage than the naturally occurring sulphide-rich ore from which zinc is obtained, and they provide structural stability to the worked-out mine.

5.43 The remaining tailings (i.e. after any material to be used for back-filling has been removed) is generally pumped to tailings ponds, in which the solids settle out of suspension, allowing water to be extracted for re-use within the mine. Depositing the tailings below the surface of the water eliminates all contact with air, and is generally considered to represent better practice where sulphidic ore tailings are concerned than depositing them onto the 'beach' of the pond and covering them with water later. However, this better practice also costs more than the alternative.

5.44 Mines which do not back-fill at all send substantially more material to their tailings ponds. Although the unit cost (per tonne of tailing) is higher for back-filling than for placing within a tailings pond, the practice of back-filling is becoming more widespread.

5.45 The lined impoundment at Lisheen required a 2 mm LLDPE (linear low density polyethylene) liner. At 634,000 square metres (63.4 ha), this was the largest liner ever installed in Europe, and almost certainly the only one ever installed at a tailings management facility. The embankment was constructed using 539,000 cubic metres of fill material lined with bentonite. On closure, it is intended that the tailings management facility will be covered with 1 metre of slurried peat to create a wetland habitat.

5.46 Some cost data were collected by the Irish Government in 2000, and submitted to Eurostat as input to an investigation into 'Environmental Protection Expenditure in Europe'. The resultant short report is available from Eurostat's website, at http://europa.eu.int/comm/eurostat, as a free download.

5.47 Capital expenditure is, by its nature, irregular, but several mines from which responses were received report that they raise their tailings dams roughly once every five years. The consultation process carried out for this study (see Annex 1) asked mining companies both about their capital and operating costs, and their output.

5.48 By combining the capital investment interval with the last reported investment in waste management facilities, it is possible to calculate a 'typical' level of annual capital expenditure. This can then be added to the reported annual waste operating cost to give an overall annual cost for waste management.

5.49 Because the metal content of ore bodies varies quite widely, so does the ratio between tailings and either concentrate or metal. As a consequence, expressing the overall annual cost for waste management as a unit cost can introduce confusion. If Mine A is extracting ore with x% zinc, while Mine B has 2x%, and both are spending the same amount to manage each tonne of tailings, Mine A will have a cost which is twice as high when expressed per tonne of metal sold.

5.50 Symonds' interpretation of the information provided by metal mining companies in response to the consultation process mounted for this study is presented in Figure 5.2. When considering these data, which come from copper mines as well as zinc mines, the following points should be borne in mind:

(i) different companies provided their data in different formats: some reported ore production, some reported concentrate production and some reported metal production;

(ii) some of the mines produce gold and silver as by-products, which distorts the economics compared to 'simple' industrial metal mines;

(iii) some respondents reported capital costs but not operating costs, and *vice versa*;

(iv) some of the respondents gave costs associated with back-filling, whereas others limited their responses to the costs of their tailings pond;

(v) some information was deemed to be too commercially sensitive to report;

(vi) all cost data were provided on the understanding that they would be treated as 'commercial in confidence'.

5.51 Some 'filling of gaps' and interpretation was therefore needed in order to generate comparable indicators, and to achieve this some supporting data were drawn from the various published sources listed in Chapters 3 and 4.

5.52 The last five rows of Figure 5.2 give weighted average costs (weighted by taking the tonnages concerned into account) for:

(i) all 10 mines;

(ii) nine of the 10 mines, excluding Mine N^{o}4, which has waste management costs that are significantly higher than for all the other mines;

(iii) the seven mines for which zinc is a significant product;

(iv) six of the seven zinc mines, excluding Mine N^{o}4;

(v) the five mines for which copper is either the main metal or a significant by-product.

5.53 In international comparisons, mining costs are generally expressed in US¢ per pound of metal. The final column in Figure 5.2 has therefore been calculated to make such comparisons easier, using an exchange rate of ε 1 = US$ 0.87. At this rate, every ε 10 per tonne (of ore or metal) is equivalent to US$ 8.70 per tonne, or US¢ 0.4 per pound.

Figure 5.2 Overall annual costs of waste management (capital plus current) at 10 zinc and copper mines

Metal(s)	Mine	ε per year per tonne of ore	ε per year per tonne of metal	US¢ per year per lb of metal
Zinc, mostly with lead	1	(*)	18.3	0.7
	2	(*)	8.4	0.3
	3	(*)	5.7	0.2
	4	(*)	76.5	3.0
	5	(*)	44.3	1.7
Zinc, copper, some gold	6	(*)	14.0	0.5
	7	(*)	41.2	1.6
Copper, some gold	8	(*)	29.0	1.1
	9	(*)	42.7	1.7
	10	(*)	21.3	0.8
Weighted average (all)		0.8	26.9	1.0
Wt ave excl Mine 4		0.5	18.4	0.7
Wt ave Mines 1-7 (Zn)		2.0	26.2	1.0
Wt ave Zn excl Mine 4		1.1	14.8	0.6
Wt ave Mines 6-10 (Cu)		0.4	30.0	1.2

(*) Individual mine data withheld to protect their identities.

5.54 Data obtained from www.minecost.com show that total cash costs (as defined and explained in Chapter 3) amount to US¢ 40 ±10 per tonne of zinc metal for the vast majority of mines in the western world. The most recent available estimates (for 2001) suggest that half of all zinc is produced by mines with a total cash cost of just under US¢ 40 per pound, and 75% by mines with a total cash cost of below US¢ 44.5 per pound. At the upper extreme, 90% of all zinc is accounted for by mines with a cost base lower than US¢ 49 per pound.

5.55 The same source shows that three mines in the EU are in the group of mines with below industry average costs (i.e. below US¢ 40 per pound), while three more are in the group of mines with costs in the range US¢ 40-44.5 per pound and a further two lie just above that range. Just two EU mines are in the highest cost group of producers (over US¢ 50 per pound). The current (September 2001) world price of zinc (which was already discussed in Chapter 4) is US¢ 36.3 per pound (US$ 800 per tonne). The implications of these findings are discussed in Chapter 6.

Copper mines

5.56 Data from www.minecost.com relating to copper mines show a different picture from the one described above for zinc. These differences can be summarised as follows:

(i) the range of total cash costs per pound of copper is much wider (from below US¢ 30 in several mines and below US¢ 20 in one huge Indonesian mine at the low extreme, to over US¢ 80 in a few cases); and

(ii) whereas EU producers are relatively evenly distributed all along the zinc cost curve, EU copper mines are all grouped in the upper half of the cost curve, with most of the EU output coming from mines in the range US¢ 55-65 per pound of metal (i.e. among the mines which produce the most expensive 25% of internationally marketed copper).

5.57 The current (September 2001) world price of copper (which is discussed in more detail in Chapter 4) is US¢ 65.4 per pound.

5.58 Figure 5.2 (see above) gives cost data from three mines for which copper is the main metal, and a further two where it is a significant by-product. The implications of these findings are discussed in Chapter 6.

Gold mines

5.59 Three basic considerations dominate any assessment of the economics of gold mining and waste management:

(i) gold mines generate much more waste for every tonne of metal recovered than industrial metal mines, so any extra costs that are in proportion to the volume of waste (rather than in proportion to metal sales) will weigh particularly heavily on gold producers;

(ii) the gold price is more volatile that the price of most other metals, and subject to external non-mining influences such as bullion sales by central banks;

(iii) a very significant share of the world's gold resources (namely those reserves which are found in South Africa) are mined by an industry with a cost base with which EU mines cannot compete.

5.60 The implications of this are that any new cost which was in proportion to the volume of waste rock and tailings rather than of metal could be expected to have a greater impact on the economics of gold production than on any other metal.

5.61 Insufficient cost data were received from European gold mines to make it possible to draw firm conclusions.

Coal mines

5.62 Where coal is concerned, the final product is commonly, if not universally, washed in response to customer demand. Although coal washing has the potential to generate impacts on the water environment, it does reduce the sulphur content of the coal which is then sent to power stations and industrial customers.

5.63 In Germany, DSK estimate that they produce 10-12 million tonnes of coal waste a year. As coal output falls, waste output will also fall, probably reaching 6-7 million tonnes by 2005.

5.64 In the UK, hard waste materials from underground coal mining (also known as minestone) are generated at a rate of around 9 million tonnes a year. Most minestone in the UK is used as bulk fill, notably for constructing tailings ponds at collieries themselves, in flood protection works and in road construction. It is generally given away rather than sold, to maximise the chances that it will be used rather than wasted. There is no clear relationship between the tonnage of coal sold and minestone production: it depends on the detailed geology of each individual mine.

5.65 Although technically feasible, there is very limited recovery of minestone from old stockpiles in the UK. The main constraint preventing this is local planning control, which strictly limits vehicle movements at those mines in urban areas.

5.66 Coal washing and preparation typically produces coarse discards (minestone) and a tailings fraction suspended in water. Tailings are mostly mudstone and shale with a particle size of less than 2 mm (of which 90% is <0.5 mm and 25% <0.01 mm). Large quantities of this fraction are produced, and are normally disposed of by settling out of suspension in ponds, usually constructed as part of active waste tips. An old tip may thus contain a number of old ponds.

5.67 Most UK tips with active tailings ponds are 15 years old or less. All are operated under the Mines & Quarries (Tips) Act and Regulations, all are covered by local Planning Consents, and any discharges to water courses are regulated by the Environment Agency. The more modern tips and extensions have basal treatments agreed with the Environment Agency as part of the planning process. Most waste water is generally recirculated through the coal washing plant to save abstracting fresh water.

5.68 A protocol for the creation of wetland features from abandoned tailings ponds has been developed, in recognition of the fact that wetlands are a scarce environmental resource, and of potentially greater value than land restored to agriculture of forestry use. Wetlands also have some role to play in treating acid drainage.

5.69 The alternative to wet (pond) storage is to install a plate and frame filter press. A typical high capacity press capable of dealing with the fines from a larger mine costs around ε 1.6 million. Multi-roll filter presses are cheaper to install, but significantly more expensive to operate. Actual filter press operating costs are not available, but are certainly higher than the costs of pond formation, use and overcapping.

5.70 Tighter regulation and the higher standards required of private operators as against nationalised industries mean that the cost of constructing the most basic spoil heaps is reckoned to have doubled in real terms since the 1960s by UK Coal. Industry sources also report that the cost of constructing a more sophisticated spoil heap of the type required in more sensitive locations is double that of the most basic design. In Germany, DSK confirm that the costs of creating landscaped spoil heaps are "… much more expensive than former conical heaps".

5.71 Information provided in response to the consultation process instigated by this study indicates that, in the UK, constructing tailings pond banks costs marginally more than depositing minestone on a tip, because of the compaction that is required. Installing a basal liner costs around ε 4.15 per square metre, or more for a more demanding specification, equivalent to around ε 0.5-0.75 per tonne of waste stored for this element alone.

5.72 Adding in allowances for materials handling, water monitoring and laboratory analysis costs, the overall 'typical' cost of waste management would be expected to fall within the range ε 2.5-4.0 per tonne of underground coal mining waste. It should be stressed that these costs are regarded as commercially sensitive in an industry with very few companies, and these estimates are Symonds' own. The implications of these findings are discussed in Chapter 6

Potash mines

5.73 As reported in Chapter 4, in Germany Kali und Salz utilise some underground disposal and deep well disposal, alongside large tailings dumps. An article in 'Les Techniques de l'Industrie Minérale' (March 2001) entitled 'Management of potash tailing dumps' by the head of the environment department at Kali und Salz reports that after crushing and grinding, 22% of their mined ore comprises saleable product, 65% is solid waste and 13% is liquid waste. The process of crushing and grinding roughly doubles the volume of the material, by halving its density.

5.74 The 65% solid waste fraction can be further divided into waste which is placed on tailings dumps (58%) and waste that is backfilled within worked-out areas (7%). Technically, backfilling is only feasible in what are called 'steeply inclined deposits', which are less common than the alternative 'sub-horizontal deposits'. The 13% liquid waste fraction comprises 8% which is pumped into a porous dolomite layer roughly 20-25 metres thick, and 5% which is discharged into rivers. These percentages are determined above all by local conditions: backfilling could be expanded if the share of steeply inclined deposits rose, and discharges to rivers could be reduced if more mines were in areas with geology suited to deep injection.

5.75 The relative costs of the different techniques are reported in the article. The lowest costs are associated with discharges to flowing water. If these are indexed at 100, the cost of deep well disposal is 400, as is the cost of surface dumping. Backfilling in steeply inclined deposits has a unit cost of 1,300, while backfilling within sub-horizontal deposits would theoretically cost 2,500. The 'weighted average' cost (i.e. (58x400 + 7x1,300 + 8x400 + 5x100) ÷ 78) is therefore 461, or 4.61 times as high as discharging all the waste to flowing water, and 15% higher than placing it all on surface tailings dumps.

5.76 By complete contrast, the Boulby mine in England is able to take advantage of its proximity to the sea to rely on under-sea discharge for almost all of its waste, rather than having to rely on tailings dumps and backfilling.

5.77 Both companies responded to the consultation process, though neither presented their data in quite the format set out above. However, on the basis that discharging to water costs around ε 0.25-0.30 per tonne, and based on the ratios given above, Symonds has estimated that for every tonne of marketed potash the costs associated with waste management are:

(i) approximately ε 0.25-0.30 for waste which is discharged to water (whether a river or the sea);

(ii) approximately ε 1.00-1.20 for waste which is injected into deep wells;

(iii) approximately ε 1.00-1.20 for waste which is placed on tailings dumps on the surface;

(iv) approximately ε 3.25-3.90 for waste which is backfilled within steeply inclined deposits; and

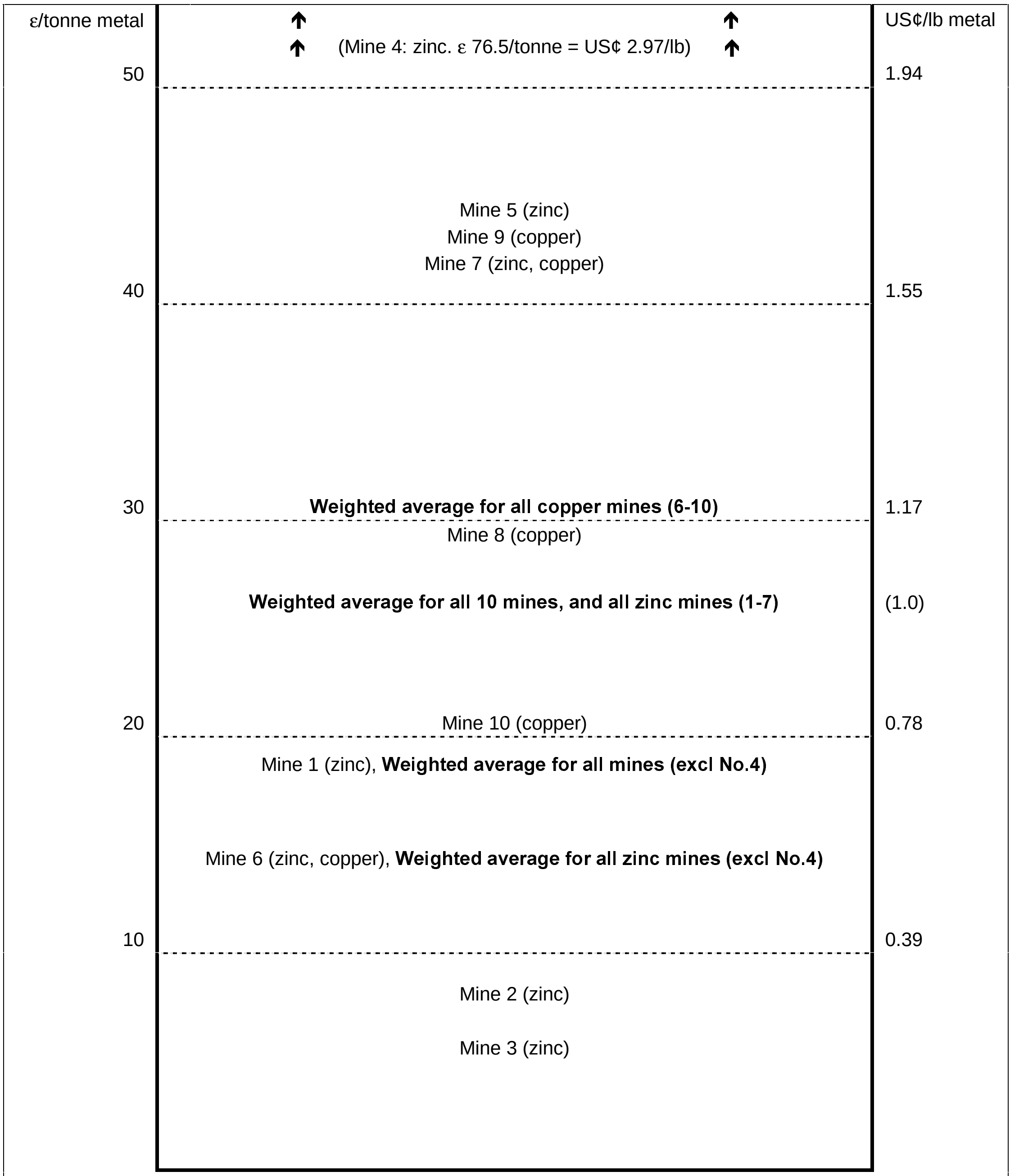
(v) approximately ε 6.25-7.50 for waste which is backfilled within sub-horizontal deposits.

6. DISCUSSION AND CONCLUSIONS

Discussion

6.1 Key cost data from Figure 5.2, relating to zinc and copper mines, can also be presented graphically. This is done in Figure 6.1.

Figure 6.1 Distribution of waste management expenditure, expressed as costs per unit of metal



Note: Vertical positions are approximate. See Figure 5.2 for actual data.

6.2 Leaving on one side the data from Mine 4, which appears to have much higher costs than any of the others in the sample, the zinc mines from which responses were received are spending around US¢ 0.6 per pound of metal sold (ε 14.8 per tonne) on waste management. For individual mines the range of costs goes from US¢ 1.7 and 1.6 per pound for Mines 5 and 7 respectively, down to US¢ 0.2 and 0.3 per pound for Mines 3 and 2.

6.3 The way in which total costs were divided between capital expenditure and running costs by different mining companies in the reports which they sent varied considerably. This reflects the fact that (as discussed in Chapter 5), much of the expenditure on waste management falls under the heading of 'semi-capital' costs: regular investments which occur with a predictable frequency, such as the raising of a tailings dam. As can be seen by reference to Annex 1, all consultees were prompted to include costs for materials handling and treatment as well as tailings dams, and for monitoring. All respondents reported on their monitoring obligations. All are required to monitor water quality, but some mines appear to have much more extensive obligations than others.

6.4 In Chapter 5, figures were given for typical cash costs at European zinc mines, ranging from under US¢ 40 to over US¢ 50 per pound of zinc. Waste management costs of US¢ 0.6 per pound would represent 1.5% of cash costs at the lower end of that range, or 1.2% at the upper end. Figure 6.2 shows the percentages which waste management costs within the range discussed above (from US¢ 0.3 to 1.5) would contribute to typical total cash costs.

Figure 6.2 Percentage contributions to zinc mining costs from current waste management expenditure

Typical waste management costs (US¢ per pound of metal)	Typical total cash costs facing European zinc mines (US¢ per pound of metal)		
	40.0	45.0	50.0
0.3	0.75%	0.67%	0.60%
0.6	1.50%	1.33%	1.20%
0.9	2.25%	2.00%	1.80%
1.2	3.00%	2.67%	2.40%
1.5	3.75%	3.33%	3.00%

6.5 It should also be recognised that, at the current world price of US¢ 36.3 per pound, even a mine with costs at the low end of the range found in Europe (i.e. below US¢ 40 per pound) will be making an operating loss, and therefore contributing nothing towards returns on shareholder capital and management skills.

6.6 Assuming that, in the longer term, world zinc costs recover to levels more consistent with those experienced in recent years, putting mines back into profit, it nevertheless follows that any measures that raise waste management costs would leave European mines slightly further down the profitability league than at present, but probably still in business.

6.7 The data from copper mines are more varied than those from zinc mines. This is at least partly because copper mines range from relatively new mines on rich ore bodies (such as can be found in Spain and Portugal), to older mines on ore bodies with a much lower metal content, such as are found in Scandinavia. For this reason, great care should be exercised when drawing conclusions and seeking to apply them to copper mines as a group.

6.8 With that qualifying statement in mind, and as reported in Chapter 5, EU copper mines have higher unit costs than zinc mines (US¢ 55-65 per pound of copper, which puts them in the bottom quartile of world producers in terms of competitiveness), a higher world price (US¢ 65.4 per pound, which, like zinc, is historically an extremely low level), and waste management costs of US¢ 1.2 ±0.4 per pound of copper sold.

Figure 6.3 Percentage contributions to copper mining costs from current waste management expenditure

Typical waste management costs (US¢ per pound of metal)	Typical total cash costs facing European copper mines (US¢ per pound of metal)		
	55.0	60.0	65.0
0.8	1.45%	1.33%	1.23%
1.2	2.18%	2.00%	1.85%
1.6	2.91%	2.67%	2.46%

6.9 Until the BAT Reference Document is produced, it is of limited value to speculate on what might be in it, and what its provisions might cost. However, it may be helpful to consider what would happen if waste management costs were to rise by 50%, or even 100%, as a consequence of new technical requirements, whatever they may be. The implications of such changes are set out in Figure 6.4 for zinc mines, and in Figure 6.5 for copper mines.

Figure 6.4 How rising expenditure on waste management might change the economics of zinc mining

	Current costs	Current costs + 50%	Current costs + 100%
Typical waste management costs (US¢/lb metal)	0.6	0.9	1.2
Typical total cash costs (US¢/lb metal)	40.0	40.3	40.6
% of total cash costs from waste management	1.50%	2.23%	2.96%
% rise in total cash costs	-	+ 0.75%	+ 1.50%
Gross Margin (GM) at zinc price of US¢ 35/lb	- 5.0¢	- 5.3¢	- 5.6¢
GM at zinc price of US¢ 45/lb	+ 5.0¢	+ 4.7¢	+ 4.4¢
GM at zinc price of US¢ 55/lb	+ 15.0¢	+ 14.7¢	+ 14.4¢
% change in GM at zinc price of US¢ 35/lb	-	- 6%	- 12%
% change in GM at zinc price of US¢ 45/lb	-	- 6%	- 12%
% change in GM at zinc price of US¢ 55/lb	-	- 2%	- 4%

Figure 6.5 How rising expenditure on waste management might change the economics of copper mining

	Current costs	Current costs + 50%	Current costs + 100%
Typical waste management costs (US¢/lb metal)	1.2	1.8	2.4
Typical total cash costs (US¢/lb metal)	60.0	60.6	61.2
% of total cash costs from waste management	2.00%	2.97%	3.92%
% rise in total cash costs	-	+ 1.0%	+ 2.0%
Gross Margin (GM) at copper price of US¢ 55/lb	- 5.0¢	- 5.6¢	- 6.2¢
GM at copper price of US¢ 65/lb	+ 5.0¢	+ 4.4¢	+ 3.8¢
GM at copper price of US¢ 75/lb	+ 15.0¢	+ 14.4¢	+ 13.8¢
% change in GM at copper price of US¢ 55/lb	-	- 12%	- 24%
% change in GM at copper price of US¢ 65/lb	-	- 12%	- 24%
% change in GM at copper price of US¢ 75/lb	-	- 4%	- 8%

6.10 As can be seen by comparing Figures 6.4 and 6.5, raising the cost of waste management by a given percentage is likely to have more serious implications for European copper mines than for their zinc counterparts. In part this is because they produce more waste per tonne of metal, but more importantly it is because EU copper mines are higher cost producers than the large majority of the industry. Figures 6.4 and 6.5 also confirm what is in any case clear intuitively: additional costs will have a more serious impact on the viability of mines at low metal prices than at high ones.

6.11 For gold mines the position could be more difficult again. At a ratio of almost 1 million tonnes of waste for every tonne of gold, even a very modest increase in the cost per tonne of waste would translate into much larger additional costs per tonne of metal sold than for other metals.

6.12 In the case of all metals (and coal, as discussed below) the competitive pressures facing EU mines would be significantly increased by any fall in the US dollar, since all world metal (and coal) prices are denominated in dollars.

6.13 Where coal is concerned, only the UK, of the EU Member States, has a mining industry that currently comes anywhere close to being able to compete at world market prices, and even the UK government has injected limited subsidies over the past two years. However, current waste management practices appear to be broadly in line with the thinking behind the potential Mining Waste Directive. If this is so, then additional costs would be modest or minimal, and the competitive position of EU mines should not be significantly affected.

6.14 Chapter 5 gives an estimate of ε 2.5-4.0 per tonne for the current cost of managing waste from underground coal mining. Putting this into further context is not particularly straightforward, because the ratio between marketable coal and mining waste varies from coal field to coal field, and from mine to mine within each coal field. However, based on a range of 250-450 tonnes of waste for every 1,000 tonnes of coal (i.e. a wastage rate of 20-31%), the above waste management cost estimates would translate into costs per tonne of coal as shown in Figure 6.6.

Figure 6.6 ***Possible range of costs per tonne of marketable underground coal due to waste management expenditure***

Cost per tonne of waste	Tonnes of waste per 1,000 tonnes of marketable coal:		
	250 tonnes	350 tonnes	450 tonnes
ε 2.5	ε 0.625	ε 0.875	ε 1.125
ε 3.0	ε 0.750	ε 1.050	ε 1.350
ε 3.5	ε 0.875	ε 1.225	ε 1.575
ε 4.0	ε 1.000	ε 1.400	ε 1.800

6.15 Unlike metals, coal is not a true commodity with a single world price. The thermal value and the physical and chemical composition of coals varies widely, and as has been discussed above, coal is subsidised in most of the EU. To take account of some of these differences, prices are sometimes expressed in terms of total carbon equivalent (tce). Thus, a coal which is sold at a price of ε 30 per tonne, and which has a carbon content of 75%, would have a price of ε 40 per tonne tce.

6.16 Information collected by the European Commission for its 'Proposal for a Council Regulation on State aid to the coal industry' (COM(2001)423 final) compares the costs of producing coal in the EU with the price of imported steam coal as follows. In 2000, costs per tonne tce were:

(i) just under ε 170 in France;

(ii) just over ε 130 in Germany and Spain;

(iii) just under ε 50 in the UK;

(iv) in the range ε 40-42 for imported coal landed in Europe.

6.17 For coal with a carbon content of 75%, the equivalent costs per tonne of 'natural' coal would be around ε 125 in France, ε 100 in Germany and Spain, ε 36 in the UK and ε 31 for imported coal. Taking ε 1.25 as a single representative cost for waste management (from the range in Figure 6.6) would imply that waste management currently accounts for around 1.0% of mining costs in France, 1.25% in Germany and Spain, 3.5% in the UK and 4.0% of the world price.

6.18 If the potential Mining Waste Directive was, contrary to the statement at the start of this Section, to add 50% or 100% to the cost of managing mining waste, this would inevitably have an indirect impact on subsidies, losses and competitiveness in the coal industry.

6.19 The differences between industrial minerals are too large to make it possible to draw general conclusions from the information collected during this study, particularly before the BAT Reference Document has been completed.

6.20 Several of the companies that responded to the consultation process for this study did so simply to report that, in their view, they produce either no waste at all, or no waste of any significance. Reflecting the fact that the consultation document was drafted primarily with metal and coal mines in mind, some of the industrial minerals companies that do produce waste found the format of the consultation document unsuited to their information, with the result that their returns were significantly less complete than those from their metals counterparts. The main exception to this was potash, as reported in Chapter 5.

6.21 With these severe limitations in mind, it can be reported that no instance was found where the costs of waste management appeared to exceed 2% of the sales value of the mineral being sold.

Conclusions

6.22 Best practice as it is applies to the processes and activities discussed in this project will in due course be identified in the 'Reference Document on BAT for Management of Tailings and Waste-Rock in Mining Activities'. This is not expected to be complete until some time in 2003. In the absence of that guidance, it has been difficult to complete all tasks within this project in equal depth.

6.23 In practice most attention has been focussed on gathering information on the current costs of managing mining waste, with the main emphasis given to metal mines, underground coal mines and potash. This was the first task set out in the study brief.

6.24 Almost certainly companies that are prepared to respond to consultation documents, and to provide information for a study of this sort are more likely than average to manage their waste responsibly, and to be well informed about the technical arguments for and against techniques such as the temporary and long-term storage of sulphidic ore tailings under water.

6.25 As a consequence, the second task (to "… assess the economic implications of implementing certain additional measures during the management of mining waste") was hampered by the lack of precision as to what the "certain additional measures" might comprise.

6.26 To overcome this insofar as it is possible to do so, the approach that has been taken has been to ask what might happen if waste management costs were to rise half as high again, or even to double from their present level. The conclusion is that a rise of 50% in waste management costs would:

(i) add 0.75% to the total cash costs of a typical zinc mine;

(ii) add 1.0% to the total cash costs of a typical copper mine;

(iii) add between 0.5% (France) and 2.0% (UK) to the production costs of coal mines; and

(iv) add up to 1.0% to the production costs of some industrial minerals.

6.27 These modest changes in operating costs must be viewed against the rapidly deteriorating economics of metals mining in particular, in which prices for metals such as zinc and copper have fallen to historically very low levels over the past 12 months, pushing several mines into a position in which their cash costs exceed their sales revenues. In this, the economics of metal mining in Europe are now comparable to those of underground coal mining, in which most mines have been able to continue in production only as a direct result of subsidy payments.

6.28 These factors make it harder for mines to implement necessary measures. However, they do not determine whether such measures are either desirable or necessary *per se*. It should be expected that if the potential Mining Waste Directive is enacted, it will come into force several years from now, by which time the economics of mining in Europe will have changed. Either prices will have recovered, or some European mines will have gone out of business.

6.29 The potential magnitude of the changes which the potential Mining Waste Directive may bring about will not be known until it is issued in draft. If the changes are significant, then that would support the argument that they should be phased in over a long time period. Most tailings management facilities are conceived and designed to operate for many years, and the cheapest way to introduce new technology is at the point when a capital investment is due to be replaced.

6.30 In order to encourage mining companies to share information which is commercially sensitive, an undertaking was given that no such information would be revealed in a form in which it could be linked to an individual mine or company. This has prevented the reporting of raw data, because most companies would be able to identify individual mines from any reasonably detailed table. However, by knowing information which companies have provided, Symonds has (hopefully) been able to avoid drawing unwarranted conclusions from other, publicly available, sources.

Information requested from individual mines

The following information request was sent to 31 mining companies, seeking information about identified individual mines.

Issues concerning the management of mining waste

Notes:

Please comment on the following topics based on experience and/or conditions at one or more specific mine(s) in Europe. Please identify the mineral(s) and mine(s) concerned in the box below:

Company: Mineral(s): Mine(s):	

In the context of this exercise 'mining waste' excludes both top soil and truly inert materials, and it also excludes any wastes coming from smelting or other thermal processes. It includes sub-economic non-inert ores and surrounding rocks that have been extracted from the mine, mill waste (tailings) and all associated primary ore processing wastes.

Please provide your answers/comments *either* by assembling them into your own document, using the topic numbers to indicate how they are arranged *or* by inserting them into the cells in this document. The cells will expand to accept whatever text you enter in them.

If it makes it easier to provide the answers for two (or more) mines on two (or more) separate reply forms, please do this, making sure that it is clear which mine(s) the answers refer to.

Whatever information you provide will be treated by us as 'commercial in confidence', and will be reported to DG ENV in a way that protects the identities of individual respondents.

Please return your response by Email to: david.knapman@symonds-group.com

My full contact details are: David Knapman, Symonds Group Ltd, Symonds House, Wood Street, East Grinstead, West Sussex RH19 2RX Great Britain
Tel +44 (0)1342 327161 Fax +44 (0)1342 315927

Topic Nos	Questions/Issues
1	***Age of facilities***
	For each mine, please specify roughly when the current mining operations started. If the current tailings/waste facilities were installed at later dates, please also give these dates.
2	***Production and remaining life***
	For each mine, roughly what was the output of minerals last year, and how many more years do you expect it to remain operational?
	If the existing tailings/waste facilities have a shorter remaining life, please also specify this. (This is to see how practical it is likely to be to introduce new waste management techniques in mid-project).
3	***Status of waste management facilities***
	For each mine, please describe as briefly as possible how your waste management system works. Please also make any comments you may wish about how modern/state-of-the-art the waste management facilities are.
4	***Capital costs of waste management facilities***
	The main costs associated with the management of mining waste are likely to be capital items. For each mine, please can you provide an estimate for the share of the initial capital investment which was accounted for by the actual tailings dam/landfill that you have, and by any waste water treatment plant primarily devoted to the mining waste management function. If you are also able to give a value figure for these waste-related investments, this would be very helpful.
5	***Running costs***
	Please can you provide an estimate for the running costs of your current waste management operations at each mine, preferably in terms of cost per unit of output. It would be most helpful if this could be divided into individual items such as 'pumping tailings to pond', 'water reclaim', 'chemical treatment', 'borehole monitoring (including laboratory costs)', 'monitoring of dam stability' etc.

Topic Nos	Questions/Issues
6	***Chemical additives***
	Do you use cyanide, xanthates or other potentially dangerous chemicals? If you do, please specify which ones, and roughly how much each year at each mine.
	If you had to stop using them, or if you had to reduce their use substantially, what would the economic consequences be for your mine(s)?
7	***Closure costs***
	If you were eventually to close your existing tailings pond(s) or spoil heap(s) as though they were landfill(s), the costs would largely be driven by their surface areas. Is it possible to estimate how many tonnes of tailings will eventually be in each pond/heap, and what their surface areas will be in order to estimate the total closure costs?
	If you have disposal sites that are already closed, you may have helpful information from these that you are prepared to make available.
8	***Environmental monitoring***
	For each mine, please describe, as briefly as possible, the type and extent of environmental monitoring which is specific to your waste management facilities.
9	***'Best practice' vs lower standards***
	Have you recently costed waste management facilities which would be wholly or mainly consistent with the current state-of-the-art approach? Are there any comments that you are prepared to make to illustrate the extra costs compared to a more traditional (1960s or 1970s) approach?
10	***Any other information***
	If there is any further information that you would like to provide, we would be very pleased to receive it.