Sub-sectoral Environmental Guidelines
COAL PROCESSING

PROCESS DESCRIPTION

Coal processing may include any of the following activities.

Coal Crushing and Screening

Coal crushing and screening activities may take place at coal depots where coal is delivered from collieries and stored prior to distribution.

Coal Carbonisation

The heating of coal in an oxygen-deficient atmosphere provides the basis for production of a range of solid, liquid and gaseous products, either of economic value in their own right or as the feedstocks for a range of chemical production processes. The following key processes may be involved:

- *Coke production process:* Coal is delivered to the site where it is crushed and screened prior to heating in an oven, either in a horizontal or vertical retort. The temperature may be "low" (typically 450 to 650°C) or "high" (950 - 1,300°C) depending upon the relative amount of products required. The coke formed is removed from the area, quenched, screened and transported away.

- *Coal tar production:* Volatile gases leaving the retort are cooled and tars removed from the gas stream by condensation or electrostatic precipitators, and collected in a tar and liquor well. The crude tar may then be distilled to provide a wide range of oil and aromatic compounds. Primary fractions include creosote, pitch and road tar, more refined products include anthracene oil, fluorene oil, biphenyl oil, naphthalene, naphtha, carbazole and benzole. The more refined fractions can also be collected by direct removal from the gaseous stream. Following acidification, treatment with alkali, distillation and further acid washing, these materials could be refined to produce benzene, toluene, xylene, naphtha and other hydrocarbons;

- *Ammonia, phenols and sulphuric acid production:* In addition to tars, the volatile gases leaving the retort contain ammonia, which is removed from the gas stream by scrubbing. The ammoniacal liquor is further processed to remove phenols and tar bases and reacted with sulphuric acid, the latter formed from the burning both of hydrogen sulphide (which is also produced in the gas stream) and "spent oxide" produced as a result of gas purification. Both ammonia solution and ammonium sulphate may be produced, together with phenols and pyridine as by-products;

- *Gas production:* Following removal of ammonia, phenols and tar, hydrogen sulphide and hydrogen cyanide are removed from the gas stream using either slaked lime (in older plants) which results in the production of "foul lime" (calcium sulphide), or iron oxide. The latter becomes "spent" when its sulphur content typically reaches 45% and it may then be burnt to produce sulphuric acid. Waste spent oxide may contain high concentrations of complex cyanide arising from hydrogen cyanide reacting with the iron present. Following removal of cyanide and sulphide, the gas may then be used for commercial supply.

Other coal processes include:

- solvent extraction of coal which takes place at 300°C or greater which is used to produce montan wax and coumarone resins;
- hydrogenation/hydrogenolysis or coal refining which involves "hydrocracking" in the presence of hydrogen to produce a gas with high heating value or motor fuel;
- production of activated carbon, in which the coal is treated with air, steam or carbon dioxide in a furnace retort or with chemical agents;
- graphite production involving calcination of coal at 1,250°C, grinding, screening, mixing with binder and baking in a furnace.

SUMMARY OF KEY ENVIRONMENTAL RISK/LIABILITY FACTORS

For coal storage depots, the environmental risk and liability factors will be relatively small in relation to sites where coal carbonisation/gasification has, or is taking place. In the case of the latter the risks will include:

- contamination of soil and groundwater due to historical and/or present use and storage of the product arising from coal processing, by-products and waste streams including both organic and inorganic compounds;
- fees and penalties (air emissions, coal dust emissions, effluent discharges, solid and hazardous waste disposal);
- run-off/stormwater drainage from raw material (coal and coke stocks), finished product, by-products and waste holding areas may cause water pollution;
- outstanding claims (health and safety) particularly in relation to toxic nature of materials handled and produced (eg. carcinogenic polyaromatic hydrocarbons in coal tar);
- risk of major spills (eg. from waste product or by-product storage) resulting in substantial liability claims or regulatory enforcement action.

FINANCIAL IMPLICATIONS

- Soil and groundwater contamination related to coal tar, phenols, and if present, complex cyanides can be very costly to remediate and due to the mobility of the contaminants may impact a significant area/volume of soil.

- Upgrade of hazardous material storage areas may be required (eg. tar wells, and if present, spent oxide repositories).

- Upgrade of pollutant abatement equipment, especially for control of gaseous emissions and dust control may be required.

- Asbestos replacement costs (eg. relating to oven retorts) may be high.

- Long-term investment and operation and maintenance costs are likely to increase as the trend towards a more stringent regulatory environment continues.

The major financial implication for any coking works is likely to be the soil and groundwater contamination arising from production of tar. For a coal depot, where only storage of coal with some crushing, screening and grading activities are taking place, the financial implications will be much less, primarily relating to dust control measures and possibly containment of fuels used for vehicles and on-site machinery and equipment.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

Coal Carbonisation and Gasification Processes

Key environmental issues associated with these processes include:

- storage and use of large quantities of coal, tar, various hydrocarbons associated with tar refining, and possibly coal gas on-site;
- solid and hazardous waste management, particularly concerning coal tar, waste residues and spent oxide;
- ground and groundwater contamination arising from a range of organic and inorganic compounds;
- atmospheric emissions;
- water supply/wastewater management;
- fire risks.

Storage and Use of Coal, Coke and Oils arising from Distillation Processes

Considerable quantities of such materials are utilised in the process. Typical storage includes the following:

- bunkers for coal and coke storage;
- underground storage tanks for tar storage (tar wells);
- above-ground storage tanks for other intermediate and final products, such as phenols, oils produced as a result of coal tar processing and refining, eg. creosote oils, benzole, benzole products and other distillates;
- storage areas for ferric oxide containing various quantities of sulphur and cyanide;
- gas holders where produced gas is used for commercial purpose.

Hazardous Waste Management

Typical solid and hazardous wastes include:

- tarry wastes, particularly sludges accumulating in underground tar-liquor wells;

- "spent" oxide used for sulphur and cyanide removal from the gas stream, consisting of a mixture of iron, free sulphur, sulphate and cyanide;
- solidified pitch, in pitch bays;
- still residues arising from coal tar distillation;
- clinker, fine dust, boiler ash arising from coal carbonisation process;
- in some cases (in old plants) as an alternative to spent oxide, "foul lime" containing calcium sulphide and calcium cyanide.

Typical liquid wastes include predominantly:

- ammoniacal liquors, containing both "free" and fixed ammonia (with sulphide, cyanide chloride, thiosulphates and phenols also present);
- phenolic liquous containing various "tar acids" (phenols), including phenol, cresol, xylenols.

Soil and Groundwater Contamination

Soil and groundwater contamination may arise from a number of substances some of which are extremely toxic. Such substances include:

- coal particles and coke breeze, potentially imparting a high calorific value to underlying soil;
- phenols, polyaromatic hydrocarbons (PAHs), and their nitrogen sulphur, oxygen containing derivatives (eg. pyridine, quinoline, thiophene), forming a key constituent of coal tar and associated with all facilities involved in tar storage, handling and distillation;
- other lighter aromatics, such as benzene, toluene and xylene associated with further refining of benzole and coal tar;
- free and complex cyanides, thiocyanate, sulphur and sulphate typically associated with spent oxide;
- ammonia and sulphate, removed from the gas stream;
- acidification of soil arising from sulphuric acid production and use on-site, or oxidation of free sulphur;
- heavy metals, arising from clinker, ash and coke breeze, spent oxide, catalysts and corrosion inhibitors used on-site.
- many of the substances are highly mobile in nature, especially phenols and some of the oil distillates and aromatic hydrocarbons.

Atmospheric Emissions

Typical atmospheric emissions include:

- particulates arising as coal dust from storage of coal or coke on-site, or processing of materials (eg. crushing, screening activities);
- particles and gaseous emissions arising from coal carbonisation process, including particulates, sulphur dioxide, oxides of nitrogen, ammonia, carbon monoxide, carbon dioxide, hydrogen sulphide and cyanide;
- aromatic hydrocarbons from tar refining and processing activities.

Water Supply and Wastewater Management

- Facilities will require significant volumes of water for process use (cooling, condensation processes, quenching of coke etc.) as well as sanitary and potable use.
- Wastewater will derive from these sources and from stormwater run-off.
- Wastewaters are collected either in separate (industrial sanitary and stormwater) drainage systems or are combined.
- Wastewater is treated either on-site or at a public wastewater treatment plant.
- Discharge from wastewater plants or from stormwater run-off is usually to a nearby river.

Asbestos

Asbestos may need to be removed from the site which can be costly. Asbestos is found in building materials, pipework, insulation, etc., and is therefore most likely to be associated with the retorts used in coal carbonisation/gasification processes.

Noise

Noise may reach or exceed nuisance/safety levels, particularly on sites where activities involve physical processing of coal (eg. screening crushing, sorting). Check regulatory compliance and complaints record.

Odour

Odour may be a nuisance in sensitive areas and provision of odour control devices may be necessary. This is particularly the case where tarworks and coal gasification processes are taking place.

ENVIRONMENTAL ACTION PLAN

Develop Environmental Action Plan (EAP) to include:

- regulatory compliance measures;
- waste management plan (waste minimisation, re-use, recycling, monitoring);
- health and safety improvements;
- costs of upgrades/compliance;
- assessment and remediation of contaminated soil and groundwater;
- roles and responsibilities, time-frame and benchmarks.

ENVIRONMENTAL IMPROVEMENTS

- Improve dust suppression facilities and protocols, eg. better screening of processing equipment, damping down stocks during dry weather and not building coal stocks too high.
- Evaluate potential for material substitution (cleaner coal, eg. low sulphur coal feedstocks) use of alternative gas supplies to coal gas.
- Improvements to recycling of waste materials during production processes;

- Upgrade material storage areas, especially underground storage facilities. Provide secondary containment facilities for all tanks and drum storage areas.
- Installation of loss detectors on long pipe runs.
- Introduction of good environmental engineering practice.
- Improve efficiency of burners for sulphur removal.
- Improvements to stack emissions including better scrubbing systems and implementation of preventative maintenance programmes for pollution control equipment.

Guide To Initial Due Diligence Site Visits

When visiting the sites of potential borrowers or during loan supervision, use the following as practical guide to the initial due diligence process.

- Perform a complete tour of the site compound if possible.
- Assess quantities and characteristics of atmospheric emissions, wastewater discharges and solid and hazardous waste arising.
- Note signs of poor housekeeping, inadequate/untidy storage areas, poor drum labelling.
- Review current status of pollution abatement technology.
- Evaluate potential for spillages and leakages to enter soil or stormwater drainage system.
- Check drainage systems, note particularly if any are blocked by coal fines, sludge or other waste.
- Note nature of solid waste disposal.

Issues to consider

- Source of process, potable and sanitary water (municipal, on-site, abstraction, surface water, etc.).
- Permits and charges for water use.
- Potential for drainage systems to become blocked by coal fines, or where drains are absent for surface run-off to impact adjacent property.
- Ability of industrial sewer system to capture all process effluents.
- Integrity of drainage system is critical, particularly when hazardous materials are discharged to sewer.
- Possibility of accidental releases of hazardous materials reaching local water courses.
- Efficiency of wastewater treatment (facility/municipal) is critical - check type, effectiveness, monitoring, final effluent and sludge disposal.
- Regulatory compliance discharge consents, enforcement, costs.
- Requirements and costs for potential upgrade of wastewater treatment plant.
- Look for localised spills, leaking pipes etc., in particular, black tarry material representing coal tar, and turquoise discolouration, indicative of complex cyanide associated with spent oxide.
- Check for distressed flora/vegetation zones near storage sites.
- Check personal protective equipment.
- Review machinery guarding.
- Assess emergency response to fires, major spills, etc.

- Review historical and projected trends for environmental fees and fines.

It is also suggested that contact is made with local regulatory agencies to determine compliance and whether complaints have been made by the public.

Sub-sectoral Environmental Guidelines
COAL MINING - OPEN CAST

PROCESS DESCRIPTION

Open cast coal mining involves the removal of coal from seams relatively near the surface by means of an open pit. These mines often occupy a large area of land for excavation of the coal and disposal of the overburden (the waste rock lying over the coal).

This kind of mining operation typically involves the following stages:
- clearance of vegetation and soil stripping;
- breakage of both overburden and coal prior to excavation. Overburden is broken mainly using explosives or dragline excavator. Coal generally requires much less breakage than overburden and restricted blasting or ripping may suffice;
- excavation of the overburden and stockpiling of this material either outside or within the excavation area. Dumps can be temporary or permanent but minimum environmental damage in the long term is achieved by the progressive backfilling of worked out areas. However, this form of overburden management is not possible at all sites;
- excavation of the coal;
- dewatering or sump pumping of the excavation is carried out to maintain dry working conditions;
- coal preparation activities include crushing, screening and washing. Washing is commonly carried out by heavy medium separation which involves gravity settlement in a viscous medium. The most commonly used heavy mediums are suspensions of magnetite or ferrosilicon in water. Chemical additives such as sodium nitrite may be added to the medium to reduce corrosion of the suspended particulates. The medium is generally recycled on site. Waste water is generally a slurry which is held in lagoons;
- treatment of mine and process waters often involving basic settlement in large settlement lagoons.

SUMMARY OF KEY ENVIRONMENTAL RISK/LIABILITY FACTORS

- The land area required for the open pit excavation, dumping of waste materials external to the pit itself and other surface facilities could destroy surface features of economic, cultural and nature conservation value.
- Mine and mineral processing operations may cause major degradation of water resources either by drawdown of groundwater levels leading to the drying up of wells, diversion or damming of surface watercourses, and contamination of waters by uncontrolled site discharges
- Mineral processing operations may lead to emission of particulate matter to the atmosphere. Key sources of particulate emissions include the handling and cleaning of coal, transportation and unvegetated surfaces of overburden and stockpile dumps.

- Stockpiles of coal and spoil may contain heavy metals and mineral oxidation products. Any run-off or leakage may contain high concentrations of these elements and be of acid pH. This run-off may pose a threat to an aquatic environment.
- Spontaneous combustion of coal stockpiles and spoil heaps may occur if coal residues are present in the heaps.
- Inadequately designed and maintained pit walls and spoil heaps may be unstable and prone to slippage or collapse.
- The storage and use of explosives creates a safety liability and risk.
- Lowering of the water table may affect supplies of water to industrial abstractors of groundwater and sensitive environments such as rivers and wetlands.
- Groundwater rebound (rising groundwater levels) may result from the cessation of pumping operations when mining operations cease leading to discharge of potentially contaminated minewater at the surface. Such water may be acidic in nature and contain high concentrations of dissolved metals due to mineral oxidation and dissolution within the excavation backfill and adjacent dewatered strata.
- Settlement of, and potential methane generation within excavation backfill can place constraints and liabilities on future developments.

FINANCIAL IMPLICATIONS

- Fees and fines will be applied by regulatory authorities for discharges to air and waters above statutory levels.
- Compensation will possibly be required by regulatory authorities for loss of natural resources such as agricultural land and forestry.
- Protest by local population and non-government organisations to defend existing surface features can lead to delays in the permitting process, reduction in extent of resource that can be exploited and increase in mine operational costs.
- Major increases in operation and investment costs could be necessary where outdated facilities at the site need to be replaced to satisfy a more stringent regulatory environment. Poor environmental performance may accelerate the demands for a more stringent regulatory environment.
- Provisions may have to be made for site decommissioning and rehabilitation costs including areas possibly affected by past activities.
- Failure of the pit wall, spoil heaps or tailings dam has the potential to cause loss of life with associated financial liabilities.
- Exposure of employees to occupational hazards may result in health compensation claims.
- Groundwater rebound may cause ground instability with potential for flooding of properties several miles by the resurgence and discharge of contaminated minewater and potential mobilisation of contaminants previously above the level of the water table.
- Groundwater rebound may increase the operating costs of other mines in the area.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

- Security and safety liabilities associated with the storage of explosives.
- High voltage electrical supplies may be required to operate machinery such as crushers, conveyors and coal screening equipment.
- Noise and vibration will be generated by drilling and blasting operations, from excavation activities, vehicle movements and mineral crushing and screening activities. Environmental noise and vibration issues will be dependent on the proximity of receptors.
- Asbestos may be present within the fabric of mine buildings.
- Mine sites often provide infrastructure for miners and coal distribution. In remote locations settlements are developed around the mine and are therefore wholly dependent on the mine. Environmental/social issues associated with housing, retail and transport can be expected.

APPLICABLE REGULATIONS AND PERMITTING REQUIREMENTS

- Permits under land-use controls.
- Water abstraction permits.
- Wastewater discharge permits.
- Atmospheric emissions permits.
- Solid and hazardous waste permits.
- Regulations relating to use and storage of explosives.
- Regulations relating to design and maintenance of tips, lagoons and tailings dams.
- Regulations and guidance notes relating to noise from opencast mining operations.
- Fire certificates.
- Environmental Impact Assessment.
- Periodic auditing of facilities may be required.
- In some countries environmental liability assessments are required by regulatory authorities before liability for a former mine site can be relinquished.
- Health and Safety at work regulations.

ENVIRONMENTAL IMPROVEMENTS

Environmental impacts of opencast coal mining operations may be reduced by employing the following mitigation techniques:

- careful control of blasting to reduce noise and vibration. Blasts should be timed to minimise noise and vibration disturbance. Proximity to roads, railways or housing may place restrictions on blasting operations;
- surface water ingress into the mine may be reduced by controlling run-off;
- the volume of wastewater can be minimised by treating and re-circulating mine effluent;
- dust emissions from the pit can be controlled by use of water bowsers on site roads. Crushing and screening machinery can be fitted with filter systems and

stockpiles can be fitted with sprinkler systems or dust caps. Emissions from vehicles can be controlled by the sheeting of loads before transport from the site and dedicated parking areas for employees' vehicles.;

- noise emissions can be minimised by careful planning of the method of working the mineral deposits, for example by leaving steep pit walls to reflect sound away from sensitive areas and by use of conveyors in place of dump trucks;
- the effects of both noise and dust can be reduced by the locating potential sources away from receptors, the use of soil storage mounds as screening bunds, and tree planting in shelter belts;
- visual impact can be reduced by techniques such as minimising the area of overburden stripped prior to coal excavation, progressive restoration of worked out areas, and screening or concealed location of processing plant and haulage routes;

ENVIRONMENTAL ACTION PLAN

An Environmental Action Plan should be developed to include:

- training of personnel in environmental management;
- introduction of targets in environmental compliance into the evaluation of the performance of management personnel;
- measures to secure and maintain regulatory compliance with respect to all environmental and health and safety issues including emissions to air, water and land;
- regular monitoring of the condition and stability of tips, lagoons and tailings dams;
- monitoring of compliance with conditions of minerals planning consent.
- monitoring and control of the effect of mining activities on the water table;
- development and implementation of a waste management plan;
- measures to reduce or suppress dust and noise generation at the mine;
- opportunities to reduce the use of toxic/hazardous chemicals;
- documentation and dissemination of examples of best practice to all mines;
- implementation of training programmes for workers to increase awareness of environmental issues;
- for future operations design of mine to minimise environmental effects.

The plan should feature costed measures and set implementation targets. The measures may require increased management supervision, or significant process upgrades which may involve considerable capital expenditure.

GUIDE TO INITIAL DUE DILIGENCE SITE VISITS

It may not be possible to inspect all of the site due to its size and due to restricted access to areas being actively worked. The success of the site visit also depends largely on the co-operation and availability of appropriate site personnel. Emphasis must always be placed, however, on the necessity to visually inspect areas considered important. Valuable sources of information are the agreements with regulatory authorities with respect to approval of planning applications and discharge consents. The information on environmental controls is often contained in an 'Environmental Passport' document. Review of this information enables identification of the site specific environmental issues at the mine.

The site inspection should concentrate on visiting the following areas.

Active excavation areas
- Is water present on the pit floor, any evidence of contamination of this water, and where water pumped from the pit floor is discharged to?
- Are there other arrangements for dewatering the pit such as pumping from peripheral boreholes. If wells are also located near the site is any monitoring of the water levels in these wells carried out? Where is the water from the dewatering discharged to? If originally clean is it contaminated by discharge onto 'dirty' areas of the site before entering natural surface/groundwaters?

Disposal of Waste Rock
- Is the pit progressively backfilled with this material or are external dumps depended on. If the latter, are there any indications that this is not necessary? Are the dumps constructed in terraces to promote stability and possible future revegetation or are excessively steep slopes produced? Is waste rock dumped near surface water courses or over areas of possible cultural or nature conservation value? Are the dumps surrounded by surface drains to collect sediment loaded surface run-off and so protect water courses? Do the dumps appear to be heavily eroding and slumping?

Stockpile Areas
- How are these organised? Does the area look well managed or are excessive areas of land used and contaminated? Is the area located near any water body or other surface feature which creates unnecessary risk of contamination? Is surface runoff from the areas collected and where is it discharged? Does any discharge look as though it is heavily contaminated by solids? What colour is it?

Coal Preparation
- What process is used, chemicals used, effluents produced, control measures employed?
- Are there any dust control measures? Do these work and are these used? Is there any build-up of dust on machinery or other surfaces?
- What amounts and quality of water are required? Where is the water obtained from? Is the water recycled? How is waste-water treated? and if so, how and where? Are there any lagoons of contaminated water on the site? Are there any discharges of water from the site either onto the ground or into surface water courses? What does the quality of these discharges look like? Is the quality tested? Where are the samples taken from, how often? what are the waters tested for? Do the discharges have to meet set standards? Are there any other discharges of effluent off the site?

Fuel and Bulk Material Storage Arrangements
- What are these? To gauge the potential for spillages and leaks consider the following: Are there any underground storage tanks? Are surface storage

tanks and usage areas hard surfaced and bunded? Are these in good condition or are cracks present? Is the size of the bunding adequate for the volume of the materials stored? Are the bunds regularly cleaned out to avoid loss of capacity due to holding rainwater etc.?

Transport of Product off the Site

- Is this by rail, road or water or a combination of these?
- Where are the areas for loading of material located? Are they located near any water bodies or other possibly sensitive features? Are they well managed or is excessive land area contaminated? Is there any containment of surface run-off from the working areas to prevent the entry of contaminated water into ground/surface water?
- In the case of road haulage does this cause excessive traffic in the vicinity of residential areas?

Other Useful Observations

- Evidence of dust emissions from the pit, such as deposits on vegetation at the site boundary.
- Are any reclamation works in progress either on stockpiles, tips, lagoons or backfilled excavation areas? What do the restoration works comprise?

Information should also be obtained on the following:

- the method of working the mine and the type of plant used;
- the history of the site and the previous existence of potentially contaminative activities at the site in the past;
- the presence of other mines, human settlements (including indigenous populations), other economic activities (including forestry and agriculture), and wildlife habitats in the area which may be sensitive to the effects of the mine;
- the proximity and sensitivity of aquatic environments;
- are there any users of water downstream from the site which might be affected by contamination of the water or lowering of water levels caused by the mine?
- noise and vibration levels at the site and proximity to sensitive receptors such as schools, and housing;
- non mineral waste management control procedures and documentation.

Sub-sectoral Environmental Guidelines
COAL MINING - UNDERGROUND

PROCESS DESCRIPTION

Underground coal mining operations aim to selectively mine coal seams and leave the surrounding waste rock in situ, however some waste material is usually removed with the coal. The quantity of waste varies greatly according to the characteristics such as the thickness and quality of the coal seam and level of mechanisation in the mine.

Methods of working underground coal can be separated into two categories: caving and non-caving.

Caving methods: Caving methods of mining involve the progressive removal of coal whilst allowing the overlying strata to progressively collapse into the void created. Longwall mining is the most commonly employed current mining technique in European coal mines. Coal is removed with a mechanical coal cutting machine and the face is advanced with roof support from pneumatic props. Following protection of roadways the strata above the mined area is allowed to collapse. Surface subsidence may result from longwall extraction.

Non-caving methods: Non-caving methods of coal extraction include the traditional room and pillar technique where substantial coal pillars are left unworked in order to support the strata above the seam. Subsequent 'pillar robbing' may lead to partial removal of support with consequent roof failure. Strata failure associated with room and pillar workings may lead to localised surface subsidence or collapse rather than regional surface subsidence.

Typically the mining process will include the following activities:

- mine development;
- fragmentation of coal seam prior to excavation. This may be achieved by drill and blast techniques using explosives. In most modern longwall mines continuous mining equipment is utilised which requires no prior blasting;
- transport of excavated material to the surface is generally achieved by armoured chain conveyor systems or belt entry conveyors. Loading shovels or conveyors may be employed to transport ore from the storage pad to the processing plant;
- coal preparation activities are carried out to remove waste from the coal and to produce a product of the desired size. Preparation includes crushing, screening and washing operations;
- washing is commonly carried out by heavy medium separation which involves gravity settlement in a viscous medium. The most commonly used heavy mediums are suspensions of magnetite or ferrosilicon in water. Chemical additives such as sodium nitrite may be added to the medium to reduce corrosion of the suspended particulates. The medium is generally recycled on site. Waste slurry is retained in lagoons;
- stockpiling of coal and spoil in surface tips.

- transport of coal to the market place which is usually achieved by rail, although waterways or roads may also be used;
- it is usually necessary to pump large quantities of mine water to the surface;
- elaborate mine ventilation systems are often necessary to provide adequate control of the quality and quantity of air underground which may be affected by high particulate loads, diesel exhaust fumes, explosive mine gas and high temperatures.

SUMMARY OF KEY ENVIRONMENTAL RISK/LIABILITY FACTORS

- Underground mining presents high risks to the health and safety of mineworkers. This is from accidents underground and exposure to damaging levels of dust, gases, radioactivity, noise and vibration.
- Surface damage due to subsidence is a major risk of underground mining. Subsidence causes structural damage to buildings, infrastructure, agricultural land and drainage systems.
- The land area required for the mine surface facilities and dumping of waste materials could destroy surface features of economic, cultural and nature conservation value.
- Mine and mineral processing operations may cause major degradation of water resources either by drawdown of groundwater levels leading to the drying up of wells, diversion or damming of surface watercourses, and contamination of waters by uncontrolled site discharges
- Colliery spoil may contain heavy metals and oxidation products. Any run-off or leakage from stockpiles or tips may pose a particular threat to the aquatic environment.
- Coal processing operations may lead to emission of particulate matter to the atmosphere. Key sources of particulate emissions include the coal processing and washing operations, crushing, screening, transportation and unvegetated surfaces of colliery spoil heaps.
- Inadequately designed and managed spoil heaps and lagoons may become unstable and prone to instability and failure.
- Safety risks associated with the storage and use of explosives.
- Lowering of the water table may result in reduced groundwater availability to industrial abstractors and environmentally sensitive receptors such as rivers and wetlands.
- Groundwater rebound (rising groundwater levels) is likely to result from the cessation of pumping operations when mining operations cease.
- Subsurface oxidation of metal sulphides may lead to the generation of contaminated minewater. Discharge or resurgence of such water at the surface could have significant environmental impacton streams and rivers.
- Methane trapped in abandoned mine workings and intervening strata may be forced to the surface by or with any rising groundwater.
- Spoil heaps may be prone to spontaneous combustion if they contain coal residues. The main associated environmental concerns relate to the migration of leachates and gases resulting from combustion.

FINANCIAL IMPLICATIONS

- Fees and fines will be applied by regulatory authorities for discharges to air and waters above statutory levels.
- Subsidence may have severe financial implications if it causes surface damage particularly to structures in the surrounding area. The effects may only appear in the long term.
- Compensation may be required by regulatory authorities for loss of natural resources such as agricultural land and forestry.
- Protest by local population and non-government organisations to defend existing surface features can lead to delays in the permitting process, reduction in extent of resource that can be exploited and increase in mine operational costs.
- Major increases in operation and investment costs could be necessary where outdated facilities at the site need to be replaced to satisfy a more stringent regulatory environment. Poor environmental performance may accelerate the demands for a more stringent regulatory environment.
- Significant provisions may have to be made for site decommissioning and rehabilitation costs including possibly areas affected by past activities.
- Failure of the spoil heaps, tips or lagoons has potential to cause loss of life with associated financial liabilities.
- Groundwater rebound may cause ground instability with potential for flooding of properties several miles from the mine and the mobilisation of contaminants previously above the level of the water table.
- Groundwater rebound may increase the operating costs of other mines in the area.
- Contamination of overlying aquifers as a result of groundwater rebound may have severe financial implications.
- Methane or radon gas generation and migration may be a hazard.
- Long term operation and investment costs could increase if there is a trend towards a more stringent regulatory environment.
- Exposure of employees to occupational hazards (eg., dust) may result in health compensation claims.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

- Mine sites often provide comprehensive infrastructure for miners and coal distribution. In remote locations settlements are developed around the mine and therefore wholly dependent on the mine. Environmental/social issues associated with housing, retail and transport can be expected.
- Mining operations may give rise to particulate emissions which have the potential to cause nuisance to neighbours. Key sources of emissions include, crushing, screening and transportation of coal and slag. Occupational exposure levels for particulates may be high.
- Security and safety liabilities associated with the storage of explosives.
- Asbestos may be present within the fabric of mine buildings.
- Noise and vibration may result from blasting activities, but if underground blasting is carried out correctly it should not be detected by residents in the surrounding area. More significant sources of noise are likely to be rock transport and processing equipment such as crushers, mills, vehicles, screen and conveyors.

APPLICABLE REGULATIONS AND PERMITTING REQUIREMENTS

- Permits under land-use controls.
- Water abstraction permits.
- Wastewater discharge permits.
- Atmospheric emissions permits.
- Solid and hazardous waste permits.
- Special requirements for training of underground personnel.
- Special emergency provisions for underground supplies of power and ventilation.
- Special requirements in certification of equipment for use underground.
- Regulations relating to use and storage of explosives.
- Regulations relating to design and maintenance of colliery spoil tips and lagoons.
- Fire certificates.
- Environmental Impact Assessment.
- Periodic auditing of facilities may be required.
- In some countries environmental liability assessments are required by regulatory authorities before liability for a former mine site can be relinquished.

ENVIRONMENTAL IMPROVEMENTS

Environmental impacts of underground coal mining operations may be reduced by employing the following mitigation techniques:

- subsidence impacts can be reduced by careful management of mining operations and adoption of appropriate mining methods;
- groundwater levels can be controlled by sumps or by abstraction boreholes;
- the volume of wastewater can be minimised by treating and re-circulating effluent where possible;
- design of colliery spoil tips and lagoons to ensure long term stability, and reduce visual impact on surrounding environment;
- groundwater rebound and its resultant effects such as groundwater contamination and methane migration may be controlled by continued pumping often at considerable cost, or treatment of minewater resurgences;
- dust emissions from surface operation can be controlled by use of water bowsers on site roads. Crushing and screening machinery can be fitted with dust filter systems and stockpiles can be fitted with sprinkler systems or dust caps. Emissions from vehicles can be controlled by the sheeting of loads before transport from the site;
- visual impact of surface operations can be reduced by techniques such as concealing access to the site and screening and sensitive location of process plant.

ENVIRONMENTAL ACTION PLAN

An Environmental Action Plan should be developed to include:

- training of personnel in environmental management;
- introduction of targets in environmental compliance into the evaluation of the performance of management personnel;
- measures to secure and maintain regulatory compliance with respect to all environmental and health and safety issues including emissions to air, water and land;
- regular monitoring of the condition and stability of spoil tips and lagoons;
- monitoring of compliance with conditions of minerals planning consent;
- monitoring and control of the effect of mining activities on the water table;
- development and implementation of a non-mineral waste management plan;
- measures to reduce or suppress dust and noise generation at the mine;
- opportunities to reduce the use of toxic/hazardous chemicals;
- documentation and dissemination of examples of best practice to all mines;
- implementation of training programmes for workers to increase awareness of environmental issues;
- for future operations design of mine to minimise environmental effects;
- site decomissioning and remediation plan.

The plan should feature costed measures and set implementation targets. The measures may require increased management supervision, or significant process upgrades which may involve considerable capital expenditure.

GUIDE TO INITIAL DUE DILIGENCE SITE VISITS

It may not be possible to inspect all of the site due to its size and due to restricted access to areas being actively worked. The success of the site visit also depends largely on the cooperation and availability of appropriate site personnel.

Valuable sources of information are the agreements with regulatory authorities with respect to approval of planning applications and discharge consents. The information on environmental controls is often contained in an 'Environmental Passport' document. Review of this information enables identification of the site specific environmental issues at the mine.

The site inspection should concentrate on visiting the following areas.

Wastewater

What are the arrangements for dewatering the pit such as pumping from peripheral boreholes. If wells are also located near the site is any monitoring of the water levels in these wells carried out? Where is the water from the dewatering discharged to? If originally clean is it contaminated by discharge onto 'dirty' areas of the site before entering natural surface/groundwaters? What are the discharge consents?

Disposal of Colliery Spoil

Are the dumps constructed to promote stability and possible future revegetation or are excessively steep slopes produced? Is spoil dumped near surface water courses or over areas of possible cultural or nature conservation value? Are the spoil tips surrounded by surface drains to collect sediment loaded surface run-off and so protect water courses? Do the tips show any signs of instability with erosion or slumping?

Stockpile Areas

How are these organised? Does the area look well managed or are excessive areas of land used and contaminated? Is the area located near any water body or other surface feature which creates unnecessary risk of contamination? Is surface runoff from the areas collected and where is it discharged? Does any discharge look as though it is heavily contaminated by solids? What colour is it? Do the stockpiles show any signs of instability with erosion or slumping?

Coal Processing

What process is used, chemicals used, effluents produced, control measures employed?
Are there any dust control measures? Do these work and are they used? Is there any build-up of dust on machinery or other surfaces?
What amounts and quality of water are required? Where is the water obtained from? Is the water recycled? How is waste-water treated, and if so, how and where? Are there any lagoons of contaminated water on the site? Are there any discharges of water from the site either onto the ground or into surface water courses? What does the quality of these discharges look like? Is the quality tested? Where are the samples taken from, how often? what are the waters tested for? Do the discharges have to meet set standards? Are there any other discharges of effluent off the site?

Fuel and Bulk Material Storage Arrangements

What are these? To gauge the potential for spillages and leaks consider the following: Are there any underground storage tanks? Are surface storage tanks and usage areas hard surfaced and bunded? Are these in good condition or are cracks present? Is the size of the bunding adequate for the volume of the materials stored? Are the bunds regularly cleaned out to avoid loss of capacity due to holding rainwater etc.?

Transport of Product off the Site

- Is this by rail, road or water or a combination of these?
- Where are the areas for loading of material located? Are they located near any water bodies or other possibly sensitive features? Are they well managed or is excessive land area contaminated? Is there any containment of surface run-off from the working areas to prevent the entry of contaminated water into ground/surface water?
- In the case of road haulage does this cause excessive traffic in the vicinity of residential areas?

Other Useful Observations

- Evidence of dust emissions from the pit, such as deposits on vegetation at the site boundary.

Information should also be obtained on the following:

- the method of working the mine and the type of plant used;
- the history of the site and the previous existence of potentially contaminative activities at the site in the past;
- the presence of other mines, human settlements (including indigenous populations), other economic activities (including forestry and agriculture), and wildlife habitats in the area which may be sensitive to the effects of the mine;
- the proximity and sensitivity of aquatic environments;
- are there any users of water downstream from the site which might be affected by contamination of the water or lowering of water levels caused by the mine?
- noise and vibration levels at the site and proximity to sensitive receptors such as schools, and housing;
- non mineral waste management control procedures and documentation.

Sub-sectoral Environmental Guidelines
METAL MINING - OPEN CAST

PROCESS DESCRIPTION

Opencast metal mining involves the removal of metal ores by means of working an open surface pit. The ore is usually separated from the waste material during excavation by selective mining techniques and initial in-pit processing. Large amounts of waste rock may be produced both in this and in the development of the mine.

Typically the mining process will include the following activities:

- Clearance of vegetation, stripping of overburden soils.
- Breakage of ore and waste rock prior to excavation. This may be achieved either by ripping the rock with bulldozers or by drill and blast techniques using explosives.
- Excavation of rock using heavy machinery.
- Dewatering or sump pumping of the excavation is often carried out to maintain dry working conditions.
- Transport of excavated material from the pit by dumper trucks or conveyor systems.
- Excavation of the overburden and stockpiling of this material either outside or within the excavation area. Dumps can be temporary or permanent but minimal environmental damage is achieved by the progressive backfilling of worked out areas. However, this form of overburden management is not possible at all sites.
- Ore treatment and mineral recovery. This process typically involves mechanical crushing followed by grinding in a rotary mill.
- After milling the mineral, a variety of techniques may be used to concentrate the metal content of the ore:
- Gravity concentration by settling in a viscous fluid such as water.
- Flotation, which involves the use of various chemical flotation agents such as cyanide and pH regulators such as lime (CaO).
- Other techniques may also be utilised, such as magnetic separation for magnetic ores.
- Dewatering of processed ore is generally required as substantial quantities of water are used in most mineral separation processes.
- Disposal of grinding mill tailings is a necessary part of the process. There is potential for water pollution as tailings may be contaminated with solids, heavy metals, mill reagents and sulphur compounds etc and be of extreme pH. Tailings are usually collected in a tailings dam close to the ore processing site

SUMMARY OF KEY ENVIRONMENTAL RSK/LIABILITY FACTORS

- The land area required for the open pit excavation, dumping of waste materials external to the pit itself and other surface facilities could destroy surface features of economic, cultural and nature conservation value.
- Mine and mineral processing operations may cause major degradation of water resources either by drawdown of groundwater levels leading to the drying up of wells, diversion or damming of surface watercourses, and contamination of surface and/or groundwaters by uncontrolled site discharges
- Groundwater rebound (rising groundwater levels) may result from the cessation of pumping operations when mining operations cease leading to discharge of potentially contaminated minewater at the surface. Such water may be acidic in nature and contain high concentrations of dissolved metals due to mineral oxidation and dissolution within the mine.
- Waste rock and tailings may contain heavy metals and mill reagents. Any run-off or leakage from the tailings dam may contain high concentrations of these elements and be of extreme pH and pose a particular threat to the aquatic environment as a result.
- Mineral processing operations may lead to emission of particulate matter to the atmosphere with potential for heavy metal and/or dust deposition over a wide area. Key sources of particulate emissions include the mineral extraction operations, crushing, screening, transportation and unvegetated surfaces of waste rock dumps.
- Inadequately designed and maintained pit faces, spoil heaps and tailings dams may become unstable leading to ground or tip collapse.
- The use of explosives to assist with ore fragmentation and removal creates a safety risk both within the mine site and in surrounding areas.

FINANCIAL IMPLICATIONS

- Fees and fines will be applied by regulatory authorities for discharges to air and waters above statutory levels.
- Compensation will possibly be required by regulatory authorities for loss of natural resources such as water supplies, agricultural land and forestry.
- Protest by local population and non-government organisations to defend existing surface features can lead to delays in the permitting process, reduction in extent of resource that can be exploited and increase in mine operational costs.
- Major increases in operation and investment costs could be necessary where outdated facilities at the site need to be replaced to satisfy a more stringent regulatory environment. Poor environmental performance may accelerate the demands for a more stringent regulatory environment.
- Provisions may have to be made for site decommissioning and rehabilitation costs including areas affected by past activities. This can involve significant and long term committments.
- Groundwater rebound may lead to ground instability and potential flooding several miles from the mine due to resurgence of contaminated minewater at surface.
- Groundwater rebound may increase the operating costs of other mines in the area.

- Failure of the pit wall, waste rock dumps or tailings dam has potential to cause loss of production time and also loss of life with associated financial liabilities.
- Exposure of employees to occupational hazards may result in health compensation claims.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

- Noise and vibration is likely to be generated primarily by blasting operations, mineral extraction activities, vehicle movements and mineral crushing and screening activities.
- Spillage of fuel, oils and other chemicals particularly in workshop areas may cause contamination of both soil and waters.
- Security and safety liabilities associated with the storage of explosives.
- High voltage electrical supplies may be required to operate machinery such as crushers, conveyors and coal screening equipment.
- Asbestos may be present within the fabric of mine buildings.
- Mine sites often provide infrastructure for miners and coal distribution. In remote locations settlement are developed around the mine and are therefore wholly dependent on the mine. Environmental issues associated with housing, retail and transport can be expected.
- Indirect impacts arrising from access roads leading into previously remote areas may place hunting pressures on the fauna and give rise to illegal logging and settlement.

APPLICABLE REGULATIONS AND PERMITTING REQUIREMENTS

- Permits under land-use controls.
- Water abstraction permits.
- Wastewater discharge permits.
- Atmospheric emissions permits.
- Solid and hazardous waste permits.
- Regulations relating to use and storage of explosives.
- Regulations relating to design and maintenance of waste rock dumps and tailings dams.
- Regulations relating to operation and maintenance of mines, tips and quarries.
- Regulations and guidance notes relating to noise, vibration and dust from opencast mining operations.
- Fire certificates.
- Planning applications and restoration conditions.
- Environmental Impact Assessment.
- Periodic auditing of facilities may be required.
- In some countries environmental liability assessments are required by regulatory authorities before liability for a former mine site can be relinquished.
- Health and Safety at work regulations.

Environmental Improvements

Environmental impacts of opencast metals mining operations can be reduced by employing the following mitigation techniques:

- Surface water ingress into the mine and tailings dam can be reduced by controlling surface run-off and minimising infiltration of precipitation into the tailings dam.
- The volume of wastewater generated at a site can be minimised by treating and re-circulating mine effluent and tailings dam run-off.
- Dust emissions from the pit can be controlled by use of water bowsers and sprinklers on site roads. Crushing and screening machinery can be fitted with dust filter systems and stockpiles can be fitted with sprinkler systems or dust caps. Emissions from vehicles can be controlled by sheeting of loads before transport from the site.
- Careful control of blasting is required to reduce noise and vibration. Blasts should be timed to minimise noise and vibration disturbance. Proximity to roads, railways or housing may place restrictions on blasting operations.
- Noise emissions can be minimised by careful planning of the method of working the mineral deposits, for example by leaving steep pit walls to reflect sound away from sensitive areas, by use of conveyors systems in place of dump trucks, and by selective siting of noisy plant.
- The effects of both noise and dust can be reduced by locating potential sources away from receptors, the use of soil storage mounds as screening bunds, and tree planting in shelter belts.
- Visual impact can be reduced by techniques such as minimising the area overburden stripped prior to excavation, construction of landscaped screening bunds, progressive restoration of worked out areas, and screening or concealed location of processing plant and haulage routes.

Environmental Action Plan

An Environmental Management Action Plan should be developed to include:

- Training of personnel in environmental management.
- Introduction of targets in environmental compliance into the evaluation of the performance of management personnel.
- Measures to secure and maintain regulatory compliance with respect to all environmental and health and safety issues including emissions to air, water and land.
- Regular monitoring of the condition and stability of tips, lagoons and tailings dams.
- Monitoring of compliance with conditions of minerals planning consent.
- Monitoring and control of the effect of mining activities on groundwater.
- Development and implementation of a non-mineral waste management plan.
- Measures to reduce or suppress dust and noise generation at the mine.
- Opportunities to reduce the use of toxic/hazardous chemicals.
- Documentation and dissemination of examples of best practice to all mines
- Implementation of training programmes for workers to increase awareness of environmental issues.

- For future operations design of mine to minimise environmental effects.

The plan should feature costed measures and set implementation targets. The measures may require increased management supervision, or significant process upgrades which may involve considerable capital expenditure.

GUIDE TO INITIAL DUE DILIGENCE SITE VISITS

It may not be possible to inspect all of the site due to its size and due to restricted access to areas being actively worked. The success of the site visit depends largely on the cooperation and availability of appropriate site personnel.

Valuable sources of information are the agreements with regulatory authorities with respect to approval of planning applications and discharge consents. The information on environmental controls is often contained in an 'Environmental Passport' document. Review of this information enables identification of the site specific environmental issues at the mine.

The site inspection should concentrate on visiting the following areas.

***Active excavation areas**:*

- Is water present or flowing in the excavation, any evidence of discolouration or contamination of this water, and where is water pumped from the pit floor discharged to?
- Are there other arrangements for dewatering the excavation such as pumping from peripheral boreholes. If wells are also located near the site is any monitoring of the water levels in these wells carried out? Where is the water from the dewatering discharged to? If originally clean is it contaminated by discharge onto 'dirty' areas of the site before entering natural surface/groundwaters?

Disposal of Waste Rock

- Is the excavation progressively backfilled with this material or are external dumps depended on. If the latter, any indications that this is not necessary? Are the dumps constructed in terraces to promote stability and possible future revegetation or are excessively steep slopes produced? Is waste rock dumped near surface water courses or over areas of possible cultural or nature conservation value? Are the dumps surrounded by surface drains to collect sediment loaded surface run-off and so protect water courses? Do the dumps appear to be heavily eroding and slumping?

Stockpile Areas

- How are these organised? Does the area look well managed or are excessive areas of land used and contaminated? Is the area located near any water body or other surface feature which creates unnecessary risk of contamination? Is surface runoff from the areas collected and where is it discharged? Does any discharge look as though it is heavily contaminated by solids? What colour is it?

Ore Treatment Process

- What process is used, chemicals used, effluents produced, control measures employed?
- Are there any dust control measures? Do these work and are these used? Is there any build-up of dust on machinery or other surfaces?
- What amounts and quality of water are required? Where is the water obtained from? Is the water recycled? How is waste-water treated, and is so, how and where i.e. are there any lagoons of contaminated water on the site? Are there any discharges of water from the site either onto the ground or into surface water courses? What does the quality of these discharges look like? Is the quality tested? Where are the samples taken from, how often? what are the waters tested for? Do the discharges have to meet set standards? Are there any other discharges of effluent off the site?

Fuel and Bulk Material Storage Arrangements

- What are these? To gauge the potential for spillages and leaks consider the following: Are there any underground storage tanks? Are surface storage tanks and usage areas hard surfaced and bunded? Are these in good condition or are cracks present? Is the size of the bunding adequate for the volume of the materials stored? Are the bunds regularly cleaned out to avoid loss of capacity due to holding rainwater etc.?

Transport of Product off the Site

- Is this by rail, road or water or a combination of these?
- Where are the areas for loading of material located? Are they located near any water bodies or other possibly sensitive features? Are they well managed or is excessive land area contaminated? Is there any containment of surface run-off from the working areas to prevent the entry of contaminated water into ground/surface water?
- In the case of road haulage does this cause excessive traffic in the vicinity of residential areas?

Other Useful Observations

- Evidence of dust emissions from the pit, such as deposits on vegetation at the site boundary.
- Are any reclamation works in progress either on waste rock dumps, tailings dams or backfilled void areas. What do the restoration works comprise?

Information should also be obtained on the following:

- the method of working the mine and the type of plant used;
- the history of the site and the previous existence of potentially contaminative activities at the site in the past;
- the presence of other mines, human settlements (including indigenous populations), other economic activities (including forestry and agriculture), and wildlife habitats in the area which may be sensitive to the effects of the mine;
- the proximity and sensitivity of aquatic environments;
- are there any users of water downstream from the site which might be affected by contamination of the water or lowering of water levels caused by the mine?
- noise and vibration levels at the site and proximity to sensitive receptors such as schools, and housing;
- non mineral waste management control procedures and documentation.

Sub-sectoral Environmental Guidelines
METAL MINING - UNDERGROUND

PROCESS DESCRIPTION

Underground metal mining operations aim to selectively mine the ore below ground level and leave the majority of waste rock in situ. However, some waste material is usually removed in gaining access to the ore and on removal of the ore. The quantity of waste varies greatly according to the mineral being exploited, the nature of the ore deposition and the method of mining. Typically the mining process will include the following main activities:

- Mine development with shafts, adits and underground roadways to gain access to the ore.
- Deposit of waste rock in surface dumps.
- Fragmentation of ore prior to excavation. This is achieved by drill and blast techniques using explosives.
- Excavation of rock by specialised underground mining machinery such as mechanical cutters and face conveyors.
- Transport of excavated material to the surface by use of conveyor systems, or underground railways.
- Ore treatment and mineral recovery. This process typically involves mechanical crushing followed by grinding in a rotary mill.
- Screening may be carried out at various stages before or after crushing and milling of the ore in order to remove oversized components. Classification by differential settling through a liquid medium may also be employed where screening is inappropriate.
- After grinding the mineral a variety of techniques may be used to concentrate the metal content of the ore:
  - gravity concentration by settling in a viscous fluid such as water.
  - flotation, which involves the use of various chemical flotation agents such as cyanide and pH regulators such as Lime (CaO).
  - other techniques may also be utilised, such as magnetic separation for magnetic ores.
- Dewatering of processed ore is generally required as substantial quantities of water are used in most mineral separation processes. Large quantities of mine water may be produced by mine dewatering operations. This minewater is usually treated in an effluent plant before disposal.
- Disposal of grinding mill tailings is a necessary part of the process and has particular relevance to the environment. There is potential for water pollution as tailings may be contaminated with solids, heavy metals, mill reagents and sulphur compounds etc. Tailings are usually collected in a tailings dam close to the ore processing site.
- Elaborate mine ventilation systems are often necessary to provide adequate control of the quality and quantity of air underground which may be affected by high particulate loads, machinery exhaust gases, mine gases and high temperatures.

SUMMARY OF KEY ENVIRONMENTAL RISK/LIABILITY FACTORS

- Underground mining presents high risks to the health and safety of mineworkers. This is from accidents underground and exposure to damaging levels of dust, gases, radioactivity, noise and vibration.
- Surface damage due to subsidence is a major risk of underground mining. Subsidence causes structural damage to buildings, infrastructure, agricultural land and drainage systems.
- The land area required for the mine surface facilities and dumping of waste materials could destroy surface features of economic, cultural and nature conservation value.
- Mine and mineral processing operations may cause major degradation of water resources either by drawdown of groundwater levels leading to the drying up of wells, diversion or damming of surface watercourses, and contamination of waters by uncontrolled site discharges.
- Waste rock and tailings may contain heavy metals, mill reagents. Any run-off or leakage from the spoil tips and tailings dam may pose a particular threat to the aquatic environment.
- Mineral processing operations may lead to emission of particulate matter to the atmosphere with potential for heavy metal deposition over a wide area. Key sources of particulate emissions include the mineral extraction operations, crushing, screening, transportation and unvegetated surfaces of waste rock dumps.
- Inadequately designed and managed spoil heaps and tailings dams may become unstable and prone to slippage or collapse.
- Safety risks associated with the use and storage of explosives.
- Ore processing operations may involve the use of hazardous and toxic substances such as cyanide.
- Noise and vibration may result from rock transport and processing equipment such as crushers, mills, vehicles, screens and conveyors.
- Subsurface oxidation of metal sulphides may lead to the generation of contaminated minewater. Discharge of such water at the surface could have significant environmental impacts.
- Lowering of the water table may result in reduced groundwater availability to industrial abstractors and environmentally sensitive receptors such as rivers and wetlands.
- Groundwater rebound (rising groundwater levels) may result from the cessation of pumping operations when mining operations cease.
- Occupational exposure to dust and contaminants such as arsenic, lead, cadmium etc.

FINANCIAL IMPLICATIONS

- Fees and fines will be applied by regulatory authorities for discharges to air and waters above statutory levels.
- Subsidence may have severe financial implications if it causes damage particularly to structures in the surrounding area.
- Compensation will possibly be required by regulatory authorities for loss of natural resources such as agricultural land and forestry.
- Protest by local population and non-government organisations to defend existing surface features can lead to delays in the permitting process,

reduction in extent of resource that can be exploited and increase in mine operational costs.

- Major increases in operation and investment costs could be necessary where outdated facilities at the site need to be replaced to satisfy a more stringent regulatory environment.
- Significant provisions may have to be made for site decommissioning and rehabilitation costs including areas potentially affected by past activities (subsidence claims).
- Groundwater rebound may lead to ground instability and potential flooding several miles from the mine, and discharge of contaminated minewater to surface water and groundwater which may be very costly to remediate.
- Failure of the spoil heaps or tailings dam has potential to cause loss of life with associated financial liabilities.
- Exposure of employees to occupational hazards may result in health compensation claims.
- Groundwater rebound may cause ground instability with potential for flooding of properties several miles from the mine and the mobilisation of contaminants previously above the water table.
- Contamination of overlying aquifers as a result of groundwater rebound may have severe financial implications depending on the nature of remediation of water quality required.
- Groundwater rebound may increase operating costs of other mines or businesses in the area.
- Mine drainage and minewater rebound and resurgence may cause contamination of groundwater which may result in significant remediation costs.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

- Mine sites often provide comprehensive infrastructure for miners and ore distribution. In remote locations settlements are developed around the mine and are therefore wholly dependent on the mine. Environmental issues associated with housing, retail and transport can be expected.
- Noise and vibration may be generated by blasting operations, vehicle movements and mineral crushing and screening activities. The significance of environmental noise and vibration issues will be dependent on the proximity of receptors.
- Mining operations may give rise to particulate emissions which have the potential to cause nuisance to neighbours. Key sources of particulate emissions to atmosphere include the crushing, screening and transportation of material at the surface. Occupational exposure levels for particulates, both at the surface and underground, may be high. This may require investment in ventilation and filtration equipment as well as protective equipment.
- Security and safety liabilities associated with explosives.
- High voltage electrical supplies may be required to operate machinery such as drills, cutting equipment, crushers, conveyors and ore processing plant.
- Asbestos may be present within the fabric of mine buildings.
- Indirect environmental impacts may arise in relation to improved access to (previously) remote areas (hunting of wildlife, illegal logging and settlement etc.) Impacts associated with transport of ore through/close to settlements.

APPLICABLE REGULATIONS AND PERMITTING REQUIREMENTS

- Permits under land-use controls.
- Water abstraction permits.
- Wastewater discharge permits.
- Atmospheric emissions permits.
- Solid and hazardous waste permits.
- Special requirements for training of underground personnel.
- Special emergency provisions for underground supplies of power and ventilation.
- Special requirements for certification of equipment for use underground.
- Regulations relating to use and storage of explosives.
- Regulations relating to design and maintenance of spoil tips, lagoons and tailings dams.
- Fire certificates.
- Environmental Impact Assessment.
- Periodic auditing of facilities may be required.
- In some countries environmental liability assessments are required by regulatory authorities before liability for a former mine site can be relinquished.

ENVIRONMENTAL IMPROVEMENTS

Environmental impacts of underground metal mining operations can be reduced by employing the following mitigation techniques:

- Subsidence impacts can be reduced by careful management of mining operations and adoption of appropriate mining methods.
- Groundwater levels can be controlled by sumps or by abstraction boreholes.
- The volume of wastewater can be minimised by treating and re-circulating mine effluent and tailings dam run-off.
- Design of waste rock tips, lagoons and tailings dams to ensure long term stability, and reduce visual impact on surrounding environment.
- Groundwater rebound and its resultant effects such as contamination may be controlled by continual pumping at considerable cost, or treatment of minewater resurgences.
- Dust emissions from surface operations can be controlled by use of water bowsers on site roads. Crushing and screening machinery can be fitted with dust filter systems and stockpiles can be fitted with sprinkler systems or dust caps. Emissions from vehicles can be controlled by sheeting of loads before transport from the site and dedicated parking areas for employees' vehicles.
- Visual impact can be reduced by techniques such as concealed access to the site and screening and sensitive location of process plant.

ENVIRONMENTAL ACTION PLAN

An Environmental Action Plan should be developed to include:

- Training of personnel in environmental management.

- Introduction of targets in environmental compliance into the evaluation of the performance of management personnel.
- Measures to secure and maintain regulatory compliance with respect to all environmental and health and safety issues including emissions to air, water and land.
- Regular monitoring of the condition and stability of waste rock dumps, tips and tailings dams.
- Monitoring of compliance with conditions of minerals planning consent.
- Monitoring and control of the effect of mining activities on the water table.
- Development and implementation of a non-mineral waste management plan.
- Measures to reduce or suppress dust and noise generation at the mine.
- Opportunities to reduce the use of toxic/hazardous chemicals.
- Documentation and dissemination of examples of best practice to all mines.
- Implementation of training programmes for workers to increase awareness of environmental issues.
- Site decommissioned and remediation plan; including long term financial provisions.

The plan should feature costed measures and set implementation targets. The measures may require increased management supervision, or significant process upgrades which may involve considerable capital expenditure.

GUIDE TO INITIAL DUE DILIGENCE SITE VISITS

It may not be possible to inspect all of the site due to its size and due to restricted access to areas being actively worked. The success of the site visit also depends largely on the cooperation and availability of appropriate site personnel. Valuable sources of information are the agreements with regulatory authorities with respect to approval of planning applications and discharge consents. The information on environmental controls is often contained in an `Environmental Passport' document. Review of this information enables identification of the site specific environmental issues at the mine.

The site inspection should concentrate on the following areas.

- What are the arrangements for dewatering the pit such as pumping from peripheral boreholes. If wells are also located near the site is any monitoring of the water levels in these wells carried out? Where is the water from the dewatering discharged to? If originally clean is it contaminated by discharge onto 'dirty' areas of the site before entering natural surface/groundwaters?

Disposal of Waste Rock

Are the dumps constructed in terraces to promote stability and possible future revegetation or are excessively steep slopes produced? Is waste rock dumped near surface water courses or over areas of possible cultural or nature conservation value? Are the dumps surrounded by surface drains to collect sediment loaded surface run-off and so protect water courses? Do the dumps appear to be heavily eroding and slumping?

Stockpile Areas

How are these organised? Does the area look well managed or are excessive areas of land used and contaminated? Is the area located near any water body or other surface feature which creates unnecessary risk of contamination? Is surface runoff from the areas collected and where is it discharged? Does any discharge look as though it is heavily contaminated by solids? What colour is it?

Ore Treatment Process

What process is used, chemicals used, effluents produced, control measures employed?
Are there any dust control measures? Do these work and are these used? Is there any build-up of dust on machinery or other surfaces?
What amounts and quality of water are required? Where is the water obtained from? Is the water recycled? how is waste-water treated, and is so, how and where i.e. are there any lagoons of contaminated water on the site? Are there any discharges of water from the site either onto the ground or into surface water courses? What does the quality of these discharges look like? Is the quality tested? Where are the samples taken from, how often? what are the waters tested for? Do the discharges have to meet set standards? Are there any other discharges of effluent off the site?

Fuel and Bulk Material Storage Arrangements

What are these? To gauge the potential for spillages and leaks consider the following: Are there any underground storage tanks? Are surface storage tanks and usage areas hard surfaced and bunded? Are these in good condition or are cracks present? Is the size of the bunding adequate for the volume of the materials stored? Are the bunds regularly cleaned out to avoid loss of capacity due to holding rainwater etc.?

Transport of Product off the Site

Is this by rail, road or water or a combination of these?
Where are the areas for loading of material located? Are they located near any water bodies or other possibly sensitive features? Are they well managed or is excessive land area contaminated? Is there any containment of surface run-off from the working areas to prevent the entry of contaminated water into ground/surface water?
In the case of road haulage does this cause excessive traffic in the vicinity of residential areas?

Other Useful Observations

Evidence of dust emissions from the pit, such as deposits on vegetation at the site boundary.

Information should also be obtained on the following:

- the method of working the mine and the type of plant used;
- the history of the site and the previous existence of potentially contaminating activities at the site in the past;
- the presence of other mines, human settlements (including indigenous populations), other economic activities (including forestry and agriculture),

and wildlife habitats in the area which may be sensitive to the effects of the mine;

- the proximity and sensitivity of aquatic environments;
- are there any users of water downstream from the site which might be affected by contamination of the water or lowering of water levels caused by the mine?
- noise and vibration levels at the site and proximity to sensitive receptors such as schools, and housing;
- non mineral waste management control procedures and documentation.

Sub-sectoral Environmental Guidelines
STONE, SAND AND GRAVEL EXTRACTION

PROCESS DESCRIPTION

This guideline covers the extraction of stone, sand and gravel; which is mainly carried out through opencast mining operations; and the pumping of sand and gravel from rivers/offshore sand banks. Operations in an opencast site may include blasting (for stone-based materials) and/or simple excavation and extraction (for sand and gravel). Additional operations may include sorting, crushing and screening to ensure that the appropriate grade and size of material is collected, primary processing (washing, separation by flotation) and transport of raw materials round the site (by conveyors, trucks and other vehicles) to stockpiles and storage areas for off grade material. Once the processed material is ready for export it will be transported, either by road or rail to the customer or point of use.

SUMMARY OF KEY ENVIRONMENTAL RISK/LIABILITY FACTORS

Project Approval and Permitting

Due to potential landscape impacts, noise, dust and traffic problems there may be significant opposition to such projects. This can give rise to lengthy project approval and public consultation processes which may have adverse impacts on projects costs.

Landscape and Visual Amenity

Visual impacts on the landscape are usually considered in depth at the planning application stage. For existing opencast mines there is usually a wide range of landscape mitigation measures that are in force to reduce the adverse visual impacts.

Dust

Dust generated at opencast mines is difficult to control. Dust emissions are likely to be a source of on-going complaints from neighbours. Traditionally, dust is controlled by 'damping down' (spraying water to dampen the dust), however, this can adversely affect the quality of some of the mineral products. There are a variety of other methods of dust abatement including the installation of dust cyclones in processing areas, a variety of housekeeping measures and the use of trees and landscaped earth mounds to screen dust generating areas.

Noise and Vibration

Significant noise may be generated at the site. Blasting and transport-related activities can be a major concern, generating both ground vibration and a boundary noise nuisance.

Effluent Discharges

Effluent discharges from the site will arise from a variety of sources including tail washings from flotation, separation and washing activities, effluent from damping down activities, vehicle washes and stormwater run-off. Effluent is likely to be pumped out and discharged, either to a local watercourse or to lagoons. Effluent from these types of operation are often high in suspended solids and various contaminants depending upon the location and geology of the mine.

FINANCIAL IMPLICATIONS

Site Remediation

The conditions under which a project is approved may include a detailed programme of rehabilitation involving grading, contouring, drainage and revegetation. The cost of such measures can be high.

Dust

Climatic conditions will affect dusty environments. In very dry or windy conditions, it may be necessary to suspend operations altogether. In general, dust control measures require low technology and may be relatively cheap to implement. The principle objective in relation to dust minimisation and abatement is to contain the emitting process in closed systems, below atmospheric pressure. Point source dust emissions from material handling operations such as grinding, milling, loading, conveying and packaging require handling with appropriate hooding and ducting, in order to maintain a reduced pressure in areas of dust laden air.

Noise and Vibration

Liabilities may arise due to high occupational or local neighbourhood noise or if vibration from blasting and quarry activities has damaged property. The main way of controlling vibration is through careful siting of the explosive with reference to the target area. Attenuation of noise levels may be achieved by the provision of screening, mounds, or sound proofing. Noise attenuation measures may be costly since they invariably involve civil workers. Restrictions on site traffic may also impose constraints on production.

Effluent Discharges

Effluent from opencast mines may need to be treated prior to discharge to sewer or local watercourses in order to trap sediment. Effluent treatment for opencast mines may be very costly to implement.

OTHER POTENTIAL ENVIRONMENTAL ISSUES

Transport Related Issues (dust, noise, damage off-site)

Transportation of raw materials on and off-site may cause dust generation, noise and, if trucks are not covered when leaving the site, may cause dust to be blown off-site. Large volumes of clays, sand, gravels, stone needs to be transported off-site each day. If road transport is the main method for removing material from the opencast mine then access, road damage and nuisance issues may be a significant cause for concern. There is also often a need for vehicle wheel washing prior to leaving site, to reduce deposition of material on nearby roads.

ENVIRONMENTAL IMPROVEMENTS

Potential environmental improvements may include:

- the installation of dust abatement equipment, for example dust cyclones, waste sprays over stockpiles, grassing of overburden mounds, water bowsers, washdown units for vehicles, paved areas within the site where practicable;
- dust can be reduced by practical housekeeping measures, such as the use of covered conveyors rather than trucks, the creation of sensitive areas in which operations are kept to a minimum and by progressive restoration of the site;
- the installation of boundary noise attenuation measures such as landscaped earth mounds and screening through tree planting;
- the vegetation of exposed overburden mounds as soon as practicable;
- the provision of bunded containment areas for storage of chemicals such as oils and fuel for plant.
- check on site remediation requirements and on relevant legislation;
- check landuse and other permits.

ENVIRONMENTAL ACTION PLAN

Recommended environmental action plans should focus on landscaping and the minimisation of noise and dust generated on and off site and should include:

- the production of a site remediation plan;
- a programme of landscaping to reduce visual, noise and dust related impacts;

- widespread use of dust minimisation techniques through a high standard of housekeeping, screening and mounding and use of abatement equipment;
- consideration of operations to minimise the impacts of excavation/blasting;
- sheeting and covering of vehicles leaving the site and the use of covered conveyors.

GUIDE TO INITIAL DUE DILIGENCE SITE VISITS

During the initial site visit, it will be important to assess the following:

- the level of dust on-site and in surrounding areas, note dust deposition downwind of the site and on all major access and export roads;
- the method of disposal and destination of water pumped from site;
- noise levels outside site boundary;
- the condition and location of overburden mounds and tailings;
- housekeeping and the general manner in which operations are carried out;
- site location/surrounding area activities.

Contact should be made with the local regulatory agencies to determine compliance record (with noise, vibration, quota, hours of operation, effluent, health and safety requirements) and whether complaints have been made by the public.