Environmental Aspects of Phosphate and Potash Mining

United Nations Environment Programme
International Fertilizer Industry Association

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Contents

Preface

This report on the environmental aspects of phosphate and potash mining is the fifth in a series published jointly by the International Fertilizer Industry Association (IFA) and the United Nations Environment Programme (UNEP). Previous studies included :

- The Fertilizer Industry, World Food Supplies and the Environment;
- Mineral Fertilizer Production and the Environment;
- Mineral Fertilizer Distribution and the Environment, and
- Mineral Fertilizer Use and the Environment.

As such, this publication completes a series that looks at environmental aspects of the fertilizer industry throughout the life-cycle of mineral fertilizer products. In this volume, the holistic way of looking at an issue is applied to the activities of the fertilizer raw materials sector, incorporating the concept of the whole-of-mine-life thinking and planning.

Chapter 1 is an introduction to environmental issues associated with mining phosphate and potash ores. Chapter 2 gives an overview of the processes involved in extracting these minerals and preparing them for fertilizer production. Chapter 3, the focus of the document, looks at some of the industry's responses to associated environmental challenges. Finally, Chapter 4 considers how the mining sector might best contribute to the sustainability of the overall fertilizer industry in years to come.

The study reinforces the fact that the environmental performance of the fertilizer raw materials industry has improved over recent decades, although challenges remain. This publication therefore, explores the variety of approaches and techniques which are being used in different parts of the world to address environmental concerns.

It is our sincere hope that, not only will this report prove useful, but that companies will continue to strive to achieve ever cleaner and safer production as part of their ongoing efforts to contribute to sustainable development.

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1. Introduction

1.1 The Mining of Phosphate Rock and Potash and the Environment

Fertilizers are a key factor in sustaining the world's agricultural output. They supply nutrients that are needed by all plants for normal growth, development and health. Maintaining an adequate supply of food for human consumption requires:

- A supplementary source of plant nutrients if the natural supply is insufficient.
- Replacement of the many possible nutrient losses.

These replacement and/or supplementary supplies can be provided through organic manures and/or mineral fertilizers.

This publication concerns the provision of raw materials for two important mineral fertilizers, phosphate and potash.

Three major nutrients are required in large quantities for plant growth, nitrogen, phosphorous and potassium. Three secondary nutrients are required in smaller quantities on some soils; sulfur, calcium and magnesium. Seven micronutrients may be required in small amounts where deficient. Each nutrient has a specific biological function and, while there may be synergies between the nutrients, none has a substitute.

By far the most important for the present publication, in terms of the quantity mined and potential impact on the environment, are phosphate and potash.

The production of phosphorous and potassium mineral fertilizers relies essentially on the mining of mineral concentrations, in the form of ore deposits from the earth's crust. Nitrogen mineral fertilizers, on the other hand, are almost entirely based on ammonia manufactured from the abundant source of atmospheric nitrogen, water and energy.

The production of nitrogen fertilizers has been discussed extensively in the earlier publication by UNEP/UNIDO/IFA on 'Mineral Fertilizer Production and the Environment: Part 1 - The Fertilizer Industry's Manufacturing Processes and Environmental Issues' and will not be covered further here.

World production of phosphorous and potassium mineral fertilizers in 1998/99 was 34 Mt P_2O_5 (1) and 25.5 Mt K_2O respectively. This required the extraction of 144 Mt of phosphate rock and more than 45 Mt of potash ore (2). Table 1.1 indicates the scale of the mineral fertilizer raw material mining industry in comparison to the mining of other bulk mineral and energy commodities.

Figure 1.1
World mineral fertilizer production

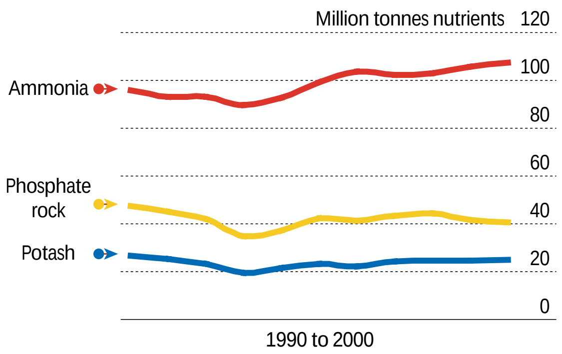

Table 1.1.
Comparison of the World Production of Some Bulk Minerals in 1998/99

Product	Tonnage
Coal	4,655,000,000
Iron Ore	1,020,000,000
Salt	186,000,000
Phosphate Rock	144,000,000
Bauxite	126,000,000
Gypsum	107,000,000
Potash Ore (2)	45,000,000

(1) Phosphate and potash may be expressed as their elemental forms P and K, or as oxide forms P_2O_5 and K_2O. In this publication the oxide form is used.

Mt = million tonnes

(3) In KCl equivalent (sylvinite). Actual tonnages are larger, including kieiserite, langbeinite and carnallite ore.

During recent decades, attention and concern has been focused increasingly on the environmental impacts of human activities, especially industrial activities such as mining. The public perception of the mining industry has been tainted by a legacy of environmental damage from past practices combined with a number of highly publicized failures of metal mining tailings dams. As the scale of operations and the area disturbed by the mining industry continue to grow, so too has the public's concern over the industry's capacity to manage and mitigate environmental impacts. In response, most governments have imposed stricter legislative and regulatory requirements on the mining industry in order to protect the ecosystem, to maintain a safe and secure environment and to protect people living in the vicinity of the mine-site.

Leading mining companies have taken up the challenge and are pushing beyond minimum legal requirements through voluntary initiatives, to ensure their continued “license-to-operate” from the community as well as increasing their competitive advantage through continuous, voluntary improvements in environmental performance.

As with all mining activities, the extraction and beneficiation of phosphate rock and potash to produce mineral fertilizer raw material has the potential to cause environmental impacts. These impacts can take the form of changes to the landscape, water contamination, excessive water consumption and air pollution.

The landscape may be disturbed through the removal of topsoil and vegetation, excavation and deposition of overburden, disposal of processing wastes and underground mining induced surface subsidence.

The quality of surface and groundwater may be adversely affected by the release of processing water and the erosion of sediments and leaching of toxic minerals from overburden and processing wastes. Water resources may be affected by dewatering operations or beneficiation processes.

The quality of the air can be affected by the release of emissions such as dust and exhaust gases.

The fertilizer raw material mining industry, as a subsector of the larger global mining industry, is not exempt from the prevailing social and political climate. This publication demonstrates how the phosphate rock and potash mining industry has responded to the challenges presented by the changing environmental, political and cultural values of society, through an overview of the industry's environmental performance worldwide. Information on company environmental practices has been gathered from an extensive series of site visits to fertilizer raw material mining, beneficiation, and processing operations, in addition to a review of available literature. The companies and organizations involved in the project are listed in Appendix B. While this does not provide a complete picture of the current state of the industry, it does demonstrate the direction of development, and the range of systems, practices and technologies employed.

The publication focuses on the environmental aspects associated with the mining of raw materials for the manufacture of phosphorous and potassium mineral fertilizers. Earlier joint publications by UNEP, UNIDO and IFA have covered the environmental issues associated with the downstream processing, distribution and use of mineral fertilizers (3).

1.2 The Global Environment Agenda and the Mining Industry

Environmental impact is an increasingly important issue against which human activities must be weighed. A key factor is the scale of natural resource consumption, such as that of minerals, agricultural land, wood and fisheries.

The issue of resource consumption requires that the causal factors be addressed, such as:

- The continued world population growth;
- The material consumption patterns of the developed world, which are increasingly being adopted by the developing world;
- The imbalance in development, opportunities and resource allocation between the developed and developing world;
- The correct pricing of the resource to account for scarcity and the environmental and social costs of production; and
- The efficiency of resource use by industry through the implementation of best available techniques.

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(3) The earlier UNEP, UNIDO and IFA publications are listed in Appendix A. These can be obtained from either IFA or UNEP.

These are complex, interlinked issues. “Sustainable development” has been proposed as a holistic approach for dealing with these complexities.

Sustainable development integrates economic, environmental and social considerations in order to improve the lives of the current generation and ensure that future generations will have adequate resources and opportunities.

Over recent decades, public awareness and concern has grown, as has knowledge of the effects of our activities on the environment. The 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil resulted in Agenda 21, an action plan for the implementation of sustainable development throughout all levels of society. Agenda 21 identified the global economic, environmental, and social issues to be addressed and provided a detailed framework for moving society towards sustainable development.

In the case of phosphorus and potassium, although the best quality and most easily accessible deposits are mined first, the total available resources are sufficient for hundreds or thousands of years. But no mineral resource is infinite and the efficient extraction and use of phosphate and potash are an important contribution to a certain degree of sustainability.

The mining industry has an important role to play in this respect:

- Rehabilitation allows the land disturbed by the extraction of the mineral resource to be returned to the pool of land available for other uses;
- Optimization of the recovery of the resource may be encouraged through the use of the most efficient techniques and technologies available;
- Any unrecovered resources can be left in a condition such that possible future improvements in technological capability and economics will be able to access and recover the resource; and
- The development of more efficient mining and processing methods and techniques can extend current resource life, and help to recover, recycle and reuse minerals.

These principles have application across all sections of the mining industry, including that of the phosphate rock and potash mining industry. The mining industry has responded to the sustainability issues that are challenging it on a number of fronts. Several of them are discussed in this report.

Mining Members of the World Business Council on Sustainable Development (WBCSD) established the Global Mining Initiative (GMI) in 1998. The GMI, representing some of the worlds leading mineral and mining companies, was established to provide leadership and direction for the future development of the mining industry in a sustainable manner. To this end, the GMI approached the International Institute of Environment and Development to commission the Mining, Minerals and Sustainable Development (MMSD) project, to determine how mining can most effectively contribute to sustainable development. Regional groups have been established, stakeholders engaged and consulted, issues identified, and research commissioned to determine how the services of the mining industry can be orientated to sustainable development and develop an action plan to guide the industry in coming decades. This action plan is to be implemented by the new International Council on Mining and Metals (formally The International Council on Metals and the Environment).

National mining associations have developed and disseminating charters or voluntary codes of practice to improve the level of environmental management. An example of this is the Australian Mining Industry Code for Environmental Management developed by the Minerals Council of Australia (see Appendix C). This voluntary code has been widely adopted by mining companies within Australia. These are required to publish public environmental reports to demonstrate progress on the implementation of the code's principles.

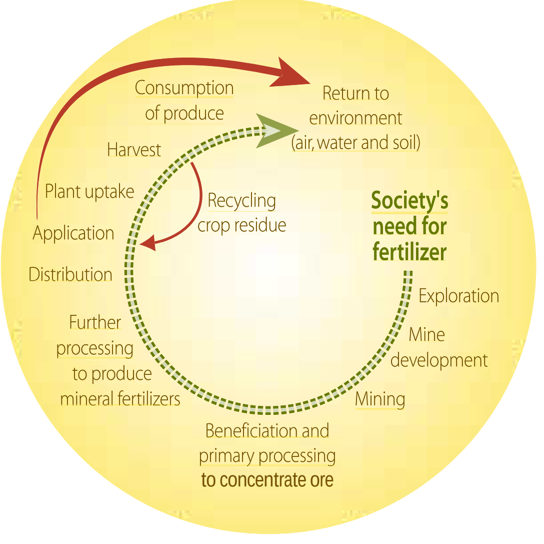
The World Bank has been actively developing mining sector capacity in developing countries. Programs have focused on drafting mining legislation, building up environmental management capabilities and creating incentives for private investment.

NGO co-operation with the mining industry has increased at local and global levels in recent years. The World Wide Fund for Nature (WWF) has been active in developing relationships with the mining industry to foster improved performance. The WWF has been leading the development of an independent mining certification system in partnership with Placer Dome (Australia). This system is based on the Forest Stewardship Council (FSC) model that has been effective in fostering improvement of the environmental performance of the forestry industry.

Figure1.2

The mineral fertilizer life cycle

The flow of the macro-nutrients phosphorous and potassium



Source : Concept for the schematic is drawn from the Natural Resouces Canada report "Sustainable Development and Minerals and Metals"

Figure1.3

The mining life cycle

Source : Concept for the schematic is drawn from the Natural Resouces Canada report "Sustainable Development and Minerals and Metals"

1.3 The Life Cycle of the Phosphate Rock and Potash Mining Industry

The industry approach to environmental issues has moved from 'end-of-pipe' solutions, towards a pollution prevention strategy. This strategy requires an integrated, holistic view of activities. Tools have been developed to assist management, including cleaner production, life cycle assessment and industrial ecology. Each of these looks at the life cycle of the product or service, to identify where the major environmental issues or problems may arise and where the most cost-effective solutions can be developed. Planning for the life of the mine, including closure and site rehabilitation, permits a more efficient and environmentally effective outcome. It identifies and creates opportunities for improving the economic and environmental performance of the operation. Previously unrecovered resources may be retrieved and former wastes converted into useful products.

A schematic view of the mining life cycle is depicted in Figure 1.3. This highlights the sequential nature of the activities of the phosphate rock and potash mining industry. Emphasis is placed on closing the circle, or life cycle, with the rehabilitation of the site, and on the importance of planning for this from the outset.

Activities of the mining life cycle may include:

- Prospecting and exploration to identify potential economic mineral deposits;
- Assessment of the mineral deposit to determine whether it can be economically extracted and processed under current and predicted future market conditions;
- Design, planning and construction of the mine, handling, processing plant and associated infrastructure such as roads, power generation and ports;
- Removal of the overburden or mining of the underground declines, shafts and tunnels to access the ore;
- Extraction of the ore;
- Handling of the ore from the mine to the beneficiation plant;
- Beneficiation and primary processing of the ore to produce a concentrated product (phosphate rock and potash);
- Treatment and disposal of solid and liquid wastes;
- Closure of the mining operation after exhaustion of the economic ore reserve and completion of rehabilitation; and

- Subsequent handing over of the site to the pool of available land.

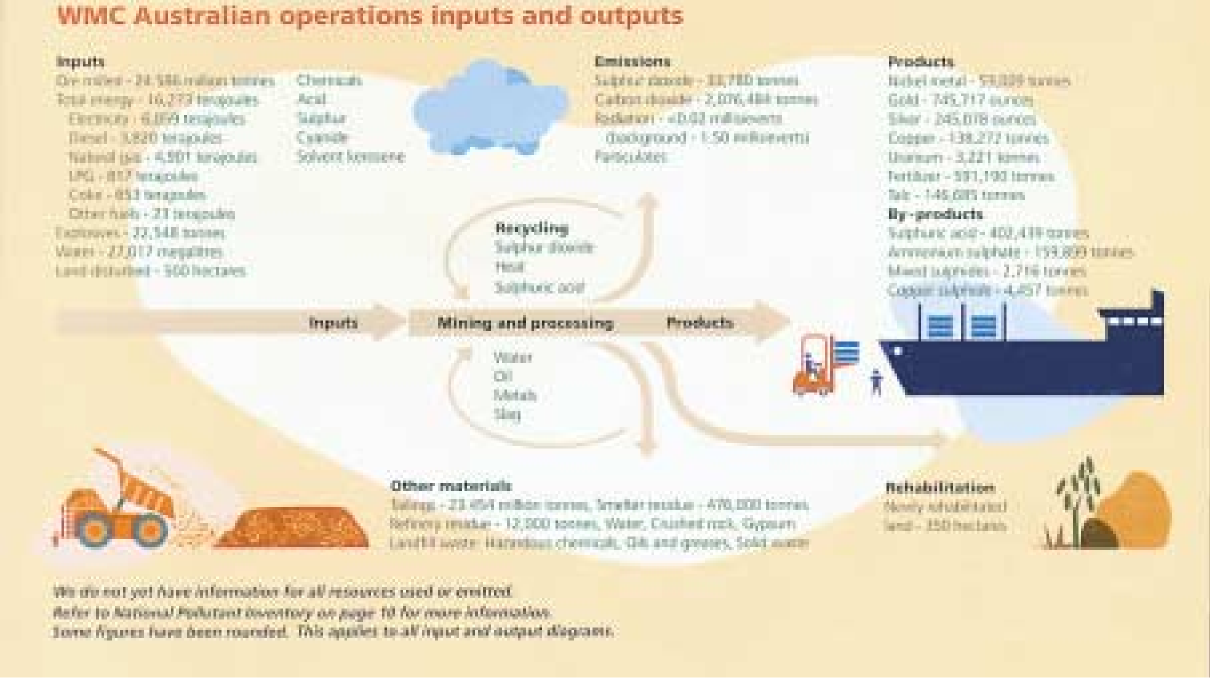
Planning, environmental management and rehabilitation are conducted throughout the mining life cycle, encompassing all other activities.

By examining each stage of the life cycle, the potential environmental effects can be identified and actions taken to mitigate or prevent them. Synergies can be developed, and opportunities identified, avoiding additional costs and potentially creating new streams of revenue, resulting in an improved of the performance both environmentally and economically.

Companies are beginning to adopt life-cycle thinking. This is evidenced through the environmental reporting example presented in Figure 1.4. The diagram is supported by figures on the input and output flows, including emissions, wastes and net land disturbance to provide a measure of environmental performance.

Figure 1.4:

WMC Community and Environment



2. Overview of Phosphate Rock and Potash Mining and Beneficiation

2.1 Phosphate Rock and Potash

Although phosphate rock and potash are used as raw materials for a wide range of applications, the most important use by far is the manufacture of mineral fertilizers.

The primary source of these minerals is geological ore deposits formed through past sedimentary or igneous activities. In the case of potash, concentrated brines are also a significant source.

This chapter provides a brief overview of the major activities involved in the mining, handling and beneficiation of phosphate rock and potash ore.

2.2 Phosphate Rock Mining and Beneficiation

Phosphate Rock Mining

At present, most phosphate rock is mined using large-scale surface methods. In the past, underground mining methods played a greater role, but their contribution to world production has declined. Major mining and beneficiation techniques and processes employed by the industry are listed in Figure 2.1.

Surface phosphate rock mining operations can vary greatly in size. Extraction may range from several thousand to more than 10 million tonnes of ore per year. In many cases, operations supply feed to a nearby fertilizer processing complex for the production of downstream concentrated fertilizer products. The economies of scale of the complex in turn influence the scale of the mining operation.

Surface mining of phosphate rock, with bucketwheel - Office Togolais des Phosphates (OTP), Togo

The land area affected by the surface operations may vary widely, depend on the orebody geometry and thickness and the ore extraction rate. At similar extraction rates, mining of flat-lying thin orebodies as found in Florida (USA) will affect a far wider area of land than the mining of thicker, or steeply dipping orebodies as found in Brazil and Idaho (USA). The depth of excavations may range from a few metres to more than 100 metres.

Surface mining of phosphate rock with dragline, Florida - Cargill Fertilizers Inc., USA

Currently, most phosphate rock production worldwide is extracted using opencast dragline or open-pit shovel/excavator mining methods. This method is employed widely in parts of the United States of America, Morocco and Russia.

Underground mining methods are currently used in Tunisia, Morocco, Mexico and India. The area of the land surface affected by these operations is generally small and limited to the area immediately adjacent to the access decline or shaft.

The following discussion will focus on surface methods due to their significance.

Figure 2.1

Common phosphate rock mining processes and equipment

Extraction

- Surface: Dragline; Bucketwheel excavator; Shovel; Front-end-loader (FEL); Excavator
- Underground: Continuous mining machine; Longwall; Shaft / Decline

Handling

- Surface: Slurry pipeline; Road or haul trucks; Conveyors; Stockpile and reclaimer
- Underground: Conveyors; Feed bins; Shaft or decline haulage

Beneficiation / concentration

- Size reduction: Crushing; Grinding; Screening; Hydrocyclones
- Concentration: Washing; Flotation
- Carbonate reduction: Calcination; Flotation; Magnetic separation; Heavy-media separation; Acid washing
- Iron mineral removal: Magnetic separation
- Dewatering: Centrifuges; Belt filters
- Drying: Rotary ovens; Fluidised bed dryers
- Storage: Conveyors; Sheds; Tanks

Phosphate Rock Beneficiation

Beneficiation (or concentration) processes are generally used to upgrade the phosphate content by removing contaminants and barren material prior to further processing. A few ores are of sufficiently high quality to require no further concentration. The naturally occurring impurities contained in phosphate rock ore depend heavily on the type of deposit (sedimentary or igneous), associated minerals, and the extent of weathering. Major impurities can include organic matter, clay and other fines, siliceous material, carbonates, and iron bearing minerals. These characteristics influence the beneficiation processes employed.

The removal of fines such as clays and fine-grained aluminium and iron phosphates is usually conducted through a combination of crushing/grinding, scrubbing, water washing, screening, and/or hydrocyclones. The fines are disposed of either to rivers, mined out areas, or specially engineered storage impoundments. Siliceous material, sand, may require an additional froth flotation stage for separation. This is typically pumped to storage impoundments or mined-out areas for disposal.

Dry screening - Copebras SA, Brazil

Cone crusher - Fosfertil, Brazil

Wet screening - IMC Phosphate, Florida, USA

Grinding mills - Fosfertil, Brazil

Flotation tanks - IMC Phosphate, Florida

The presence of carbonates in the form of dolomite and calcite may cause downstream processing problems and may reduce the quality of the end product. They are primarily removed through the use of calcination followed by slaking with water to remove the CaO and MgO produced.

Iron minerals may be present in the form of magnetite, hematite and goethite. These are typically removed through scrubbing and size classification, or magnetic separation.

Following beneficiation, the concentrated phosphate rock is stockpiled prior to transport to downstream processing plants for the manufacture of phosphate mineral fertilizers. In some instances, phosphate rock with suitable properties may be directly applied to crops as a soil amendment by farmers.

Phosphate fertilizer plant, Conda, USA - Agrium Inc., Canada

Generally, the major waste streams produced during phosphate rock beneficiation are clay fines, sand tailings and significant quantities of process water. Magnetite tailings may also be associated with igneous orebodies. These are disposed of by a number of means including discharge to rivers or other water bodies, and disposal to engineered storage dams, or mined-out areas. The process water may be recovered and reused.

Decantation of clarified water - Cargill Fertilizers Inc., USA

Clay settling pond - Cargill Fertilizers Inc., USA

Drying plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Surface Mining and Beneficiation Operations in Morocco

Phosphate rock mining and beneficiation are illustrated by the operations of Office Chérifien des Phosphates (OCP) in Morocco.

At the Khouribga and Benguerir opencast dragline mining operations in Morocco, the overburden is initially drilled and blasted. Bulldozers prepare the surface for draglines to remove the broken overburden and expose the ore. The ore is excavated without blasting into trucks using smaller draglines, shovels or front-end loaders. The trucks transport the ore to a screening plant for the separation and disposal of the oversize low-grade material followed by stockpiling. The screened ore is reclaimed from the stockpile and transferred by conveyor to the beneficiation plant. The ore is washed and dried to remove clay fines and in some instances is subjected to calcination, to produce a concentrated phosphate rock.

The concentrated phosphate rock is transported by rail either to the industrial complexes located at Jorf Lasfar and Safi for further processing, or directly to port for export.

Sizing and stockpile plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Loading phosphate rock - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Conveyor and stacker - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Washing plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Port, Jorf Lasfar - Office Chérifien des Phosphates (OCP), Morocco

2.3 Potash Mining and Beneficiation

Potash is a generic term applied to all potassium salts that are used as fertilizers.

Potash Mining

Potash ore is extracted from two major ore deposit types, deeply buried marine evaporite deposits that typically range from 400 metres to greater than 1,000 metres below the surface, and surface brine deposits associated with saline water bodies such as the Dead Sea in the Middle East and the Great Salt Lake in North America.

Most potash is sourced from buried deposits using conventional mechanized underground mining methods, though solution mining methods also are employed. Generally these underground operations produce between 1 to 10 million tonnes of potash ore per year. The land area affected is typically confined to the immediate area of the shaft, plant and waste disposal area but may be up to several square kilometers.

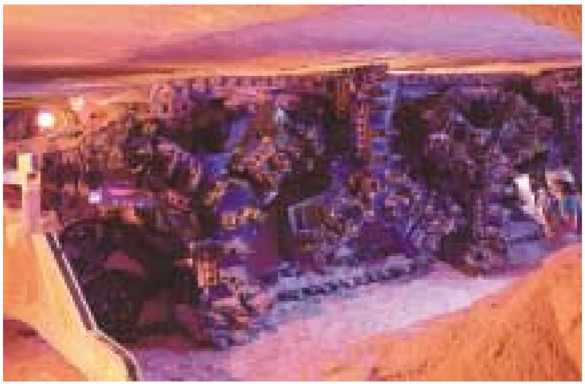
Surface brine deposits are exploited using solar evaporation ponds to concentrate and precipitate the potash. The evaporation ponds are extensive, with some operations covering in excess of 90 square kilometers of land area to produce around 8 million tonnes of potash ore per year.

Conventional mechanized underground mining operations are the most widely used method for the extraction of potash ore. A variety of mining techniques and equipment may be employed depending on factors such as: the orebody depth, geometry, thickness and consistency, the geological and geotechnical conditions of the ore and surrounding rock, and the presence of overlying aquifers. Methods in widespread use include variations of room and pillar, longwall, cut and fill, and open stope techniques.

After the ore is extracted, it is generally transferred by bridge conveyor, shuttle cars or load-haul-dump units to a system of conveyors that carry it to underground storage bins, prior to haulage to the surface through a shaft by automated skips. On rare occasions shallow mines may use a decline and conveyor arrangement.

Solution mining is currently used at a number of operations in North America. The process relies on the greater solubility at elevated temperatures in brine of sylvite in comparison to salt (NaCl). Commonly, brine is heated on the surface then injected into the orebody through wells. The heated brine absorbs sylvite from the orebody and is then pumped back to the surface to a series of ponds, where the potash precipitates as the brine cools. The potash is recovered from the ponds by dredges and pumped to the plant for processing. The brine is heated again and the process repeated. An advantage of the method is that it allows ore extraction at greater depths than with conventional underground mining methods.

Potash mine head and plant - Potash Corporation of Saskatchewan (PCS), Canada



Continuous mining machine - Potash Corporation of Saskatchewan (PCS), Canada

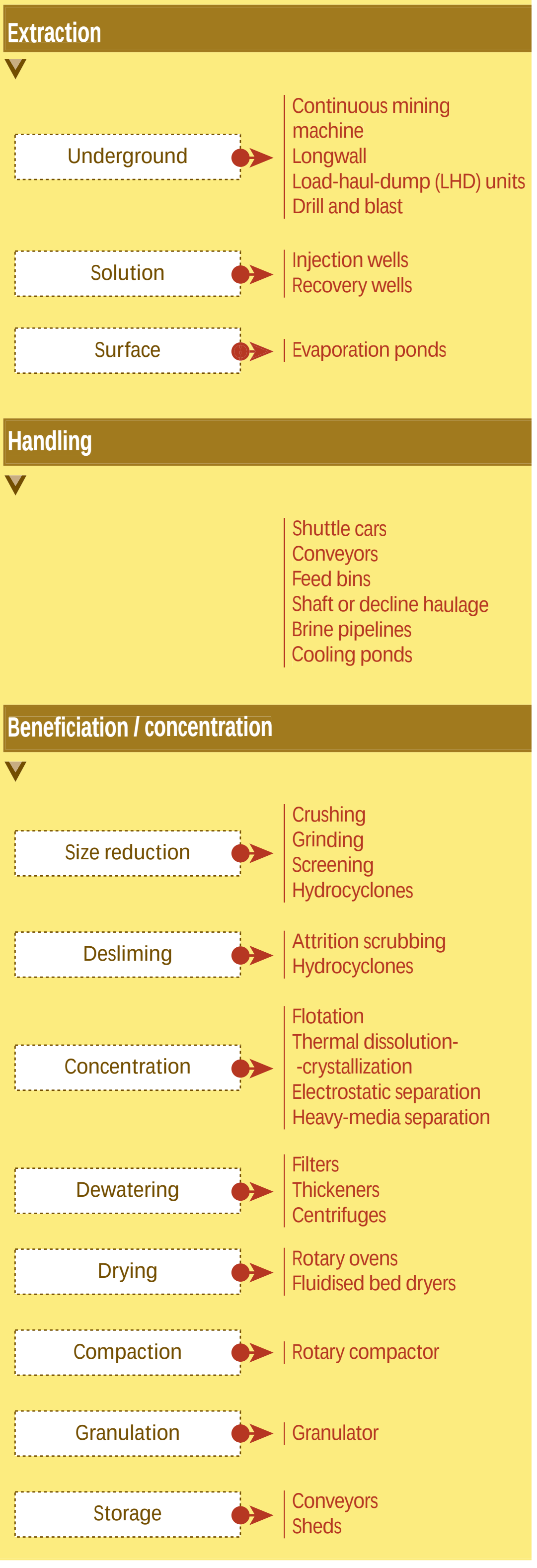
Longwall mining - Mines de Potasses d'Alsace, France

Continuous mining machine - Potash Corporation of Saskatchewan (PCS), Canada

Drilling holes for blasting explosive - Kali und Salz GmbH, Germany

Loader (LHD-Load, hold, dump unit) - Kali und Salz GmbH, Germany

Figure 2.2
Common potash mining processes and equipment



Although it is not strictly mining, the concentration of brine in solar evaporation ponds is another method of producing potash ore. The method relies on the evaporation of brine through a series of shallow ponds. The initial ponds are used to precipitate halite (NaCl) and concentrate the desired minerals, the brine is then pumped into a second series of ponds in which the potash ore, mostly carnallite, is precipitated. The carnallite is harvested and pumped as a slurry to beneficiation facilities for processing.

Potash Beneficiation

The processing of potash generally involves a series of steps including:

- Size reduction;
- Desliming;
- Separation;
- Drying;
- Compaction and granulation;
- Disposal of the waste streams.

The specific process employed will depend on factors such as the characteristics and constituents of the potash ore and the market specifications.

Generally, the ore is reduced in size using a system of crushing and grinding to liberate the different minerals from each other. This is usually followed by desliming by intense agitation followed by flotation or hydrocyclones to separate the fines consisting of clays, dolomite and sand from the potash ore.

Four basic techniques are used to separate the waste minerals or by-products such as salt and concentrate the potash; flotation, electrostatic separation, thermal dissolution-crystallization, and heavy media separation. Several of these may be used together to enhance recovery.

Flotation is the most widely used technique, relying on the difference in surface properties between minerals to selectively float the desired mineral. Electrostatic separation is a dry process in which the minerals are separated using their different electrical conductivities. Thermal dissolution-crystallization relies on the same principle as solution mining, whereby a heated brine preferentially dissolves potassium chloride. Heavy media separation relies on the difference in specific gravity between sylvite and halite to selectively float and remove the lighter sylvite particles.

After concentration, the potash concentrate is generally dried in a rotary or fluidized bed dryer to reduce the moisture content. Depending on market requirements, this may be followed by compaction at high pressure between rollers and then granulation to produce a uniform size potash product.

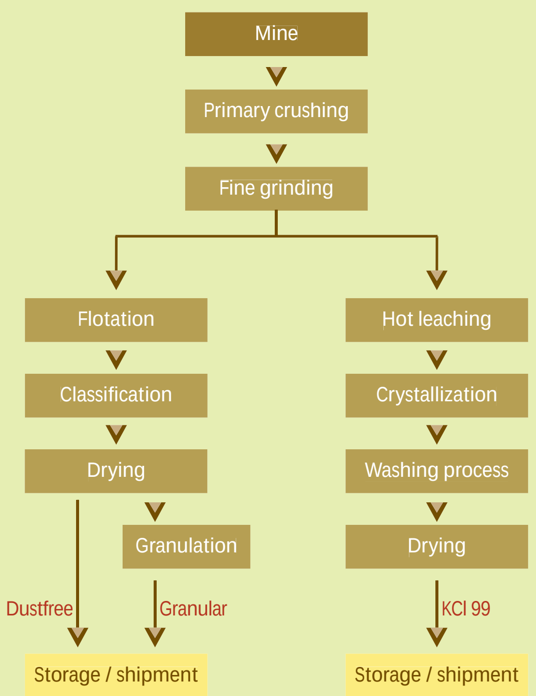
Three major waste streams are produced during beneficiation; brines, fines, and salt tailings. A variety of disposal methods are currently used, including:

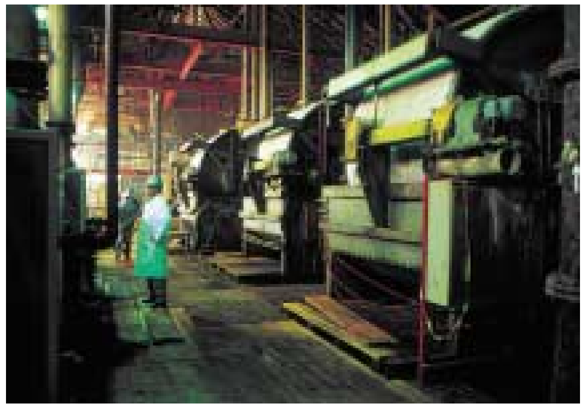
- Stacking of the salt tailings on the surface;
- Retention of the fines and brines in surface ponds for solar evaporation;
- Deep well injection of brines into confined permeable geological strata;
- Backfilling of mined underground openings with salt tailings, fines and brines;
- Release of wastes to water bodies such as rivers or seas.

These are discussed in greater detail in Chapter three.

Figure 2.3

Typical potash beneficiation process Kali and Salz GmbH, Germany





Filtering potash before drying - Kali und Salz GmbH, Germany

Potash rotary drier - Potash Corporation of Saskatchewan (PCS), Canada

Potash compaction rollers - Potash Corporation of Saskatchewan (PCS), Canada

2. Overview of Phosphate Rock and Potash Mining and Beneficiation

2.1 Phosphate Rock and Potash

Although phosphate rock and potash are used as raw materials for a wide range of applications, the most important use by far is the manufacture of mineral fertilizers.

The primary source of these minerals is geological ore deposits formed through past sedimentary or igneous activities. In the case of potash, concentrated brines are also a significant source.

This chapter provides a brief overview of the major activities involved in the mining, handling and beneficiation of phosphate rock and potash ore.

2.2 Phosphate Rock Mining and Beneficiation

Phosphate Rock Mining

At present, most phosphate rock is mined using large-scale surface methods. In the past, underground mining methods played a greater role, but their contribution to world production has declined. Major mining and beneficiation techniques and processes employed by the industry are listed in Figure 2.1.

Surface phosphate rock mining operations can vary greatly in size. Extraction may range from several thousand to more than 10 million tonnes of ore per year. In many cases, operations supply feed to a nearby fertilizer processing complex for the production of downstream concentrated fertilizer products. The economies of scale of the complex in turn influence the scale of the mining operation.

Surface mining of phosphate rock, with bucketwheel - Office Togolais des Phosphates (OTP), Togo

The land area affected by the surface operations may vary widely, depend on the orebody geometry and thickness and the ore extraction rate. At similar extraction rates, mining of flat-lying thin orebodies as found in Florida (USA) will affect a far wider area of land than the mining of thicker, or steeply dipping orebodies as found in Brazil and Idaho (USA). The depth of excavations may range from a few metres to more than 100 metres.

Surface mining of phosphate rock with dragline, Florida - Cargill Fertilizers Inc., USA

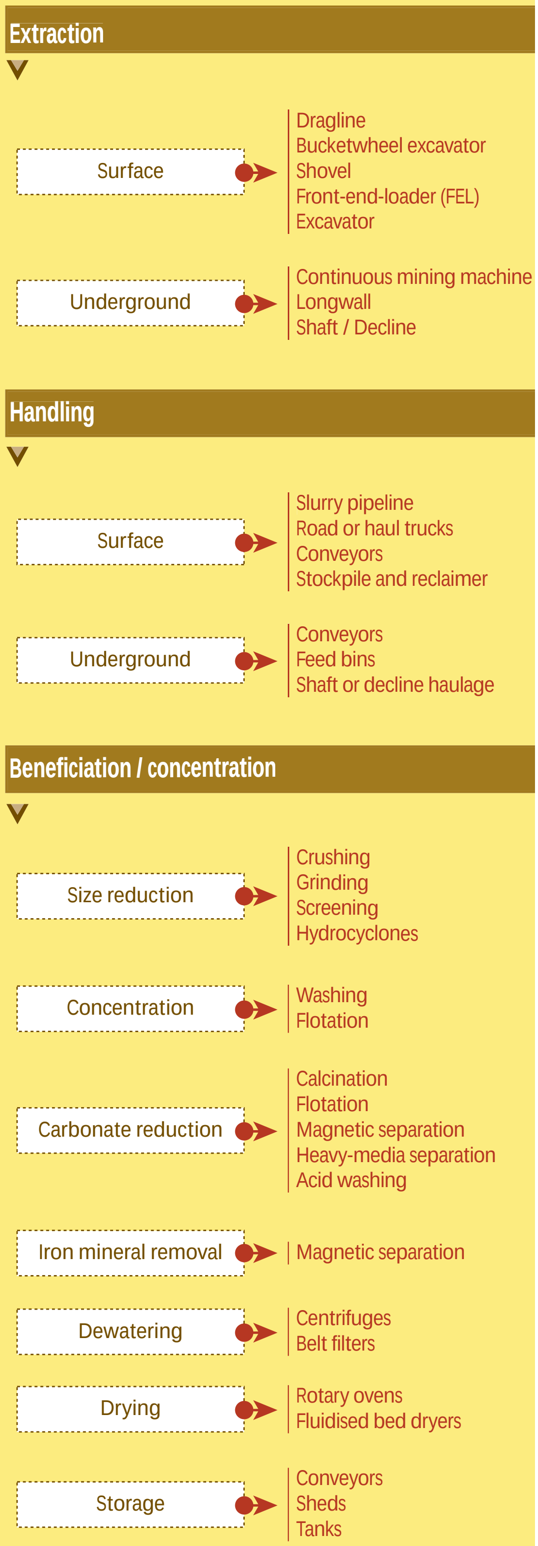
Currently, most phosphate rock production worldwide is extracted using opencast dragline or open-pit shovel/excavator mining methods. This method is employed widely in parts of the United States of America, Morocco and Russia.

Underground mining methods are currently used in Tunisia, Morocco, Mexico and India. The area of the land surface affected by these operations is generally small and limited to the area immediately adjacent to the access decline or shaft.

The following discussion will focus on surface methods due to their significance.

Figure 2.1

Common phosphate rock mining processes and equipment



Phosphate Rock Beneficiation

Beneficiation (or concentration) processes are generally used to upgrade the phosphate content by removing contaminants and barren material prior to further processing. A few ores are of sufficiently high quality to require no further concentration. The naturally occurring impurities contained in phosphate rock ore depend heavily on the type of deposit (sedimentary or igneous), associated minerals, and the extent of weathering. Major impurities can include organic matter, clay and other fines, siliceous material, carbonates, and iron bearing minerals. These characteristics influence the beneficiation processes employed.

The removal of fines such as clays and fine-grained aluminium and iron phosphates is usually conducted through a combination of crushing/grinding, scrubbing, water washing, screening, and/or hydrocyclones. The fines are disposed of either to rivers, mined out areas, or specially engineered storage impoundments. Siliceous material, sand, may require an additional froth flotation stage for separation. This is typically pumped to storage impoundments or mined-out areas for disposal.

Dry screening - Copebras SA, Brazil

Cone crusher - Fosfertil, Brazil

Wet screening - IMC Phosphate, Florida, USA

Grinding mills - Fosfertil, Brazil

Flotation tanks - IMC Phosphate, Florida

The presence of carbonates in the form of dolomite and calcite may cause downstream processing problems and may reduce the quality of the end product. They are primarily removed through the use of calcination followed by slaking with water to remove the CaO and MgO produced.

Iron minerals may be present in the form of magnetite, hematite and goethite. These are typically removed through scrubbing and size classification, or magnetic separation.

Following beneficiation, the concentrated phosphate rock is stockpiled prior to transport to downstream processing plants for the manufacture of phosphate mineral fertilizers. In some instances, phosphate rock with suitable properties may be directly applied to crops as a soil amendment by farmers.

Phosphate fertilizer plant, Conda, USA - Agrium Inc., Canada

Generally, the major waste streams produced during phosphate rock beneficiation are clay fines, sand tailings and significant quantities of process water. Magnetite tailings may also be associated with igneous orebodies. These are disposed of by a number of means including discharge to rivers or other water bodies, and disposal to engineered storage dams, or mined-out areas. The process water may be recovered and reused.

Decantation of clarified water - Cargill Fertilizers Inc., USA

Clay settling pond - Cargill Fertilizers Inc., USA

Surface Mining and Beneficiation Operations in Morocco

Phosphate rock mining and beneficiation are illustrated by the operations of Office Chérifien des Phosphates (OCP) in Morocco.

At the Khouribga and Benguerir opencast dragline mining operations in Morocco, the overburden is initially drilled and blasted. Bulldozers prepare the surface for draglines to remove the broken overburden and expose the ore. The ore is excavated without blasting into trucks using smaller draglines, shovels or front-end loaders. The trucks transport the ore to a screening plant for the separation and disposal of the oversize low-grade material followed by stockpiling. The screened ore is reclaimed from the stockpile and transferred by conveyor to the beneficiation plant. The ore is washed and dried to remove clay fines and in some instances is subjected to calcination, to produce a concentrated phosphate rock.

The concentrated phosphate rock is transported by rail either to the industrial complexes located at Jorf Lasfar and Safi for further processing, or directly to port for export.

Loading phosphate rock - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Drying plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Sizing and stockpile plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Conveyor and stacker - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Washing plant - Office Chérifien des Phosphates (OCP), Khouribga, Morocco

Port, Jorf Lasfar - Office Chérifien des Phosphates (OCP), Morocco

2.3 Potash Mining and Beneficiation

Potash is a generic term applied to all potassium salts that are used as fertilizers.

Potash Mining

Potash ore is extracted from two major ore deposit types, deeply buried marine evaporite deposits that typically range from 400 metres to greater than 1,000 metres below the surface, and surface brine deposits associated with saline water bodies such as the Dead Sea in the Middle East and the Great Salt Lake in North America.

Most potash is sourced from buried deposits using conventional mechanized underground mining methods, though solution mining methods also are employed. Generally these underground operations produce between 1 to 10 million tonnes of potash ore per year. The land area affected is typically confined to the immediate area of the shaft, plant and waste disposal area but may be up to several square kilometers.

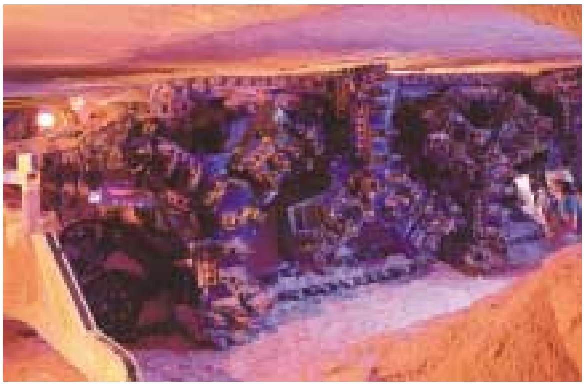
Surface brine deposits are exploited using solar evaporation ponds to concentrate and precipitate the potash. The evaporation ponds are extensive, with some operations covering in excess of 90 square kilometers of land area to produce around 8 million tonnes of potash ore per year.

Conventional mechanized underground mining operations are the most widely used method for the extraction of potash ore. A variety of mining techniques and equipment may be employed depending on factors such as: the orebody depth, geometry, thickness and consistency, the geological and geotechnical conditions of the ore and surrounding rock, and the presence of overlying aquifers. Methods in widespread use include variations of room and pillar, longwall, cut and fill, and open stope techniques.

After the ore is extracted, it is generally transferred by bridge conveyor, shuttle cars or load-haul-dump units to a system of conveyors that carry it to underground storage bins, prior to haulage to the surface through a shaft by automated skips. On rare occasions shallow mines may use a decline and conveyor arrangement.

Solution mining is currently used at a number of operations in North America. The process relies on the greater solubility at elevated temperatures in brine of sylvite in comparison to salt (NaCl). Commonly, brine is heated on the surface then injected into the orebody through wells. The heated brine absorbs sylvite from the orebody and is then pumped back to the surface to a series of ponds, where the potash precipitates as the brine cools. The potash is recovered from the ponds by dredges and pumped to the plant for processing. The brine is heated again and the process repeated. An advantage of the method is that it allows ore extraction at greater depths than with conventional underground mining methods.

Potash mine head and plant - Potash Corporation of Saskatchewan (PCS), Canada



Continuous mining machine - Potash Corporation of Saskatchewan (PCS), Canada

Longwall mining - Mines de Potasses d'Alsace, France

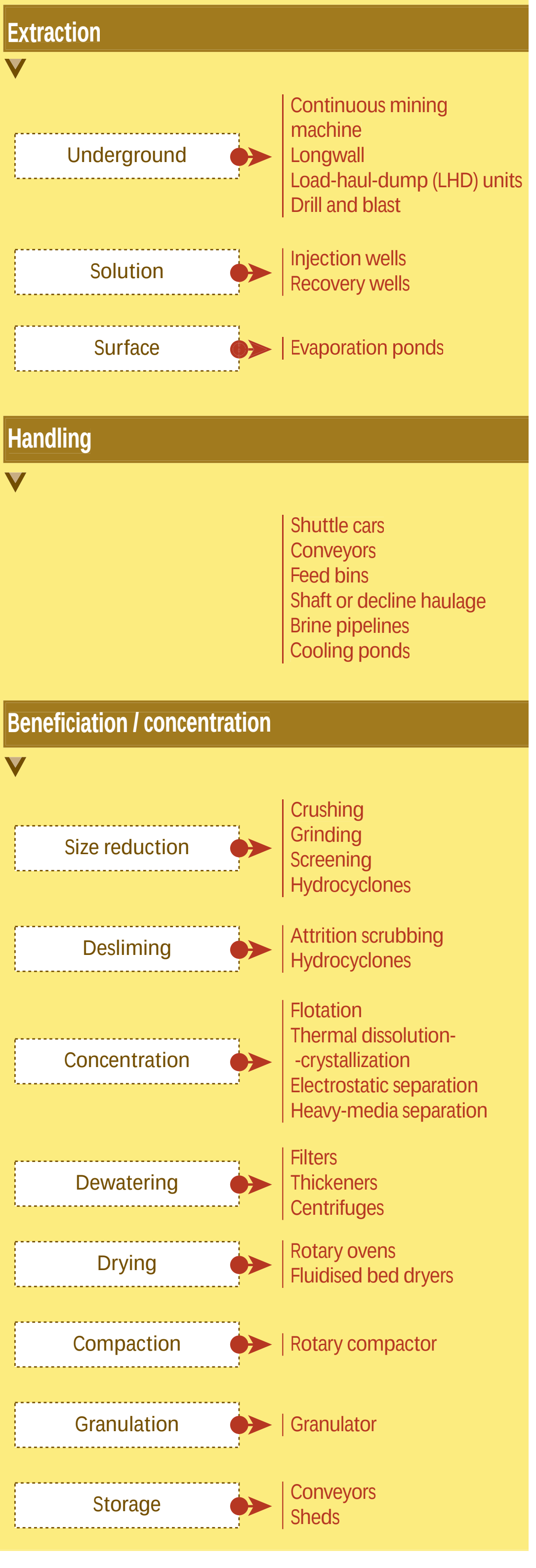
Continuous mining machine - Potash Corporation of Saskatchewan (PCS), Canada

Drilling holes for blasting explosive - Kali und Salz GmbH, Germany

Loader (LHD-Load, hold, dump unit) - Kali und Salz GmbH, Germany

Figure 2.2

Common potash mining processes and equipment



Although it is not strictly mining, the concentration of brine in solar evaporation ponds is another method of producing potash ore. The method relies on the evaporation of brine through a series of shallow ponds. The initial ponds are used to precipitate halite (NaCl) and concentrate the desired minerals, the brine is then pumped into a second series of ponds in which the potash ore, mostly carnallite, is precipitated. The carnallite is harvested and pumped as a slurry to beneficiation facilities for processing.

Potash Beneficiation

The processing of potash generally involves a series of steps including:

- Size reduction;
- Desliming;
- Separation;
- Drying;
- Compaction and granulation;
- Disposal of the waste streams.

The specific process employed will depend on factors such as the characteristics and constituents of the potash ore and the market specifications.

Generally, the ore is reduced in size using a system of crushing and grinding to liberate the different minerals from each other. This is usually followed by desliming by intense agitation followed by flotation or hydrocyclones to separate the fines consisting of clays, dolomite and sand from the potash ore.

Four basic techniques are used to separate the waste minerals or by-products such as salt and concentrate the potash; flotation, electrostatic separation, thermal dissolution-crystallization, and heavy media separation. Several of these may be used together to enhance recovery.

Flotation is the most widely used technique, relying on the difference in surface properties between minerals to selectively float the desired mineral. Electrostatic separation is a dry process in which the minerals are separated using their different electrical conductivities. Thermal dissolution-crystallization relies on the same principle as solution mining, whereby a heated brine preferentially dissolves potassium chloride. Heavy media separation relies on the difference in specific gravity between sylvite and halite to selectively float and remove the lighter sylvite particles.

After concentration, the potash concentrate is generally dried in a rotary or fluidized bed dryer to reduce the moisture content. Depending on market requirements, this may be followed by compaction at high pressure between rollers and then granulation to produce a uniform size potash product.

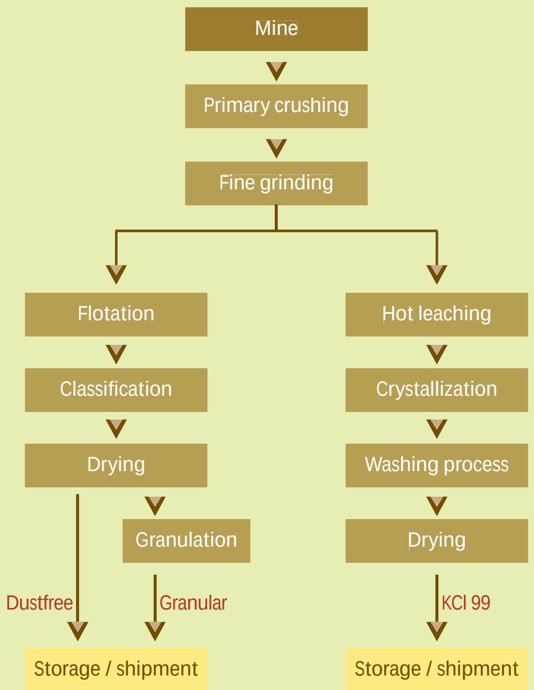
Three major waste streams are produced during beneficiation; brines, fines, and salt tailings. A variety of disposal methods are currently used, including:

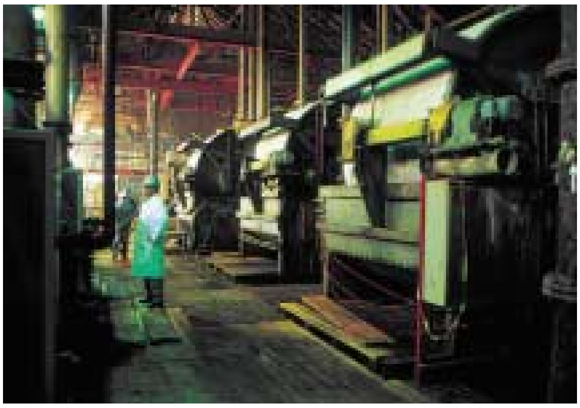
- Stacking of the salt tailings on the surface;
- Retention of the fines and brines in surface ponds for solar evaporation;
- Deep well injection of brines into confined permeable geological strata;
- Backfilling of mined underground openings with salt tailings, fines and brines;
- Release of wastes to water bodies such as rivers or seas.

These are discussed in greater detail in Chapter three.

Figure 2.3

Typical potash beneficiation process
Kali and Salz GmbH, Germany





Filtering potash before drying - Kali und Salz GmbH, Germany

Potash rotary drier - Potash Corporation of Saskatchewan (PCS), Canada

Potash compaction rollers - Potash Corporation of Saskatchewan (PCS), Canada

3. The Environmental Approach of the Phosphate Rock and Potash Mining Industry

3.1 The Environmental Challenges

The activities of the phosphate rock and potash mining industry potentially result in a wide variety of adverse environmental effects. Typically, these effects are quite localized, and in most cases, confined to the mine site. At a specific site, the type and extent of environmental effects may depend on factors such as:

- The characteristics of the ore and overburden;
- The surface land profile (wetlands, plains, hills, and mountains);
- The local climate;
- The surrounding ecosystem.

However, of greater importance may be:

- The mining methods and equipment;
- The beneficiation and concentration processes;
- The waste disposal methods;
- The scale of the operation;
- The sites location to existing population centers and infrastructure.

Environmental aspects that can be affected by mining activities were grouped under 'air, 'water', 'land' and 'social values'.

Air quality can be affected by emissions of:

- Dust;
- Exhaust particulates and exhaust gases such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur oxides (SO_x);
- Volatile organic compounds (VOC's) from fueling and workshop activities;
- Methane released from some geological strata.

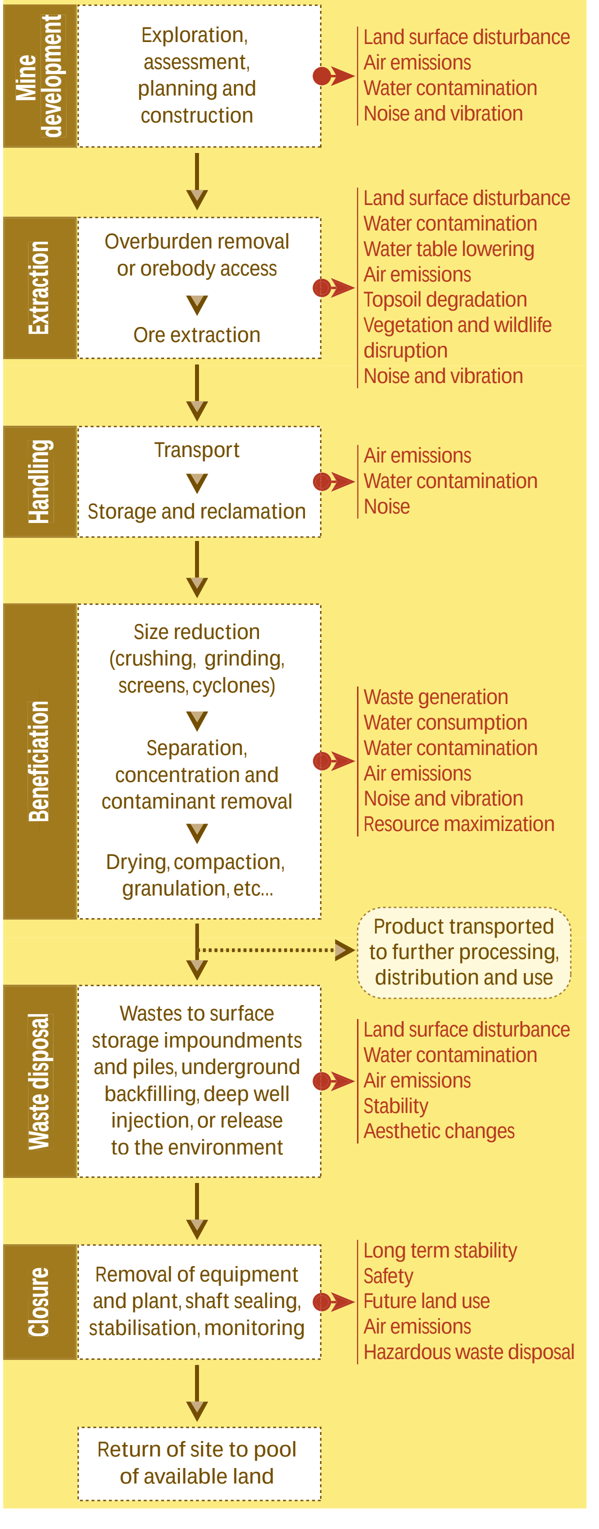
Greenhouse gases such as CO_2 and methane are believed to contribute to global warming.

Dust is a common problem throughout all mining activities. Dust generated by vehicle traffic can be reduced through a variety of means. Where water resources are not limited, regular watering with mobile water trucks or fixed sprinkler systems is effective. Otherwise the application of surface binding agents, the selection of suitable construction materials and the sealing of heavily used access ways may be more suitable. Dust emitted during beneficiation can be controlled by means such as water sprays, baghouses and wet scrubbers. Captured dust can generally be returned to the beneficiation process.

Figure 3.1.1

Major potential environmental effects that may occur during phosphate rock and potash mining activities

...Environmental management and rehabilitation...



Water quality can be affected by the release of slurry brines and contaminants into process water. Surface waters may be contaminated by:

- The erosion of fines from disturbed ground such as open-cut workings, overburden dumps and spoil piles and waste disposal facilities;
- The release or leakage of brines;
- The weathering of overburden contaminants, which may then be leached.

Large volumes of water are typically required by mining and beneficiation activities. This water consumption may lead to a fall in the level of the water table, affecting the surrounding ecosystem and potentially resulting in competition with other users.

The land surface and sub-surface is disturbed by activities such as:

- The extraction of ore;
- The deposition of overburden;
- The disposal of beneficiation wastes;
- The subsidence of the surface.

These activities could result in wide range of potential impacts on the land, geological structure, topsoil, aquifers and surface drainage systems. Additionally, the removal of vegetation may affect the hydrological cycle, wildlife habitat and biodiversity of the area. In some instances, sites of archaeological, cultural or other significance may be affected.

Social goods and intangible values such as community lifestyles, land values and the quality of the ecosystem in the vicinity of the mine site could be affected by factors such as:

- Modification of the landscape;
- Noise and vibration from activities such as blasting and the operation of equipment;
- Changes in wildlife habitat.

The major potentially adverse environmental effects could occur during the different activities of the mining life cycle in Figure 3.1.1. Generally the activities of most significance are construction, extraction, beneficiation and waste disposal. Associated activities may have an impact but these tend to be relatively less important. Rehabilitation and closure can have some impact, but these activities are carried out with the objective of repairing any adverse effects that may have occurred during mining, to leave a safe and stable site. Rehabilitation is more effective when conducted progressively throughout the life of the operation. Adopting a holistic approach to planning and environmental management, that encompasses the entire life cycle, helps to prevent or mitigate environment effects from the outset, while fostering stewardship of the ore resource and the land under which it lies.

The present chapter has been organized according to the major activities associated with the mining lifecycle. Within each activity, the major environmental issues are raised, followed by a general discussion of the environmental practices employed by industry. The discussion is illustrated by examples of good and innovative environmental practices identified during the project site visits. These demonstrate specific industry responses.

3.2 Mine Development: Exploration, Planning, Approval and Construction

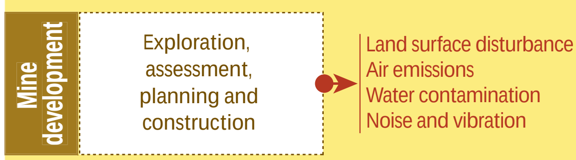
Mine development consists of a sequence of activities:

- Prospecting and exploration work to locate and delineate the ore resource;
- Economic, environmental and technical feasibility assessment of the orebody;
- Planning and design of the mine layout, site infrastructure and the mining sequence;
- Obtaining relevant government permits and approvals;
- Construction and commissioning of the operation.

Most environmental impacts during this stage of the mining life cycle are typically associated with exploration and construction. Effective planning, commencing at this stage and continuing throughout the life of the mine, has a great influence on minimizing the impact of the operation.

Figure 3.2.1

Potential environmental effects : mine development



Planning is important to avoid or reduce adverse environmental impacts over the life of the mine and after closure. Planning is most effective when the entire life of mine is encompassed. Defining the final objectives of mine closure from the outset allows an optimum balance between operational, rehabilitation and closure goals to be selected, thus minimizing the cost of these activities.

Planning takes account of factors such as air and water quality, land surface disturbance, noise and vibration, surrounding and post-mining land uses, wildlife and biodiversity and cultural and historic site locations. Valuable information for planning purposes is gathered during the preparation of environmental impact assessments (EIA) and permit applications. This allows sensitive aspects to be identified and potential risks evaluated. The knowledge developed creates a strong foundation for the development of later operational management systems, procedures, and practices.

Repeated evaluation of different options addresses the environmental impacts, the changing regulatory requirements, community expectations, and engineering and cost limitations, while also allowing new technology to be more easily incorporated.

Exploration

Exploration activities have some environmental impacts. These are largely related to land disturbances from the clearing of vegetation, construction of camps, access roads, drilling sites and sumps for drilling fluids and fines. Noise and vibration from seismic surveys and drilling operations may also be of concern.

Effective planning of the exploration activities reduces potential impacts by using existing infrastructure where possible, taking appropriate care during the construction of access tracks and containing any drilling fluids and fines in sumps. On completion of exploration, rehabilitation of disturbed areas is enhanced by the capping or grouting of drill holes, the filling of sumps, the ripping of compacted areas, and the replacement of removed topsoil and revegetation.

Modern remote sensing exploration techniques reduce the area disturbed by exploration activities. The use of gravity and geomagnetic surveys allows wide areas to be covered with little or no impact,

Mine site - Foskor Ltd, South Africa

Dragline avoids bird's nest - Cargill Fertilizers Inc., USA

The 'Team Permitting Process'

IMC Phosphate in central western Florida, (USA) has applied a "team permitting process" to the Consolidated Development Application (CDA) for the proposed Ona and Pine Level mines.

The CDA covers the majority of permits required for approval to mine phosphate in Florida. Permits typically focus on the areas of:

- Water quality;
- Water supply;
- Wetlands;
- Wildlife.

Typically, several permits will be required for each area, encompassing a wide range of issues. Once achieved, the permits apply to the life of the mine.

The team permitting process speeds up the development and approval of the CDA through two major innovations. First, at the outset all stakeholders are brought together. This allows major concerns to be identified before the CDA starts. The issues can then be addressed efficiently, reducing the need for multiple iterations of the CDA.

Second, the CDA undergoes concurrent review by both the community and regulatory agencies. The review provides an opportunity for questions to be raised about the CDA. The company must address these sufficiently before approval is granted.

As a trade-off for benefiting from the accelerated team permitting process, the company must provide environmental benefits beyond those required for the standard permitting process. This results in a win-win solution for the company and community. The company obtains its mine permit approval faster, the community has a greater sense of ownership through early involvement and input, and enjoys more environment benefits.

reducing the need for more intrusive exploration techniques.

Construction

Construction activities have significant potential to have adverse environmental impacts. During this phase, often a large transient workforce is employed, workforce numbers tend to peak and material and equipment movements tend to be large. Impacts are typically related to land disturbance caused by earthworks, air emissions from dust, noise from equipment and construction activities and heavy volumes of traffic on access roads.

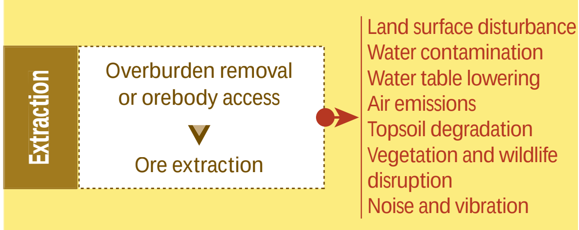
In many cases, specialized third party companies and consultants conduct mine construction activities. 'Turn key' construction contracts are commonly awarded. The ability of the mine site's owner to control environmental impacts can be maintained to some extent by considering potential issues and explicitly addressing them in the drafting of the tender and contract.

3.3 Extraction

Surface mining methods, by nature, tend to affect a wide area of land and could result in a variety of effects such as: land surface disturbance, contamination or depletion of ground and surface water, and a reduction in air quality. Currently, most **phosphate rock** and a small quantity of **potash** ore are sourced using surface mining.

Figure 3.3.1

Potential environmental effects : ore extraction



Underground mining methods tend to create fewer environmental problems, the major issue being possible surface subsidence. This is induced by the removal of extensive flat-lying ore deposits, followed by the subsequent collapse of overlying rock. Some minor environmental effects may be associated with the disposal of rock removed to access the orebody. Also, ground water inflow into the underground openings may become contaminated or deplete overlying aquifers. Underground mining methods are used to source potash ore from deeply buried marine evaporite potash deposits. A lesser quantity of phosphate rock is sourced using underground methods.

Land Surface Disturbance

Extraction activities disturb the land surface through clearing of vegetation, removal of topsoil, excavation of ore and overburden and the construction of overburden dumps or solar evaporation ponds.

Removal and stockpiling of topsoil for subsequent rehabilitation is carried out at many mining operations. In a number of cases, topsoil is removed and placed directly on landscaped reclaimed areas. This avoids the cost of re-transporting topsoil from stockpiles and the possible reduction of biodiversity. Moreover, close coordination and planning is required between the mining and rehabilitation operations to ensure that areas are prepared in a timely manner. The re-planting of small trees from areas to be mined and the placement of dead trees on rehabilitated areas has been used to accelerate the establishment of vegetation and provide a wildlife habitat.

Generally, overburden (4) is either dumped directly into the adjacent mined-out areas or placed in specially designed overburden dumps. On closure, this material is landscaped, covered with a layer of topsoil and revegetated. These activities are discussed further in Section 3.7 "Rehabilitation".

The costs associated with transporting and landscaping overburden are minimized in many cases by designing and managing overburden dumping operations so as to ensure that they are placed as close as possible to the final desired location and to the final shape. Bucketwheel excavator operations are particularly flexible, allowing selective placement of the overburden in the order of extraction and the creation of a flat final landscape. This has advantages for later rehabilitation.

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(4) The term overburden is usually applied to the barren material (clay, sand, or rock) removed to expose the ore in surface mines. Underground mines produce a far more limited volume of barren waste rock during excavation of the access ways such as shafts and tunnels. Finally, processing operations generally produce a number of solid wastes such as salt tailings, sands, and clays. The term overburden will be applied to all barren material stripped from the surface to allow the ore to be extracted.

Open Cut Backfilling

The Rasmussen Ridge mine, located in mountainous terrain in southeast Idaho, is owned and operated by Agrium, Inc. Open pit mining methods are used to extract two closely spaced, steeply dipping ore bodies using shovel, front-end-loaders and trucks. The pit is around 100 metres deep, and will ultimately be mined around 3,000 metres along the strike of the orebody.

The mine and reclamation plan sequences the pit, which is to be mined to its final depth progressively along the strike. Once a sufficient length of pit has been mined, backfilling with overburden removed from the active mining area is carried out. External overburden dumps are thus only required during the initial stage.

The backfilled pit is landscaped to blend in with the natural mountainous topography, re-establishing surface drainage patterns while minimizing the potential for erosion. Topsoil, generally from clearing in front of the pit face, is applied, followed by seed and fertilizer application to re-establish vegetation.

This approach significantly reduces the area of land disturbed by external overburden dumps, and reduces the volume of pit left empty on completion of mining operations. This in turn prevents the formation of post-mining pit lakes and the safety risk of exposed steep pit walls.

An additional benefit is the isolation of selenium-contaminated overburden. Selective placement at the bottom of the pit prevents selenium leaching into surface waters, potentially causing toxicity in livestock and fauna downstream. The development of best management practices for selenium control is discussed further in Section 3.9 "Environmental Management".

Landscaped pits with snow, Conda, USA - Agrium Inc., USA

Open pit mining, Conda, USA - Agrium Inc., USA

Landscaped overburden dump with transplanted trees in distance, Conda, USA - Agrium Inc., USA

The wide area of land surface disturbed by surface mining operations could require relocation and compensation of people living above the orebody.

In some instances, surface subsidence induced by underground mining may alter river and stream drainage patterns, disrupt overlying aquifers, and damage buildings and infrastructure. The degree of subsidence depends on factors such as orebody thickness and geometry, the thickness of the overlying rock and the amount of ore recovered. The effects of subsidence have been reduced to some extent, through either:

- The design of the ore extraction layout so as to reduce the rate and extent of subsidence, or
- By backfilling openings with processing wastes such as salt tailings, to reduce or prevent subsidence.

Where subsidence occurs, there is potential for damage to overlying buildings or infrastructure. To avoid safety risks and property damage, close coordination and communication is required between the company and relevant government bodies, other companies and communities. This needs to be supported by a well-defined system for reporting and repairing damage, or

Land Rental

The phosphate rock orebody in Togo being extracted by the Office Togolais des Phosphates (OTP) is located near the coast in an area of intensive small-scale farming. Surface mining methods are used to remove the overburden and extract the phosphate rock ore. This requires the progressive relocation of farmers and village communities as mining occurs. In compensation, the company pays farmers a rental for the land disturbed during the mining process. New villages are constructed in advance outside the mining area, to rehouse displaced villagers. The land rental continues until rehabilitation is completed and the land is once again suitable for farming.

for providing compensation to avoid conflict.Solar evaporation ponds used to extract potash from surface brine deposits usually cover a wide area of land, with operations in the region of 90 square kilometres. The precipitation and build up of salt in the ponds over time presents an issue.

Water Consumption

In some locations, water consumption during extraction activities may lead to a lowering of the surrounding water table.

Water inflow is a common problem where open pits and underground openings intersect aquifers. Generally, water is pumped from the excavations or from nearby wells to maintain a dry, safe and efficient operating environment for the equipment. This may potentially lead to the lowering of the surrounding water table and the depletion of nearby surface water bodies. In some locations, measures have been taken to confine the area affected by water table depression and protect the surrounding ecosystem.

Waste water produced during the extraction stage can be used for downstream processing operations, reducing the demand on other sources. In some places, water of suitable quality has been used for the irrigation of local farming operations. This is of greater importance in arid climates where water resources are limited.

Water Contamination

Excavation activities may contaminate surface water through the release of fines generated during clearing, blasting and excavation operations, the weathering of overburden contaminants susceptible to leaching and the release of salt from brines and potash ore.

Ecosystem Protection Through the Use of Perimeter Ditches

The elevated water table is a prominent feature of the Florida ecosystem. Frequent surface appearance of the aquifer has produced a patchwork of wetlands, streams, rivers and lakes. This presents an issue for the efficient extraction of the phosphate rock deposit by draglines. If the opencast pit contains water, dragline operators have difficulty identifying the boundary between the ore and overburden, potentially resulting in the loss of ore or dilution by barren rock. To maintain dry excavations and an efficient operating environment, the water table may be depressed to a level below the ore by pumping from wells or sumps. However, this may lead to negative effects on the surrounding water-sensitive ecosystem. To overcome this, companies such as IMC Phosphate and Cargill Fertilizers Inc have implemented protection systems, using a perimeter ditch to confine the impact on the water table to the immediate mining area.

Before pumping commences, a perimeter ditch is excavated around the mining area to a depth below the water table. The ditch is filled with water that is maintained at a level consistent with the original water table, using a series of weirs and pumps. When the water table is depressed by mining activities, recharge occurs from water in the ditch.

Performance of the system is monitored by both daily visual inspection of the ditches and by weekly measurements of the water table, through a series of piezometers located outside the perimeter ditch.

The effectiveness of the method has been improved by reshaping the overburden immediately adjacent to the perimeter ditch as soon as possible on completion of mining. This allows the water table to partially reestablish itself inside the perimeter ditch.

The application of this approach protects the surrounding water-sensitive ecosystem by confining the depression of the water table to the area delineated by the ditch.

Perimeter ditch - IMC Phosphate, USA

Irrigation of Local Agricultural Production Using Waste Water from Dewatering and Washing Operations

In Morocco, at the Youssofia operation, the Office Chérifien des Phosphates (OCP) pumps groundwater inflow out of the underground phosphate rock mines. The water is pumped to the surface and used for both phosphate rock washing operations and for irrigation of the local farmer's fields. A system of pipes and aqueducts is used to transport the water. Farmers apply to receive approval to tap the water. Produce from the farms is used for their own requirements with excess sold in the local township.

Farms irrigated by mine water - Office Chérifien des Phosphates (OCP), Youssofia, Morocco

Jordan Phosphate Mines Co. Ltd. (JPMC) supplies phosphate rock beneficiation plant waste water to local Bedouin farmers for farm irrigation. The water is piped to several nearby fields and used to irrigate a variety of vegetable and grain crops. Produce is for own-consumption, and sold to the mine kitchen, nearby markets and passing road traffic on the nearby Desert Highway.

Testing of the contaminant levels in the waste water is conducted in both cases.

Mine-enabled irrigation thus improves the welfare of the local communities by contributing to a reliable food supply and providing the opportunity to generate cash income through the sale of excess food produce.

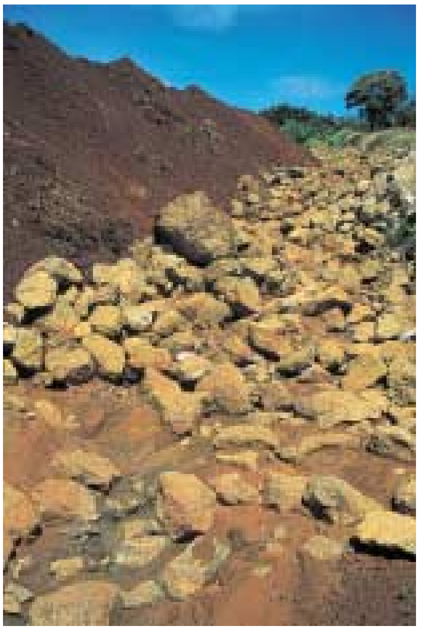
Elevated sediment levels in surface water are caused largely by uncontrolled water run-off, mobilizing the fines from disturbed areas.

Mining operations have employed a variety of control techniques, including:

- The lining of drainage channels with large rocks to prevent erosion and trap sediments;
- The landscaping of overburden to create a flatter, more stable land area slowing the rate of run-off;
- The rehabilitation of disturbed areas as soon as is operationally possible, through seeding with grass, spreading of mulch, laying of geofabric and cross-ripping with bulldozers.

In some situations, natural drainage systems have been channeled around mining areas or vegetation buffer zones have been retained to reduce the movement of sediments off-site. These measures have been strengthened by the use of silt traps and settling dams to retain and clarify contaminated water before release.

Brines may potentially contaminate surface or ground waters. Operations commonly employ monitoring and containment systems to detect and control spillages and prevent widespread contamination occurring.



Lined drainage channel - Fosfertil, Brazil

Sediment ponds - Foskor Ltd, South Africa

Solution Mining Pump and Pipeline Monitoring and Control System

The PCS Patience Lake Division, located in Saskatchewan, Canada, extracts potash from a flooded conventional underground mine using a solution mining method. The extraction method uses a system of brine injection and recovery well linked with pipelines to cooling and precipitation ponds adjacent to the processing plant. The wells are scattered over a wide area requiring an extensive network of pipelines.

To avoid the potential risk of failure and release of brine a number of design features and control and monitoring techniques have been employed. Brines are transported through buried, large diameter HDPE pipes at a low pressure. The buried pipeline is lined, with drainage manholes located at low points to detect leaks. A monitoring system is in place to detect spillages at the wells and a containment system using bunds (earth walls) has been constructed around the recovery well site.

Visual inspection of the system is conducted each shift, while an electromagnetic survey is conducted at regular intervals to detect hidden leaks from buried pipelines or ponds. PCS has developed this method that allows changes in ground conductivity, caused by the presence of salts, between surveys at different times to be detected.

Spillage detectors - Potash Corporation of Saskatchewan (PCS), Patience Lake, Canada

Recovery of potash from ponds - Potash Corporation of Saskatchewan (PCS), Patience Lake, Canada

Emergency spillage recovery pump, Potash Corporation of Saskatchewan (PCS), Patience Lake, Canada

Heating potash brine prior to injection - Potash Corporation of Saskatchewan (PCS), Patience Lake, Canada

Air Emissions

Effects on air quality tend to be of a localized nature and are largely related to the generation and emission of dust particulates by blasting, excavation and equipment movement or exhaust gases and particulates from engines. Control techniques are discussed in Section 3.1.

Underground operations control exhaust particulates by installing particulate filters on the exhausts of mobile equipment. Retrofitting equipment with new, more efficient and cleaner engines also reduces exhaust particulate and gas emissions, as well as contributing to reduced fuel consumption and maintenance costs.

Other Potential Impacts

A variety of other impacts may occur because of extraction activities, including noise and vibration due to blasting and the operation of equipment. The local biodiversity could be affected and the landscape deteriorated due to the excavation of large pits, dumping of overburden into spoil piles, and construction of elevated overburden dumps.

Restricting operating and blasting to periods when the nearby community will be least disturbed can help to mitigate the effects of noise and vibration.

In some places, unsightly landscapes have been improved by maintaining buffer zones, planting greenbelts or the constructing barrier fences. Prompt rehabilitation of disturbed areas that are most visible can reduce the visual impact and improve relations with the local community.

3.4 Handling

Handling encompasses the transportation and stockpiling operations that occur between the extraction of the phosphate rock or potash ore and their beneficiation to produce concentrated products. Surface transportation methods include: road trucks and off-road haul trucks, trains, conveyors and slurry pipelines. Underground transportation methods include shuttle cars, front-end-loaders, conveyors, slurry pipelines and ore skips for shaft haulage. Stockpiles are used at various points in the transportation chain to allow for delays.

Figure 3.4.1

Potential environmental effects : handling

The environmental impacts due to handling tend to be of a localized nature and are largely related to dust, exhaust emissions, noise from vehicles and equipment and the contamination of water with fines or brine.

Air Emissions

Dust and exhaust emissions from equipment are among the most prevalent issues related to handling. Dust may be generated from traffic on unsealed road-

Dust Control During Potash Ore Handling

At the IMC Potash Carlsbad operation, located in New Mexico (USA) ore is extracted using underground room and pillar mining. Continuous mining machines are used predominately with a small amount of drill and blast. Ore is hauled to the surface through two shafts, one for langbeinite and the other for sylvite, and conveyed to separate processing facilities.

Because dust emissions have been an issue in the past, a variety of baghouse and wet scrubber emission control equipment has recently been installed throughout the sylvite and langbeinite ore handling and processing facilities. An element of this is the dust extraction system on the langbeinite ore haulage shaft that is designed to reduce dust generated during skip dumping. The system draws air through the skip and feed bin and into the baghouse where the dust is trapped. Product loss is avoided by depositing the collected dust onto the conveyor to the plant.

Langbeinite shaft with baghouse (blue) - IMC Potash, Carlsbad, USA

As well as the environmental benefit provided by reducing dust emissions from the handling and processing of langbeinite and sylvite ores, there has been an improvement in the working environment for personnel. Additionally, product loss has been reduced by the capture and return of the dust to the process creating a small economic benefit to partially offset costs of putting the controls in place.

ways, during loading and unloading operations, at conveyor transfer points and during the stacking of stockpiles and reclamation operations. Exhaust gases and particulates are largely produced by the operation of transport.

A variety of dust control techniques are used, as discussed in Section 3.1.

Equipment emissions are reduced by the use of exhaust filters, regular equipment maintenance programs and replacing old engines with new, more efficient and cleaner models.

Watershed Protection

Regulations in Florida to protect watersheds from disturbance have restricted the development of floodplains, streams and rivers. Accordingly, phosphate rock mining operations must establish buffer zones and work around these features. However, on occasions crossings may have to be constructed across them to facilitate access to mining areas.

Development of a new mining area at the IMC Phosphate Four Corners operation in central Florida required the construction of a river crossing. This was designed to allow vehicle and equipment access and the passage of several large diameter slurry pipelines between the mining area and the beneficiation plant. The design has a number of features to mitigate potential environmental impacts.

Culverts have been placed under the earthen vehicle crossing, allowing normal river flow to be maintained. Silt traps contain minor erosion sediments from the crossing.

During heavy rain, the water level rises and passes over the crossing. Surfacing the vehicle roadway with coarse aggregate and the planting of grass on adjacent roadside areas has reduced the potential for erosion.

The large-diameter ore slurry pipelines have been placed alongside the crossing roadway and elevated to allow water to pass underneath. In the event of failure, the pipes are double lined at the crossing, discharging to a containment pond at one end, while an automated monitoring system alerts management.

Watershed protection is an integral part of the crossing design. The construction of a stable, non-eroding river crossing and the installation of a monitoring and containment system in the event of a slurry pipeline failure prevent contamination of downstream areas.

Transport of Ore and Concentrate by Slurry Pipeline

The transport of ore and concentrates as a slurry (a mixture of water and ore particles in suspension) has benefits such as less road transport congestion, reduced vehicle exhaust emissions and the elimination of sources of dust emission. Slurry pipelines are used at a number of operations worldwide.

In Florida, the phosphate mining operations of companies such as Cargill Fertilizer Inc. and IMC Phosphate use high-pressure water jets to convert the ore excavated by the draglines into a slurry which can be pumped to the beneficiation plants through large diameter pipelines.

In Brazil, Fertilizantes Fosfatados S.A. (Fosfertil) uses a 125 kilometre long pipeline to transport phosphate rock concentrate slurry from the beneficiation plant at the Tapira mining complex to the fertilizer processing complex at Uberaba.

Uberaba Fertilizer processing complex - Fosfertil, Brazil

Phosphate rock concentrate slurry tanks and pumping - Fosfertil, Brazil

Slurry pipelines require significant quantities of water. This may present issues in areas of limited resources. Recycling or re-use of the water for other processes may be possible.

Water Contamination

Water contamination may occur through spillage of ore slurries or brines from pipelines and the mobilization of fines by rain run-off from roads or stockpiles.

The effects of slurry pipeline spillages are reduced through the use of monitoring and containment techniques. Automated monitoring systems allow management to be notified in a timely manner in the event of a failure. Earth walls and double-lined pipes contain and reduce the extent of the spill until remedial action can be taken.Soil and groundwater contamination may also result from the spillage of brines.

Fines generated from heavy vehicle traffic on unsealed roadways and from stockpile areas may contaminate run-off water. The fines can be contained by the use of techniques like silt traps and sediment retention dams. Methods are discussed further in Section 3.3, "Excavation".

Noise

Heavy vehicles and equipment use can generate significant noise, sometimes around the clock, affecting the well-being of neighboring communities. The impact is reduced by the careful location of roads, use of noise barriers or buffer zones, sequencing of mining operations and restricting the operating hours of the equipment.

Slurry pipelines address this concern, as they produce little noise.

3.5 Beneficiation and Concentration

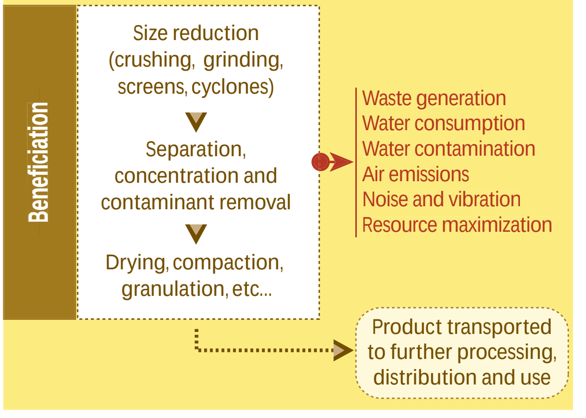
Beneficiation and concentration may adversely affect the environment by:

- The generation of wastes such as sand, magnetite and salt tailings, clay fines and brines;
- The consumption and contamination of large volumes of fresh water during processing with fines, chemical reagents, and brines;
- The emission of dust from processing operations such as crushing and drying;
- The emission of exhaust particulates and gases during the generation of electrical power and the drying of product.

Other potential impacts include noise and vibration produced by equipment such as rock breakers, crushers and grinding mills.

Figure 3.5.1

Potential environmental effects : beneficiation



Waste Generation

The large volumes of waste generated during beneficiation of phosphate rock and potash may potentially cause adverse environmental effects. The volume and type of wastes will depend on the ore characteristics (ore grade, constituent minerals, and contaminants), in addition to the specific beneficiation process employed.

A variety of wastes is generated from the beneficiation of phosphate rock, and may include:

- Oversize low-grade rock from screening;
- Coarse tailings composed of sand;
- Fine tailings composed of clays and similar size materials;
- Process water contaminated with fines and process reagents.

In some instances, magnetite tailings have also be generated.

The beneficiation of potash produces wastes such as:

- Tailings consisting largely of impure salt (NaCl) with smaller amounts of other minerals such as anhydrite;
- Slimes consisting of insoluble fines such as clay and dolomite;
- Brines containing salt or magnesium chloride.

In most countries, wastes are disposed of to specially engineered impoundments such as dams and ponds or released in a controlled manner to the environment. Disposal methods are discussed in detail in Section 3.7 "Waste Management and Disposal".

Beneficiation plants frequently implement measures to contain and recover process spillages, in order to minimize environmental effects and product loss.

Water Consumption

Beneficiation operations generally consume large quantities of fresh water for processes such as washing and flotation. The water is usually sourced from nearby surface and ground water supplies. In arid areas, local water supplies may be limited, requiring water to be piped considerable distances.

Water piped in from distant sources may provide a suitable source for other users.

Provision of Water Resources to Other Users

In New Mexico, the Mississippi Chemical Corporation pipes water from a distant freshwater aquifer to their Carlsbad potash operation. Local groundwater in the vicinity of the operation is high in total dissolved solids and not suitable for human or livestock consumption. The freshwater pipeline has provided a water source available for local ranchers, reducing reliance on variable rainfall in this arid area.

Water management is an important aspect of the operation and is usually integrated with waste disposal. Where possible, recirculation or recovery of the waste process water/brine is effected. In many cases the process waters/brines are used to transport the wastes as a slurry to the disposal areas. Typically, they are recovered for reuse, minimizing the need for additional fresh water input.

Where fresh water sources are not available for phosphate rock beneficiation, salt water has been used for processing. A clean water wash is required afterwards, to reduce the chloride content of the ore concentrate.

Utilizing dry beneficiation processes reduces water consumption. However, it can create additional dust problems.

Water Contamination

Contamination of surface and ground water may occur from the spillage of process water, brines, ore concentrates, wastes or chemical reagents during processing. A variety of methods to contain spills are used, including drains, bunds around storage and processing tanks and dams for major process spills.

Electrostatic Separation and Pneumatic Flotation for Potash Ore

The Kali und Salz GmbH operation in Germany has developed the ESTA electrostatic separation process and the pneumatic flotation cell to improve the recovery of potash from complex mineralized ores. Implementation of these techniques has also created additional environmental benefits through reduced energy consumption and waste water production.

The ESTA electrostatic separation process requires that complex potassium/magnesium ores are dry ground to less than 1 millimetre to separate the different minerals. The particles are conditioned to create differential positive and negative charges between them. Separation occurs as the mineral particles are subject to a 125,000-volt potential drop during free fall. A multi stage separation process allows the various product and waste minerals to be isolated and concentrated. Environmental and economic benefits arise from the dry separation process that produces no waste brines and the relatively low energy requirements.

A non-mechanical, pneumatic flotation cell has been developed for the separation of kieserite (magnesium sulphate) from halite. In comparison to conventional mechanical flotation cells the pneumatic cells consume less energy and recover more kieserite.

Pneumatic flotation cell - Kali und Salz GmbH, Germany

These allow spills to be recovered and returned to the process or be disposed of safely.

Air Contamination

Dry processing operations may generate significant quantities of dust during operations such as crushing, grinding, compaction and drying. This can be controlled to some extent through the use of emission control equipment such as baghouses and wet scrubbers.

Air Emission Control By-Products

Zirconium is recovered as a co-product during phosphate rock processing at the Phalaborwa operation of Foskor Limited in South Africa.

Dust emissions from the zirconium plant prompted the installation of an emission control system. Fine silica fume generated during processing is recovered by the system and subsequently sold, producing a revenue stream. The revenue generated has resulted in the rapid payback of the installation costs for the air emission control system.

The system has produced environmental benefits from the reduction in dust emissions as well as an additional revenue stream for the company.

The problem of dust emissions may be compounded by processes such as calcination and drying, which generate high levels of exhaust particulates and gases. These emissions are reduced through the use of cleaner fuels such as natural gas, applying emission control equipment to exhausts, using more efficient equipment and making use of cogeneration possibilities and heat recovery. In some cases, minor adjustments have improved the efficiency of old equipment.

Steam-Heated Fluidized Bed Dryers for Potash Ore

The installation of steam-heated fluidized bed dryers to dry potassium chloride at the Hattorf operation of Kali und Salz GmbH in Germany has resulted in 35% less energy consumption, with markedly lower flue gas and dust emissions in comparison to rotary dryers.

Exhaust emissions from vehicle engines, electrical power generation and product dryers may contain greenhouse gases such as carbon dioxide (CO_2) and other gases such as NO_x. The use of improved fuel or energy consumption techniques and technologies reduces the emission of greenhouse gases and other exhaust particulates and gases.

Dryer Burner Modifications

The IMC Potash Carlsbad operation in New Mexico (USA) has significantly reduced the exhaust emissions from an aging product dryer through minor modifications. A small adjustment to the angle of the burner fuel injection nozzles created more turbulent flow conditions, improving the mixing of fuel and air and hence, the combustion.

The result has been greater fuel efficiency and a significant reduction in the quantity of carbon monoxide.

Noise and Vibration

Beneficiation processes may generate high levels of noise and vibration, especially during crushing and grinding. Noise pollution has been reduced in many cases by enclosing the plant, retaining suitable buffer zones around the plant site, planting greenbelts and constructing earth bunds. Some of these measures also assist in reducing the visual impact of the site.

Resource Maximization

The efficiency of resource recovery influences the environmental impact of other activities such as extraction or waste disposal.

Product loss during beneficiation through the loss of ore to waste streams, dust emissions and process spillages results in both an economic loss as well as the need to extract and process additional ore to meet demand. An example of this is the fine particles of phosphate that are lost to waste, as they cannot be efficiently separated.

Ultra-Fine Phosphate Recovery

In Brazil, the Tapira mining complex and Uberaba fertilizer complex operated by Fertilizantes Fosfatados SA (Fosfertil) are expanding production. A component of this is the implementation of a process to recover the ultra-fine phosphate previously lost to the clay tailings. The system will use column flotation cells to recover around 200,000 tonnes of ultra-fine phosphate rock per year. This ultra-fine product will be used to produce single super-phosphate (SSP) fertilizer.

Recovery of the ultra-fine phosphate rock has provided an additional source of revenue for the company, enhancing its competitiveness in the market place. Environmental benefits are derived from greater recovery of the resource and consequently, a minor reduction in the waste volume generated.

Spillage of ore and concentrated product may occur during beneficiation, prevention or recovery of these can assist maximizing the resource.

Product Spillage Recovery

In South Africa, Foskor has been using hand shovels and wheelbarrows to recover small amounts of spillage associated with the loading of phosphate rock concentrate into rail cars. Approximately 20,000 tonnes of product were recovered in one year providing a significant saving.

Phosphate rock and potash minerals are frequently found in association with a variety of other minerals that may have an economic value if recovered and separated.

Salt is commonly found either in association with potash ore, or as separate salt orebodies, adjacent to or near the potash orebody. Many operations recover salt for purposes such as industrial grade salt or road de-icing.

Complex potash ores frequently occur in association with magnesium chloride. The potential exists for the magnesium to be separated and converted into a variety of magnesium products.

Igneous phosphate deposits are frequently associated with a variety of minerals such as: niobium, titanium, zirconium, baddeleyite and copper. In many instances these are recovered and marketed.

Recovery of these products could assist the economics of the operation by creating additional revenue streams. An environmental benefit arises by meeting some of society's demand for certain minerals without disturbing additional land area.

Maximizing Resources Through the Recovery of Co-products

In Jordan, the Arab Potash Company produces potash fertilizer from carnallite ore precipitated through solar evaporation of the Dead Sea brines. In conjunction with this operation, the brine resource is also used to produce:

- Industrial and table salt from the halite precipitated in the initial series of evaporation ponds;
- Raw materials for the cosmetic industry.

Planning and construction are underway to produce magnesium oxide, bromine, chlorine, caustic potash and other derivatives. Further into the future, projects aim to produce potassium nitrate and upgrade the magnesium oxide to magnesium metal.

The development of these associated co-products up to commercial production permits synergies while maximizing the use of the available resource.

Although the life of reserves of phosphate rock and potash ore vary depending on factors such as the production cost, market prices and technological development, the total available resources are finite in the long term. Currently, extraction and beneficiation have been focused on the easily recovered, higher grade minerals. There exists a wide range of more complex, lower grade minerals that could have an increasingly important role in the future for the production of mineral fertilizers. Research is being carried out to develop beneficiation techniques that can handle the complex mineralogy and contaminants of these materials and bring these potential resources into commercial production. These will help to extend the supply of mineral fertilizers as far into the future as possible.

Removal of Dolomite Contamination in Phosphate Rock Ore

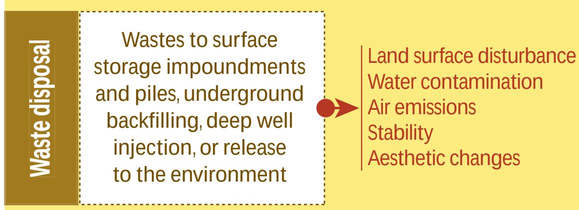
In Florida (USA), The Florida Institute of Phosphate Research has been involved in research into methods to separate dolomite from phosphate rock. The dolomite increases the consumption of acid during processing. A new flotation technique has been tested. Commercial application of this technique would allow phosphate orebodies with a high dolomite content in the central western Florida area to be mined, extending the life of the resource.

3.6 Waste Management and Disposal

The beneficiation of phosphate rock and potash typically produces large volumes of waste that may cause a variety of adverse environmental effects if not managed and disposed of in a safe, stable and environmentally sound manner.

Figure 3.6.1

Potential environmental effects : waste disposal



Major environmental concerns are typically related to:

- Land surface disturbance from the construction and operation of large waste disposal impoundments such as dams, ponds and stacks;
- Surface and ground water contamination by wastes such as fines, tailings effluents and brines;
- The safety and stability of the storage facility. Failure can result in extensive and widespread off-site effects.

Other impacts may include: wind-generated dust from fines tailings; adverse effects on wildlife; and the visual disturbance resulting from large elevated dams or tailings stacks.

Waste Disposal Methods

A wide variety of waste disposal methods are employed, including:

- Discharge of wastes to rivers and oceans. This may be accompanied by treatment to remove contaminants;
- Stacking wastes such as sand tailings and salt tailings in piles;
- Retention of wastes such as brines, sand tailings, magnetite tailings, clays and process water in dams or ponds for storage, settling and clarification;
- Backfilling of solid and liquid wastes into mined-out underground openings;
- Deep well injection of brines.

The methods used at a specific location are influenced by the characteristics of the waste and the site, and the regulating requirements.

In some instances, liquid wastes such as brines, tailings, effluent or clay fines have been discharged to rivers or oceans. This may be done in a controlled manner using monitoring systems to ensure that levels of contaminants do not rise above prescribed levels and threaten the aquatic ecosystem. Treatment of phosphate rock tailings effluent improves the quality of the release.

Riverine Brine Disposal

Kali und Salz GmbH operate three potash operations in the Werra region of Germany: Hattorf; Unterbreizbach; and Wintershall. The operations extract a complex mineralized ore 'Hartsalz', that consists of a mixture of sylvinite, carnallite, kieserite, and halite from a deeply buried potash deposit.

The ore is beneficiated using both dry electrostatic separation and wet thermal dissolution separation processes to produce a variety of potassium and magnesium products. For each tonne of ore beneficiated, 22% becomes product, while 78% becomes waste. The waste consists predominantly of salt tailings and magnesium chloride ($MgCl_2$) brines. The process employed allows the salt to be largely separated dry from potash, producing dry salt tailings. On the other hand, magnesium chloride can only be separated from the potash in solution. This results in significant quantities of brine being produced.

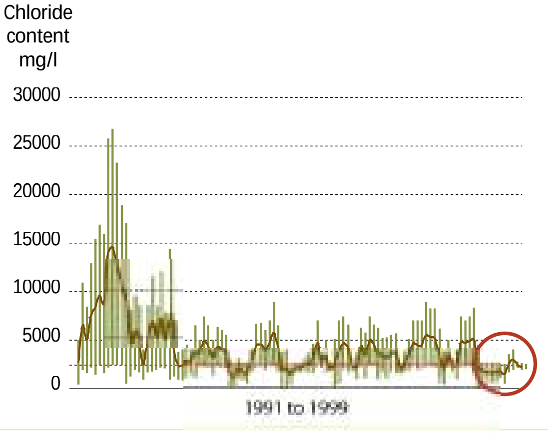
The salt tailings are generally conveyed to a salt stack on the surface for disposal. Some salt tailings are used to backfill carnallite rooms produced at the Unterbreizbach underground mining operation. Brines are disposed of by either deep well injection into a suitable pervious dolomite formation or discharged to the Werra and Ulster river system.

Brine waste produced at each beneficiation plant is pumped to a series of lined retention ponds from which discharge occurs to the river system. The discharge is monitored and controlled using a computer system to ensure that the permitted salt concentration of 2.5 grams per litre of river water is not exceeded as the river conditions and flow rate vary.

The system prevents adverse effects on the aquatic ecosystem downstream.

Figure 3.6.2

Control of salt concentration in Werra River. Kali und Salz GmbH, Germany.



Brine retention ponds for controlled release to Werra River - Kali und Salz GmbH, Germany

Stacking salt tailings - Kali und Salz GmbH, Zielitz, Germany

Pond receiving slimes and brine from the stack - Potash Corporation of Saskatchewan (PCS), Canada

Discharge into clay settling pond (note dragline in back-ground) - Cargill Fertilizers Inc., USA

Magnetite tailings dam - Fosfertil, Brazil

Deep well injection of brines - Kali und Salz GmbH, Germany

Deep well injection of brines - Potash Corporation of Saskatchewan (PCS), Canada

Surface Disposal of Potash Waste

In Saskatchewan, Canada the salt tailings, insolubles and brines are typically disposed of to a salt tailings pile as a slurry. The insolubles and brine drain to the settling ponds at the base of the pile. The brine is then either recirculated to the process or disposed of through deep well re-injection to suitable geological formations.

In Germany, dry separation processes allow dry disposal on a salt tailings pile. The salt tails are stacked using a conveyor and spreader system that allows steeper, higher stacking than wet stacking.

Industry research in Canada is currently focusing on higher salt tailings piles that allow more waste to be accommodated within the same footprint. This has been driven by regulations on the expansion of waste disposal facilities. This technique also reduces surface-to-volume ratio, and fewer brines are produced by precipitation.

Salt tailings pile - Potash Corporation of Saskatchewan (PCS), Canada

Dry salt tailings pile - Kali und Salz GmbH, Germany

In many cases, engineered surface containment methods such as stacks (or piles), dams and ponds are used to contain liquid and solid wastes. This involves an integrated system comprising engineered impoundments, walls, containment dykes, liners, drains, ditches and capture wells. These confine any adverse environmental effects of the waste to a limited area, while providing a high degree of management control. Stacking may reduce the area of land disturbed.

Backfilling of waste into underground openings produced during extraction of the ore is conducted at a few operations. When feasible, this provides a safe and secure long-term disposal method.

The technical feasibility of backfilling flat-lying orebodies has been studied through large scale trials. However, its wider adoption has been hindered by a number of factors including the difficulty of placement, safety concerns, and the cost.

Currently, the cost of backfilling flat-lying orebodies may be a factor of 10 higher than surface disposal methods.

Safety concerns arise from the placement of unconsolidated waste into underground workings that experience rapid convergence. If not restrained by a bulkhead of suitable strength it will be squeezed into the adjacent open workings, endangering the workforce. Alternatives such as converting the salt tailings to paste fill are being explored.

Deep well injection is used to dispose of brines at operations where suitable, confined permeable geological strata are available.

Converting waste to an environmentally benign form reduces the difficulty and cost of disposal. In certain instances, there is also potential for creating a saleable by-product.

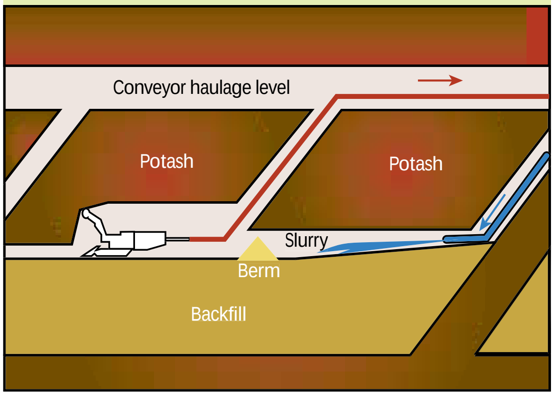
Integrated Underground Disposal of Potash Wastes

The Potash Corporation of Saskatchewan (PCS) New Brunswick Division is located in Eastern Canada. The operation consists of an underground mining operation utilizing shaft access with surface processing and storage facilities. Production capacity is around 770,000 tonnes of potassium chloride and 650,000 tonnes of rock salt per year.

The folded potash orebody is extracted using a cut and fill method while the salt is extracted using a multi-level room and pillar method. All mining is conducted with continuous mining machines.

Figure 3.6.3

Potash stope long-section showing extraction and backfilling methodology. IMC Potash, Canada.



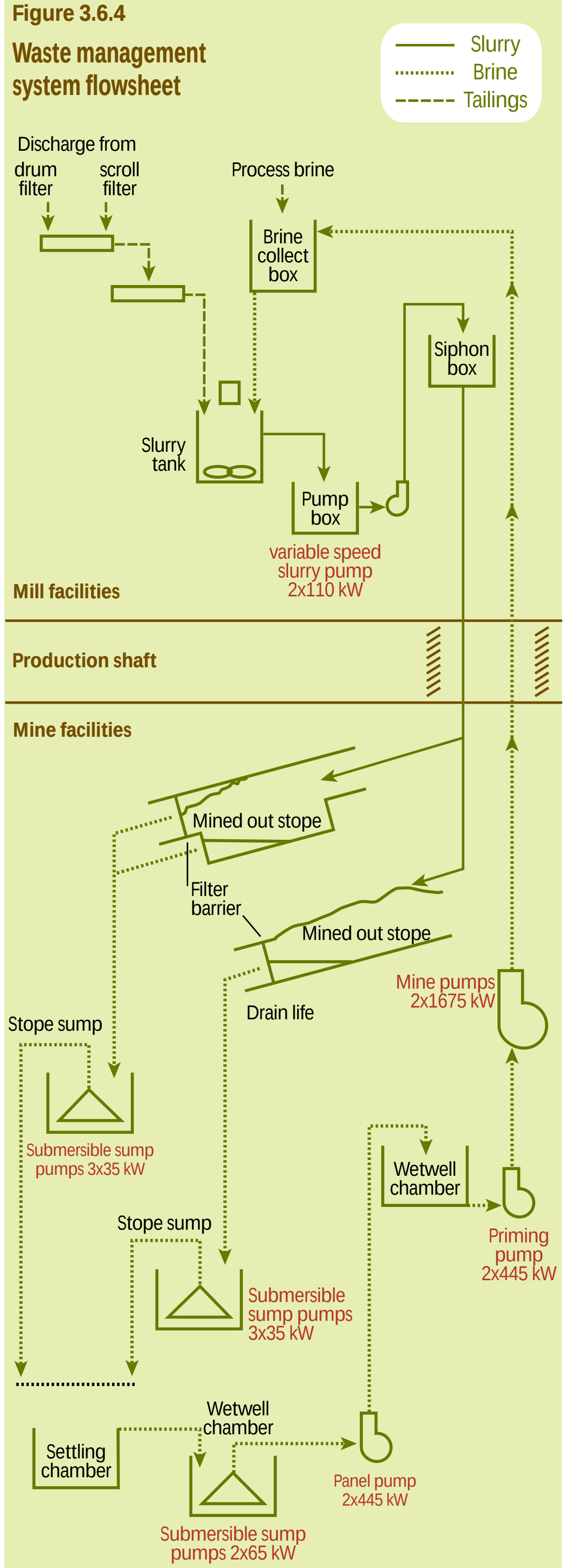
The operation employs effective and environmentally sound waste management by returning all waste to the underground workings. The development of this closed system has been driven by provincial regulations that prevent the deposition of waste on the surface. The approach relies on the extraction of the salt (for use as road salt) to create sufficient storage space underground to accommodate the potash wastes and has also been influenced by the lack of a suitable geological formation in the region to inject waste brines.

Beneficiation of the potash ore produces three major waste streams: salt tailings, slimes and brine. The salt ore is of high quality and produces little waste.

Salt tailings from the beneficiation plant are used as fill in the potash cut and fill stopes. They are transferred to the underground workings through a pipeline down one shaft. The tailings are conveyed from the base of the shaft to the vicinity of the mining operations from where they are placed into the stope either by conveyor or pipeline.

Figure 3.6.4

Waste management system flowsheet



Source : Pollution Control in Fertilizer Production

The waste slimes and brine are transferred underground through a slurry pipeline and discharged to the excavated salt rooms. Generally, two or three salt rooms are filled simultaneously. Deposition and settling of the slimes occurs in one room, while the clarified brine overflows into the second and/or third.

The clarified brine is recovered from the salt rooms and returned to the processing plant where it is evaporated to produce both a fresh water condensate, and a concentrated brine. The fresh water condensate is used largely as an input to the process with excess released through the holding pond. The concentrated brine is returned to the crystallization circuit for recovery of residual potassium chloride.

The water balance of the operation is essentially closed. Water released from the site is related to either on-site rain or snowfall or the excess fresh water condensate from the processing facility. Both of these sources are retained in a continuously monitored holding pond prior to release to the local river.

The adoption of the closed circuit waste loop, demonstrates some of the benefits that arise from an effective pollution prevention program. The potential sources of pollution in the form of the three major waste streams have been integrated into the mining process. The salt tailings have become an essential component of the cut and fill mining method, recycling of the brines has increased product recovery and eliminated the need for contaminated discharges, and the slimes and some brine are effectively disposed of in the salt rooms.

The major environmental benefit of the approach is the small surface impact of the operation. The lack of any surface salt tailings stack, slime and brine ponds has reduced the potential for surface environmental impacts to negligible levels.

The approach does incur an additional cost in comparison to conventional surface waste disposal methods. In the case of the New Brunswick operation, this has been partially offset by greater recovery of the potash ore resource, lower product transportation costs due to the operations location with respect to markets and a potentially a lower future rehabilitation cost during operation closure.

Treatment of the Clay Fines to Remove Salts

The IMC Potash Colonsay operation in Saskatchewan, Canada is developing a process to remove salt and brines from the clay slimes waste. Removal of the salt allows the insolubles to be disposed of without special precautions.

The process involves a number of steps:

- Separation of the slime component by thickening to remove brine;
- Washing of the slimes with water to dissolve any residual salt;
- Cycloning to remove brine;
- Filtering with the addition of fresh water to produce a relatively dry, desalinated product.

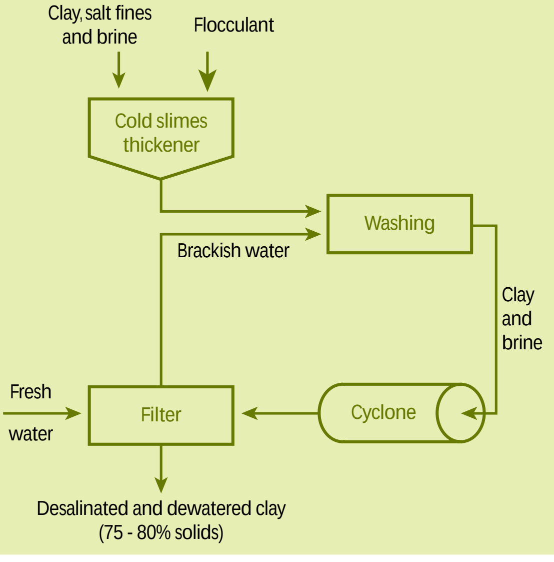
The filtered slurry forms small, stable, agglomerated particles, facilitating handling and reducing the likelihood of dust problems.

Results from earlier trials are being used to improve the process.

This method removes the need for large areas to be set aside for clay slimes settling ponds. The slimes are instead converted into an environmentally benign, easily disposed product that may possibly be sold as a clay substitute for brick and pottery or a water retention amendment for sandy soils.

Figure 3.6.5

Flowsheet of the slimes desalination and dewatering process. IMC Potash, Canada.



Water Management and Treatment

The Foskor Ltd. operation at Phalaborwa is located in the semi-arid northeast of South Africa, adjacent to the Selati River and upstream from the Kruger National Park.

The processing operation uses 250 million litres of water per day, the majority of which is recirculated. Excess water is transferred to the tailings dam before release to the Selati River. The tailings water is high in both total dissolved solids (TDS) and sulfates. The sulfates are largely introduced with tailings sourced from the adjacent Phalaborwa Copper mine, which currently supplies about 40% of the phosphate ore feed for the Foskor beneficiation plant.

Concerns by Kruger National Park management about the potential effect of contaminated water on the downstream aquatic ecosystem led to the implementation of a water treatment system.

After consideration of the most suitable water treatment processes on the market, the 'Paques' process was selected. This bacterial process converts sulfates in the tailings water to sulfur. The sulfur is subsequently recovered and sold to the adjacent fertilizer processing complex for use in the production of sulfuric acid.

The process is used to treat about 40 to 50 mega-litres per day. Monitoring of the release is conducted as part of a comprehensive surface and ground water monitoring system for the site that includes biological monitoring points located on the Selati River.

The water treatment system protects the downstream aquatic ecosystem and the natural values of the Kruger National Park. Additionally, the sulfur by-product can be sold to recover a portion of the operating costs.

Selati River flowing adjacent to the tailings dam - Foskor Ltd, South Africa

Water Contamination

Surface and ground water contamination may occur through the release or seepage of tailings effluent and brines from dams, ponds and stacks. Contaminants might include clay fines, chemical reagents, sulfates, salt and magnesium chloride. In addition, rainfall may dissolve salt tailings or cause erosion and mobilize fines.

Depending on the operation, water releases are required to maintain the water balance of the operations storage facilities. In most countries, this water must meet established water quality standards. To achieve this, excess water is treated through a system of dams and wetlands to clarify and remove contaminants.

Where possible clean water and contaminated water on the mine site are kept separate and handled through different systems, to reduce the quantity of water that must be treated before release.

Aquatic species are sometimes used as an indicator of the performance of the waste management system. Monitoring the biodiversity of aquatic species downstream from release points provides an indicator of environmental response.

The leakage of liquid wastes such as brines from storage and disposal ponds is controlled to a large extent by containment techniques such as plastic or clay liners, ditches, drains and containment pumping wells.

Landscape Disturbance

The construction and operation of surface waste storage facilities typically disturbs a significant area of land. Some operations have reduced the area affected by stacking wastes higher. In other cases, wastes are disposed of to mined-out areas, avoiding impacts on undisturbed areas.

Rehabilitation of disposal areas to mitigate environmental effects is discussed in Sections 3.7 "Closure" and 3.8 "Rehabilitation".

Tailings Stability and Failure

The potential for accidental failure of waste disposal dams and ponds is of concern. This can cause rapid, extensive and widespread impacts on the surrounding environment. The installation of monitoring systems, preparation of emergency response plans and procedures, and the regular auditing of performance assist

Solid Waste Disposal and Water Management System with Performance Feedback

The Tapira mining and beneficiation complex is located in the state of Minas Gerais, Brazil and owned and operated by Fertilizantes Fosfatados S.A. (Fosfertil). Phosphate rock is extracted from an igneous deposit using an open-cut truck and shovel mining method. Annual production is around 11 million tonnes of ore per year. The phosphate ore is concentrated in the beneficiation plant before transport through a slurry pipeline to the Uberaba fertilizer processing complex.

The waste disposal and water management system consists of five dams in total, three of which are used for waste storage and the other two are used to clarify and treat water before release.

The beneficiation wastes (clay fines, sand and magnetite tailings) are disposed of into two valley-style tailings dams, while a small dam is located adjacent to the plant to capture any spills. Clay fines are transported from the beneficiation plant to one of the tailings dam through an 8-kilometre-long open canal flowing under gravity, while the sand and magnetite are disposed of to the other tailings dam.

Effluent releases from the magnetite and sand tailings dam and the plant spillage dam are passed to a clarification dam.

The fresh water dam receives the water releases from the clarification dam and the clay fines tailing dam as well as the natural inflow of the Ribeiro Inferno a local stream. This dam completes the treatment/clarification process before excess water is released to the Rio Araguari, a major regional river. The water quality meets Brazilian water quality standards while the release rate is adjusted to correspond to the normal inflow of the Ribeiro Inferno into the dam.

The company has chosen to locate the fresh water intake for the beneficiation plant at the release point of the fresh water dam. Performance of the beneficiation plant is sensitive to water quality with any deterioration imposing a cost on the company in terms of reduced product recovery.

The water management system lends itself to improved performance through the built-in positive feedback loop. This is consistent with the company's management system that fosters performance improvement by invoking behavioral change. The Fosfertil management system is discussed further in Section 3.9 "Environmental Management".

Dam wall, clay fines tailings - Fosfertil, Brazil

Magnetite tailings dam - Fosfertil, Brazil

in responding to such failures (5). Examples of monitoring and containment systems are presented in Section 3.3 "Extraction" on 'Solution Mining Pump and Pipeline Monitoring and Control System' and 3.4 "Handling" on 'Watershed Protection'.

Other Potential Impacts

Wildlife may be adversely affected by exposure to contaminants in waste. This is especially the case with aquatic species that are sensitive to elevated contaminant levels. In some situations, water birds may be susceptible to entrapment on brine ponds due to salting of their feathers. A variety of techniques have been used to discourage them landing on brine ponds, including horns, gas, noise cannons and airboats.

Windblown dust or the erosion of fines from waste disposal stacks and dams can be controlled to some extent by stabilization techniques similar to that discussed in Section 3.3 "Extraction". These include: covering with topsoil followed by revegetation, mulching with organic material, spraying bonding agents on the surface, or maintaining elevated water levels in dams.

(5) Further information is available from other UNEP publications on talings management and emergency preparedness and response. These are listed in Appendix A.

Tailings Dam Audit Program

The Catalão phosphate rock mining and beneficiation complex in the state of Goiás, Brazil is owned and operated by Copebras S.A., part of the Anglo American Corporation of South Africa group.

The operation deposits phosphate and magnetite tailings streams in a conventional valley style tailings dam. The dam wall has been constructed from compacted clay and coarse phosphate tailings.

The dam is inspected about once a year, as part of an ongoing monitoring and audit program. The inspection encompasses the general condition of the dam and associated infrastructure, including the dam wall, decant facilities, slurry delivery and deposition and monitoring piezometers. Information is documented in a comprehensive report with numerous photographs to illustrate the current state of the facility.

The annual inspection and review complements the daily monitoring and supervision of the facility by providing a check on performance and identifying and proposing remedial actions for longer term issues. This is supported by numerical evaluations using monitoring data to confirm the continued structural integrity of the dam wall.

Water release quality is evaluated twice a year (dry and wet seasons) as part of the regular surface and ground water monitoring program for the entire complex. This program includes an analysis of the pond water, seepage from the tailings dam and any effects on surrounding groundwater.

The annual monitoring and audit program facilitates informed management of the tailings disposal facility and reduces the risk of failure.

Tailings dam, wall in distance - Copebras S.A., Brazil

Tailings dam seepage water release - Copebras S.A., Brazil

Wind-blown Tailings Dust Control

In South Africa, Foskor Ltd. has controlled windblown dust by ploughing furrows in the surface of dry tailings, perpendicular to the prevailing wind direction. The furrows create eddies that trap dust particles mobilized by the wind reducing air pollution.

Furrows in dry tailings - Foskor Ltd, South Africa

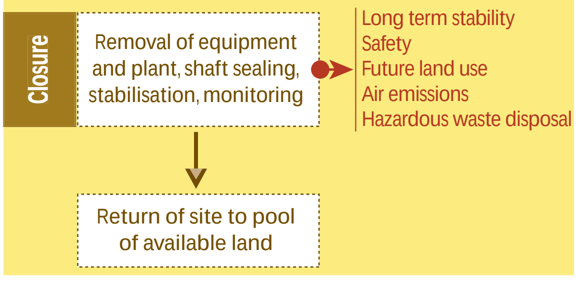
3.7 Mine Closure

Mine closure activities occur on cessation of mining and beneficiation activities, following the exhaustion of the ore reserve. The aim focus of mine closure is to leave the mine site in a stable and safe condition. This involves:

- Finalizing rehabilitation that commenced earlier in the mine life;
- Rehabilitation and other activities such as sealing shafts and removing plant and equipment that could not be removed until after mining and beneficiation were completed;
- Monitoring the keep of rehabilitation and closure activities in the long term;
- Rehabilitation is generally conducted progressively throughout the mine life, as discussed in detail in the next section;
- Social impacts on the workforce and on the community, associated with the closure of an operation, may be complex. They are important but fall outside the scope of the present publication.

Figure 3.7.1

Potential environmental effects : closure



Monitoring

Ongoing monitoring and management is important to satisfy local communities, government agencies and other stakeholders, that the agreed post-mining land use has been established. Once verified, the site may be returned to the pool of available land.

Financial Surety

Governments increasingly move towards securing adequate financial provisions to deal with closure liabilities associated with mining operations. Environmental financial sureties are one of the mechanisms that governments have adopted to ensure that companies meet closure liabilities.

Various forms of financial surety instruments have been applied in different jurisdictions. Instruments that leave the funds available for use by the company may include:

- Self-funding through financial reserves;
- Balance sheet tests;
- Asset pledges to government in the event of default;
- Parent company guarantees.

More commonly, governments require that producers set aside financial resources. These instruments may include:

- Cash deposits with government institutions;
- Trust funds;
- Financial institution guarantees such as performance bonds and letters of credit.

Mine Closure Case Study

In view of the large reserves and extended life of most phosphate rock and potash mining operations, there are few experiences of mine closure in the fertilizer raw material mining industry to learn from and provide guidance.

The MDPA potash operation in France has been developing and implementing plans as it approaches closure.

3.8 Rehabilitation

Rehabilitation activities generally involve the design and creation of stable and safe landforms, followed by the establishment of self-sustaining ecosystems to replace those disturbed during the mining process. The effectiveness of rehabilitation is enhanced by integration with the mine plan and conducting it progressively throughout the life of the mine. The objectives of rehabilitation can range through a spectrum of:

- Complete restoration of the areas original natural values;
- Reclamation to re-establish the pre-mining land use;
- Development of a completely new land use for the area, such as lakes, forestry or agriculture;
- Leaving land of marginal value in a safe and stable condition.

In some countries, the post-mining land use is determined through discussion and consultation with stakeholders, such as state and local government agen-

Environmental Financial Sureties: South African and Australian Cases

In **South Africa**, financial provisions for closure have been required since 1994. Four types of financial surety are currently permitted:

- A dedicated trust fund;
- A cash deposit to an account with the Department of Minerals and Energy;
- A guarantee from a financial institution;
- Other arrangements approved by the Director General of the Department of Minerals and Energy.

Trust funds are the most common instrument adopted by larger companies, both because of the greater in-house financial management resources, and the tax advantages offered. Contributions are spread evenly over the life of mine with the financial liability assessed on an annual basis. Allowances are made for new disturbance and rehabilitation activities conducted during the period.

The financial provision system is currently being reviewed through ongoing discussion between government and industry. Several additional financial surety methods are being proposed, such as parent company guarantees and the use of insurance policies. A means of recognizing and providing credit for previous good performance is also proposed.

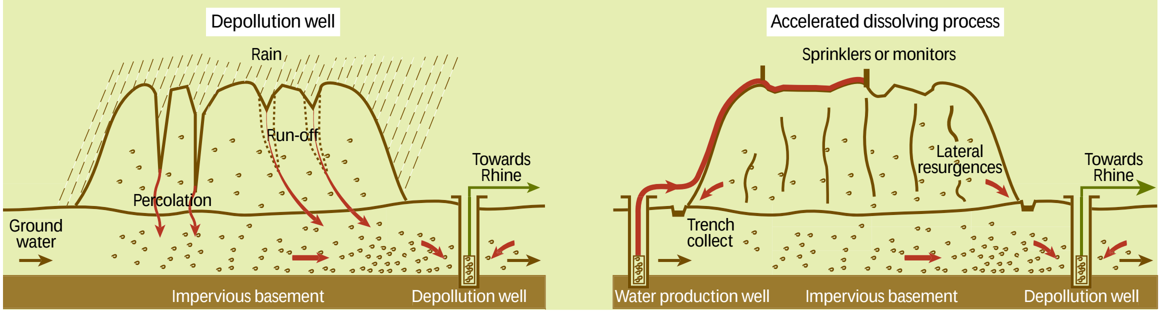
The Phalaborwa operation of Foskor Limited has established a trust fund to satisfy the environmental financial provision requirements. The fund is registered with the government, but operated by the company. Contributions to the fund are determined by the quantity of production and made on a monthly basis, with regular audits conducted by financial advisers. When the company wishes to use some of the funds for the purpose of rehabilitation, a proposal must be submitted for government approval.

In **Australia,** WMC Resources Ltd. owns and operates the Phosphate Hill phosphate rock operation in the State of Queensland. The state government requires the lodging of financial assurances to guarantee conduct of the rehabilitation plan as outlined in the Environmental Management Overview Strategy (EMOS), prepared in accordance with regulatory requirements. The amount is based on the maximum cost of rehabilitating the net disturbance of the lease during the life of the current plan of operations, reduced by a discount for past good environmental performance. This discount can vary from 15 to 75%, creating an incentive for good performance by companies demonstrating their environmental credentials through past behavior.

Closure of the Mines de Potasse d'Alsace (MDPA) Operations

Figure 3.7.1

Waste piles dissolution schematic. MDPA, France.



Mines de Potasse d'Alsace (MDPA) currently operates the Amelie underground potash mine and processing plant and the Marie-Louise underground mine near Mulhouse in northeast France.

Mining of the potash orebodies in the region began in 1910. The workforce peaked in 1965 at around 14,000 and dropped to 1,300 by mid 2000. The number of operating mines and plants has fallen similarly, and at present two mines and one plant are in operation. The ore deposit is approaching exhaustion, with completion of mining anticipated by 2003. Planning and preparation for this eventuality began a number of years back.

The long potash mining history of the region has left a legacy of challenges. Closure planning and preparation has focused on:

- Rehabilitation of the surface waste piles (referred to as terrils);
- Remediation of the salt-contaminated surface aquifer;
- Removal of decommissioned plant, equipment and materials;
- Creation of alternative employment for the workforce and community.

The major environmental issue revolves around the waste piles dumped adjacent to the beneficiation plants prior to 1934. These were placed without liners or other containment features. Subsequent dissolution of the salt by rain has contaminated the underlying aquifer giving rise to plumes of salt contamination down flow from the piles. Rehabilitation activities have focused on both removing the source of the pollution (the waste piles) as well as reducing the level of salt contamination in the groundwater.

Seventeen salt piles covering an area of 220 hectares are to be rehabilitated. Two methods are currently used to rehabilitate them. One involves reshaping the piles, capping them with plastic, clay or bituminous liners to isolate the waste from the rain, then covering with a growing medium and revegetation with grasses.

The other method involves accelerating the dissolution of the salt component of the pile using fresh water. The resulting brines are discharged in a controlled manner to the adjacent Rhine River, while the insoluble clay residue piles are reshaped and revegetated. Both these methods are intended to prevent any further contamination of the groundwater.

The existing salt contaminated groundwater is contained and remediated by a de-pollution pumping program. A series of wells have been drilled at the downflow from each of the piles. Pumping from these wells both restricts further contamination of the aquifer by salt, while providing the processing operations with a source of industrial water.

The former mine land is being converted mainly to industrial use following removal of unwanted plant, equipment and infrastructure.

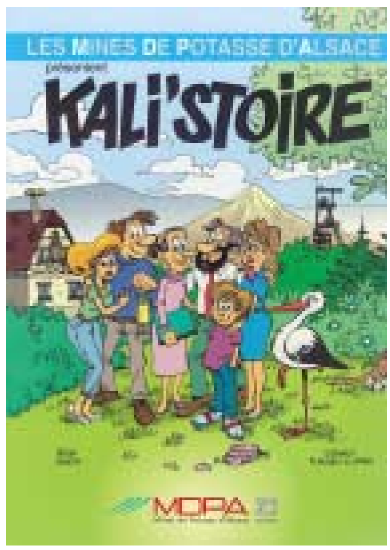
Shaped and revegetated terrils - MDPA, France. 0329

Incentives have been provided for the creation of new businesses with an emphasis on small and medium size enterprises. A number of the old mine buildings are being refurbished to provide space to house some of these new enterprises.

Training is provided to interested employees to allow them to develop their own businesses or prepare for work in a new industry.

Besides, a hazardous waste management company has begun operation, using underground openings created by mining rock salt for long-term storage of hazardous waste.

Communication with employees and the community on the closure plans and activities has been important in alleviating concerns. An interesting method that has been used to assist this process is the publishing of a comic book story on the MDPA operation. The story conveys information about the forthcoming closure in a manner and style that is easily understood by all.



'KALI'STOIRE' comic book. - MDPA, France

cies, local communities and private landholders, to develop an appreciation of their needs and desires. Important considerations for decision-making include the climate, topography, soils, pre-mining land use of the site and surrounding areas, legal requirements and the degree of post-closure maintenance and management.

Rehabilitation involves a sequence of activities such as:

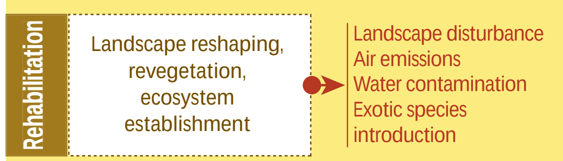
- Topsoil removal and placement;
- Landscaping of disturbed areas;
- Revegetation and reestablishment of the nutrient cycle;
- Wildlife introduction;
- Maintenance of rehabilitated areas;
- Monitoring and determination of rehabilitation success.

These are discussed in greater detail below.

Rehabilitation activities themselves may result in some minor environmental impacts, associated with landscaping and topsoil placement. These could include dust emissions and the erosion of fines from newly disturbed topsoil and overburden, while exotic plant species may be introduced to disturbed areas.

Figure 3.8.1

Potential environmental effects : rehabilitation



Landscaping

Landscaping tends to be associated primarily with surface mining methods and the decommissioning of waste disposal sites. The major objective of landscaping is to leave a stable non-eroding surface. A variety of methods is employed to achieve this, including:

- Using sand tailings to fill in the low areas between dragline overburden spoil piles;
- Shaping the sides of overburden dumps with bulldozers to leave gentle slopes or blend with the natural landscape;
- Leaving berms (narrow benches) on steep slopes such as pit walls or the sides of overburden dumps with a bulldozer;
- Cross-ripping slopes with a bulldozer tine;
- Reestablishing surface drainage systems such as streams.

These methods slow the rate of rainfall run-off and prevent excessive erosion.

Revegetated overburden dump - Fosfertil, Brazil

Placing topsoil on dam wall - Foskor Ltd, South Africa

Post-mining Landform Reshaping with Phosphate Clay Fines

The Khouribga operation operated by Office Chérifien des Phosphates (OCP) in Morocco extracts phosphate rock using large-scale opencast dragline mining method. This method leaves the overburden in steep spoil piles.

A new method has been implemented for the disposal of phosphate clay fines in the low areas between the spoil piles. This technique creates a more stable post-mining landform as well as providing a better growing medium for vegetation.

The new disposal method reduces the water consumed during slurrying and disposal of the fines. Water consumption is of particular significance as the operation is located in an arid environment with water sourced from limited ground water supplies 90 kilometres away. The cost of disposal is also reduced compared with the previous method.

Landscape after extraction of ore - Office Chérifien des Phosphates, Morocco

Landscape around the mine - Office Chérifien des Phosphates, Morocco

Pit Wall Erosion Control

Heavy weathering of the overburden and orebody at the Catalão phosphate rock mine of Copebras S.A. means the pit walls are extremely prone to erosion creating concern about the stability of the 80 metre high final pit walls. The company has implemented a number of measures in response.

Temporary internal pit walls are designed and excavated to a steeper overall slope. As excavation occurs against the designed pit limits, the pit wall slopes are flattened to enhance long-term stability. Final pit walls are designed with an overall slope of 34o, consisting of five metre wide catch berms placed every five metres vertically, with an intervening wall slope of 60o. The catch berms are sloped back into the pit wall to capture any rainfall and prevent erosion of the pit wall by run-off. Excess water collecting on the berms is transferred to the bottom of the pit through a series of pipe drains constructed from 44-gallon drums welded together. The berms are vegetated to enhance stability.

The approach leaves a final pit wall that resists the erosion effects of rainfall, enhancing establishment of vegetation and long-term stability.

Final pit wall with drains - Copebras S.A., Brazil

Vegetated pit wall - Copebras S.A., Brazil

Beneficiation waste disposal impoundments, dams, and ponds may contain materials that may present an ongoing threat to the environment if not rehabilitated effectively.

At some operations, the clay fines generated during beneficiation of phosphate rock are drained and allowed to consolidate. Landscaping is required to establish suitable drainage. The clay fines may be suitable for conversion to agricultural land due to the elevated phosphate levels and good water retention properties, grassland or forest.

Potash salt tailings present an ongoing issue due to the potential for dissolution of the salt by rain. In response to this, a number of rehabilitation methods have been implemented including dissolution of the salt, disposal of the resulting brines and capping of the salt pile with impermeable layers.

Commonly, the surface of shafts are capped to prevent humans or wildlife falling into them. In potash mines, shafts are sealed just above the orebody to prevent water from overlying aquifers entering, dissolving ore, and presenting a future water contamination issue.

Sealing of Decommissioned Shafts

Kali und Salz GmbH in Germany has conducted research into the sealing of disused potash mine shafts, in partnership with a local University. The purpose of the shaft sealing is to prevent water from entering the orebody and dissolving salts from the evaporite beds. If this occurs the overlying aquifers may become contaminated with salt.

Research has focused on the use of bentonite clay plugs placed in the shaft above the evaporite horizons. Water coming into contact with the bentonite will cause it to swell, sealing any possible paths of ingress.

Revegetation

Revegetation is typically conducted to stabilize the disturbed areas and prevent wind and water erosion. This can vary from planting or seeding with a single grass species, conversion to agricultural or forestry purposes, through to the establishment of quite complex ecosystems involving upland forests, grasslands and wetlands. Where natural ecosystems are being re-established, native species tend to be used, but faster growing non-native grass species are sometimes used

Capping Salt Tailings Pile with Demolition Rubble

The Kali und Salz GmbH former Fredrickshall operation is located near Hannover in northwest Germany. The relatively small salt tailings pile, containing 11 million tonnes of salt and kieserite, closed in 1978. Rehabilitation of the pile by capping with demolition rubble, commenced in 1997, using a patented method.

Capping is conducted using inert demolition rubble from the city of Hannover, 25 kilometres away. The rubble is delivered to a waste management station located adjacent to the stack where it is weighed and visually inspected. Sampling occurs at regular intervals to check for potential contaminants that could present an environmental hazard. Any metal is removed and the rubble is crushed and sorted by coarseness. A portion of the aggregate is suitable for resale to be used in new civil construction activities.

Capping of the salt tailings pile is conducted by placing the coarse fraction adjacent to the salt to create a capillary break and drainage layer followed by the placement of the fine fraction on the outside. The capping is designed to leave a stable final slope and requires the placement of material in a layer from 1 to 30 metres thick. After capping is completed, a 3 metre thick layer of soil will be placed on the outside as a growing medium for revegetation.

The rate of capping is limited by the supply of demolition rubble. At current levels of supply the capping is expected to be completed in 30 years. Monitoring of the capped areas has indicated that capillary action is affecting only the first 10 to 20 centimetres of overlying material.

This capping method appears to provide an effective means of isolating salt tailings from the external environment. Additional benefits arise from the recovery of formerly landfilled urban waste for use as both a salt stack capping material and a raw material for new construction. This extends the life of the city's landfill.

Sorting and crushing demolition rubble - Kali und Salz GmbH, Germany

Placing rubble against salt pile - Kali und Salz GmbH, Germany

to quickly stabilize the surface and allow the establishment and succession of other slower growing species.

Topsoil cover provides a suitable growing medium on the tailings.

A number of companies have conducted trials to determine the viability of sealing the surface of potash salt tailings piles, to isolate the salt from the environment, allow vegetation to be established and leave a stable landform. Typically, techniques employed use an impermeable layer to isolate the salt tailings from the environment, followed by placement of a growing medium above. The impermeable sealing layer is important to prevent water percolating through and dissolving the salt, leading to the loss of foundations and collapse of the sealing layer and growing medium. A variety of sealing layers have been used including: coarse aggregates to prevent capillary action drawing the salt upwards to the surface and impermeable barriers such as a plastic liner, bitumen, or cement.

The growing medium is placed on top of the sealing layer to allow revegetation and prevent erosion. In some instances temporary stabilization techniques, such as geofabric, may be applied until the vegetation has established.

Conversion of the post-mining land use to agriculture or other purposes would require trials to select species best suited to the environment and growing medium.

Revegetation of Magnetite Tailings

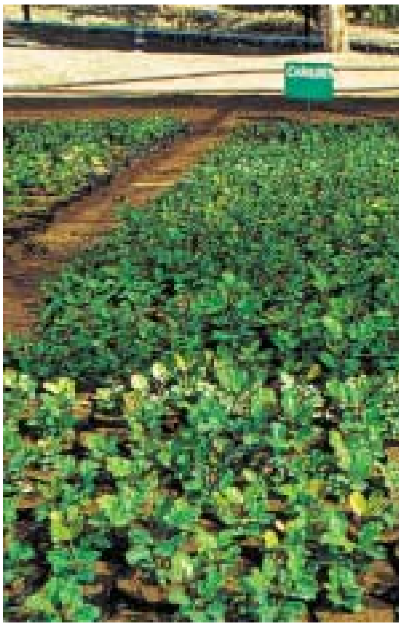
In Brazil and South Africa, magnetite tailings generated during the beneficiation of phosphate rock have been rehabilitated by covering with a suitable growing medium and revegetating with grasses and trees.

The magnetite tailings present a potentially valuable future resource of iron.

Vegetated magnetite tailings - Copebras S.A., Brazil

Revegetation of magnetite tailings - Foskor Ltd, South Africa

Large Scale Tree Plantations



Nursery - Office Chérifien des Phosphates, Morocco

The Office Chérifien des Phosphates (OCP) Khouribga mining and beneficiation operation in Morocco uses opencast dragline methods to extract ore from below 20 to 30 metres of overburden. In 1995 an extensive tree planting program in mined lands and surrounding areas began.

Around 150,000 trees of various species were planted during 2000, with plans to increase this to around 300,000 per year. Seedlings are transplanted to areas surrounding the mining and beneficiation operations and the overburden spoil piles. Regular watering in this arid environment is needed during the first year to ensure rooting.

The tree-planting program has been implemented at the OCP Benguerir and Youssofia operations in a similar manner. Benefits, apart from visual aesthetics, include the creation of a wood and animal feed source in an area largely devoid of trees as well as a potential future food and cash resource from olive, carob and citrus production. Since the program was initiated there have been observable positive changes in the local microclimate and increased sightings of fauna species, formerly rare to the areas, in the new habitat.

Tree plantation adjacent to mine - Office Chérifien des Phosphates, Morocco

3.9 Environmental Management

Environmental management is an activity that is ongoing throughout the entire mining life cycle, from initial exploration to the final closure of the operation and handing over of the site. It encompasses and influences all the different activities of the mining life cycle and is most effective when integrated with the day-to-day management and planning of the operation. Environmental management consists of systems, procedures, practices and technologies that vary depending on the specific characteristics of the surrounding ecosystem, the legal framework and the mining methods and beneficiation processes employed.

As appreciation of the complexity of environmental considerations has grown, a variety of management tools have been developed to assist companies better control the effects of their operations and provide a higher level of environment protection. These tools include: environmental management systems (EMS); environmental impact assessment (EIA); environmental technology assessment (EnTA); environmental auditing; life cycle assessment (LCA); cleaner production and environmental reporting (6).

Recent developments such as LCA and cleaner production have adopted a more holistic, pollution prevention, approach to environmental issues. They look at the life of a product or service to determine where the greatest impacts may occur and then where and how the most effective action, in terms of cost and results, can be taken to prevent the impact to potentially occurring. These tools assist management by providing information to improve decision-making. Their effectiveness depends in a large part on the commitment and motivation of management and the workforce.

Amongst other things, better environmental management contributes to:

- Prevention of problems;
- Identification and implementation of effective solutions to environmental issues;
- Compliance with environmental legislation; regulations and standards;
- Engagement of and improved relations with stakeholders such as employees, community, regulatory agencies and customers;
- Greater control by management of the company's activities.

(6) Additional information on environmental management tools is available from the UNEP, UNIDO and IFA Technical Report on "Fertilizer Production and the Environment", Part 2: Environmental Management Systems and a variety of other publications by UNEP.

This section provides an indication of some of the approaches being taken by the phosphate rock and potash mining industry to provide more effective environmental management.

Corporate Environment Policy

A company's environment policy is a key element of an EMS. This public statement commits management to a set of principles that guide their activities.

Leading companies have moved from an environment-specific focus, to a wider, sustainable development stance, recognizing the integration of economic, environment and social needs.

Environment Policy

WMC have framed their environment policy in terms of sustainable development since 1995.

WMC Environment Policy

The Company is committed to achieving compatibility between economic development and the maintenance of the environment.

It therefore seeks to ensure that, throughout all phases of its activities, WMC personnel and contractors give proper consideration to the care of the flora, fauna, air, land and water, and to the community health and heritage which may be affected by these activities.

To fulfill this commitment, the Company will observe all environmental laws and, consistent with the principles of sustainable development, will:

- Progressively establish and maintain company-wide environmental standards for our operations throughout the world;
- Integrate environmental factors into planning and operational decisions and processes;
- Assess the potential environmental effects of our activities, and regularly monitor and audit our environmental performance;
- Continually improve our environmental performance, including reducing the effect of emissions, developing opportunities for recycling, and more efficiently using energy, water and other resources;
- Rehabilitate the environment affected by our activities;
- Conserve important populations of flora and fauna that may be affected by our activities;
- Promote environmental awareness among Company personnel and contractors to increase understanding of environmental matters.

Source: WMC Environment Report 1996.

Environmental Management Systems

The ISO 14000 Environmental Management system and the European Union Eco-management and Audit Scheme (EMAS) standards provide widely recognized frameworks and guidelines that companies can use to develop their own environmental management systems. These are third-party certified, providing a means by which the company can demonstrate its commitment to improved environmental performance.

Many phosphate rock and potash mining companies are looking at the ISO 14000 standards to guide the development of systems that are specific to their needs.

Quality management systems are more prevalent than environmental management systems. Adoption of these has been assisted by perceived greater benefits in terms of improved product quality and consistency and greater recognition in the market place. Even though not specifically orientated to environmental performance, systems such as the ISO 9000 Quality Management series tend to produce environmental benefits from an improvement in the overall performance of the operation. In many cases companies have found such systems to be an excellent foundation upon which to build an environmental management system.

Recognition of the growing importance of environmental management systems is evident in a number of countries including many developing countries, where producers understand the competitive advantage of meeting the increasing demands of consumer markets such as the European Union and Japan.

Environmental Best Practice Guidelines

Best practice guidelines provide a valuable source of information to help companies to develop and implement appropriate systems, practices and technologies. These are based on the experience of others, increasing the learning curve and reducing time and cost.

Though the guidelines may have been developed for other countries or regions and different minerals, the similarity of the mining processes and their potential environmental effects means that they are applicable to many operations.

Environmental Impact Study and Management System

Industries Chimiques du Sénégal, (ICS) is the owner of a phosphate rock mine with a yearly production capacity of 2 million tonnes and phosphoric acid plants with a yearly capacity of 330,000 tonnes P_2O_5. Two large projects were initiated by ICS in 1996:

- Opening the Tobène panel mine at the end of the Keur Mor FALL panel;
- Doubling the phosphoric acid production capacity.

An environmental impact study was carried in October 1997. The study concerned the existing and future installations. The main objectives were to:

- Describe how the environment is likely to be affected by these projects;
- Examine the potential impact of the projects on the environment and provide information on their nature and the extent;
- Describe preventative measures for protection of the environment;
- Evaluate the socio-economic impacts.

The conclusions of the impact study allowed ICS to establish an Environmental Management System in the context of ISO 14001.

Source: D. Fam, M. Bocoum, IFA Technical Conference, New Orleans, USA, October 2000.

Management System Certification

In Jordan, the Jordan Phosphate Mines Company Ltd. has attained ISO 14000 Environmental Management System and ISO 9000 Quality Assurance certification for part of their operation, soon to be all. The Arab Potash Company Limited has implemented a certified ISO 9002 Quality Management system and is in the process of developing a certified ISO14000 Environmental Management System for its Dead Sea solar evaporation operations. Both of the companies acknowledge the performance improvement that comes from the implementation of these systems and see the benefits these systems will offer in increasingly more demanding consumer markets.

Fosfertil Program 5S

In Brazil, Fosfatados Fertilizantes SA (Fosfertil) adopted the "Program 5S" quality management system in 1995.

The system, that originated in Japan, is based on the five principles of:

- Seiri - Sense of selection;
- Seiton - Sense of tidiness;
- Seisou - Sense of cleanliness;
- Seiketsu - Sense of health;
- Shitsuke - Sense of self-discipline.

Objectives are:

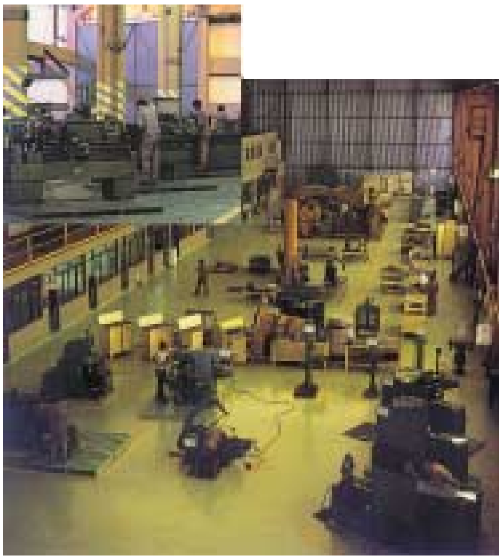
- Improving the work environment;
- Preventing accidents;
- Providing incentives for creativity;
- Eliminating waste;
- Promoting team-work;
- Improving the quality of services and products.

These are accomplished by changing behaviors at all levels of the company to improve the working environment and welfare and the quality of products and services.

Continuous improvement of the system is an important aspect. Regular internal auditing of the system's performance is conducted in each section of the company, with the results posted in prominent positions throughout the sites.

The performance of the system is visible; all workplaces are typically ordered, neat and clean. Safety has benefited; the company has won the Brazilian mining safety award for seven years running. Additionally, the economic performance of the company has improved in recent years.

The Program 5S has improved the control and management of all aspects of the organization, in turn creating environmental benefits. The system has been acknowledged as important to attaining ISO 9002 Quality Management certification and has created a strong foundation for gaining ISO 14001 Environmental Management certification.



Equipment workshop, Tapira mine - Fosfertil, Brazil

Rating of company sections - Fosfertil, Brazil

The "Best Practice Environmental Management in Mining" Modules

Environment Australia publishes a valuable source of environmental management information through the "Best Practice Environmental Management in Mining" modules. Each module collects and presents information on a specific aspect of environmental management relevant to the mining industry. The modules are illustrated with examples of current best practice that are practical and cost-effective. A wide variety of modules are available, including:

- Mine Planning for Environment Protection;
- Rehabilitation and Revegetation;
- Landform design for Rehabilitation;
- Hazardous Materials Management, Storage and Disposal;
- Cleaner Production;
- Environmental Management Systems;
- Environmental Auditing.

Though orientated to the Australian mining industry the topics, principles and case studies have relevance to all areas of the fertilizer raw material mining industry worldwide.

Front cover of the Environment Australia 'Best Practice Environmental Management in Mining - Mine Planning for Environment Protection' module.

Issue Specific Guidelines

At times, specialized guidelines may need to be developed for issues specific to a single operation or regions. One such example is provided by the development of guidelines to mitigate the selenium contamination issue in southeast Idaho (USA). These have been documented in a comprehensive manual, 'Best Management Practices Guidance Manual for Active and Future Phosphate Mines: Southeast Idaho Phosphate Resource Area Selenium Project'.

The guidelines have been developed in response to the selenium contamination of downstream waterways and vegetation from current and historic phosphate mining operations in southeast Idaho. The selenium is released by weathering of shale excavated during phosphate rock mining. The issue was first identified in 1996 when a number of livestock were diagnosed with chronic selenosis. Subsequent investigation identified the mining operations as the source of the problem and regulatory agencies required corrective measures.

The guidelines present both tested and experimental methods for the control of selenium release and encompass practices related to mine planning, waste rock management, water management, soil stabilization, revegetation and livestock range management. They are regarded as a 'work in progress' with performance monitoring a key feature to ascertain their effectiveness and refine techniques.

A stakeholder-inclusive process was used to develop the guidelines that involved representatives from the phosphate mining companies, federal, state and local government agencies and the Shoshone-Bannock Tribe.

Front cover of the 'Best Management Practice Guidance Manual for Active and Future Phosphate Mines' - Agrium Conda Phosphate Operation, USA.

Environmental Reporting

Increasingly, importance is placed on the value of open and transparent communication of a company's environmental (and social) performance with stakeholders. Stakeholders can be internal to the company, such as employees and shareholders, or external such as adjacent landholders, local communities, elected officials, government and NGO's. The purpose of communication is to inform of potential effects, create awareness of the operations activities and receive comments and input from the various stakeholders. Development of a good relationship with stakeholders reduces disruptions and increases tolerance in the event of unplanned occurrences or accidents.

A method of conveying information to stakeholders is through public environmental reporting. This is emphasized through inclusion in voluntary industry codes of practice such as the '*Australian Mineral Industry Code for Environmental Management*' and voluntary initiatives such as '*The Global Reporting Initiative*'.

Standards for environmental reporting have been developed by a number of groups. Work is currently underway to develop reporting elements for the mining industry. These can be used as a framework by companies to develop their own customized reporting system.

A variety of less formal and structured methods exist to keep stakeholders informed, including: magazines, newsletters, open days, workforce meetings, public meetings and school or community group involvement in rehabilitation activities.

Mine "open days" are effective in raising the awareness of the mining process and activities amongst employees' families and the general community. These provide a valuable mechanism to communicate the environmental practices and technologies that have been put in place, showcase rehabilitation that may have occurred and build rapport with the community.

Involving schools and clubs in rehabilitation activities such as tree planting can extend awareness raising. This has been employed successfully at operations in the USA and Brazil.

Environmental Reporting Review and Commentary

The World Wide Fund for Nature (WWF) Australia is conducting annual reviews of the quality of public environmental reports released by companies signatory to the *Australian Mineral Industry Code for Environmental Management*. They see the importance environmental reporting has in communicating environmental and social performance to stakeholders.

Reports are assessed against nine performance indicators. These have been selected to assist stakeholders use environmental reports as a tool for assessing the environmental and social performance of the company. They believe that environmental reports should reflect the company's performance, define goals, address stakeholder concerns arising from operations and provide independent verification of the contents.

WWF emphasizes the importance of external third party verification for stakeholders to assess the report contents and the company's performance.

The Global Reporting Initiative (GRI)

The GRI was established in 1997 by UNEP and the Coalition for Environmentally Responsible Economies (CERES) to encourage the wider adoption globally of public sustainability reporting, including environmental, and social as well as the more traditional financial aspects. Other stakeholders actively participate.

The initiative is working to improve the standard of sustainability reporting to a level comparable with current financial reporting practices and develop and disseminate standardized reporting practices and measurement indicators to enhance comparability between different companies reports.

The reporting framework is documented in 'Sustainability Reporting Guidelines' that have been developed with stakeholder input. The framework allows stakeholders to gauge progress and organizations to benchmark and identify best practices, enhancing the move of society towards sustainable development.

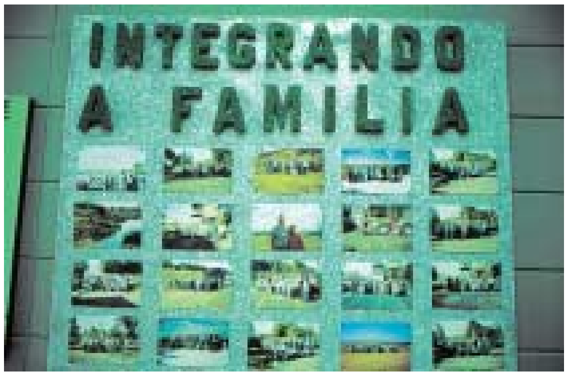
Information on the GRI is available at the Website: http://www.globalreporting.org.

Magazines and Newsletters

IMC Phosphate in Florida (USA) publishes the 'Phosphator' magazine on a monthly basis for its employees and other stakeholders. A wide range of articles on the activities of IMC Phosphate are featured. Environmental matters are dealt with in a regular column, 'The Green Piece', or by feature articles.

IMC 'Phosphator' magazine - IMC Phosphate, USA

Office Chérifien des Phosphates in Morocco publish a company newsletter, "P_2O_5" on a regular basis. In June 2000, a special edition was published to communicate to the workforce information on the company's recent voluntary adoption of the "Responsible Care" program.



Notice board at the Tapira mining complex, displaying photographs taken during family open days - Fosfertil, Brazil

4. Emerging Environmental Issues and Trends

The environmental performance of the fertilizer raw material mining industry has improved over recent decades, as has that of other industry sectors. Significant causes include:

- Growing public awareness of environmental issues;
- Greater appreciation by companies of the environmental issues;
- Increasing regulation;
- Scientific and technical progress that permits resolution of some of the issues;
- Technological developments that improve environmental performance as a by-product of better efficiency.

Today information is available much more easily than in the past, through media such as the Internet, while the understanding of the issues and of the underlying problems and linkages continues to progress.

A number of emerging issues and trends may affect the industry in coming years, including:

- Consumers as a political and economic force;
- The public's demand for accountability and transparency across the board, for both businesses and government;
- Sensitivities about globalization;
- A multidisciplinary approach to resolving issues
- Ongoing public debate on what constitutes sustainability and good environmental performance;
- Increasingly stringent expectations of environmental performance;
- Scrutiny of business at a local and international level.

As community awareness has grown, demands on industry have increased accordingly. In many countries, both industry and governments are becoming more accountable for the decisions and actions they take. This is partly because of the increased availability of information concerning their actions and more stakeholder involvement in the decision-making process. The general public increasingly demands involvement in decision-making on issues that affect them. This was evident in a variety of situations at the operations visited in preparation of the present report. Likewise the public is requiring companies to demonstrate their environmental (and social) performance. This requires an effective monitoring system to measure the impacts of a company's activities and often a reporting system to communicate their achievements to stakeholders. External, third party verification increases the plausibility of company statements and provides stakeholders with an independent assurance.

A number of fertilizer mining companies are signatories to voluntary codes of practice such as the chemical industry's Responsible Care® program or The Australian Mining Industry Code for Environmental Management. These codes implicitly recognize the importance of monitoring and reporting. An independent international mining certification system to assess environmental management performance is an option to secure environmental accountability.

In future, community concerns may shift away from a focus on environmental damage at the mine site to the need to balance competing demands for limited natural resources such as fresh water and agricultural land. The mining industry, as a consumer of natural resources, will not be isolated from these pressures. Foresight and the adoption of adequate and effective solutions to arising issues will assist the industry's response.

Governments are responding to community pressure through new legislation. The European Union's Integrated Product policy is one such response. Policy implementation will lead to increasing producer responsibility for their products. It will also increase the use of market instruments to internalize the external environmental costs of products over their entire life cycle. This responsibility will concern not only companies' own activities but also those of their suppliers, transporters and service providers.

What should companies do in order to meet these current and future challenges?

Several approaches to environmental issues are reviewed in Part 2 of the IFA/UNEP/UNIDO publication entitled “Environmental Management Systems”(7). Topics discussed include:

- Compliance with the ISO 9000 and ISO 14000 series of standards;
- Environmental impact, risk and life cycle assessments;

(7) See Appendix A for reference.

- Monitoring and incident reporting;
- Corporate environmental reporting;
- Integrated pollution prevention and control;
- Voluntary initiatives;
- Cleaner production.

This publication draws attention to the importance of preventative, rather than remedial action in order to reduce the potentially environmental impacts of company activities. The publication also argues that a comprehensive environmental management system can be of intrinsic value to the company. New approaches are likely to be developed in the future.

The present publication has explored a variety of approaches and techniques being used by the fertilizer raw material mining industry in response to environmental issues. In many instances, new technologies and practices have been developed or applied to resolve specific problems. In others, the implementation of new management systems has improved environmental performance - in many cases with economic benefit - through a better understanding of the environmental causes and effects.

Companies are starting to perceive marketing and even economic advantages from the implementation of such systems. This trend is expected to continue as consumer awareness and demands for improved industry performance grow and government legislation evolve to reflect this. Markets are becoming more discriminating; environmental and “ethical” investment funds have been established; and some financial institutions are beginning to examine a company's environmental performance when making loan assessments.

Many complex issues face the mining industry and these are best tackled using a multidisciplinary approach. Achieving a balance between the environmental, economic, and social needs of society is important if development is to be sustainable. This is most effective when a long-term perspective is adopted. The life-cycle approach used to structure this publication demonstrates one method of examining the impact of companies' activities and products as a whole. A variety of strategies and tools, such as cleaner production, life cycle analysis and industrial ecology have been developed to assist management for this purpose.

The mining life-cycle approach highlights the importance of planning, environmental management and rehabilitation from the outset and throughout the life of the mine. This fosters a preventative approach, allowing:

- Identification of potentially adverse environmental effects;
- Implementation of plans, systems, procedures and practices to avoid or mitigate potentially adverse impact;
- Detection of variance from plans by monitoring environmental performance.

Communication and dissemination of information within and between companies through means such as newsletters, workshops and conferences are important to continually improve environmental performance.

A particular characteristic of the mining industry is the need to anticipate when the economic ore reserve will be depleted and the operation will close. The site must be left in a safe and stable form, allowing it to be returned to the pool of land available for society. The closure and rehabilitation of sites needs to be planned from the outset, not left for future generations. Many governments now require, or are examining, financial provisions for mine closure to be set aside by companies during its operations to avoid environmental liabilities being handed over to the community.

How can industry associations facilitate improved performance? Encouragement and support from industry associations and companies can assist the fertilizer mining industry in its response to future challenges.

They can:

- Provide leadership;
- Assemble and communicate information on good practices, new developments and trends that may affect the industry, through means such as conferences, workshops, and publications;
- Develop guidelines on good practices;
- Encourage the adoption of voluntary codes to foster continued improvement.

Appendix A. Selected References and Reading Resources

Environment Australia (Various years) *Best Practice Environmental Management in Mining. (Various titles)*. Commonwealth of Australia.

ICME/UNEP (1998) *Case Studies on Tailings Management*. UNEP, Paris.

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IFA/UNEP (2000) *Mineral Fertilizer Distribution and the Environment*. IFA, Paris.

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UNEP (1999) *Global Environment Outlook 2000*. Earthscan Publications Ltd, London.

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UNEP/UNIDO/IFA (1998) *Mineral Fertilizer Production and the Environment. Technical Report No. 26*. Part 1. The Fertilizer Industry's Manufacturing Processes and Environmental Issues. UNEP, Paris.

UNEP/UNIDO/IFA (1998) *Mineral Fertilizer Production and the Environment. Technical Report No. 26*. Part 2. Environmental Management Systems. UNEP, Paris.

UNIDO/IFDC (1998) *Fertilizer Manual*. Kluwer Academic Publishers, The Netherlands.

Appendix B. Illustrated Examples Contact Information

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Fax: +1 208 5472550
Email: jgoode@agrium.com
Web: www.agrium.com

Arab Potash Company Ltd (APC)
P.O. Box 1470
Amman 11118
Jordan
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Email: apc@go.com.jo
Web: www.arabpotash.com

Cargill Fertilizers Inc.
8813 Highway 41
South Riverview
Florida 33569
United States of America
Tel: +1 800 237 2024
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Copebras S.A.
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Bartow
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Fax: +1 (863) 534 7165
Web: www.fipr.state.fl.us

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Fax: +27 15 7892070
Email: grobbels.msmail@foskor.co.za
Web: www.foskor.co.za

IFDC - Africa
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Lome
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Tel: +228 217971
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Email: ifdctogo@cafe.tg
Web: www.ifdc.org

IMC Phosphate
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Mulberry
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United States of America
Tel: +1 863 42 825 00
Web: www.imc.com

IMC Potash
Belle-Plaine
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Regina,Saskatchewan
54P4L8
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Fax: + 306 345 8211
Web: www.imc.com

ICS - Industries Chimiques du Sénégal
19, rue Parchappe
B.P. 1713
Dakar
Senegal
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Fax: +221 8 231256

Jordan Phosphate Mines Co.
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Web: www.jpmc-jordan.com

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Fax: +49 561 9301 1753
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Web: www.k-plus-s.com

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Fax: +33 3 89266293
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Web: www.groupe-emc.com/Portail/filiales/MDPA/mdpa.shtml

Mississippi Potash, Inc.
P.O. box 101
Carlsbad, NM 88220
505.887.5591 phone
505.887.0705 fax
Web:www.misspotash.com

Mississippi Chemical Corporation
P.O. Box 388
3622 Highway 49 East
Yazoo City, Mississippi 39194-0388
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Fax: +662 746-9158
United States of America
Web: www.misschem.com

OCP - Groupe Office Chérifien des Phosphates
Angle Bd de la Grande Ceinture et
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Morocco
Tel : +212 22 230424
Fax: +212 22 230635
Email: ocp.dc@ocpgroup.ma
Web: www.ocpgroup.com

O.T.P. - Office Togolais des Phosphates
B.P. 379
Lome
Togo
Tel : +228 213901
Fax: +228 217152

Potash Corporation of Saskatchewan (PCS)
New Brunswick Division
P.O. Box 5039
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Fax: +506 433 6617
Web: www.potashcorp.com

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Appendix C. Australian Mining Industry Code for Environmental Management

Secretariat

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Email: environment@minerals.org.au
Web: www.enviro-code.mineral.org.au/

The following is an extract of the Australian Mining Industry Code for Environmental Management:

The principles: Elements and Activites

We, the signatories to the Australian Minerals Industry Code for Environmental Management, commit to progressively implementing the Code by:

1. Accepting Environmental Responsibility for all our Actions

Driving environmentally responsible behaviour throughout the organization by:

- Demonstrating management commitment;
- Allocating clear roles, responsibilities, accountabilities and resources;
- Providing necessary information, performance targets, training, resources and management support;

2. Strengthening our Relationships with the Community

Engaging the community about the environmental performance of our operations by:

- Fostering openness and dialogue with employees and the community;
- Respecting cultural and heritage values and facilitating cross-cultural awareness and understanding;
- Consulting with the community on the environmental consequences of our activities;
- Anticipating and responding to community concerns, aspirations and values regarding our activities;

3. Integrating Environmental Management into the Way we Work

Ensuring environmental management and related social issues are high priorities by:

- Establishing environmental management systems consistent with current standards;
- Incorporating environmental and related social considerations into the business planning process along with conventional economic factors;
- Applying risk management techniques on a site-specific basis to achieve sound environmental outcomes over the life of the project;
- Developing contingency plans to address any residual risk;
- Ensuring resources are adequate to implement the environmental plans during operations and closure.

4. Minimising the Environmental Impacts of our Activities

Responsibly managing immediate and longer-term impacts by:

- Assessing environmental and related community effects before and during exploration and project development;
- Evaluating risks and alternative exploration and mining project concepts, taking into account community views and subsequent land use options;
- Adopting a proactive and cautious approach to environmental risks throughout the life of each operation;
- Applying ecological principles that recognize the importance of biodiversity conservation;
- Planning for closure in the feasibility and design phases of a project and regularly reviewing plans to consider changes in site conditions, technology and community expectations.

5. Encouraging Responsible Production and Use of our Products

Pursuing cost-effective cleaner production and product stewardship by:

- Employing production processes that are efficient in their consumption of energy, materials and natural resources;
- Minimizing wastes through recycling, and by reusing process residues;
- Safely disposing of any residual wastes and process residues;
- Promoting the safe use, handling, recycling and disposal of our products through an understanding of their life cycle.

6. Continually Improving our Environmental Performance

Continually seeking ways to improve our environmental performance by:

- Setting and regularly reviewing environmental performance objectives and targets that build upon regulatory requirements and reinforce policy commitments;
- Monitoring and verifying environmental performance against established criteria so that progress can be measured;
- Benchmarking against industry performance and addressing changing external expectations;
- Researching the environmental aspects of our processes and products and developing better practices and innovative technologies.

7. Communicating our Environmental Performance

Being open and transparent in the effective disclosure of our environmental performance by:

- Identifying interested parties and their information needs;
- Providing timely and relevant information including publication of annual public environment reports on our activities and environmental performance;
- Encouraging external involvement in monitoring, reviewing and verifying our environmental performance;
- Continually reviewing and evaluating the effectiveness of our communications.

Appendix D. Glossary of Fertilizer and Mining Technical Terms

Term	Description
Apatite	$Ca_5(PO_4)_3F$ - A fluorine rock containing calcium phosphate ore, of which there are several varieties, which is the main constituent of phosphate rock.
Berm	Narrow benches excavated into side of pit walls at regular height intervals. They are intended to catch any rocks that may fall from the sides of the pit and present safety hazards to people working below. They may also slow or prevent rainfall run-off preventing erosion.
Bund	Earthen wall constructed to prevent access by people or equipment. They may also be used for reducing noise or the visual impact of the site.
Carnallite	$KCl.MgCl.6H_2O$, Potash ore consisting of potassium chloride and magnesium chloride.
Continuous Mining machine	Mechanized machine that extracts ore in a continuous fashion. Typically they use rotating drums or heads that break the rock loose from the orebody, retrieve it from the floor and load it onto a conveyor or shuttle car.
Crushing	Breaking of the mined ore to finer particles using jaw crushers, cone crushers, etc.
Decline	Underground tunnel that generally descends from the surface to the orebody.
Dewatering	Pumping of groundwater from bores or sumps to keep excavations such as open-cut pits dry.
Grinding	Grinding of the ore particles following crushing to liberate the different minerals using ball mills, rod mills, etc.
Halite	NaCl - Common Salt.
Hydraulic Water Monitor	High pressure, high volume water jet used to break up ore and produce a slurry for pumping.
Kainite	$KCl.MgSO_4.3H_2O$
Kieserite	$MgSO_4.H_2O$
Landform	The shape of the land surface. The landscape or land profile.
Langbeinite	$K_2SO_4.2MgSO_4$
Longwall Mining	Underground mining method that involves progressive shearing of the ore from a long panel. The overburden is allowed to subside in a controlled manner into the resulting void.
Magnetite	Iron oxide (Fe_2O_3) Often associated with phosphate rock deposits of igneous origin.
Ore Horizon	Flat lying orebody.
Orebody	Ore deposit.
Phosphogypsum	Waste produced during the production of phosphoric acid.
Phosphate rock, igneous	Phosphate that originates from volcanic activity.
Phosphate rock, sedimentary	Phosphate that originates mostly from sediments deposited on former ocean beds.

Slimes	Fine insolubles found in potash ores. Generally consists of clay, sand and dolomite.
Slurry	Mixture of solid particles and water that allows pumping through a pipeline.
Stope	Underground opening excavated in the orebody to extract the ore.
Sylvinite	Potash ore consisting of a mixture of Sylvite (KCl) and Halite (NaCl).
Sylvite	Potash ore mineral consisting of potassium chloride (KCl).
Void	Underground opening in orebody after the ore has been extracted.

Appendix E. Acronyms

Acronym	Full Name
Agrium CPO	Agrium Conda Phosphate Operation
APC	Arab Potash Company Ltd
DAP	Di-Ammonium Phosphate fertilizer.
Fosfertil	Fertilizantes Fosfatados S.A.
GMI	Global Mining Initiative
GRI	Global Reporting Initiative
ICME	International Council on Metals and the Environment
IFA	International Fertilizer Industry Association
IFDC	International Fertilizer Development Center
IMC	IMC Global Inc.
JPMC	Jordan Phosphate Mines Co. Ltd
MAP	Mono-Ammonium Phosphate fertilizer
MDPA	Mines de Potasse d'Alsace
MMSD	Mining, Minerals and Sustainable Development project
OCP	Office Chérifien des Phosphates
OTP	Office Togolais des Phosphates
PCS	Potash Corporation of Saskatchewan
SSP	Single Super-Phosphate fertilizer
TSP	Triple Super-Phosphate fertilizer
UNIDO	United Nations Industrial Development Organization
UNEP	United Nations Environment Programme
WMC	Western Mining Corporation
WBCSD	World Business Council for Sustainable Development

Appendix F. Selected Organizations

Australian Mineral Industry Code for Environmental Management

In developing the Australian Minerals Industry Code for Environmental Management, the minerals industry wishes to demonstrate its commitment to excellence in managing the environmental aspects of its operations. The Code provides a framework and is the centrepiece for an ongoing program of continual improvement in environmental management.

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Australian Minerals and Energy Environment Foundation (AMEEF)

The Australian Minerals & Energy Environment Foundation (AMEEF) is an independent, not-for-profit body established in 1991.

AMEEF encourages and celebrates sustainable development in the resources sector by:

- Facilitating dialogue amongst stakeholders;
- Promoting excellence in research, education and training relevant to sustainable development; and
- Recognizing achievements in environmental performance and sustainable development. They publish a series of Best Practice Environmental Management in Mining modules.

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Web: www.ameef.com.au

Global Mining Initiative (GMI)

The Initiative brings together many of the world's largest mining and minerals companies. This leadership exercise aims to ensure that an industry which is essential to the well-being of a changing world is responsive to global needs and challenges.

Global Mining Initiative
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London SW1Y 4LD
Tel: +44 20 7753 2273
Email: contact@globalmining.com
Web: www.globalmining.com

Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI) was established in late 1997 with the mission of developing globally applicable guidelines for reporting on the economic, environmental, and social performance, initially for corporations and eventually for any business, governmental, or non-governmental organization (NGO).

Global Reporting Initiative
11 Arlington Street
Boston, MA 02116
USA
Tel: +1 617 266 9384
Fax: +1 617 267 5400
Email: info@globalreporting.org
Web: www.globalreporting.org

International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from some 130 countries, one from each country.

ISO is a non-governmental organization established in 1947. The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.

ISO's work results in international agreements that are published as International Standards, including ISO

14000 Environmental Management and ISO 9000 Quality Assurance series.

ISO Central Secretariat
International Organization for Standardization (ISO)
1, rue de Varembé, Case postale 56
CH-1211 Geneva 20, Switzerland
Tel: +41 22 749 01 11
Fax: +41 22 733 34 30
Email central@iso.ch
Web: www.iso.ch

Mineral Resources Forum - Environment

The Minerals Resources Forum (MRF) is an Internet framework for international co-ordination on the theme of minerals, metals and sustainable development, bringing together governments, intergovernmental entities, resource companies, and other concerned organizations and civil society.

Web: www.mineralresourcesforum.org/

Mining, Minerals and Sustainable Development

The Mining, Minerals and Sustainable Development Project (MMSD) is an independent two-year project of participatory analysis seeking to understand how the mining and minerals sector can contribute to the global transition to sustainable development. MMSD is a project of the International Institute for Environment and Development (IIED) commissioned by the World Business Council for Sustainable Development (WBCSD).

Mining, Minerals and Sustainable Development
1A Doughty Street,
London WC1N 2PH, United Kingdom
Tel: +44 20 7269-1630
Fax: +44 20 7831-6189
Email: mmsd@iied.org
Web: www.iied.org/mmsd/index.html

Responsible Care

Responsible Care is the worldwide chemical industry's commitment to continual improvement in all aspects of Health, Safety and Environment performance and to openness in communication about its activities and achievements.

National chemical industry associations are responsible for the detailed implementation of Responsible Care in their countries. Each Responsible Care programme now incorporates eight fundamental features. The last feature, verification, was incorporated into the programme in 1996 by the International Council of Chemical Associations (ICCA) which oversees Responsible Care.

The individual countries' Responsible Care programmes are at different stages of development and have diferent emphases.

The location of the ICCA secretariat rotates between members every two years.

Web: www.icca-chem.org

World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development (WBCSD) is a coalition of some 150 international companies united by a shared commitment to sustainable development, i.e. environmental protection, social equity and economic growth. Members are drawn from 30 countries and more than 20 major industrial sectors.

World Business Council for Sustainable Development
4, chemin de Conches
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Web: www.wbcsd.org

World Wide Fund for Nature

WWF's goal is to stop, and eventually reverse, the worsening degradation of the planet's natural environment, and build a future in which humans live in harmony with nature. WWF is working to achieve this goal through:

- preserving genetic, species, and ecosystem diversity;
- ensuring that the use of natural resources is sustainable both now and in the longer term, for the benefit of all life on Earth;
- promoting action to reduce pollution and wasteful consumption to a minimum.

WWF International
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About UNEP - United Nations Environment Programme

UNEP's mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP works closely with stakeholders to provide a common information and knowledge base which assists government and industry in making environmentally sound decisions.

About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics (UNEP DTIE) is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

- are cleaner and safer;
- make efficient use of natural resources;
- ensure adequate management of chemicals;
- incorporate environmental costs; and
- reduce pollution and risks for humans and the environment.

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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About IFA - International Fertilizer Industry Association

IFA, the International Fertilizer Industry Association, comprises around 500 member companies world-wide, in over 80 countries. The membership includes manufacturers of fertilizers, raw material suppliers, regional and national associations, research institutes, traders and engineering companies.

IFA collects, compiles and disseminates information on the production and consumption of fertilizers, and acts as forum for its members and others to meet and address technical, agronomic, supply and environmental issues.

IFA liaises closely with relevant international organizations such as the World Bank, FAO, UNEP and other UN agencies.

IFA's mission

- To promote actively the efficient and responsible use of plant nutrients to maintain and increase agricultural production worldwide in a sustainable manner.
- To improve the operating environment of the fertilizer industry in the spirit of free enterprise and fair trade.
- To collect, compile and disseminate information, and to provide a discussion forum for its members and others on all aspects of the production, distribution and consumption of fertilizers, their intermediates and raw materials.

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UNEP

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