Mining and Environment

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Mining Life Cycle Modelling for Environmental Control and Waste Minimisation

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ABSTRACT: Life cycle assessment methodology has been applied to mineral processing cycles considering as inputs the volume of materials used and the energy consumed in the process to compare the economic benefits and the waste production for different metals. However, a holistic life cycle assessment system for the extractive industries, which accounts for all stages of minerals production, from exploration and development of a mineral deposit to mining, processing, waste disposal, remediation, decommissioning and aftercare has not yet been developed. Currently, a large European Commission funded project is developing an LCA methodology to minimise the "full life-cycle" impact of metalliferous mining projects, adopting an integrated approach to production and process design, and the costs involved. This paper presents the main principles used in designing the mining production and solid waste handling LCA developed in this project. The methodology developed for the life cycle database is illustrated using examples from the model.

1 INTRODUCTION

Notwithstanding their economic importance, the mineral's extraction and processing industries are considered to have significant impacts on the surrounding environment. In recent years modern mines have implemented the best available technology in environmental management and monitoring with a view to control and minimise their impacts on the surrounding environment. In addition, modelling of the monitored parameters has now started to provide scientifically proven indicators about the state of the environment around these operations.

Over the past 20-30 years, life cycle assessment (LCA) has been widely used by many organisations. Beginning in 1990, the Society of Environmental Toxicology and Chemistry (SETAC) and from 1993 the International Standards Organisation (ISO) began promoting consistency in the design of LCA systems. These efforts produced a number of guidelines and draft standards on different aspects of life cycle assessment, with varying degree of success. The development of LCA methodology in Europe has been further promoted by the Society for the Promotion of LCA Development (SPOLD) and a number ot EU initiatives such as the European network for strategic life-cycle assessment research and development (LCANET). In the minerals industry, life cycle assessment has mostly been applied to mineral processing cycles (Pétrie & Clift, 1995; Stewart & Petne, 1997; Hake et al., 1998; Bruch et al., 1995a, b).

The methodological framework of conventional life cycle analysis can be described in four phases: i) goal and scope definitions, ii) inventory analysis, iii) impact assessment and iv) interpretation. However, it is clear that for any product, process or service, in addition to the environmental aspect considered in this conventional LCA framework, there is a strong interaction between the process and scientific development, legislative requirements and most importantly the economical viability of a project. This is particularly true for the minerals industry, which faces a serious challenge in combining good environmental practice and compliance with regulations, with issues of social acceptance in the local communities and financial feasibility.

Conventional life cycle assessment focuses on relative comparisons of whole systems with respect to resource use and emission loadings in relation to defined functional units. This reveals the contrast between LCA and other environmental impact assessment tools (e.g. pollution dispersion models) which work with absolute measures without normalisation by functional units. Additionally, LCA generally has no spatial or temporal resolution (Barnhouse, et al., 1998), so that emissions, wastes and resource use are combined over time and from different sources. Furthermore, environmental processes may display thresholds or non-linear dose-responses, however, LCA generally is based on assumptions that no threshold exists and that a linear response exists between the system loading and the environment (Fava, et al., 1991). Research described in this paper is part of a larger project aiming at addressing these issues:

- by developing a complete LCA framework for a cradle-to-gate assessment of minerals extraction projects,
- by developing a modelling system that will integrate the LCA framework with the quantitative environmental impact assessment models and financial models,
- by accounting for the financial costs and benefits of alternative mining scenarios within the LCA model,
- by accounting for the long-term effects of alternative mining scenarios examined by the LCA model to be developed.

One of the main drivers of the research described in this paper is the fact that an increasing number of new environmental permits issued require the long term monitoring and control of the waste disposal sites, such as tailings dams and waste dumps, after mine closure. In some cases, the specified monitoring period is longer than the productive life of the mining operation itself. Therefore, the main project emphasis is on minimising the waste disposal requirements, through the application of "'design for decommissioning" concept. The partner industrial sites were selected with a view to facilitate the development of a range of case studies, emphasising waste minimisation through engineering design and life cycle modelling. Mining operations considered as the basis for LCA development fall into three categories:

- Greenfield sites where provision for minimising the impact of mining on the environment can be an integral pan of the mine design.
- Redevelopment projects where mine design is constrained by old surface and/or underground operations and their existing impacts.
- Ongoing investments in active operations where fundamental modifications to the existing mine design may not be practical or may even be counterproductive.

2 THE MINING LCA MODEL

The first step in mining LCA model development involved the definition of the system boundaries for the complete system and for the functions of the different sub-systems within the LCA model. The region in which the mining activities take place is considered as the system, which is enclosed by the system boundaries (Fig. 1). The region surrounding these boundaries is the system environment. In relation to the environmental impacts, the life cycle impact assessment (LCIA) system boundaries were defined as the effective impact radius around a minerals extraction operation.

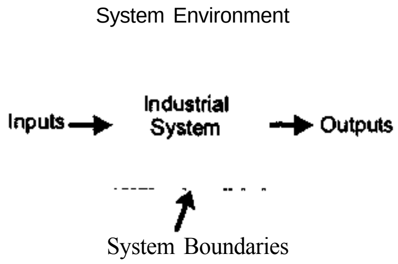


Figure I : Mining LCA system boundaries.

In order to describe the mining system sufficiently, and to include enough detail to enable quantitative assessment of its performance during the modelling stage, the overall system was divided into subsystems (phases) that will be linked to each other by flows in the LCA system. Figure 2 presents the three main subsystems identified: extraction, processing and waste disposal and rehabilitation, as well as the energy, material and emission flows and the waste streams. Special emphasis was given to mapping the waste streams. These subsystems were further broken up to sub-subsystems. During this second classification, three types of subdivisions, meaningful in the way of the stream flow, were identified: *operations, processes* and *activities.* While an operation is a planned action to achieve something in terms of physical changes, a process is a series of actions carried out to achieve a particular result and include chemical changes. An activity only implies 'doing' something. Operations and processes would be relevant when dealing with mass flow, whereas activities would be relevant when dealing with cost flows.

The system was then broken into components such that each subsystem corresponded to a small convenient size function, suitable for the technical, economic and mathematical purposes and needs and for ease of use. This small convenient function will be referred to as a *functional unit.* The mining phases indicated in Figure 2 link with the functional units through the structure: *Phase - Process - Functional Unit.*

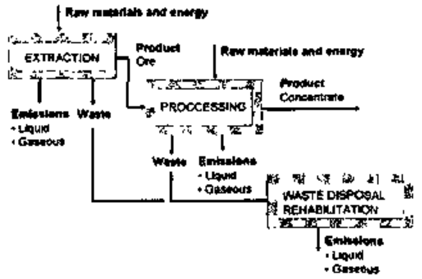


Figure 2: Schematic representation of the Mining LCA system.

Inputs

1. Energy

2. Materials
   a. Main process
   b. Secondary process
   c. Services

3. Costs

Outputs

1. Product

2. Discharges
   a. Emissions to aJr
   b. Effluents to surface waterfgrojjdwator
   c. Solid waste
   d. Energy
   e. Other

Figure 3: The inputs and outputs of functional units.

As a result, once the physical, real life aspects of the mining phases are described, each and every phase can be represented by an appropriate number of unit processes. For every process assigned, the relevant characteristics that define the specific function are attributed to the process as *variables,* which relate to either the inputs or the outputs. The flows of mass, energy and costs are allocated to each process and the relationships between inputs and outputs are identified and described. Figure 3 illustrates the types of inputs and outputs for each functional unit. The variable related to each input and output are generic type variables that may be related to any process, be it extraction, processing, waste disposal and rehabilitation, in the mining life cycle.

Once the functional units were characterised, their inputs and outputs were identified and classified, as illustrated for a rope shovel in Figure 4. Only after this process it is possible to relate the inputs and the outputs and express them as mathematical functions of quantities that may be modelled. The tabulated example in Table 1 illustrates the above concepts for a functional unit from the production operations, namely a truck, which transports the extracted ore to the process phase. The truck in this example uses diesel fuel and the emissions to the atmosphere due to combustion are considered as environmental outputs.

A functional unit was also declared in terms of the product for each subsystem. Thus the functional unit for the extraction system was chosen to be one tonne of dry ore extracted, while the functional unit for the mineral processing system was one tonne of concentrate produced. The extraction and mineral processing functional units are related as a mass fraction ratio.

The definition of such functional units for the waste disposal subsystem was a more complex issue. It was decided that for the backfill plant, the functional unit should be 1 tonne of backfilling material, while for the water treatment plant the functional unit would be 1 Mm^1 of treated effluent discharged.

2.1 Mining LCA inventory system

The structure of the system developed was reviewed and revised a number of times in order to organise, manage and utilise most efficiently the information required to describe all the phases, processes and functional units within the mining LCA system. The inventory system analysis work carried out led to the decision to structure the database in specialised compartments. This structure was designed to enable faster data access and update capabilities for the detailed models, while providing the platform for the LCA model.

Functional Unit: **Rope shovel**

CHARACTERISTICS
Dimensions ? units
Life span: ? years

INPUTS
Energy
Type Electric
Power requirement 500 kW
Material
Type ROCK
Volume 20 cubic yards
Costs
Type Purchase
Price 3 700 000 €
Type Spare parts
Costl 25 91 €/hr
Type Maintenance labour
Cost2 21 59€/hr
Type Electric power
Cost3 29 64 Ohr
Type Lubncants
Cost4 10 57€/hr
Type Operator wage
Costs 23 18€/hr
Other Freight and installation
Cost6 *1*

OUTPUTS
Products
Type Rock
Volume 20 cubic yards
Discharges
Air emissions Airborne particles
Composition Silica
Concentration 2 000 mg/mVhr
Max Permitted level
Potential impact Hazardous to health
CAS 7 631-86-9
Ld50
NIOSH TWA 6 mg/m'

Ftguie 4- Chaiactenslics. inputs and outputs of the 'rope shovel' functional unit.

Table 1: 'Truck' as a functional unit and associations amongst the relevant defining variables.

TRUCK	Description	**Formula**	Units
Inputs			
Energy	due to fuel	Eji$_{ese}$| = f (Truck_power_requirements. time) E	kW
Ma.\.	of ore to transport	More = f (Truck_capacity)	tonne
	of consumed fuel	Mdiesel = f (Mass_consumed_per_unit_time)	1
Ca.\t.	of machine	^machine = depreciation + maintenance + consumables + interest	**e**
Outputs '>			
Protlui t.	mass of transported ire	"lore = ^{M}ore	tonne
Dı.\ıharge.\ tıs emissions to the atmosphere	mass of naphthalene	^{m}nanhthalene = ^{f}\ (Mjiesel- truck_engine_efficiency)	g/m'
	mass of benzene	'"benzene $^=$ *2 (Mdiesel- truck_engine_efficiency)	g/m'
	mass of ethyl-benzene	'"edivl-benzene = *h* (Mdieseb truck_engine_efficiency)	g/m'
	mass of toluene	'"Minene = f4 (Mdiesel. truck_engine_efficiency)	g/m'
	mass of xylene	'"xylene = fs (Mdiesel. lruck_engine_efficiency)	g/m'
	mass of SO$_x$ (and/or N„ CO. CO?)	'"gas = ffi (Mdiesel- truck_engme_efficiency)	g/m'

As described earlier, the mining LCA system was divided into three phases (mine production, processing, waste disposal and rehabilitation) reflecting the types of operations, processes and activities in each phase. The waste composition, structure and the volume generated from processing are largely influenced by the ore mineralogy, the physical and chemical processes used and the reagents consumed. On the other hand, the type and amount of waste generated from mine production is influenced by the geological setting which would also dictate the choice of suitable mining method to extract a specific ore deposit. In terms of the mining methods available, the two broad categories considered are surface mining and underground mining. Their use and the choice of a specific production technique depends, to a great extent, on the deposit type.

The volume and complexity of the information required to design and populate the mining LCA inventory system necessitated that each of the three main subsystems is first studied separately. The design process followed for each subsystem was essentially the same as described in the previous section. The first step was to create the conceptual framework, break down the system into components, then identify activity functions and finally assign material, energy and emission flows according to each function. Tables 2-3 illustrate some of the subsystems/sub-activities defined for surface mining production phase and for waste disposal and rehabilitation phase for a surface mining operation respectively.

Two inventory forms were created for the extraction subsystem based on the detailed system structure, one for surface and one for underground mines. The inventory forms were populated with information provided by industrial partners of the project and from the literature. The LCA inventory database was designed following a hybrid format under the object-relational model. The backbone of the database consists of six object tables designed to store technical information regarding:

- the geological setting (depth, geometry, etc)
- inputs (primary supplies, energy, etc)
- outputs (amount and composition of solid waste, effluents etc).

Table 2 Sub-systems/sub-activities defined lll surface mining production phase

Surface mining production phase

Geological settings	***Pre-production work subsystems sub-activities***	***Production work subsystems /sub-activities***
• Deposu ch.ır.ıcterısııcs • Ore/counhy rock strength • Ore tonnage and grade	• Site clearing (removal of vegetation, levelling ot land) • Construction of access roads • Construction ot surface infrnstruclures (buildings, waste disposal facilities) • Surveying • Primary supply need • Personnel requirement during preproduction • Pre-pioduction scheduling	• Dense vegetation removal • Cyclic overburden removal • Drilling • Blasting • Loading • Cyclic ore extraction • Drilling • Blasting • Loading • ln-pit crushing and material transport • Auxiliary operations • Pit dewalenng • Dust suppression

Table .V Sub-systems/sub-activities defined in the waste disposal and rehabilitation phase for a surface mining operation.

Waste disposal phase	**Rehabilitation and maintenance phase**
Solid waste disposal sub'Systems/sub-activüies	*Mine rehabilitation and maintenance sub-systems/sub-activities*
• Top soil storage	• Site reclamation
• Overburden and mine ladings disposal	• Demolition and salvage of surface infrastructures
• Aggregate processing	• Backfilling and grading of spoil
• Primary supply need	• Revegetation of the mine site including waste disposal sites
• Personnel requirement	• Monitoring
	• Air quality
	• Groundwater quality
	• Surface water quality
	• Soil and herbage quality
	• Primary supply need
	• Personnel requirement

The object tables were developed in Oracle Release 2 (8.1.6) for Windows NT. The methodology used to create the LCA model object tables is as follows:

1. Entities and entity relationships were identified; the main entities became objects, and the entity relationships became references. All main entities were complex object types, therefore simple object types were identified as building blocks for each complex object type.
2. The simple object types were defined for each complex object type. Then, a set of attributes for each simple object type was specified.
3. According to the level of dependency, the object types were used to create object tables, nested tables or object referred tables.

Table 4: Primary supplies values inserted in the relevant nested table for the production subsystem.

Daily supply requirement	Quantity	Cost. (C/hr)
Diesel fuel	1,470 l/day	0 65
Electricity	160 I/day	0 08
Bulk ANFO	890 kg/day	100
Caps	72 units/day	0 20
Detonation cord	730 units/day	0.20
Drill bits	1.4 units/day	0 10

Once the object tables are created, values were inserted into object tables, nested tables and referred object tables, as instances of specific objects. Table 4 illustrates an example of the values inserted in a nested table, which stores information relevant to primary supplies. The relationship among entities was tested, through SQL (Structural Query Language) queries. The objective of such queries was to navigate through the whole data structure and test reference links, object availability, access time and abstraction conceptualisation. Finally, data in the object tables were allocated to parameters and used to perform calculations, using PL/SQL (Procedural Language extensions to SQL).

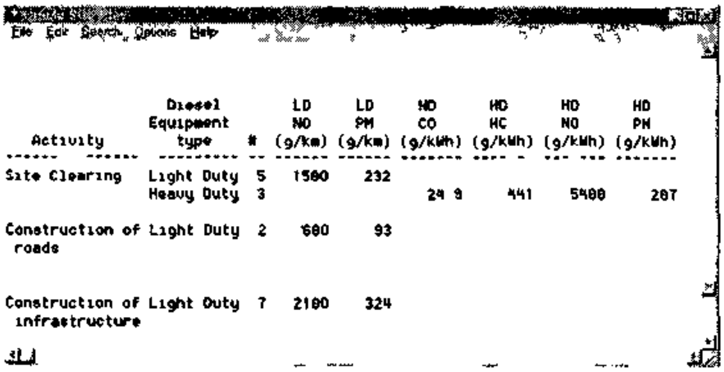
The database was designed to provide calculation methods for variables required to run the LCA model. These procedures were coded as subprograms together with the relevant object table and can calculate, for example, the amount and composition of waste, blasting fumes and gaseous emissions from fuel combustion to compliment the available data in assessing a mining scenario.

Table 5 presents the object-relational representation of the sub-activity object table. For example, in the case of gaseous emissions, the equations developed by the European Programme on Emissions, Fuel and Engine Technologies (EPEFE) research programme (Camarsa, 1996) were used to estimate the volume of exhaust emissions from vehicles used in a mining system. The EPEFE equations combine both engine technology and fuel properties and cover gasoline, light duty (LD) and heavy-duty (HD) diesel. The example in Figure 5 illustrates the output of the relevant calculations in the LCA model developed.

Table *5:* Object-relational representation of the sub-activity object table

Subactno	Subactivityname	Startmgdate	Duration	Machineuntts_ntab	Prjmarysupplyunits_ntab	Contractorcost	A£tmty_ref
NUMBER **(•1,0)**	**VARCHAR ßS)**	**DATE**	**NUMBER** *(1.1)*	NESTED TABLE Machınelınk_ntalıtyp	NESTED TABLE Supplieslmk_ntabtyp	NUMBER	**REFERENCES** **Acf«rcty_objtyp**
PK							FK

```
MEMBER FUNTION Macmne_gaieoiM_emission(Gasa!k VARCHAR2) RETURN NUMBER
MEMBER FUNTION Bla«ina_PM.suet(Choict NUMBER) RETURN NUMBER
MEMBER FUNTION Total_SuspeniiedJ˃arMUates(Event NATURAL, Parameterl NATURAL. Parameter! NATURAL Parameter NATURAL)
  RETURN NUMBER
MEMBER FUNTION PMJ0(Event NATURAL. Parameterl NATURAL. Parameter NATURAL. Parameters NATURAL) RETURN NUMBER
MEMBER FUNTION C02_Blastmg(E!tplosive NATURALN) RETURN NUMBER
MEMBER FUNTION Bla«Ms_fumes(Fumein NATURALN, Watercon NUMBER, Fuelcon NUMBER) RETURN NUMBER
```



```
                   Diesel          LD      LD      HD      HD      HD      HD
                   Equipment       NO      PM      CO      HC      NO      PM
   Activity          type     #  (g/km) (g/km) (g/kWh) (g/kWh) (g/kWh) (g/kWh)
------   -----   --------- -- ------ ------ ------- ---- -  --- --- -------
Site Clearing    Light Duty  5   1500     232
                 Heavy Duty  3                    24 9     441    5400     207

Construction of Light Duty  2    600      93
 roads


Construction of Light Duty  7   2100     324
 infrastructure
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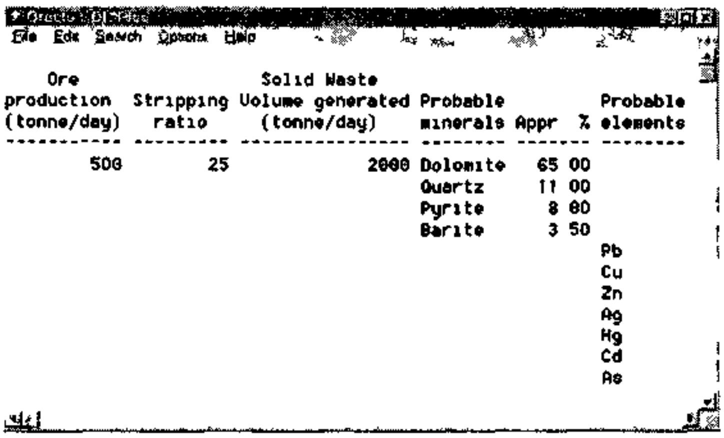
f-ı^uıı. i Gaseous Linissinns Mom dıesLİ equipment USLCI in eaelı ot the jLlmties ifuiing IIIL piL piodiiLtion stagL



```
   Ore                       Solid Waste
production  Stripping  Volume generated  Probable           Probable
(tonne/day)   ratio      (tonne/day)     minerals Appr  %  elements
----------- ---------  ----------------  -------- -------  --------
      500        25                2000  Dolomite   65 00
                                         Quartz     11 00
                                         Pyrite      8 00
                                         Barite      3 50
                                                           Pb
                                                           Cu
                                                           Zn
                                                           Ag
                                                           Hg
                                                           Cd
                                                           As
```

FiguiL 6 Volume and pıobabİL Loınposıtıon ol solid waste geneiattd dunng SUIIJLL mining

Fıguıc 6 piescnts the output ol the algorithm which calculates the volume and composition ot the solid waste generated using mining and ore grade data entered in the LCA database In doing so, the piogiam navigates through a number ot object tables, including the surface mining extraction phase and oi e grade tables

The emissions and waste stieams wcie allocated in a two step piocess as suggested by Knoepfel (1994)

1 The direct allocation step (based on engineeiıng knowledge) An exhaustive analysis ot the sub systems was earned out until the mam lelcvant activities and/oi processes weie identılıed and their functions descıibed Chemical and physical causes tor emission and waste geneıatıon weie charactensed loi each activity and/oi piocess accoiding to then functions Emissions and waste weie allocated directly As an example the emission categories allocated to the activity blasting aie gı\en in Table 6
2 The geneial allocation step is based on mass units The remaining encigy and matenal Hows were allocated according to mass tractions of the ore extiacted, oıe piocessed and waste stream composition

Table 6 Emissions categoues allocated to the ac lıvıty blasting in the exiiaclion sub system

Cause	Emission
Chemical	CO_2
	CO
	NO
	NH_3
Physical	PM10
	TSP

2 2 *The Life C\cle Impact A\iestment i\ stem*

The next stage in lite cycle assessment is to assess the outputs of the lite cycle inventory (LCI) analysis stage from an environmental perspective using impact categories and category ındıcatoıs connected with the LCI icsults The **LCIA** phase also provides mtoimalion lor the hie cycle interpretation (ISO 140042 2000(E)) and is composed of three mandatory elements: the impact category selection, the classification and the characterisation. There also are optional elements for normalisation, grouping or weighting of the indicators resulting from the mandatory steps. Current research at Imperial College involves the implementation of ISO guidelines in developing the LCIA model as the last phase of this project.

3 CONCLUSIONS

This paper presented the modelling framework used in the development of a mining life cycle model at Imperial College.

During the initial stages of model development, the LCA system boundaries were defined for the complete system and for the functions of the different sub-systems. The region in which the mining activities take place was defined as the system, enclosed by the system boundaries. Beyond these boundaries is the system environment. In relation to environmental impacts, the LCIA system boundaries were defined as the effective impact radius (being dependent on the impact category) around a minerals extraction operation.

A data inventory was designed and coded in an object-relational database model. The calculation procedures accounting for the input/output balance of the alternative scenarios for mining production, processing, waste disposal and rehabilitation were programmed into a software system. In developing the LCA system the following assumptions were made:

- the mine, the plant and the waste disposal areas are located in close proximity of each other,
- final product (metal) use by the downstream industries and end users are not considered. In this context, the model presented in this paper is a cradle-to-gale, rather than cradle-to-grave LCA model.

The LCIA model development, which is the last phase of this research project, is currently being undertaken by the authors.

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Environmental Issues and Eco-Based Mine Planning

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ABSTRACT: The activities of mining unavoidably have impact on the environment while providing invaluable resources to our standard of living. Since human beings cannot survive without the mining industry what we should do is to minimize its environmental effects and make it a more sustainable enterprise. In this article we would like to discuss major environmental challenges related to mining industry and especially concentrate on how to deal with and minimize acid mine drainage generation through careful mine planning. The International Law regulating environmental issues related to mining will also be briefly discussed.

1 INTRODUCTION

Mining is an essential activity that provides the raw materials for our industrialized society. However, unless adequate precautions are taken, mining can be accompanied by serious negative impacts on the environment, on human health and on the immediate community. With modern practices, many of these effects can be avoided, or at least greatly reduced. Much of the negative impact can be minimized through careful project planning, choice of appropriate mining technologies, and careful ongoing operation.

Unless preventive measures are taken mining can cause changes in landscapes, water tables and animal habitats, as well as air and water pollution, and permanent degradation of land. Toxic chemicals, dusts, heat and noise can seriously affect the health of workers and community. Impacts may occur from mining itself or from ancillary operations such as transport, laboratories, etc. Potential environmental impact, including pollution effects, which may arise from poorly planned and operated mines are summarized below:

- Solid waste disposal
- Acid Mine Drainage (AMD)
- Cyanide & heavy metals contamination
- Air pollution

Each of these pollution types has a different significance and the effect and the amount of pollution generated depends mainly on mining and processing technology applied among other parameters. Each stage of mine planning such as:

- Exploration
- Project development
- Mine operation
- Mine processing
- Transport and storage, and
- Mine closure

can also have different environmental impacts and all of them should be considered separately.

It is paramount importance to deal with and address the potential of water and soil pollution due to mining at a very early stage of a mining activity in order to avoid serious potential of a future pollution. Therefore while trying to treat the present pollution in an ecologically and economically effective way we should also find some prevention measures before bringing any new mining project into operation.

Apart from being an environmentalist or believing the importance of willingness, there are some other reasons to consider environmental issues in mining projects. For example, we can increase profitability of a given project with a good environmental management plan. Also we need to emphasize that getting financing from any monetary organization requires a detailed Environmental Impact Assessment (EIA). The other reason to prepare a detailed EIA is to comply with the continuously stringent national or international laws and regulations.

As we have mentioned earlier due to quantity constraints we are going to address the issues related to Acid Mine Drainage (AMD) in this paper.

2 ACID MINE DRAINGE (AMD)

Following information about acid mine drainage was reiterated from MEND Manual Volume 4 (Tremblay & Hogan, 2001).

In many mining operations, especially base metal, precious metal, uranium, diamond and coal mines, it is common to encounter sulphide minerals both in the mined ore and in the surrounding rock. When these sulphide minerals, particularly pyrite and pyrıhotıte. are exposed to oxygen and oxidize to sulfite and the oxidi/ed minerals subjected to any water will create acidic mine drainage unless sufficient acid-neutralizing minerals such as calcite are present. The acidic mine water may contain elevated concentrations of metals and salts. These metal elements can include many of the typical major rock constituents (Ca, Mg. K, Na, AI, Fe, Mn) as well as trace heavy elements such as Zn, Cu. Cd, Pb, Co, Ni, As, Sb and Se

On the surface, rainfall and snowmell Hush leachate from the waste sites with reduced pH values. II this acidic drainage left uncontrolled and untreated, the drainage can contaminate water streams and groundwater, affecting negatively all aspects of life. What complicates the issue is that depending on the iron sulphide and carbonate content of the minerals the acid irunc drainage may be generated within few days perhaps years or decades after the exposure.

There are numerous examples of acid mine drainage throughout the world where elevated concentrations of metals in mine drainage have adverse effects on aquatic resources and prevent the reclamation on mine land.

The treatment of acidic mine drainage and/or the ecological damage and lost revenue due to unusable land 01 watei resources create huge liability and result in huge lost revenues. For example in North America acidic drainage has resulted in significant ecological damage and multimillion-dollar cleanup costs for industry and governments. Table I shows some liabilities for Acid Mine Drainage.

Table I. Liability for Acid Mine Drainage

Location	Refeience	Estimated liability (US$>
Leadulle Coloi.ido USA	USEPA	290 million
Suinmilville. Coloiado. USA	USEPA	175 million
Abandoned Mine Land«, Wyoming USA	Richmond. 1995	>25? million (have been spent)
An updating Mine. Utah. USA	Muney et al. 1995	500-1200 million
557.01)0 abandoned mines in 32 slates USA	Tiemhlay & Hegau. 2001	32-72 billion
"iiistiaha	Haines 1997; Gustatsson 1997	900 million
Sweden	Haines. 1997. Gustatsson 1997	300 million
Canada	Tiemhlav & Hoiran, 2001	1 9-5.3 billion

Based on these data, after including other sites not shown here (Europe. South America, Africa), the total worldwide liability is estimated to be around US$100 billion (Tremblay & Hogan, 2001). Finding the appropriate prevention and control measures to prevent the creation of acidic mine drainage not only ecologically but also in financially is a huge enterprise.

3 ENVIRONMENTAL LEGISLATION ON AMD

The environmental issues were first introduced into world environmental conscious agenda mainly after the World Environment Summit of Stockholm in 1972. On this summit the participant probably at the first time described a new terminology, the definition of sustainable development. Namely, the sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition at least in appearance addressed mostly the environmental issues and did not addressed the equally important social issues. This is the probable explanation that countries started to develop or enhance their own environmental regulations aligned with the new international environmental laws. Among these regulations the Environmental Impact Assessment (EIA) is the one what gained the strongest momentum what most directly affecting the industries in a large extend the mining industry. Although there are some differences in application of EIA procedures in each country, the main idea is to define all possible environmental impacts and their prevention measures before a company can get permit for any operation. Especially countries having significant acid mine drainage problem have changed their mining permit procedures and required to submit detailed information to be used to access the site's potential for generating AMD due to the mining activity.

In the USA, standards and rules related to AMD issue is regulated by Environmental Protection Agency (EPA) throughout the United States. Although there are some differences between the different environmental regulations related to AMD the basic requirement set by the Environmental Protection Agency (EPA) assures communality in the requirement through the entire United States. The EPA's set baseline limitations and regulations, which can be found in 40 CFR, Part 434. Also the National Pollution Discharge Elimination System (NPDES) include water quality standards. These regulations define minimum effluent concentrations from the Acid Mine Drainage plant which are normally applied in AMD design and treatment systems (http://www.cee.vt.edu/program-areas/envi ronmenlal/teach/awprimer/grouD 19/section-3.htm)

The additional requirements on AMD in USA resulted in a decrease for new mine permits. In some states tor example in Pennsylvania the introduction of a new amendment to the Clean Streams Law requiring mine operators to treat mine drainage resulted in a significant drop for permit application since 1984. In addition to the treatment requirement, the law requires that the mine operator should demonstrate lhat the mining would not create water quality problems on a long term (http://www.dep.state.pa.us/dep/deputate/minres/districts/AMDPostMortem.htm).

Another example can be given from South Dakota where mining is regulated through the South Dakota Mined Land Reclamation Act (SD Codified Law, SDCL 45-6B) and the South Dakota Mined Land Reclamation Regulations (Administrative Rules of South Dakota, ARSD 74:29). South Dakota's mining laws attempt to strike a balance between economic development and environmental protection by promoting mining as an industry while requiring 1) pollution prevention and 2) reclamation of affected lands to a level usable for alternative land usage. The trust of this law is a multi-media (contaminant) permitting approach that requires all critical pollutant should be monitored and controlled. This regulatory approach stresses the importance of AMD prevention from the start of operations using improved predictive capabilities (Durkin et al, 1998).

Having reviewed a number of similar examples from different states suggests that probably the stale of California has the strictest environmental regulations within United States.

It is probably safe to say that countries, which have had already serious AMD problems, introduced the strictest regulations. Among these countries are, the USA, Canada and Australia who are applying strict standards for AMD. The introduction of the Metal Mining Effluent Regulation in 2002. Canada probably set the highest standard. These new rules were developed through consultations with the mining industry, environmental organizations, native land users, and provincial and territorial governments.

AMD is also considered as an important issue for international monetary organizations such as World Bank. According to World Bank Operational Policies (OP 4.01: Environmental Assessment) any mining project can only be funded after scientific proof of prediction, prevention and treatment measures of acid mine drainage. In addition to the AMD issues, the International Finance Corporation (IFC) that is the largest multilateral source of loan and equity financing tor private sector projects in the developing world recently changed their practices and now they want to ensure that their investments are environmentally and socially sound. This demxinstrates a positive development and assessment of more complex impact due to mining activity beyond the economic growth criteria.

4 ACID MINE DRAINAGE TREATMENT

Although, there are many successful techniques to treat acid mine drainage, the importance of this topic is providing the need for further research for new alternatives. In the following we list the three main techniques most frequently used for AMD treatment.

Active treatment methods:
1. Chemical treatment
2. Metal recovery

Passive treatment methods:
1. Anoxic limestone drainage systems
2. Aerobic wetland treatment systems
3. Passive anaerobic treatment systems
4. Biosorption treatment methods
5. Passive *in-sim* treatment methods

Hybrid active/passive treatment systems

In order to chose the best treatment alternative several parameters such as. geochemistry, hydrology, cost, the experience of the operator, technical and operational limitations, etc. should be considered. The last couple of decades provides many good as well as bed examples of different AMD treatment techniques. In the present practice the mine operator can develop a much better mid reliable AMD treatment techniques by carefully analyzing and studying and learning from the previous bed experiences. This analysis can be easily done because there are many documents giving Ihe technical and practical details of each conventional and innovative technique.

5 PREVENTION AND CONTROL OF AMD

Prevention and control techniques included in this cuticle were directly reiterated from MEND Manual Volume 4 (Tremblay & Hogan. 2001).

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In the following we described a few acid mine drainage prevention techniques what applied and can be considered for specific site. There are several techniques can be applied to prevent acid mine drainage. Followings are most commons:

5. / *Water covers*

This technology based on that the oxidation of sulphide minerals can be inhibited by the presence of a water cover, as the water acts as a barrier to the diffusion of oxygen from the atmosphere to the submerged sulphides. Potential disposal options include; (1) the subaqueous disposal of unoxidized sulphidic wastes under a water cover; (2) and Hooding of oxidized wastes.

Water covers have been applied at many sites, such as Quirke (Ontario) and Solbec (Quebec), but arc not universally applicable. Related issues such as the ability to maintain a water cover over the long-term, the integrity of the containment structures, locality and site-specific potential risks due to seismic events, severe storm events, etc. can negate the use of this technology. However, under suitable conditions, the present state of knowledge is sufficient to allow for the responsible design, operation and closure of waste management facilities using water covers for both fresh and oxidized tailings and waste (Tremblay & Hogan, 2001).

Estimated cost for self-sustained water cover is changing between $75,000-$370,000 depending on the site-specific properties. The highest estimated unit cost is based on a scenario where the site is poorly suited for a water cover (Tremblay & Hogan, 2001).

5.2 *Dry covers*

The key objective for dry cover systems is to provide a barrier that minimizes the influx of atmospheric oxygen to the mine waste, and to limit moisture infiltration. Apart from these functions, dry covers are also expected to be resistant to erosion, and provide a media for vegetation.

Dry covers can range from a single layer of earthen material to several layers of different material types, including native soils, non-reactive tailings and/or waste rock, geosynthetic materials, and oxygen consuming materials. Multi-layer cover systems utilize the capillary barrier concept to keep one (or more) of its layers near saturation under all climatic conditions. This creates a blanket of water over the reactive waste material, which reduces the influx of atmospheric oxygen and subsequent production of acidic drainage.

Use of alternate cover materials such as sulphide-free tailings and organic waste materials, instead of natural soils can make this technique more challenging and cost effective. Especially the use of low cost waste materials from other industries such as, crude compost, lime stabilized sewage sludge, paper mill sludge would make it possible to use one waste to solve a problem of another waste.

Dry cover systems are commonly used to decommission waste rock piles and tailings impoundments at sites around the world. Barrick's tailings site in Northwest Quebec, provided the first full-scale demonstration project of using tailings in a cover system (Tremblay & Hogan, 2001).

The unit cost for construction of a dry cover system is extremely site-specific. It is difficult to develop an average value because of the impact of the various components that influence cost. For example, the Equity Silver mine cover system (0.5 m compacted til! and 0.3 m non-compacted till) was constructed for approximately $35,000 (CAD) per ha (including reshaping, etc.) (Aziz & Ferguson 1997). The borrow area for the till cover material was immediately adjacent to the waste rock piles at the Equity site and large mbber tired scrapers were used to pick up and place the till. Hence, the cost for construction of the cover system was minimal when coupled with the sound site construction management that occurred. A similar cover system at another site might cost twice or three times more per unit area if the cover material borrow is at a greater distance and truck and shovel/backhoe construction technique needs to be used. The Rum Jungle waste rock cover system in Australia was constructed over 51 ha area for approximately $67,000 (AUD) per ha (ineludins reshaping, etc.) (Tremblay & Hogan, 2001).

5.3 *Saliiration*

Saturation refers to the moisture saturation of tailings pore spaces to make good use of the low rate of oxygen diffusion through water-filled pore spaces in comparison to those that are gas-filled. Saturation can be achieved by elevating the water tables in tailings. An elevated table by itself does not prevent acid generation, as there may be zones of near-surface exposed and drained tailings that remains available for oxidation. The use of an elevated water table can, however, significantly reduce the inventory of .sulphide tailings available for oxidation. The use of elevated water table concept may be cost advantageous when applied in tandem with other approaches to prevent and control acid generation. The saturation of pore spaces in waste rock piles as a means of controlling acid generation is normally not an option.

There are some applications of saturation techniques in Canada and Australia. Site-specific conditions determine the suitability of this technique. Closure costs indicate that elevated water table technique", when suitable, can provide significant closure cost savings in comparison to collection and treatment, and the use of an engineered dry cover.

5.4 Separation and Segregation

Key driver in separation and segregation is to identify techniques to separate sulphide solids for disposal, or produce reduced sulphur content tailings for use in site rehabilitation. Laboratory and field tests show that depyritized tailings have excellent potential for use in dry covers. Flotation has been shown to be an effective, less costly, method of reducing the sulphide content of tailings prior to their discharge. The quantity of sulphide minerals that would need to be segregated and removed using mineral processing techniques is dependent on the characteristics of the tailings and as such this aspect needs to be assessed on a site-specific basis. Economic analyses are subject to variation due to the specific characteristics of the tailings, the depyritization process, and the low-sulphur tailings application. The estimated unit cost for depyritization at an operating mill is expected to be in the range of \$0.35/t for non-cyanide tailings, and about \$0.60/t tor cyanide tailings (Tremblay & Hogan, 2001).

5.5 Permafrost unci freezing

Permafrost and freezing is an area of continuing and evolving research for cold climatic conditions to inhibit acid generation. Sulphide oxidation rate slows considerably as the temperature of the waste drops and approaches 0 °C. Permafrost forms is present across Northern Canada and covers about 40% of the country land mass. A reasonable and sufficient knowledge base exists with regards to the construction of a variety of structures over permafrost. However, knowledge and experience in the use of permafrost, including the natural and assisted freezing of sulphide wastes, is an area that continues to be developed.

5.6 Backfilling (in-pit) and co-disposal

The backfilling of mine openings, both open pits and underground workings, has been practiced extensively internationally. It is only recently, however, that pit backfilling programs have been designed for the disposal of sulphide tailings and waste rock with mine closure in mind. As a result, some mine openings that may have previously been considered a legacy may be beneficially used for mine waste disposal.

The key objective in placing sulphide wastes in a mined-out pit is to provide a suitable physical and geochemical environment to prevent acid generation and thereby reduce adverse impacts to receiving groundwater and surface water resources. The level of engineered controls that are required to prevent acid generation can be determined to a large extent by predicting the future quality of the pore water within the wastes. The degree *of* oxidation of the wastes to be disposed in a pit will determine the stability of an in-pit disposal program, and significantly influence the design of the in-pit disposal program. The quality of the pore water in the disposed wastes may vary over time. In some cases, the initial rates of contaminant release will be high, and then reduce as the leachable fraction *of* the waste declines, possibility to levels where the potential for environmental impacts is negligible. Conventional testing (i.e. pore water sampling, sequential leaching tests, humidity cells) can be used to predict pore water characteristics, leachable fractions, and ultimate concentrations of contaminants.

While backfilling has been extensively applied and there is a sound technical base for in-pit disposal programs, few sites provide scientific databases that can be used to assess the performance of these technologies.

Backfilling can provide significant cost saving in comparison to other closure operations for tailings and waste rock. This technique can also be cost advantageous for the disposal of historic wastes, provided conditions are suitable. The application of backfilling is, of course, subject to site-specific conditions and regulatory review, and as such these programs need to have well founded technical and environmental bases (Tremblay & Hogan, 2001).

5.7 Blending and Layering

The blending and layering of waste rock is an approach that is founded on the geochemistry of sulphide oxidation. In concept, a net acid generating waste could be blended with, or layered between, alkaline materials to produce a non-acid generating waste that has seepage water quality acceptable for discharge without additional measures. This is a challenging area that continues to be under development given the potential benefits.

Major factors should be considered when designing a blended waste rock dump are; mineralogy and reaction kinetics; relative proportions of the acid generating (AP) and acid consuming (NP) rock types, and resulting overall NP/AP ratio; proximity and arrangement of acid generating and acid consuming materials; orebody geometry and mining plan; construction methods; hydrogeology of the waste rock dump; and operational commitment and monitoring. The second factor is probably one of the most significant factors affecting the degree to which blending can achieve the objectives.

There are very few well-documented examples of waste rock blending. Coal mines in the Appalachian region of the eastern USA have used waste rock blending, however, it was found that other control measures were often applied and these prevented evaluation of the success of blending. Many examples of older hard rock mine waste rock dumps with non-acidic drainage are known, but the source characteristics are not adequately understood. Recently, waste rock dumps have been characterized during construction, but the monitoring records are not yet sufficient to evaluate blending. A significant issue is the question of how long the drainage must be monitored before blending can be judged successful.

Waste rock blending can significantly increase the cost of waste handling due to stricter scheduling requirements, the potential requirement to re-handle wastes, greater personnel requirements for monitoring, and analytical costs for blast hole cutting analysis. Including waste rock characteristics during scheduling can simply minimize this cost. This new approach is called "eco-based scheduling'* and explained below.

6 ECO-BASED STRATEGIC MINE PLANNING

Bearing in mind that it is always easy and less expensive to prevent any pollution then to solve if after being created, researches were concentrated on promising prevention techniques such as layering and blending ihrough strategic mine planning.

In eco-based scheduling the physical layout of an open pit mine, and the locations of open pit mine waste disposal areas, are planned in advance of ore mining and waste stripping operations. The pit planning process focuses on optimizing the profitable extraction of ore in a safe and environmentally responsible manner. In concept, the economic value of a tone of ore must be greater than the cumulative costs associated with the mining and processing of that tone of ore, plus any other costs associated with the stripping and disposal of perhaps several tones of mine waste per tone of ore.

Economic evaluations of open pits at the planning stage are typically used to develop a cut-off grade, which is the minimum grade of ore that can be mined profitably or, in some cases, to breakeven. The cut-off grade is different for each open pit mine and is a function of the anticipated revenues and costs. The cut-off grade and the physical limits of an open pit mine are, therefore, sensitive lo changes in revenue (e.g. metal price fluctuations) and costs (i.e. mining, processing, taxes, mine decommissioning, etc.).

At most new open pit mines, the potential for acidic drainage is determined early in the planning process. A decision can be made at the planning stage to segregate reactive wastes and relocate the wastes to the open pit or locate properly according to layering or blending technique once it is mined out. In such a case, the economic evaluation of the open pit and the pit design would take into consideration all anticipated costs to implement an in-pit disposal or layering/blending program.

In this concept, all the rock types with acid generating potential are identified and tagged within the block model. The strategic mine planning and scheduling program is constraint such that the best open pit schedule is obtained by balancing profit maximization objective with controlled production of acid generating rock. To accomplish this, operational research based pit scheduling techniques like CSM-LP can effectively be used (Dagdelen et al, 2002).

7 CONCLUSION

In many mining operations, especially base metal, precious metal, uranium, diamond and coal mines, it is common to encounter sulphide minerals both in the mined ore and in the surrounding rock. When these sulphide minerals, particularly pyrite and pyrrhotite, are exposed to oxygen and oxidize to sulfite and the oxidized minerals subjected to any water will create acidic mine drainage (AMD). International Laws regulate discharge of AMD. International Financial institutions does nol allow financing of a given projects unless they provide scientific proof of prediction, prevention and treatment measures of acid mine drainage. Although a lot of effort is being spent on treatment and prevention of AMD, we believe there is still significant work to be done for reduction and prevention of AMD through eco-based strategic mine planning practices.

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Environmental Issues in the Extraction of Phosphate Ore from Abu-Tartour Mine, Egypt

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ABSTRACT: The main objective of this paper is to address the environmental issues that arise during the extraction of phosphate ore at Abu-Tartour mining area, Western desert, Egypt. Although the mine locates in the heart of the desert, the mining operations for ore extraction either from the underground mine, or from the surface mining work, do have several environmental impacts that affect the human being, agriculture, and natural resources (groundwater and rare animals). Those impacts are occurring during loading, unloading, mining operations (development, extraction, supporting, ventilation, blasting) and washing of the ore. Other environmental issues at the same area include the movement of sand dunes with its impact on the oic transportation via the roads and railroads. The paper addresses the different issues and suggests a monitoring system based on remote sensing and GIS techniques for better understanding of the environmental problems around the area.

1 INTRODUCTION AND OBJECTIVES

The last two decades have seen a growing concern for the conservation of the natural environment. Industry in general, and mining industry in particular is one among many such activities that can produce significant environmental impacts.

The objective of this study is to address the environmental issues arising at Abu-Tartour mining area in Egypt and suggests an approach based on an integrated methodology of remote sensing and Geographic Information Systems (GIS) in order to aid the regional development in at that area. While the application of remote sensing to other types of surface mining has been well documented, its practical application to the unique problems associated with phosphate mining has been not widely studied and is one subject of this work.

Other objectives are:

u Identify the environmental and health impacts arise at all stages of the phosphate cycle: extraction, storage, and transportation of the ore at the study area in its present situation,

j Identity the best combination of remote sensing techniques and GIS on study the environmental impacts of mining industry, especially in desert areas.

2 OVERVIEW OF THE ENVIRONMENTAL IMPACTS OF MINERL EXTRACTION

Minerals can only be worked from where they are found and that is often in the heart of unspoiled countryside. In the past, mineral extraction was at a relatively low level and people were not too concerned about the environment. However, today intensive mining practices and increasing environmental awareness has resulted in a need to find ways of reducing environmental impacts.

The principal environmental impacts and concerns associated with ore extraction are:

a) Surface mines: large scale land use, overburden removal and disposal, noise, blast vibration, fly rocks, dust, transportation/traffic high-wall stability, etc.
b) Quarries: were given permission to work with hardly any planning control. The most obvious feature is the loss of surface vegetation and creation of large hole in the ground.
c) Underground mines: the mining operation themselves, unless they result in extensive subsidence, do not result in surface changes, and sumps are generally much smaller than for opencast. The major concerns may be the spoil heaps created from waste rock excavated during tunnelling beside mine drainage, ventilation, illumination, supporting and noise.

d) Ore transportation: environmental impacts of ore transport may occur during loading, en route or during unloading. All the forms of transport exhibit certain common environmental concerns:
    - Rail transport and trucks cause damage to buildings and sometimes cause structural damage to main roads.
    - Air pollutants are emitted from engines powering the transportation facility and noise levels may be high.
    - Accidents and injuries as a result of collisions between trains and motor vehicles at road rail crossing.

e) Dressing operations: wastes and tailings of rock to local lands. Also, dust is produced during crushing operations.

f) Human health is at risk due to the dangerous involved in the extraction process.

3 NEW TECHNIQUES FOR MINING ENVIRONMENTAL MAPPING

This paper investigates into the potential of applying an integrated methodology based on two advanced technologies (remote sensing and geographic information systems to assist the preparation of environmental impact assessment for the mining area and demonstrate a case study around a phosphate mine in Egypt. Figure 1 shows the outline of the idea.

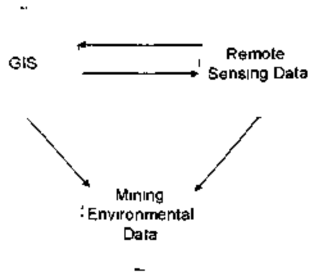

Figure 1 Interrelationship between remote sensing and GIS for environmental studies

3.1 The role of remote sensing

Remote sensing has been extensively used to monitor effects of surface mining. A number of studies have applied satellite remote sensing data to investigate the environmental impacts of mining areas. (Borden *et al.* (1973), Krumwiede (1980), Gupta *et al.* (1982). Irons *et al.* (1986), Parks *et al.* (1987), Legg (1986, 1990), Ralhore *et al.* (1993), Molhibi (1994) and others).

Currently, the availability of low cost and high-resolution data has focused increased attention on the use of satellite data for monitoring mining activity. The use of this technique is based on the fact that there are differences in reflection between surface materials at different electromagnetic (EM) wavelengths. It is therefore, possibly to classify surface cover types and map their distribution. Due to the sensor's wide field of view, satellite data can prove extremely cost-effective over large areas.

Remote sensing can be useful during the planning stages either of a new mine, or for extension of an existing mine. It can also be of assistance during mining operations to update thematic maps of the mining district, and assist in monitoring changes related to mining activities. Other global phenomena around the area that is hardly to be noticed in a short term monitoring programme can be recorded and studied using remote sensing.

3.2 The role of Geographic Information Systems (GIS)

A GIS is a system that facilitates the description of real world entities in terms of their location position, non-location attributes and their inter-relationships with each other and their topographical setting, Burrough (1986).

Geographic Information systems are relatively new computer tools, which combine various forms of spatial geographic data into one master database. This facilitates ease of interpolation between the various types of data. GIS provide the means capturing. storing, checking, integrating, manipulating, analysing and displaying the data. GIS have also been used for many applications related to mining industry and its environmental impacts.

For environmental mapping related with mining aspects, GIS could be applied for the following investigations, Bernard *et al.* (1995):

1. The application of GIS to environmental impacts assessment in the mineral industry.
2. Integrating GIS and remote sensing for environmental management at the mining areas.
3. Using GIS techniques to provide a sensitivity environmental map showing the areas of highest and lowest environmental impacts.

3.3 Computer aids

For the constantly changing environment, it is important to be able to monitor the effects of development and land-use as well as document natural changes. By digitally combining satellite data from different years or seasons, the location and extent of changes (e.g. the movement of sand dunes or difference in land usage) can be mapped. The computer allows changes to be determined rapidly over large regions, and information to be updated frequently using new imagery. Note that the same exercise undertaken by conventional techniques might take years of groundwork and be out of data even before completion.

3.4 Mining environmental maps

Each company may map its operations at a different scale: or use a different classification system for land-cover types. There is often a requisite, either from the government agencies or public relation purposes; to produce maps showing current land-cover and its changes every two or five years. If the final product is to be at scales of between 1:25,00 and 1:100,00, this task can readily be undertaken using remote sensing. Image processing techniques can be used to obtain quantitative measures of the proximity of environmentally significant land-cover classes to propose mine-sites or transport route. This allows a choice of the best sites for mine dumps or access roads, based on the maximum possible distance between new developments and areas of environmental importance.

3.5 Monitoring and map updating

While surface mining operations are in progress there is often a need for both relevant planning authorities and mine operations to monitor activities within sites. General surveys of sites are often undertaken using aerial photographs, which may be out of date. For relatively large sites and for studies involving numerous sites over large administrative districts, satellite remote sensing data could be used to provide updated land-cover maps and derivative change maps, at relatively low cost.

3.6 Restoration quality assessment

Once mining is complete, there is commonly a requirement to restore the land surface to its pre-mining use. Remote sensing can play an important and cost effective role in assessing the quality of restored land, as well as in comparing the sue and shapes of fields in restored and un-mined areas.

4 A CASE STUDY: ABU-TARTOUR MINE

Abu-Tartour phosphate project is one f the largest phosphate mines in the Middle East. The mining area is located in the Western desert of Egypt (60 km from El-Kharga City, and 10 km from the main road between the two Oases El-Kharga and El-Dakhlah), Figure 2.

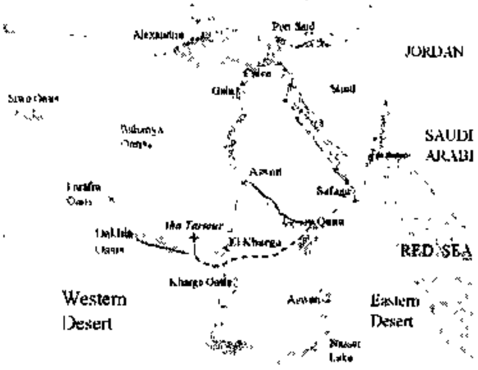

Figure 2. Location map of the study area

The ore reserves have been estimated as 100 million tons of phosphate (200 million tons as proved ore). The mine has started to export the ore since 1995. The exploration and experimental studies were started in 1975 and recommended the following:

- Extraction of the phosphate layer from two zones, underground mine, where the thickness of the overburden (shale's) is 60m in average, and a surface mine, where the overburden is small.
- Construction of a railway for exporting from Safaga port at the Red Sea,
- Constructing a small town at the mining area for 10,00 people.
- Use trucks for transporting the ore to Assiut factory,
- Drilling 10-water wells near the mining area.
- Long-wall retreating method with hydraulic support as the best solution for mining.

The aim of demonstrating this case study is to identify the environmental and health impact arise at all stages of the phosphate cycle: extraction, storage, and transportation of the ore at Abu-Tartour mining area in its present situation (2003).

4.1 Environmental impacts

Environmental impacts of the phosphate ore occur during loading, unloading and mining operations and cap be classified as:

a) Surface mine

- Dust created during operations causing respiratory problems
- Blast effects.
- Noise and vibration effects from machinery.

- Creation of large hole in the ground.
- Waste materials leading to the pollution of groundwater.

b) Underground mine

- Waste rocks excavated during tunnelling.
- Subsidence, (surface stability due to change in the underground excavations).
- Machine dangers.
- Water consumption.

c) Ore transportation

The transportation of phosphate ore at Abu-Tartour mining area is carried out by the following utilities:

- Conveyors, belt conveyors are used to transport the ore from the mines to the loading points.
- Truck (lorry): used to transport the ore to Assiut laclory (300 km).
- Railway: to export the ore through Safaga port at the Red Sea.

All the above forms of phosphate transportation exhibit certain common environmental features such as.

- Dust clfecls during operations.
- Trucks and rail transport will cause damage to building inside the town.
- Road damage, by haulage trucks is a major environmental cost (Abu-Tartour - Assiut).
- Losses of ore during the loading and unloading processes in the form of dusts, which affect the human health.
- Air pollution from engines powering the transportation facility.
- Noise as a result of engine, horn, and wheel-rail intei section.

d) Oilier issues at the study area

Beside the above points, the ore transportation is lacing a major problem due to the movement of the sand dunes over the main roads and railways. Therate ot advance and direction of movement are beyond the scope of this paper, however, the over it is believed that remote sensing would contribute in the study of this phenomenon.

5 SUGGESTED APPROACH

The paper suggests an approach for enviroiimentalimpact assessment that integrating i emote sensing data and environmental information into a geographic information system (GIS) as illustiates in Figure 3.

Among all the environmental impacts associated with the extraction of phosphate ore at the study aiea, the most important factors that could be identifying by using remote sensing techniques are subsidence and ore transportation.

5. / *Subsidence:*

Remote sensing data has been used to delect and delineate areas of subsidence as a result of mining. A wide variety of surface manifestations can appear due to collapse of underground mines and can be detected using remotely sensing data. Recently, Volk *et al.* (1990), have used Landsat-TM data to determine environmental effects of subsidence in the Ruhr region of Germany.

At Abu-Tartour mine, one of the main problems obstructing the last development and extraction of the ore is the supporting system due to the presence of subsidence. The rate of advance and the limits of this subsidence is still causing a problem and the mine has suffered from a high collapse I n 1987. It is suggested that satellite remote sensing data are used for the detection of the rate of subsidence in the mining area.

5.2 Ore transportation:

The movement of sand dunes, around the railways and the roads, in the Western desert of Egypt can be studied as a part of the investigation. Satellite remote sensing can play an important role in this task. The socio-economic effect due to the present ot the new mining industry is another task that can be achieved through the suggested study.

Remote sensing can also used to detect the changes in the movement of the sand dunes around the study area; a scene or more of suitable remote sensing data is required for different years to study the rate and direction of advance of the sand dune. Having succeeded to define such technique a further work is needed to prevent the railroads and main roads for the effect of sand dunes.

5.3 Input Data:

Q Satellite imagery (1978 - 2003) Landsat TM and SPOT PAN
a Topographic maps,
ü Digital elevation models
- Iso-gradc maps (PiOs distribution)

a Geological maps
u Wind direction map in the different seasons
a Water wells distribution and characteristics
- Transportation scheme (trucks, trains, others)
- Storage areas

a Layout of the mining area
a Artificial lack
u Mining plant
a Administration zone
- Green areas

a Residential city
- Others

Attributes

a X. Y coordinates (using GPS)
a Noise level at different zones
u Water quality parameters
- Others

5.4 Output Data:

- Sensitivity maps for the environmental zones.
- The best storage place for the waste materials.
- Static water level maps.
- Future expansion of the residential city.
- Determining the areas of the most environmental impacts.
- Future studies for the expansion of the mining works:
- Socio-economic studies of the project;
- Updating maps; and
- Statistical analysis.

For environmental mapping related with mining aspects, **GIS** could be applied for the following investigations:

Integrate GIS and remote sensing for environmental management at the mining areas.

Use GIS techniques to provide a sensitivity environmental map showing the areas of highest and lowest environmental impacts.

6 COMMENTS

1) The choice between surface and underground mining as the optimum mining method can no longer be based primary on mining, geo-lechnical, and economic considerations, environmental impacts should be considered.
2) The working methods and restoration should be controlled to a much higher degree so that mines and quarries case less environmental harm. This stems from two sources: general concern about environmental matters and specific concern be local residents not to have their lives and enjoyment of the countryside spoiled.
3) Reclamation of land-use after the mining compilation is a must.
4) Mining safety regulation (M.S.R.) should be changed for more safely and environmental consideration.
5) The monitoring of sand dunes movement could he done using suitable remote sensing technique and has to be assisting the ore transportation.
6) It is recommended that the company starts to protect the residential area from dusts and other hazards by constructing green fans around the residential area.
7) Groundwater wells need continuous monitoring for more safety and better control of the contaminants.

- The company is advised to establish a GIS system to monitor its progress.

7 CONCLUSIONS

The environmental impacts of mining operations have briefly listed and a case study was demonstrated to develop an environmental monitoring system using GIS, remote sensing and computer aids,

The study recommends the following steps to take place in the near future at the Abu-Jartour mining area in order to monitor its environmental impacts:

a Design and implement a suitable technique for rapid low-cost production of sensitivity maps by integrated Geographic Information System with digital image processing system to handle remotely sensed data, other forms of map data and associated non-spatial data. Such technique will have potential uses in environmental investigations, particularly lor mining industries.
a To create a Geographic Information System database for Abu-Tartour mining area, which will facilitate the management of the environmental impacts in the area and to evaluate environmental trends over a 25-year period extending from 1978-2003 and be used for future monitoring.
a Outline recommendations for monitoring existing projects and also for future projects environmental strategy.

ACKNOWLEDGEMENT

The author expresses his gratitude to the El-Nasser Phosphate Company who provided the information about the project.

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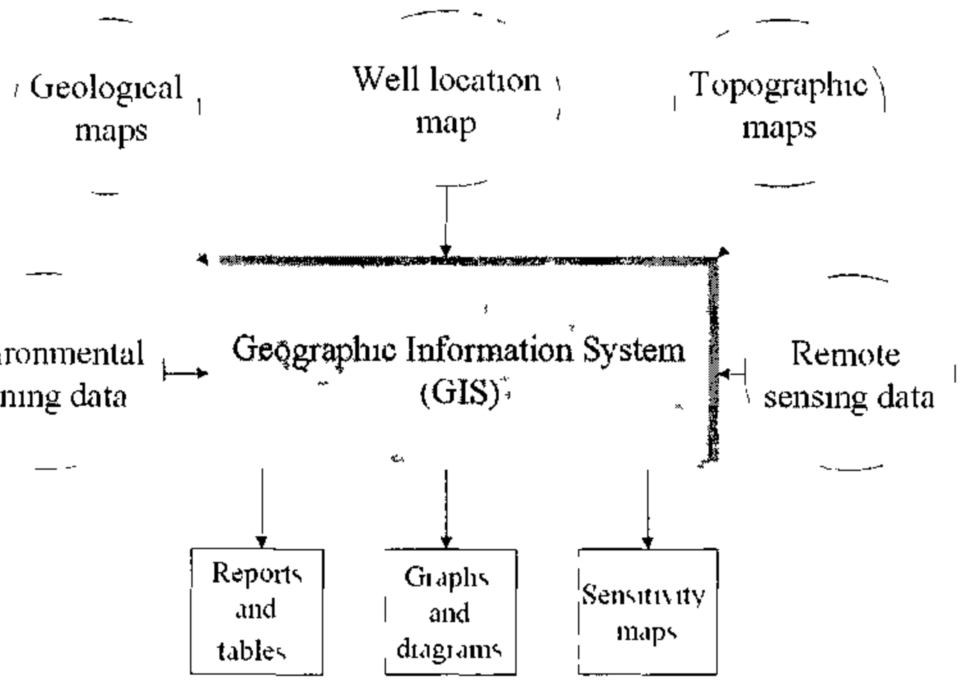

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Addressing Small-Scale Gold Mining Problems in Ghana

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ABSTRACT: Small-scale gold mining in Ghana is characterised by lack of capital asset and minimum use of advanced technology, especially during the beneficiation of the minerals into finished products. The industry is also associated with degradation of the land and stream pollution from spillage of chemicals including mercury compounds. The paper addresses some of the problems associated with small-scale gold mining operation in Ghana. The strategies proposed are aimed at providing the appropriate technology to better manage the environment. These include establishment of cooperative ventures with reasonable technical backing provided by the local research groups.

I INTRODUCTION

In Ghana, small-scale mining is defined as any mining operation in which explosives are not used and operated by an individual on less than 25 acres of concession or groups not exceeding nine or cooperatives of 10 or more people (Ntibrey 2001). Such operations in Ghana include diamond, gold, limestone, silica and stone quarry. Small-scale mining in Ghana is traditionally manual, with very low technology. The PNDC Small-Scale Gold Mining Law. 1989 (PNDCL 218) brought the activities of illegal gold miners into the formal economic sector of the country. Under the PNDCL 218 Part 1(2), any Ghanaian over eighteen years old can apply for a licence to operate a small-scale gold mine. The law expects the licensed small-scale gold miner to mine by an effective and efficient method and shall observe good mining practices, health and safety and pay due regard to the protection of the environment. Unfortunately, these are words and not actions. The structure for the implementation of PNDCL 218 initially developed around an implementation Committee comprising of Minerals Commission, Geological Survey, Mines Department and the Precious Mineral Marketing Corporation. The Committee determines long-term policy and monitoring and the performance of project personnel. The day-to-day activities are coordinated by a network of field staff whose functions are coordinated by Project Director at the office of Mineral Commissions.

2 ACQUISITION OF MINERAL RIGHTS

Concessions with minable reserves are unknown to small-scale gold operators owing to lack of availability of exploration data. As such gold exploration and mining is done on trial and error basis. Several pitted, trenched or excavated areas such left unfilled and the land unclaimed because during the preliminary exploratory stages such concessions are barren and not minable. These abandoned pits without reclamation are usually environmentally unfriendly. The number of abandoned pits can be reduced if the country's Geological Survey and Minerals Commission to provide geological information including gold resource potential to all prospective miners.

The procedure for acquisition of a mining licence involves the following steps:

1. Submitting and application with topographical plan of the area being applied for, to the District Officer who coordinates the small-scale mining activities in the district.
2. The District Officer conducts a field inspection to verify the map. The application form is then forwarded to the District Chief Executive for publication and approval.
3. The approved application form and the site plan are then forwarded to the Minerals Commission for approval

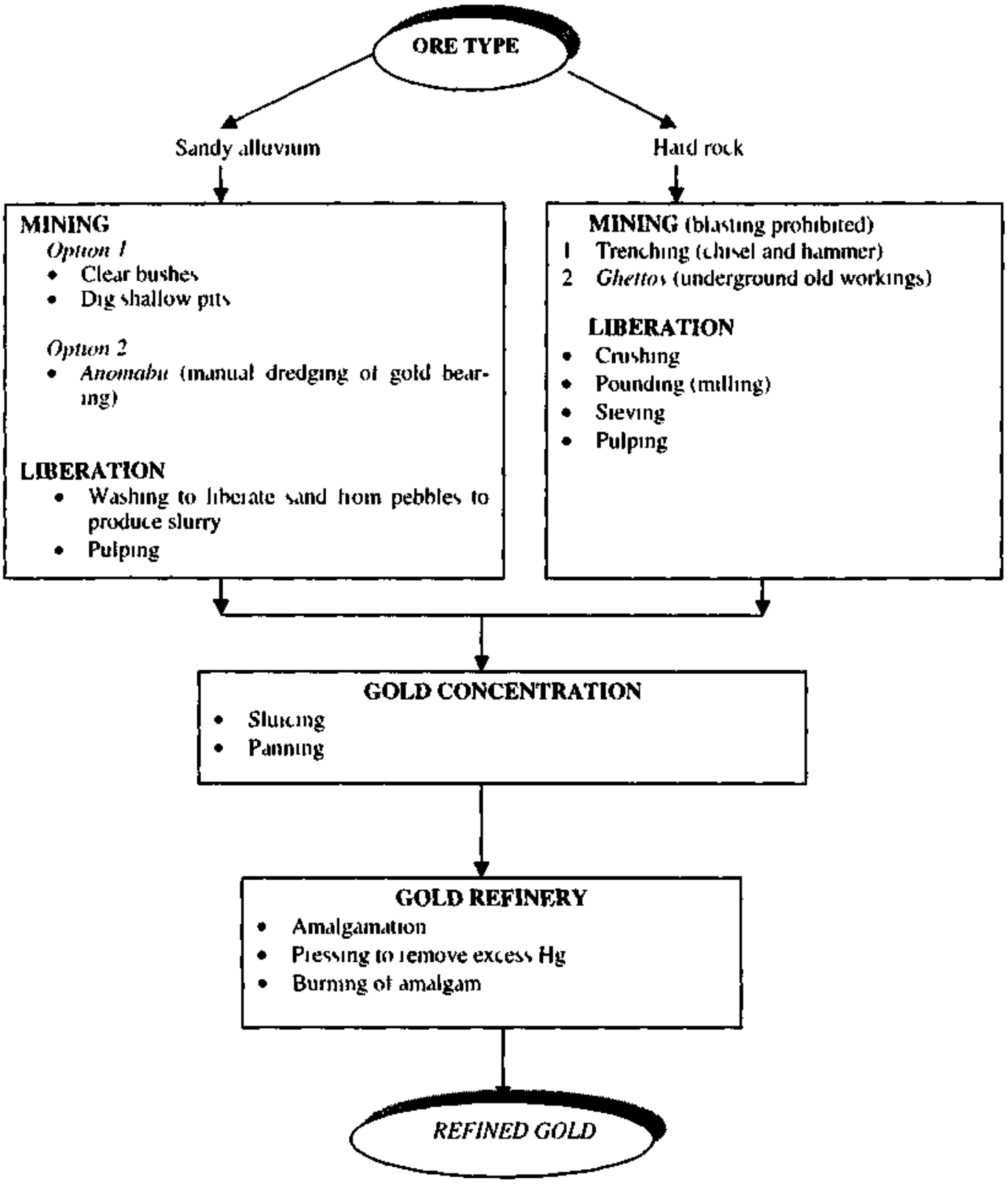

Figure I Flowchart of small-scale gold operation

If approved the applicant takes the signed agreement to the Chief Inspector of Mines to obtain an Operating (Mining) Licence.

3 SMALL-SCALE GOLD MINING AND PROCESSING

Figure 1 summarises the mining and processing stages for both alluvial and lode type deposits.

The mining method used at a small-scale mining operation depends the type of the deposit, either an alluvial or lode type. Small-scale gold mining relies primarily on deposits containing free gold and may be classified as shallow alluvial, deep alluvial or lode type.

- *Shallow alluvial deposits* - locally referred to as *dig and wash* ore found in valleys and streams at depths not more than two metres.
- *Deep alluvial deposits* are found along major riverbanks and older river courses and usually at depths exceeding than six metres. They are usually along the banks of rivers such as the Ankobra, in the Tarkwa, Asankrangwa and Biabiani districts and rivers Tano and Offin in Asankrangwa and Dunkwa districts, respectively.
- *Lode deposits* are usually composed of partially weathered gold bearing reefs, which either outcrop or are too close to the surface. These deposits are commonly found around dis-used shafts and adits (Figure 2).

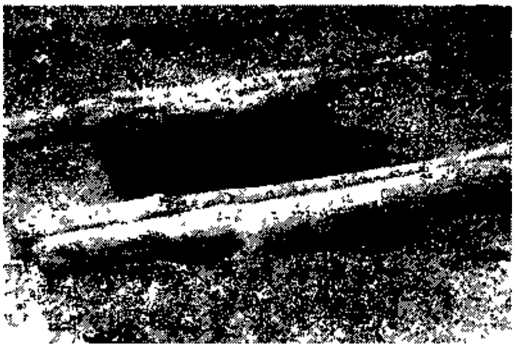

Figure 2 A dis-used ventilation shaft

3 I *Mining of alluvial deposits*

Mining of shallow alluvial deposits involves digging the material and transporting it to for sluicing at a nearby place. With deep alluvial deposits, large pits are dug to the gravel horizon: workings are maintained in the dry seasons since the pits are flooded during the rainy seasons. The sides of the pits are usually terraced to maintain stability.

The gold bearing gravels are removed and sluiced using water from nearby streams. Gold particles are trapped on the sluiced carpets (Figure 3). After about an hour of washing, the carpets are removed and washed to obtain gold concentrate, which is then amalgamated. The excess mercury is squeezed out and the sponge gold is put in open fire to burn off the mercury.

Figure 3 Sluicing gold concentrate

3.2 *Mining of lode deposits*

These deposits are commonly found around dis-used shafts and adits. Pits are sunk across the reefs and the lode is further followed along strike. The pits are sunk from the surface at about 8m intervals along strike. Where reefs are weathered the miners use chisel and hammer to break the rock. Where the ore is hard, holes are bored and blasted with explosives although explosive use is illegal.

The lode type ore is crushed manually or mechanically. Where manual crushing is used to liberate the gold (lode type):

- Five-pound hammer is used.
- Fine crushing entails the use of steel mortar and pestle in 2-3 cycles after sieving to -0.5mm undersize
- Fine milling *of* +0.5 mm is done with corn mill
- Ore-waste materials are sorted on sluice boxes prior to pulping.

Manual method of ore liberation has given way to mechanical means using portable hammer mill (wet milling) before the ore is pulped and sluiced. In general gold recovery rate is normally less than 70%. The recovered gold is sold to the Precious Minerals Marketing Corporation (PMMC); the company Miramex is also authorised by the State to purchase, export and market gold produced by small-scale miners. Gold exceeding 50kg may be exported directly by small-scale miners through PMMC.

4 HEALTH AND ENVIROMENTAL ISSUES

The Ghanaian small-scale gold mining continues to provide employment for the locals and at national level is a Ghanaian foreign exchange earner. However the operation is associated with sensitive health and environmental issues. Some of these are summarised below:

4.1 Gas emissions and health hazards

1. Illegal blasting produces fumes of noxious gases into the mining atmosphere although its concentration is insignificant in most cases.
2. Some miners rely on old shafts and adits and the trapped noxious gases such as H_2S are released into the mine atmosphere.
3. Exhaust gases from stationary machines, such as hammer mills, modified corn mills and pumps pollute the immediate atmosphere.
4. Mercury fumes are emitted into mine atmosphere during the heating of amalgam in the open.
5. Nitrous fumes from nitric acid during gold refining process.

4.2 Noise

Noise is usually generated from mills used for hard rock crushing. Some residents close to mine sites complain about the noise. Some of the miners suffer hearing loss, although few use ear protectors.

4.3 Impact on water

1. Water pollution occurs during the ore processing. Some operators locate their sluice boxes in the stream. Silting and stream coloration of the river are very common.
2. Drainage of lubricants and oil products from stationary machines present problems such as de-oxygenation of the water posing a threat to aquatic life.

4.4 Land usage

Old gravel pits are usually abandoned without reafforestation. Pits filled with stagnant water are common scenes (Figure 4). Farmlands are usually destioyed through the mining activities. Small-scale mining operations destroy forests, food and cash crops for the local farmers without compensation.

4.i Dust pollution

Crushers are not enclosed and dust particles settle on plants affecting plant growth and human health.

Figuie4 Abandoned pits with stagnant water

4.6 Forest degradation

Where mining is carried out closer to trees, the roots are exposed and hardly support the tress, which eventually fall with the slightest wind or erosion from rain.

4.7 Social problems

Small-scale mining technology is simple and as such attracts many unskilled people for survival. The desire for economic and social survival have attracted many people to the industry. Loss of fertile land and adequate drinking water due to small-scale mining activities put socia-economic pressure on the community.

5 COOPERATIVE VENTURE

There are various means of increasing the recovery of gold ore mined by small-scale operators during the processing phase. One possibility is by establishing a gold processing cooperative owned and operated by the small-scale miners. The local research groups can provide technical expertise to such a venture. The major activities of the group are:

1. Purchasing gold concentrate from small-scale miners and refining the gold
2. Renting gold refinery facilities to small-scale gold miners.

Since the cooperative venture is centralised it will reduce effects of chemical pollutants, such as mercury, on the environment. Figure 5 summarises the potential activities of such a venture.

6 CONCLUDING REMARK

Small-scale gold mining operation in Ghana has serious negative environmental impacts. The Implementation Committee of PNDCL218 must take steps:

- To make detailed geological information available to potential small-scale gold operators
- To initiate some form of taxation system on gold sales to fund land restoration
- To initiate educational campaigns on good mining practices
- To institute a cooperative venture operated by the local small-scale miners similar to a model adopted by international smelters of metals

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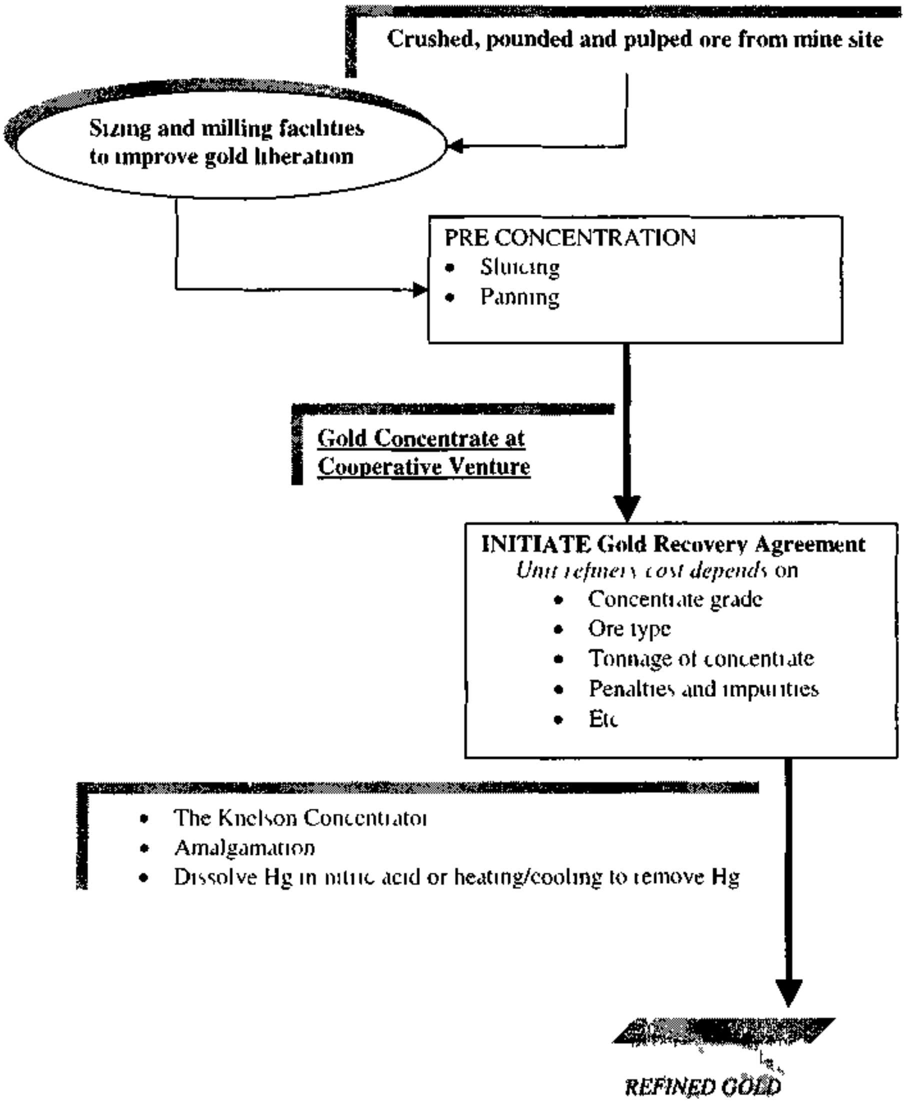

Figure 5 Activities of Small Scale Gold Mining Cooperative Venture

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Mining Method Selection in Third Anomaly of Gol-E-Gohar Iron Ore Deposit

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ABSTRACT: Nowadays application of fuzzy logic has been paid attention for selection of mining exploitation method. The Mining Method Selection (MMS) system takes account of the uncertainty associated with boundary conditions of the categories used to describe input parameters. The Gol-E-Gohar (GEG) iron ore deposits which is located in south east of Iran, Kerman province which has six anomalies out of which, the first one is under extraction by open-pit method. In this paper mining method selection using numerical selection methods such as Nicholas and UBC which proposed in University of British Colombia using fuzzy logic has been studied for mining method selection the third anomaly of GEG iron ore deposit. Finally by comparing the results, it has been found that sublevel stoping and open-pit mining methods are more suitable than others.

I INTRODUCTION

One of the most important steps in decision to extinct a deposit is selecting an optimum mining method. Owing to the considerable impact on the required mining investing time and making profit, the method should have the most compatibility with characteristics of deposit. Some methods like caving require a great value of development and enormous pre-production expenditure. Some others have short pre-production investment period, with low production rate and high operational costs.

Until now, different researches dealing with mining method selection subject have been done by many investigator such as Bshkov and Wright (1973). Morrison (1976), Laubscher (I98I), Hartman (1987), Nieholus (1993), Hamrine (1998), Miller et al. (1995). Karadoğan et al. (2001). Clayton et al. (2002).

In this paper those method selections, which include both surface and underground mining method selection, have been studied, such as Hartman llow chart, Nieholus approach, University of British Colombia UBC mining method selection and MMS system for the third anomaly of GEG deposit.

2 OBJECTIVES

The main aim of the present study is to determine the optimal mining methods for exploitation of the third anomaly of GEG deposit. The GEG iron ore deposits which is situated in south east of Iran, in Kerman province has six anomalies out of which the anomaly number one is under extraction by open-pit mining method. It has been estimated that the third ore body of GEG area has a length of about 2200 meter (north-south) and an average width of 1800 meter (east-west). The ore zone is magnetite (SG=4.5) with hanging and footwall of schist (SG=2.79) and shale (SG=2.35) respectively.

Physical parameters such as deposit geometry (general shape, ore thickness, dip and ore depth); grade distribution and rock mechanics characteristics and all other necessary data needed for evaluation are collected using field and laboratory tests, which are given in Table I.

3 HARTMAN FLOW CHART

Hartman (1987) has developed a selection flow chart procedure for determining mining method, based on the geometry of the deposit and ground conditions of the ore zone and enclosure rocks. Using this flowchart for area 3 GEG deposit resulted in open-pit and slop and pillar mining methods respectively.

4 NICHOLAS APPROACH

The Nicholas method (1981 and 1993) numerically ranks ore and exploitation methods according such parameters as geometry and rock mechanical proptines ol oie, looiwall and hanging wall /ones Each rankine consists ot numbets 0 to 4" oı '-49'

Table! Input paiameteis toi mining methods selection in third anomaly GEO non deposit

	Pai ametei s	Descııptıon
Ore zone	Genual deposit shape	Platy
	Ore thickness	40 meteis
	Ol e dip	20 degrees
	Gıade dıştı ıbulıon	Gi adual
	Depth	150 nıeteı s
	Uniaxial Conıpıessıve Sticngth (UCS)	128 MPa
	Oveı binden pıessuie	15 MPa
	ROD	*IYA*
	Joint condition	Filled with talk sliength less than rock substance sti ength
	Rock Substance Sti ength (RSS)	8 7
	Rock Mass Rating (RMR)	6 1 5
Hanging wall	Uniaxial sti ength (UCS)	46 MPa
	Oxei binden pıessuıe	9 4MPa
	RQD	*W/<*
	Joint condition	Clean loinl with a smooth sulfate
	Rock Substance Strength (RSS)	4 9
	Rock Mass Rating (RMR)	50
Foot wall	Uniaxial Conıpıessıve sticngth (UCS)	100 5 MPa
	Oveı binden pıessuıe	7 7 MPa
	RQD	15'/
	loınt condition	Clean |omt with a lough suiface
	Rock Substance Stiength (RSS)	IV/r
	Rock Mass Rating (RMR)	50

RIX KSUBST\N(I S1RLNG I'll I RSS) = IK S/OVtRBURDhN PRLSSl RL

This system provides, a quantitative appioach loi selecting a mining method Weight lactois loi geomctiy condition oie zone, hanging wall and lootwalls mechanical charactenstics are '1 1 0 8.0 5' lespectively Top eight mining methods using the Nicholas method ıesulted are given in Table 2

Table 2 Summary ot evaluation using Nicholas method loi numbeı 1 lion oie GEG deposit

VU tb d	OP | (1	SH	SS	TS	SO	BC	S(
Rink	12 '1 W	2« 1	2S S	2S S	2S	i(> 1	2117

OP upuı pil mmini. BC block nuns: SS subL\c*l stoppnm SC subkvU c iwnc I W lonu \\ ill RP room and pill u Sil slıııııLmc CI H I! md till IS top \IIUIIL SO squiii? set nimmg

Nicholas mining method selection system shows that open-pit and cut and till mining methods aie most suitable

5 UBC MINING METHOD SELECTION

The UBC method selection pioposcd by Miller et al (1995) ıs simply a modified version ot the Nicholas approach Its rating system follows a veiy similar way to the Nicholas appioach But a value '-10' was inlioduced to stiongly reduce a method chance without totally eliminating it as with '-49' value Moıe oveı, the ıock mechanics tarings (RMR) wcie adjusted to icflect impiovemcnts with giound suppoit and momtoiing techniques

The modifications emphasize sloping methods with lowci pioduction late These changes weie empıııcally deıived to lellect current Canadian mining cxpenences Besides, The UBC selection method utilizes deposit depth pmnaiily to eliminate oı ıestnct use ot open-pit mining Using this method with a procedure in a similai manner to Ntcholas appioach, the top eight mining methods resulted which ıs given in Table 1

Table 3 Summary of evaluation using UBC method toi number 3 lion oie GEG deposit

Mi.lll.nl	SS	OP	CF	SC	BC	S H	TS	SO
Rink	14	11	11	:S	24	I T	IC	1»

OP open pıt minin» BC block L iving SS sublevij stopping SC sublevel (."ivıng I W long will RP room inü pilhr Sil sluinkage CF cut mil till TS top slicing SQ squire set milling

Accoiding to the UBC method sublevel stoping and open-pit mining methods are most suitable respectively Unfortunately neıtheı ol these methods takes account ot the unceıtaınty associated with boundary conditions ot the categories used to descnbe input parameters For example, the ore dip may be "Flat', Intermediate' and 'Steep' The thud anomaly GEG deposit dip is 20 degrees, which lies near a boundary between adjacent cnsp sets, and then the rating ot dip becomes uncertain It means that for mining methods the dip rating toi 20 degıees is similar to that of 40 oi 55 degrees

6 MINING METHOD SELECTION (MMS) SYSTEM

The MMS system proposed by Clayton, et al (2002) This approach is similar the UBC mining method selection algorithm, but incorporated tuzzy logic in analysis procedure This system modifies the UBC approach by considenng the uncertainty associated within the boundaries between input paiameter categories The rating toi geometiy and grade distribution rock mass rating and rock substance strength are modified by multiplying the degiee ot confidence in membeiship range determined from memoiy maps by respective rating weights A single iule is used toi each output level, while the output level ot each individual mining method taking in consıdeıatıon

Total MMS rating=l(s,g,d,p,rmr,rss)
=I|DOB(s,g,d p,rmr,iss)*RANK(s,g,d,p,rrnr,rss}(l)

where,
DOB Membeiship degrees
s deposit shape
g deposit grade distribution
d deposit depth
p deposit plunge or dip
rmr rock mass rating ot hanging wall, ore zone, and toot wall
lss rock substance strength ot hanging wall, ore zone, and toot wall

Based on the tuzzy set, membership distributions ot dip in MMS shown in Fig I

This equates to a 0 5 certainty that the dip is "Flat" and a 0 5 certainty that the dip is "Intermediate' Therefore it can be written

Dip (20 degree)= {0 5/flat, 0 5/intermediate, 0/steep}
= {0 5/flat, 0 5/intermediate)

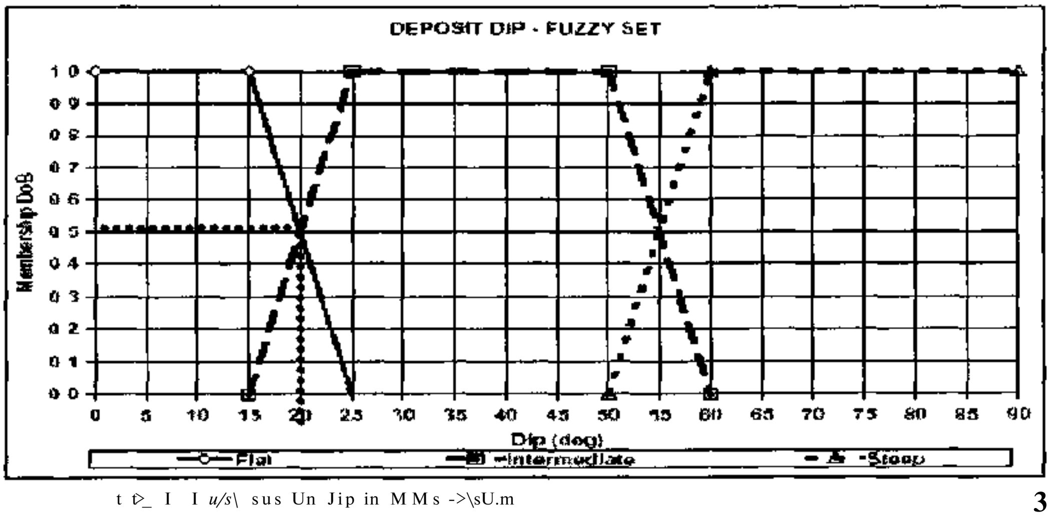
Theretoie in this deposit, the deposit dip in the final ranking for sublevel stopping would be

Ore dip rating (sublevel stopping)=
2*membership degree (oie dip flat)
+ 1 * membeiship degree (ore dip intermediate)
+4* membership degiee (oie dip steep)

Ore dip rating (sublevel stoping) =2* 5+1* 5+4*0= 1 5

The RMR evaluation in this system according to tuzzy set distribution shown in Fig 2, which shows that RMR ot ore zone (63 5) membership degree is 0 3 ot "Fair' and 0 7 ot "Good"

RMR ot ore zone (63 5)={0 3/tair 0 7/good)



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After calculation, the RMR rank of third anomaly GEG deposit for each method's has been shown in Table 4.

The map for RSS has been developed so that the crossover point between categories determined in Figure 3. According to above-mentioned map the following equations can be written for ore hanging wall and footwall zones respectively:

RSS ore zone (8.7)={0.75/weak, 0.25/moderate}
RSS hanging wall (4.9)={0.55/very week, 0.45/weak)
RSS foot wall (13) =0.8/moderate, 0.2/strong}

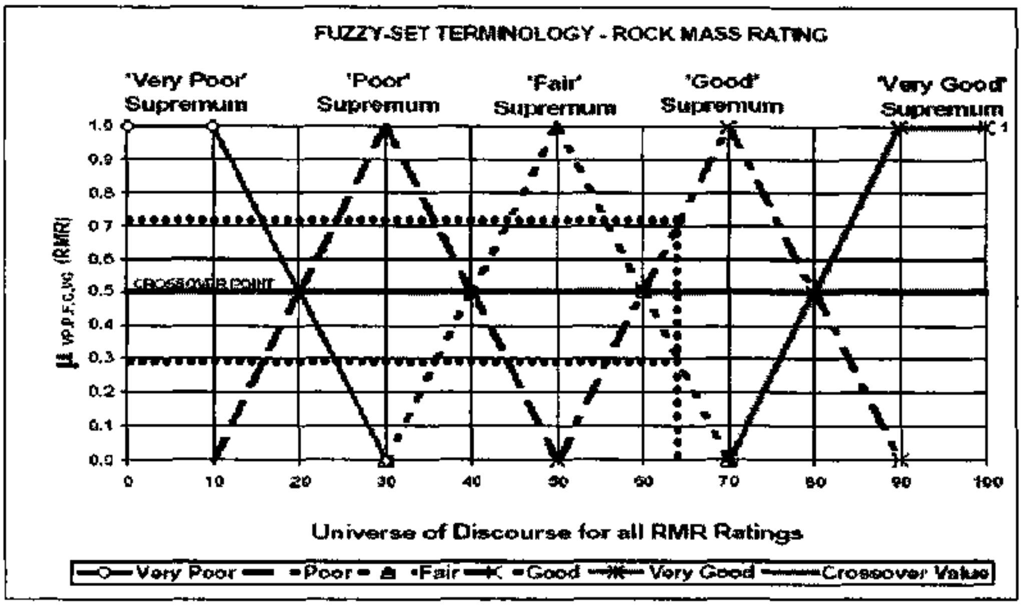

Fig 2: Fuzzy set for RMR in MMS system

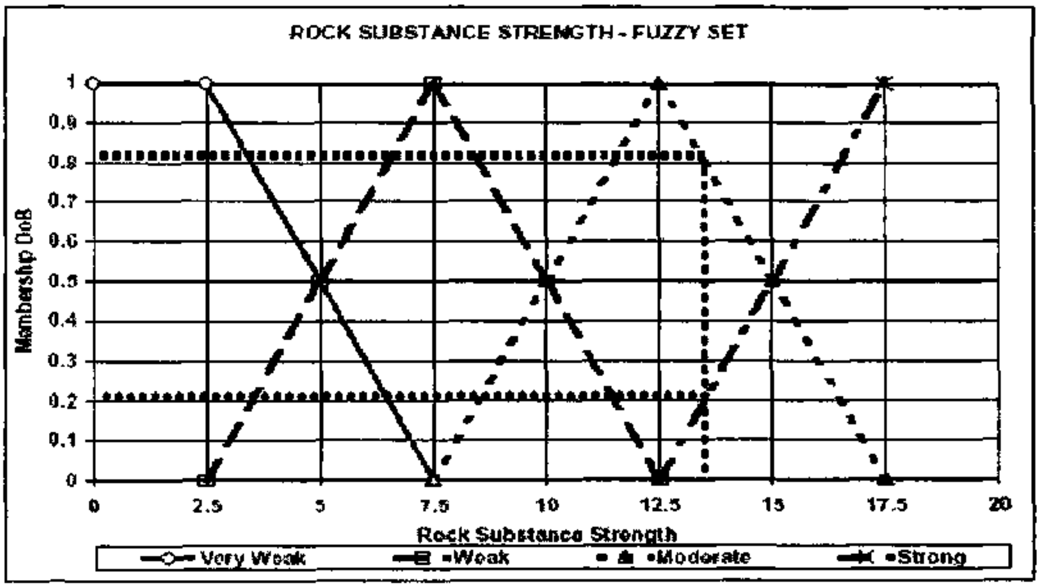

Fig 3: Fuzzy set for RSS in MMS system

Table 4 MMS system ranking for third anomaly of GEG Iron ore deposit

Method	UP	BC	SS	SC	LW	RP	SH	CF	TS	SQ
General shape	2	2	4	4	4	4	4	4	2	1
Ore thickness	4	3	4	4	-49	-49	-49	-49	2	0
Ore dip	3	25	1 5	'	2	2	-2.45	-24.5	3	2 5
Grad distribution	3	2	4	T	1	2	2	2	1	1
Depth	Ü	3	4	2	2	3	3	3	1	i
RMR										
Ore zone	3	Ü.6	4	1 6	26	4.4	3	3	1	0 3
Hanging Wall	3	3	3	3	4	3	2	2	1	1
Foot Wall	4	3	2	?	-	-	2	2	1	0
RSS										
Ore zone	3	1 75	25	3	4.25	0.75	1.5	1.5	1.75	2.5
Hanging Wall	3	3 55	0.45	3 5	5.55	0	0 45	3.9	2 55	3 1
Foot Wall	4	1 8	3	2	-	-	3	2	1	0
Total	22	19.6	23.45	21.5	-37 25	-37 25	-59.55	20 4	14.3	11.1

OP: open-pit mining, BC: block caving, SS: sublevel stopping, SC: sublevel caving, LW: long wall, RP: room and pillar, SH: shrinkage, CF: cut and fill, TS: top slicing, SQ: squire set mining

For the other ranking parameters such as deposit depth, thickness, RMR of walls there was not any difference between MMS system and UBC method in No.3 anomaly because their rate was far from boundaries.

Finally by comparing the results, it has been found that sublevel stoping and open-pit mining methods was more suitable than others, while based on geometric condition and grade distribution sublevel stopping has the highest rank and based on rock mechanics characteristics the open pit method is the most suitable one.

7 CONCLUSION

Typically, systems used to select potential mining methods based on rating a number of input parameters do not account for the inherent uncertainty associated with the selection process. These uncertainties are particularly very important and deterministic in the boundaries between the categories. The MMS system is a method built on the UBC mining method selection algorithm that incorporates fuzzy logic in the analysis which can be used as, a remediation tools for above mentioned short- comings. Using MMS system for selecting optimum and most suitable method according to conditions of number 3 anomaly of GEG Iron deposit, sublevel stopping and open-pit mining methods has been identified as more suitable methods. Compared with open-pit and cut and fill from Nicholas method and sublevel stopping, open-pit and cut and fill from UBC selection methods

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Stability Analysis of the Second Site of the Sarcheshmeh Heap Leaching

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ABSTRACT: The second site of the Sarcheshmeh valley leach facility extends over 300,000 irr which may eventually reach heights of nearly 90 m, is situated in the west side of the mine. This paper discusses the stability analysis of heap leaching structure. Hence, it is important to be able to assess the bonding properties of the interface between the geomembrane and inclined surface. The bonding strength results from friction, cohesive forces or combination of the two. Thus the interface friction between texture and smooth HDPE geomembranes and granular soil of cushion layer was investigated by a series of shear box tests. A conventional limiting equilibrium technique based on Carter and Janbu methods was employed using STABL and CLARA softwares. The results of analysis indicated that some profiles along the valley might not be stable due to PLS (Pregnant Leach Solution) level in the heap and blast vibrations.

I INTRODUCTION

Slope stability is an extremely important consideration in the design and construction of heap leach piles. The task of the designer therefore is to minimize the ongoing construction costs of this kind of structure by maximizing the volume of material that the facilities can contain without unduly risking failure (East & Valera 2000).

The second site of the Sarcheshmeh heap leaching is a lined valley leach facility that extend over 300000 m" on a steep valley situated in the western side of the mine which contain 6 million m of low grade copper ore.

Liner systems placed to contain the Pregnant Leach Solution (PLS) often introduce low interface friction angles along the base of the ore heap. Certain geometric shapes associated with valley fills can produce ore heaps for which the heap slopes are stables but the entire ore mass is not.

The most probable causes for geomembrane liner failures under high fill-load conditions, based on post-failure review of available literature, second-hand verbal information, and site or photo observations of 12 known heap leach pad slope failures that have occurred since 1985 (Breitebach, 1998). Another more than 16 failures that have occurred as recently as 2003 are not included due to insufficient information to confirm these failures.

This paper presents the potential for massive heap failure by performing the results of stability analyses using low interface friction angles derived from laboratory test data and a sample cross section typical of some valley fill heap constructed in steep terrain.

2 MECHANISM OF FAILURE

The critical failure surface and factor of safety depend upon the shear strength of the weakest material in the heap, liner and subsoil system. For synthetic materials, the critical failure surface and factor of safety may depend upon the frictional resistance between the ore and geomembrane or between a sand blanket and the geomembrane.

Slope failures on geomembrane liner are far less the three main conditions of instability before or during heap leaching:

a)- sliding along the slope due to low value of the interface friction of the granular veneer with the geomembrane,

b)- tensile tearing of the geomembrane, normally at the crest of the slope where the force is maximum,

c)- failure of the anchorage of the geomembrane when its maximum pullout strength is achieved, Figure 1 (Goure et al„ 1998).

this paper is focussed on condition '"a", establishing the strength characteristics of the geomembrane and second cushion layer interface. Figure 2 illustrate the details of the liner system at Sar-cheshmeh heap leaching.

The bottom lining system of the heap is composed of 2 sections: one section constructed over the rock, which consists of a 0.3 m compacted impermeable.

a) sliding along the liner

b) tensile failure of the geosynthetic

c) pullout failure of the geosynthetic

Figure 1 Different cases of slope failures on geomembrane liner.

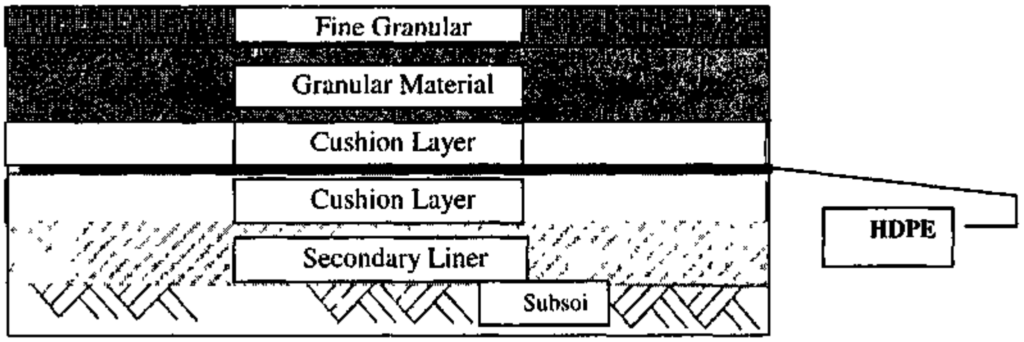

Figure 2 Schematic illustration of base liner.

clay layer that play as a "second liner", and another section constructed over the second liner and comprises a 0.2 m thick fine grained protective "cushion layer".

The 1.5mm HDPE geomembrane liner is laid on the cushion layer. Another cushion layer constructed over the HDPE liner that comprises a 0.2 m thick fine-grained protective. Over the second cushion layer perforated HDPE pipe, was placed within col-lection ditches with sized gravel, surrounding the pipe to prevent plugging by fines. Finally the liner was covered with 350 mm of select granular mate-rial.

2.1 Laboratory studies

Critically important for the proper design of geomembrane-lined side slopes of heap leaching sites, is the soil-to-geomembrane shear strength.

A number of site-specific conditions must be addressed in order to have realistic results, for example: the type and gradation of soil to be placed, the moisture condition during test, the normal sties«, to apply, the time for saturation and/or consolidation, the strain rate to use during shear, and the deformation required to attain residual strength, (Koerncr, 1999).

The shear strength developed at a geosynthetic interface is dependent on both the normal stress applied to the interface and the displacement at the interface. Several authors (Seed et. al., 1988; Byrne 1994) have indicated that most geosynthetic interface are strain softening.

Quick direct shear tests of that interface were performed with the material prepared at a range of dry densities and moisture contents representative of the as-placed condition.

2.2 Method and results of shear testing

Test methods to determine the bond strength at a geomembrane soil interface fall into the two broad categories of pullout tests or direct shear tests.

Direct shear testing is dominant since, among other things, there can be difficulty in interpreting results from pullout tests on extensible materials.

Essentially there are five basic methods which can be used for direct shear testing, (Ingold, 1992): fixed shear box, free shear box, large base shear box, central base shear box, and partially fixed shear box

In this research, the method of fixed shear box was performed. This method employ ASTM D532I. This standard on direct shear evaluation of geosynthetic-to-soil, or geosynthetic-to-geosynthetic, recommends a 300 mm x 300 mm square shear box, in which the geomembrane is mounted on a rigid block which is placed in lower half of the shear box. The upper half of shear box is filled with soil which is sheared over the geomembrane below. Measured peak strength of the smooth and textured geomembrane and second cushion layer interface carried out at normal stresses of 0.5. 1. 1.5, 2. 2.5 and, 3 kg/cm^2 A straight line of the Mohr-Coulomb failure envelop gives adhesion (of geomembrane to opposing surface) 0.03 kg/cm^2 and friction angle 19° for smooth geomembrane. For textured geomembrane, the value of 0.07 kg/cm^2 and 31" obtained for. adhesion and friction angle respectively.

The roughened surface of a textured geomembrane results in a significant increase in interface fric-tion with adjacent materials versus the same geomembrane with a smooth surface.

3 STABILITY ANALYSES

At Sarcheshmeh, high density polyethylene (HDPE) in heap leaching is placed in direct contact with cushion layer. This will lead to a component of gravitational force acting in the plane of the geomembrane, which can cause it to slide down the inclined surface. Consequently it is important to be able to assess the bond properties of the interface between the geomembrane and inclined surface. The bond strength which can be made available may be frictional, cohesive or combination of the two, (Karimi Nasab el. al., 2001). Heaps may also fail by sliding along a high slope leach pad because the saturated solution layer in the blanket over the impervious liner lubricates motion. This is also illustrated in Figure 3 (Bartlett, 1995).

The geometrical configuration of the Sarcheshmeh heap area consists of four small valleys Figure 4. So this site is variable and complex and the results ol the analysis do not necessarily apply to the whole site.

Due to some significance in terms of the difficulty of a two-dimensional representation of slope stability analysis, it was therefore decided that stability analysis should utilize a slope stability methodology that incorporated three-dimensional effects for each valley.

A conventional limiting equilibrium technique, based on the Carter and Janbu approaches were employed by using STABL and CLARA softwares for 2-D and 3-D analyses respectively. For non-circular failure surfaces the analyses were conducted using a two-dimensional software of Carter method of slices. The tree-dimensional representation of the base and basal sideslopes used in the stability analysis, one of these results is shown on Figure 5 by CLARA software

Assuming the simultaneous mobilization of peak strength over the entire sliding surface, the predicted factor of safely from the 2-D and 3-D analyses lies within the range of about 1.3 to 1.6, for the zones of saturation above the liner lower than 2 m.

In a number of cases, instability has been due to build-up of high level of PLS in the heap from poor heap drainage or high rates of infiltration due to high rales of leachate application or rainfall (Breitenbach, 1998).

The results of analysis by STABL and CLARA indicated that some profiles along the valley might not be stable due to PLS level in the heap and blast vibrations. So the collection system within the heap must be designed to maintain zones of saturation above the liner at levels as low possible lo provide adequate stability and minimize the risk.

The other controlling factor for the stability of the second site of heap leaching was the interface friction between the geomembrane and the heap in the area of the toe. For providing a satisfactory factor of safety an area of HDPE about 150 m from the toe was identified as requiring textured liner instead of smooth liner, with its higher angle ot friction. The geometrical configuration of the heap area dictate to perform textured liner from the toe to a point ap-proximately halfway up the valley side.

4 CONCLUSION

- The site is variable and complex and the results of the analysis do nol necessarily apply lo the whole site.
- Stability analyses indicate that a textured liner is required from the toe to a point approximately half way up the valley side.
- The presence of fluid pressures acting along all or portions of potential failure plane has the consequence of reducing stability.
- Proper drainage of leach solution above the geomembrane is critical in the performance of the heap leaching project.
- With complex pad geometries such as second site of the Sarcheshmeh heap leaching, some tnal-and-error searching is necessary to locate the more critical sections.

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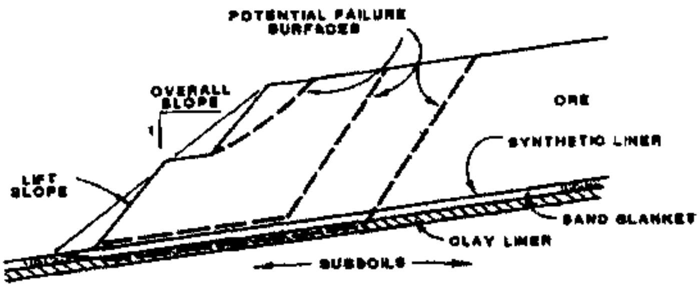


Figure 3 Potential ground failures in a wet ore heap

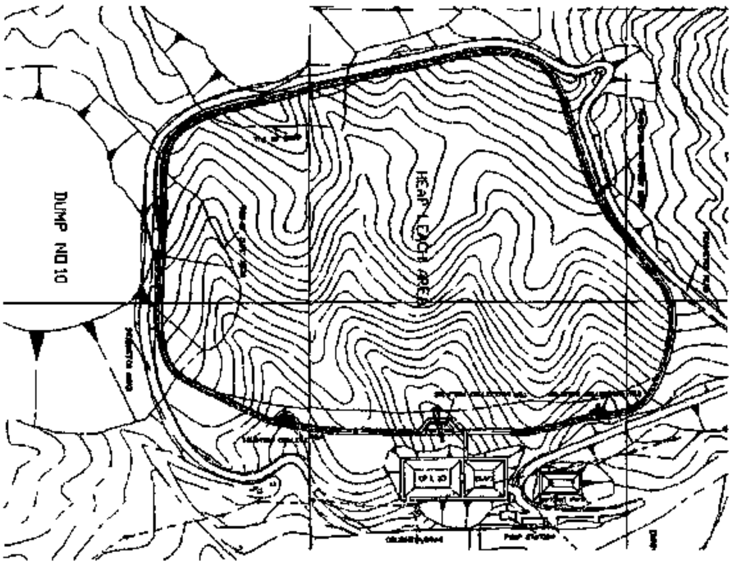
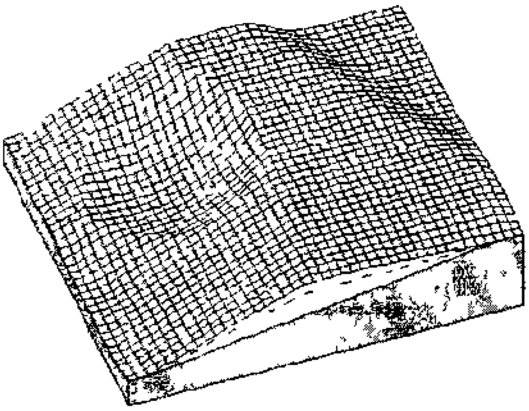


Figure 4 Geometrical configuration of the Sarcheshmeh heap area



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ACKNOWLEDGMENTS

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Problems of Environment Protection During the Utilization of Spent Vanadium Catalysts

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ABSTRACT: In the paper technology is presented which allows environment protecting and utilizing completely the main components of spent vanadium catalysts with high-quality products receiving.

I INTRODUCTION

Modern conditions of mineral-raw materials basis, generally change owing to processing of more poor ores. This allows regarding some industrial wastes as promising repeated raw materials, which are high-concentrated and include valuable components. Spent vanadium catalysts from sulphuric acid production, nitrogen industry, Claus-process, selective catalytic reduction of NO_x gases by ammonia are such repeated materials. They include toxic components, and their burial without disactivating is prohibited. The technologies for spent vanadium catalysts processing offers ensuring environment protection which were tested in industrial conditions.

2 DETAILS OF THE STUDY

Today in the Republic of Kazakhstan, like in other countries of the world, a tendency is observed as mining of poor ores at deep levels in hard mining and geological conditions. These factors decrease the profitability of exploitations of a number of ore deposits. That is why it is possible to regard some industrial wastes as promising repeated raw materials. Such high-concentrated mineral raw materials are spent vanadium catalysts (SVC) which are used for sulphuric acid production by contact method. For its production, gases from roasting of copper, lead and zinc ores are used, characterized by non-stable composition and presence of harmful admixtures, which cause the quick decreasing of vanadium catalysts' activity. Average service life of vanadium catalysts is 1-2 years. And the most harmful admixtures are arsenic, fluorine and selenium, in fact they are very toxic elements. SVC may be: stored in special waste fields, buried and utilized. *SVC* storing and burying are very dangerous for environment because in these cases pollution of surface and underground water and soils takes place. SVC utilization may be carried out in two directions:

1. Immediate usage of spent vanadium catalysts without their regeneration by a way of charging at different stages *of* process new made vanadium catalysts. This method may be used only for catalysts, which do not include contact poisons.
2. Extracting the main components from spent vanadium catalysts and their usage in new made vanadium catalysts production. By this way we may receive pure compounds of vanadium.

Scheme of SVC processing is presented in Figure I.

Technology was worked out for spent vanadium catalysts processing, which allows the utilization of the main components of SVC (vanadium, potassium, silicon) and receiving high-quality products (catalyst and pure solution of fertilizer K_2S0_4). This technology was tested in industrial conditions. Received new made catalysts have catalytic intensity of 84-86% and 40-45% when temperature is 485°C and 429"C, respectively. Pure solution K_2S0_4 was tested both in industrial conditions as a raw material for liquid potassium fertilizer production and in agricultural conditions as an independent fertilizer. This method of spent vanadium catalysts excludes gas emission and water discharge at all stage of SVC processing.

3 CONCLUSIONS

Using of offered technology of spent vanadium catalysts processing allows avoiding of industrial areas pollution by toxic elements, decreasing negative technical-in-gcnesis action of mining and metallurgical complexes on environment and, at the same-time, receiving necessary goods for industry and agriculture of the Republic of Kazakhstan.

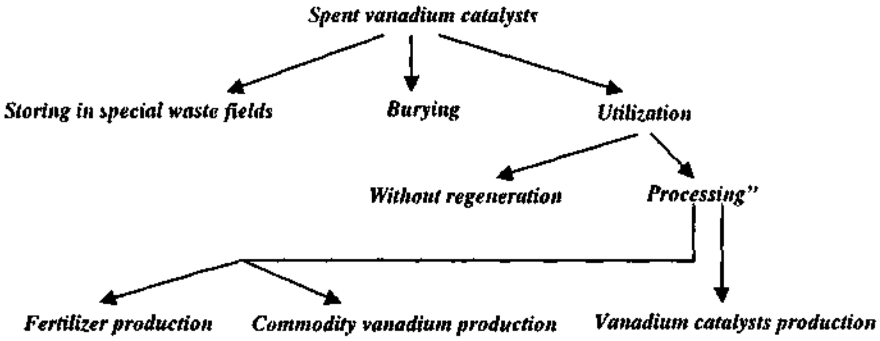

Figure 1 Scheme of spent vanadium catalysts processing

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Technologies for Environment Protection at Mines of Non-ferrous Metallurgy and Their Introduction in Practice

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ABSTRACT: Mines of non-ferrous metallurgy account for third part of solid, liquid, dust-like and gaseous materials polluting soil, water reservoirs and atmosphere. The main sources of pollution are: dumps of non-commercial ores and broken rock, ore tailing piles; mine water; mine dust; harmful waste of mines (acids, iron cut and so on); public waste from mine settlements; dust from different kinds of roads. In the paper worked out technologies are presented for environment protection.

I INTRODUCTION

As a result of mining operations at any mine 15-20 thousand ha are occupied and 40% of them are used for rock dumps and ore tailing piles forming. As of 1999, total quality of solid waste of mining-and-metallurgical complex of the Republic of Kazakhstan was 9 million tons. They occupied land area of 2752 km^2. For environment protection at mines it is necessary to create and to introduce technologies which exclude pollution and transform waste into innocuous and useful products saving funds and labor.

2 RESULTS AND DISCUSSION

Waste-free technologies were worked out and introduced for processing of oxidized copper ore of Zhezkazgan deposit by heap leaching at Aktehiy-Spasskiy open cast. During the utilization of this technology the following technical-economic indexes were received: production of a unit on ore - 110 000 tons, copper content in ore - 1.2 %, copper quantity in ore - 1320 tons, copper extraction into solution was 91.5 %, silver- 60%; copper extraction into precipitate was 94.8 %, silver - 100 %. Solid waste of this process was used as filler for preparing of filling mixtures, used at Northern-Zhezkazgan mine. This allowed increasing of strength of filling mixture by 2 times and decreasing cement consumption by 20-30%. At Kazakhstan's mines there are large reserves of oxidized and lean ores, some of which may be processed by the method of heap leaching, and this will allow widening of mineral raw materials base of mining enterprises and decreasing ore losses.

Today a tendency is observed of increasing of worked-out space of mines using for location of harmful waste. Experience of worked-out mine workings using is not so large in the Republic of Kazakhstan in comparison with foreign countries where this problem was paid attention taking into account its high technical and technological efficiency. Technologies were created by us for worked-out space of mines using for location of harmful waste of mines and mine settlements (iron cut, washing acid from, ore processing and so on). When burying of harmful waste, including liquid component, constructions of cofferdams are used, technologies of constructing of which were run in when deposits mining with consolidating stowing. Harmful industrial waste location in worked-out mine workings will allow decreasing costs on burial by 2 times in comparison with their surface burial and ensuring minimum influence on environment and maximum technical-economic effect.

We also worked out and introduced technologies of dust suppression at ore tailing piles, rock dumps, roads of open casts and mines. For dust suppression at ore tailing piles emulsions were worked out on the basis of bituminous rock with bitumen content 10-20%, including sodium silicate and surface-active materials. When this emulsion was used dusting surface remained homogeneous for 6 months. For dust suppression at tailings piles of copper ores of Zhezkazgan deposit emulsions were the most effective, when they were prepared from bituminous rock including 5% of sodium silicate, 1% of surface-active materials with bitumen concentration 10 and 20%' (patent). When testing surface of ore tailing piles, covered with bituminous emulsion (bitumen concentration was 10%), under air temperature 20-25°C the surface was homogeneous during all period of observations for 6 months.

Dust precipitation from mine air is of great importance. When powerful winning and transport self-propelling machines operated different harmful pollutants are formed and they pollute mine atmosphere. It was established that through air shafts large volume of mineral dust and toxic gases are threw into atmosphere. As a result of blasting operations toxic gases and dust are threw into atmosphere, too. Dusts, including toxic metals: mercury, arsenic, selenium, cadmium, nitrogen and carbon oxides are the most dangerous ones. Copper-smelting and sulphuric acid productions of Zhezkazgan are sources of tens tons of CO., $S0_2$ and other harmful compounds. In correspondence with limiting permissible concentrations (LPC) standards mine dust content in air must be not more than 0.5 mg/1, nitrogen oxides - 0.03 mg/l, carbon oxide - 1.8 mg/l. Practically in all technological processes dust concentration in air is greater by several fold of LPC. Worked-out methods of dust collecting allow air purification from dust up to 46-70% depending on the place of dust formation. And dust content in air decreases from 6.9-27.4 mg/m^1 up to 3.0-14.9 mg/m^3. So, air of working zones needs additional purification by a way of methods of deep air purification and special apparatuses (hydrofilters, electrofillers, cyclones of different constructions and so on) using.

Ore tailing piles are harmful sources of environment pollution, which are of great danger for human health as far as they include up to 80 % of silicium dioxide, activity of which increases when lead and rhenium is found in air. It is known that when wind speed is 5-6 m/s movement of particles (1-100 u) takes place at a height of 20 cm of day surface. In many regions of the Republic of Kazakhstan, including Zhezkazgan oblast, windy weather is 100-150 days a year, and wind speed is 20-25 m/s. That is why dust from ore tailing pile rises up to a considerable height and is carried off boundaries of ore tailing pile. Two compositions were worked out for dust suppression at ore tailing piles. These compositions ensure forming strong (0.18-0.21 MPa), proof against water crust which discourages wind erosion.

3 CONCLUSION

All worked out technologies for environment protection are covered by patens of the Republic of Kazakhstan. Their usage may decrease harmful effects of mining-and-metallurgical complex of Kazakhstan on environment and ensure widening of mineral raw materials base of mining and metallurgical enterprises.

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Sustainable Development in The Salt Industry of Romania

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ABSTRACT: At present, in Romania are 7 salt exploitations (Slänic Prahova, Tg.Ocna. Ocnele Mari, Ocna Mures. Ocna Dej and Praid). In the last 13 years, the salt exploitations are in a production reorganisation .

1 INTRODUCTION

/. / The rock salt

Salt has always represented one of Romania's main assets. It has been identified over 200 salt massifs, which generally contain much NaCI (97-99%). In salt, there are the following mineral associations with generally subunit values: oxides (rare hematite aggregates as well as minerals belong to quartz family);sulphides(marcasite aggregates, associated with cubic pyrite crystals, crystals of chalcopyrite and yellow-brownish sphalerite), carbonates (dolomite rhombohedrons occur 0,3-0,5mm); sulphates (gypsum crystals, anhidrites, hunlitts); more rarely grains of glauconite and fragments of reddish-brown rock spotted with green , as well as several remains ot volcanic glass . In salt massifs there are organic residues made up of wood fragments silicifiation, bituminous coal fragments and amber fragments. There are also forms of nannoplanctons and foramimfers.

The main mineral - NaCI - often present in surface made historically possible not only barter relations but also the development of a road network through different peoles wondered.

1.2 The salt mines

Alter thousands of years' activity, salt has been extracted from 46 salt massifs. Several exploitations are already closed. Some of them had ephemeral existence, others worked for hundreds of years (Slänic. Praid. Târgu Ocna. Cacica), and others have continuity since antiquity until today (Ocnele Mari. Ocna Mures).

At present there are 7 salt exploitations (Figure 1) out ot which 3 with gema salt (Slanic Prahova, Ocna Dej and Praid), 2 with gema salt and in solution (Râmnicu Vâlcea, Târgu Ocna) one with solution and crystal ised(Ocna Mures) and one with gema salt and recrystalized (Cacica).

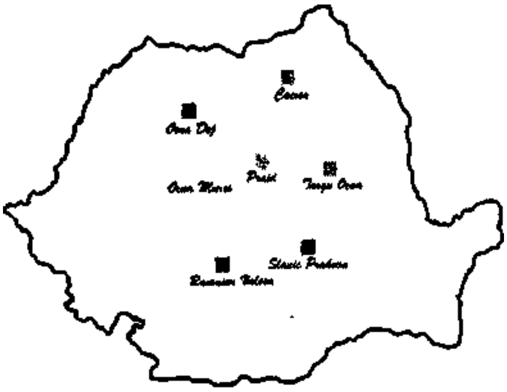

Figure 1 : Map of the salt exploitation from Romania.

2 THE ECONOMIC MONOPOLY

In the Middle Ages, salt was under the rulers' monopoly (those who noticed the opening or closing of an exploitation), sometimes in the property of princes, of ride boyars, monastries. or peasant community. During the lanariot princes confirmed by Ottoman Empire, at about I7S0 salt exploitation started to be leased for sums of money paid at different periods of time, I -2 years.

Documents certified the names of those who bought and exploited : loan Moscu (1791, 1797, 1803. 1812) Dragoman Manu (Manuc Bei - 1809), Russian commenders Kokieaki (1810-1811); Filiph and Stefan Meitani (1827-1829. 1830-1834). After theı Russia Turkey war (1828-1829) under the influence of Russian occupation, a new set of laws appeared known as 'Organic Regulations' and sail is owned by the state in 1834 at Elbna Ocnelor(the first state owned salt company). Pont the old economic relations were stronger than the lames and on the I"^{1} January, 1836 Eforia Ocnelor was abolished and leased again by Otätäiäsescu (1840) and then by others. After the union of the two provinces, "Tara Româneaseâ" and "Moldova"(1859). the slate started to exploit salt again on 9^{1h} July. In 1929 it change into C.A.M.t Autonomous House of State Monopolies. In 1949 salt passed to the Ministry of Food Industry, in 1952 to Ministry Of Chemical Industry, in 1961 to Ministry of Mines, Oil and Geology) After 1968 salt exploitation belonged to the same Ministry but was organized by Salt and Nemetaliferous Bueharest-C.S.N.(I968-I990). In 1981 CSN became subordinated by the Ministry of Mines, in 1986 by Ministry of Mines, Gas and Geology and since 1987 by the Ministry of Mines. In 1990 CSN became the Autonomous Administration of Salt Bucharest. It was under the management of the Ministry of the Industries (1991- 1997) R.A.S Bucharest was reorganized under the form of National Salt Society in 1997 and was subordinated to the Ministry of the Industries and Trades (1997-2001) and since 2001 it has been managed by the Ministry of Industries and Resources.

3 ACTUAL TIMES

Since 1990 there has been a change in salt exploitation in Romania. These changes will be dealt with under the following aspects: legislative frame, exploitation activities, new equipments, standardization, production reorganization, reusing mining holes, entering in profile associations, privatization program.

3.1 *Legislative frame*

Mining activity in the last century has had the following evolution: an important event took place in 1895. which was the Law of Mines, which confirmed the State property of the underground. After a new Constitution appeared in 1921, another law of mines was necessary in 1929. As a result of the social changes occurred after 1989 in Romanian society the issue of a new Constitution was needed (1991) which by article 135 alinéa 4 claimed that underground resources are exclusively public property and can be leased, confessed or hired. Afterwards, in 1998, mineral resources capitalization was regulated by a new law called Mine Law. On its basis, in 1990, Salt National Society- Share society-gets exploitation licenses for twenty years for all its branches

3.2 Exploitation activities

On the basis of the increase of geological research the following activities were materialized: opening new mines(S15nic Prahova - Cantacuzino Mine-1990) Ocnele Mari (Coceneşli Mines- 1993); putting into service new exploitation derricks.

3.3 New Equipment

For both mining and grinding and packing activities great efforts have been made in order to get new equipment! perforation: Secoma- France, sifting -Italy; packing machines Italia).

3.4 Standardization

A new quality system was started in 1994. The subunits were certified with standard ISO-9001 (2002) a CONDEX ALIMENTARIUS.

3.5 Production Reorganization

As a result of setting new markets and of closing of some chimie factory a new market configuration was reshaped. The number of the employees was also modified. In the last 13 years, employees have been made redundant for times in September 1994, in 1997 with the aid of a rambursy, loan from World Bank, in 1999 and 2002. At present only half of the staff employed 13 years ago still work in the mine field.

3.6 Reusing mining holes

Ten years exploitation created underground spaces of thousands of square meters. They were used for ami asthma sanaloriums(Slanic Prahova, Praid. Tagu Ocna), museums(Slanic Prahova ,Praid), churches(Cacica. Târgu Ocna). tourism (Slänic, Ocna Dej, Târgu Ocna , Praid , Cacica).

3.7 Entering in profile organizations

In order to prom ovate the image of the Romanian salt, S.N.S. Bucharest has joined the European Salt Producers Association (ESPA).

3.S Privatisation

In order to improve this activities S.N.S. Bucharest and its branches were included in PSAL-2 privatisation program.

4 CONCLUSIONS

Salt exploitation in Romania, has a long tiddmon and in oder to keep it ertoits have to be made and the best ways of development must need to be found

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1a" International Mining Congress and Exhibition of Turkey-IMCET 2003, « 2003, ISBN 975-395-605-3*

Evaluating the Loss of "Geological" Lignite in "Zebra" Type Deposits

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ABSTRACT: Zebra type lignite deposits are characterized by the multiple interchanges of lignite and thin sterile intercalations consisting mainly of clays, marls and sands. In zebra type deposits knowledge of the geometry and of the quality characteristics of both the lignite and the sterile intercalated layers is of the utmost importance in designing the optimum lignite recovery of lignite reserves. The application of selective excavation requires the determination of recoverable lignite blocks fulfilling specific technical and quality criteria. This procedure results in losses of thin "geological lignite" layers having thickness < 50 cm and losses due to the cleaning of interfaces between lignite and sterile blocks. Both losses are included in the term "geological" lignite losses.

1 INTRODUCTION

The Southern Field Mine, the biggest lignite mine in the Balkan peninsula, is located in Ptolemais basin and has fed the Agios Dimitrios Power Plant since 1983. The annual excavations range between $80x10^6$-$90x10^6$ m^J (bulk), while the lignite production ranges between 18-22 tons. Between 2001-2004 mining activities are being developed in an area of 2.4 Km" as it is shown in Figure 1.

The Southern Field Mine deposit is characterized as a "zebra" type or multiseam lignite deposit, presenting multiple interchanges of lignite and thin sterile intercalations of marly limestones, marls, clays and sands. This type of lignite deposit require'.¯ selective excavation, where thin sterile layers are unavoidably coexcavated with lignite ones thus reducing the mined lignite quality (Kolovos et al. 2002a. b). Furthermore, for mining reasons, thin lignite layers having thickness < 50 cm have to be removed as sterile layers resulting in the loss of "geological" lignite.

In selective mining, lignite and sterile layers are excavated as individual layers or as blocks of layers. The determination of excavated layers or block of layers is a matter of special study work, known as borehole evaluation. During borehole evaluation lignite layers and thin sterile intercalations are combined together according to specific technical and quality criteria in order to maximize the thickness of excavation blocks to achieve productive mining (Karamalikis 1993; Mevorach et al. 1994; Kolovos 2001). Tliese criteria are described in the "Materials and Methods" section. In order to avoid further reduction in lignite quality due to dilution from the top and bottom excavated sterile layers or block of layers, careful cleaning of interfaces between lignite layers or block of layers is required. However for a better mining design, this dilution has to be taken into account subtracting 10 cm from the top and 10 cm from the bottom of the lignite layer or block of layers, thus resulting in further "geological" lignite loss.

The knowledge of the quantity and the quality of "geological" lignite as well as its distribution is of the utmost importance in order to design the optimum lignite exploitation.

2 MATERIALS AND METHODS

For the purpose of this project 1179 lignite samples from 36 drilled boreholes were studied. The investigated area is presented in Figure 1.

"Geological" lignite is considered any lignite layer having thickness > 10 cm and ash (db) content < 40%. "Recoverable" lignite is considered to be any lignite layer or block of layers having thickness <50 cm and ash (db) <40#.

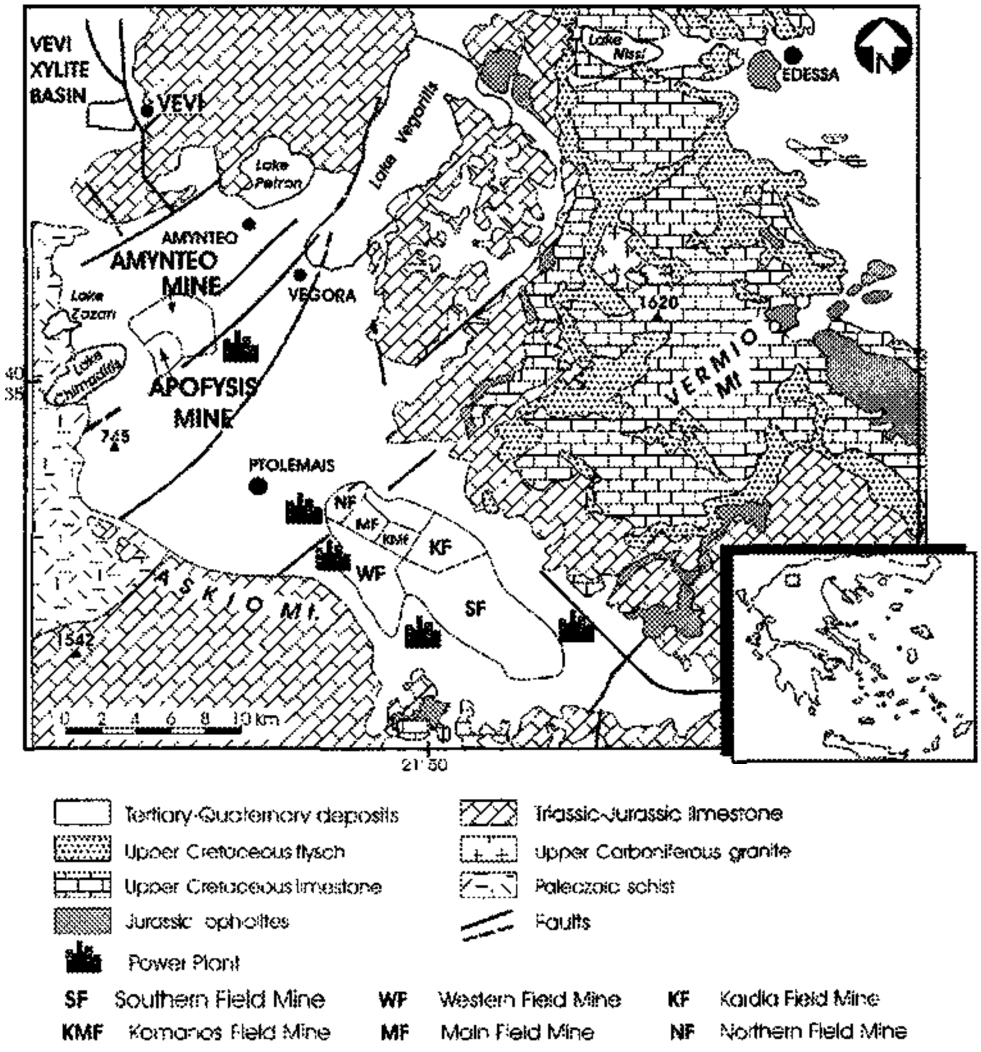


Figure 1. Geological map of the study area

The evaluation of boreholes was carried out by a computer program called METAL, developed by the Public Power Corporation of Greece (PPC) (Karamalikis 1993) and the following criteria were used:

- The geometry and quality characteristics of sterile layers included in recoverable lignite blocks
- The geometry and quality characteristics of sterile layers or block of layers to be dumped
- The geometry and quality characteristics of recoverable lignite layers or block of layers
- The specific gravity of lignite
- The ash (db) content of sterile layers
- The specific gravity of sterile layers
- The calorific value of sterile layers
- The moisture content of sterile layers
- The loss of lignite due to the cleaning of interfaces (the removal of 10 cm from the top and 10 cm from the bottom of lignite blocks).

The aim of borehole evaluation is to achieve the maximum lignite deposit recovery with an average ash (db) content < 30% and net calorific value > 1300 kcal kg"'.

3 RESULTS AND DISCUSSION

The distribution of geological lignite thickness is presented in Figure 2.

..........TaWeJLjtesulfciof site investigation and borehole evaluation

	Recoverable lignite blocks					Geological Lignite layers				
Borehole	Lignite thickness (m)	Number of blocks	Total moisture content (%)	Ash <%)	Net calorific value (kcal kg'1)	Number of strata	Thickness (m)	Loss due to selective mining i!n>	Loss due to .small thickness (m)	Addition of intercalations (111)
1	28.88	12	57.01	24.48	1390	42	30.61	2.40	1.35	2.02
2	54.10	11	54.98	29.23	1390	43	46.90	2.10	0.00	9.30
3	39.40	8	56.47	26.13	1415	3t	39 20	1.60	0.40	2.20
4	40.17	12	58,33	28.23	1275	57	41.14	2.20	1.60	2.8.3
5	28.02	17	58.31	27.38	1290	57	32.94	3.40	2.05	0.53
6	51.60	6	56.44	29 00	1370	39	47.10	1.00	0.40	6.00
7	41.20	14	53.83	28.75	1439	34	39.90	2.40	0.50	4.20
8	62.60	12	54.24	32 02	1341	47	55.20	2.10	0.40	9.90
9	59.05	12	55.95	28.63	1331	46	54.35	2.20	0.90	7.80
to	41.30	8	56.42	28.17	1399	30	39.30	1.60	0.00	3.60
11	39.25	11	58.07	24.27	1479	19	41.40	2.20	0.00	0.05
12	54 00	10	54.92	30.04	1334	40	48.80	1.60	0.85	7.65
13	39.08	22	58.44	28.12	1391	60	42.42	3.90	1.20	1.76
14	44.05	8	54.68	28.24	1356	32	42.45	1.50	0.00	3.10
IS	38.30	12	53.60	25.96	1558	36	37.20	2.00	0.40	3.50
16	56.10	7	51.50	31.29	1481	37	49.10	1.30	0.30	8.60
17	37.80	10	52.13	29 99	1477	28	34.40	1.70	0.70	5.80
18	57.15	17	54.96	30.33	1316	46	52.70	3.20	0.95	8.60
iy	21 35	8	56.59	28.21	1396	12	21.10	1.50	0.00	1.75
20	41.19	15	58.10	30.37	1.302	55	42.05	2.70	2.65	4.49
21	38.10	9	52.40	31.14	1238	30	36.00	1.60	0.00	3.70
22	27.85	15	55 67	31.08	1336	52	33.66	3.00	4.37	1.56
23	20 93	11	54.51	32.22	1293	49	26.02	2.20	5.02	2.13
24	54.30	12	52.79	34.78	1155	37	41.70	1.60	0.00	14.20
25	25.60	8	48.17	37.04	13.39	19	18.10	1.20	0.90	9.60
26	5.50	7	53.75	31.14	1455	12	7.80	1.40	0.90	0.00
27	22.20	7	48.58	32.67	1380	17	17.90	1.20	0.00	5.50
28	23.50	8	52.82	30 68	1290	19	20 90	1.40	0.00	4.00
20	20.60	11	57.87	27 71	1401	13	22 80	2.20	0.00	0.00
30	28.80	13	53.77	28.19	1385	31	29.50	2.50	0.00	1.80
M	7 55	6	47.98	34.26	1370	9	5.95	0.90	0.20	2.70
12	25.70	19	54.22	28.9	1.334	29	27.30	3.60	0.00	2.00
33	23.90	7	54.64	34.79	1218	21	24.20	1.30	0.00	1.00
34	13.80	7	45.47	34.16	1451	14	12.80	1.00	0.20	2.20
35	20.80	8	51.16	34.6	1022	15	19.30	1.40	0.00	2.90
36	19.50	10	54.73	26 27	1243	21	20.80	2.00	0.20	0.90
Sum	1253.22	390				1179	1202.99	71.10	26.44	147.87

Boreholes presenting small lignite thickness are located near faulted zones or near the east edge of the basin. The number of lignite layers per borehole ranges from 9 to 60 with an average value of 32.7.

In Table 1 the results of site investigation and borehole evaluation are presented. The total lignite thickness is 1202.99 m, and the total geological lignite thickness per borehole ranges between 5.95 m and 55.2 m with an average value of 33.4 m.

The distribution of the number of layers per borehole is presented in Figure 3.

After borehole evaluation, 390 lignite blocks were formed with a total thickness of 1253.22 m. The thickness of the recoverable lignite per borehole ranges between 5.5 m and 62.2 m with an average value of 34.8 m. The distribution of the thickness of the recoverable lignite is presented in Figure 2. The number of recoverable lignite blocks ranges between 6 and 22 with an average value 10.8 Its distribution is presented in Figure 3.

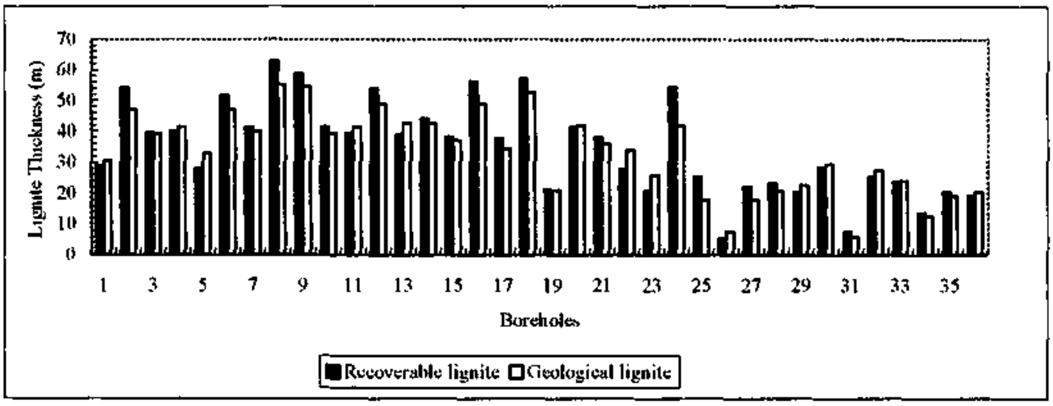


Figure 2 Distubution ot geologic.il lignite and the thickness of recoverable lignite

According to the borehole evaluation the recoverable lignite thickness seems to be greater than the initial "geological"' lignite thickness. This is because thin sterile intercalations are included in the recoverable lignite blocks.

The total geological lignite loss due to thin lignite layers is 26.44 m. The thickness of geological lignite loss due to thin layers ranges between 0 and 5.02 in. It is indicated that 14 of the 36 boreholes (38.9%) have no geological lignite losses and 34 of the 36 boreholes (94.4%) have lignite losses less than 3 m. The distribution of the losses due to thin lignite layers is presented in Figure 4.

The total geological lignite loss due to selective mining is 71.10 m. This lignite loss ranges between 0.9 m and 3.9 m with an average value of 1.97 m. 24 of the 36 boreholes (66.7%) have total lignite losses of less than 3 m, while 33 of the 36 boreholes (91.7%) have total lignite losses of less than 5 m. These values indicate the goixl lignite recovery characteristics. The distribution of the selective mining losses per borehole is presented in Figure 4.

Due to selective mining thin sterile intercalations are co-excavated with lignite layers thus increasing the thickness of the recoverable lignite block. The total thickness of thin sterile intercalations co-excavated with the lignite layers is 147.87 m. The thickness per borehole ranges between 0 m and 14.2 m with an average value of 4.1 m. The distribution of the co-excavated intercalations is presented in Figure 5.

Boreholes evaluation indicates that the recoverable "geological" lignite is

1202.99 m - 26.44 m = 1176.55 m (97.80%).

The geological lignite loss due to thin layers <50 cm is

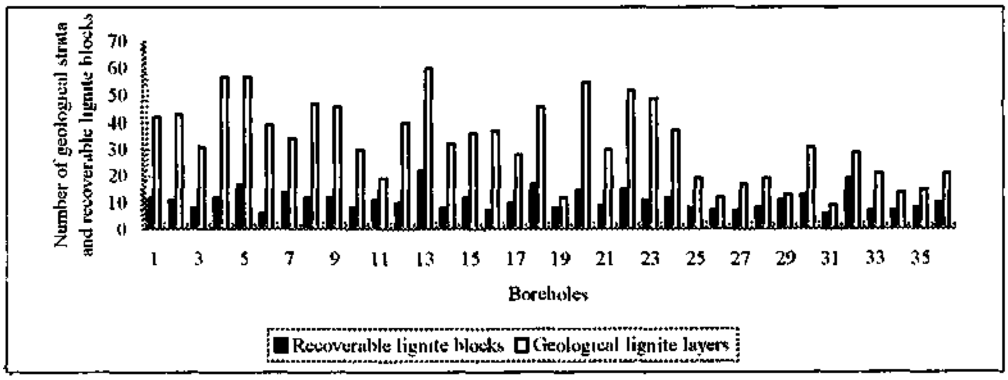
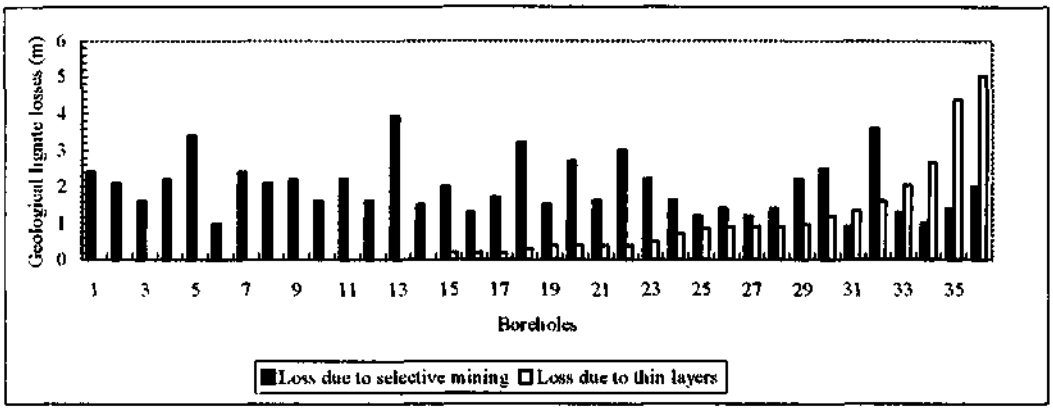
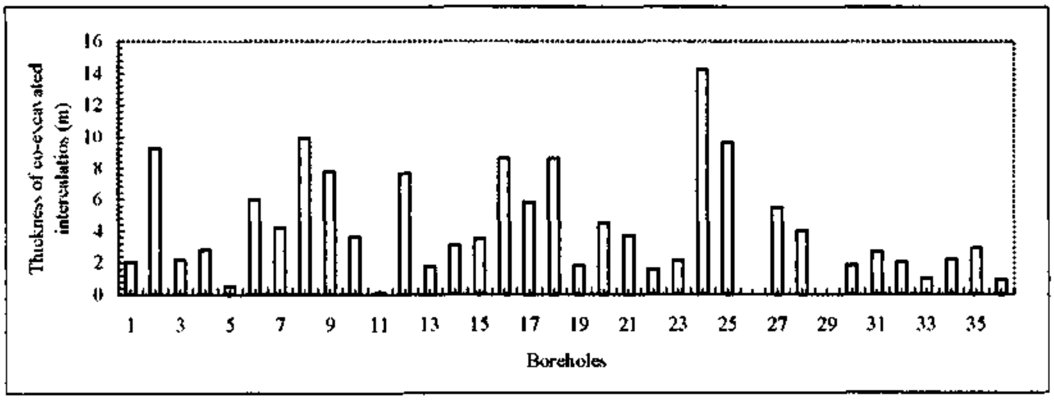


Figure 1 Dıstıhuııun ofgeologic.il lignite and recoverable lignite layers

26.44 m / 1202.99 m = 2.19%.



Figuie4 Geological lignite losses



Figuie 5 The distribution of thin 1nierc.1ljt10iKcocxcdV.1ted with lignite

The geological lignite loss due to selective mining is

71.10 m/1202.99 m = 5.91%

The total '"geological" lignite recovery

is 100 % - 5.91 % - 2.19 = 91.90%.

It is stated that this percentage is not the amount of recoverable lignite since thin sterile intercalations are coexcavated with ""geological" lignite due lo selective mining. The recoverable lignite contains

147.87 / 1253.22= 11.8% sterile intercalations.

Following borehole evaluation the quality of the recoverable lignite is characterized by a total moisture content of 54.68%, an ash content of 29.72% and a net calorific value of 1353 kcal kg'".

4 CONCLUSIONS

Zebra type or multiseam lignite deposits are characterized by the multiple interchanges of lignite and thin sterile intercalations. This type of deposit requires selective excavation where thin sterile intercalations are unavoidably coexcavated with lignite thus reducing the recoverable lignite quality.

Borehole evaluation has to consider lignite losses due to both the thin lignite layers and the cleaning of interfaces due lo selective mining. The recoverable "geological" lignite of the South Field Mine is 97.8%, however after the selective mining losses this becomes 91.90%. This lignite is not the actual amount of recoverable lignite, since due to selective mining, thin sterile intercalations are coexcavated with lignite inci easing the total ıecoveıable lignite quantity Theietoie the final ıecoveıable lignite contains 118% slenle intetcdidtions

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