# HEAP LEACHING TECHNIQUE in MINING

***WITHIN THE CONTEXT OF***

# BEST AVAILABLE TECHNIQUES (BATs)

**Caner Zanbak, PhD**

***Environmental Coordinator,* Turkish Miners Association**

***Environmental Advisor,* Turkish Chemical Manufacturers Association**

**Istanbul, Turkey**

Society for Mining, Metallurgy & Exploration

Society of Mining Professors

Greek Mining Enterprises Association

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# MINING in general

The primary objective of mining is:

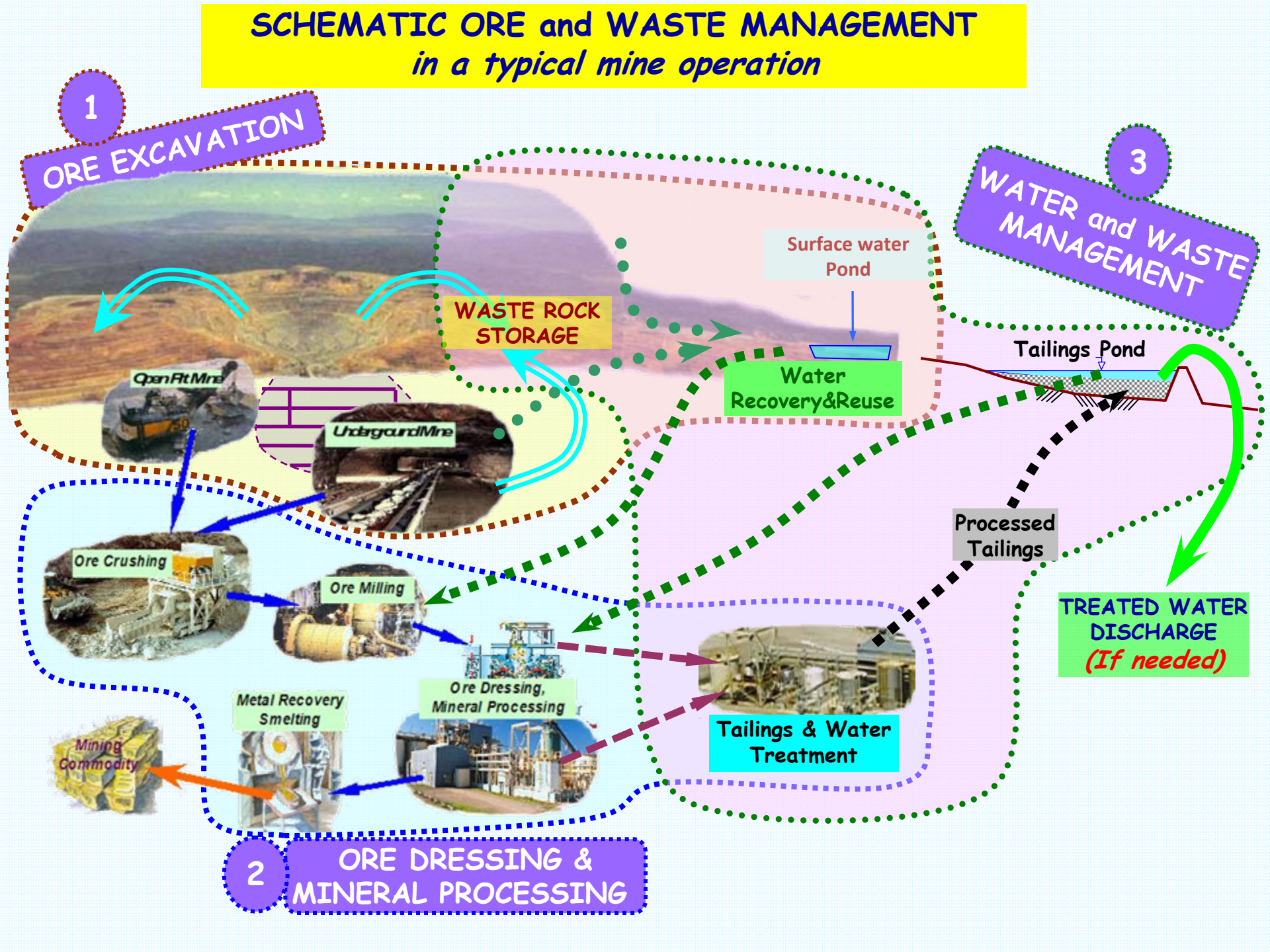
- to supply raw materials to downstream users,
- extracted from ore deposits in the earth's crust,
- using applicable excavation and ore enrichment processes with:
- economically feasible and
- environmentally sound engineering operations.

There are several mainframe ore preparation/ beneficiation methods available in mining practice based on physical, chemical and smelting processes:

- ***Concentration:*** Gravity concentration *heavy/dense media, Shaking tables, spiral separators, jigs), Electrostatic separation, Magnetic separation*
- ***Hydrometallurgy:*** Leaching, Electrolysis, Precipitation *(cementation)*
- ***Pyrometallurgy:*** Calcining, Roasting, Smelting, Refining

All of these processes require crushing and/or grinding/milling of run-of-mine ores for liberation of mineral particles of interest for efficient application of appropriate processes of beneficiation.

# SCHEMATIC ORE and WASTE MANAGEMENT
## *in a typical mine operation*



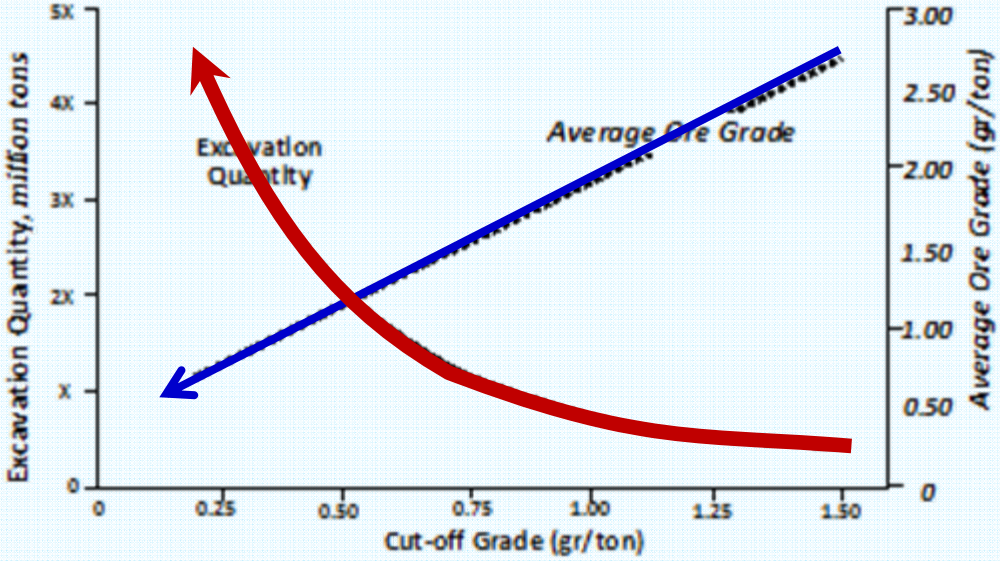
# Selection of a mining/beneficiation technology

is based on **economic viability** which is directly dependent on:

- **ore type** (*namely*, oxide or sulphide),
- **mineral composition, matrix features** of ore
- **reserves** and **average grade** *(based on the "cut-off grade")* of the ore.

Lowering in cut-off grade of ores:

- **increases** asymptotically **the quantity ore to be excavated and treated**
- **increases energy and chemical usage** in pressure/tank leaching technologies,
- **generating larger volumes of tailings** to be managed;
- **decreases profitability**, making beneficiation processes uneconomical **below certain grades**.

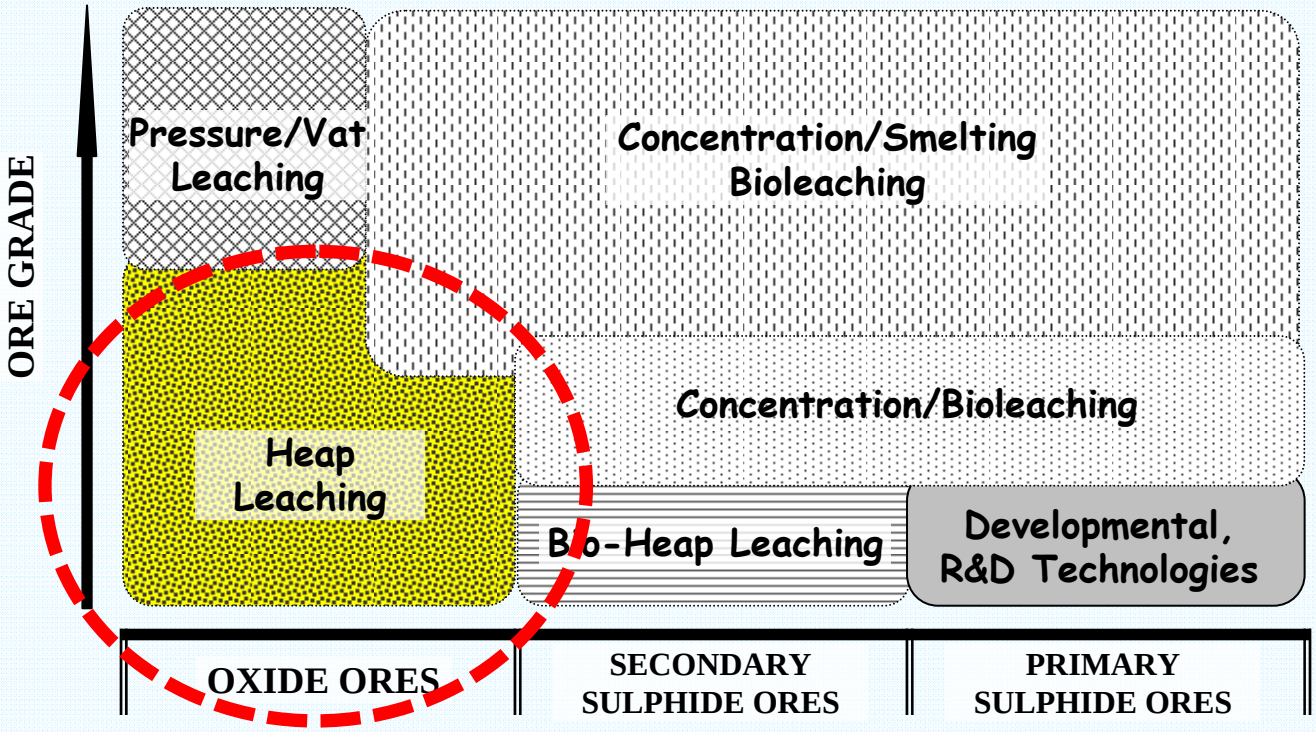


# Selection of Beneficiation Technologies for Low-Grade Ores

In response to global increases in metal commodity prices

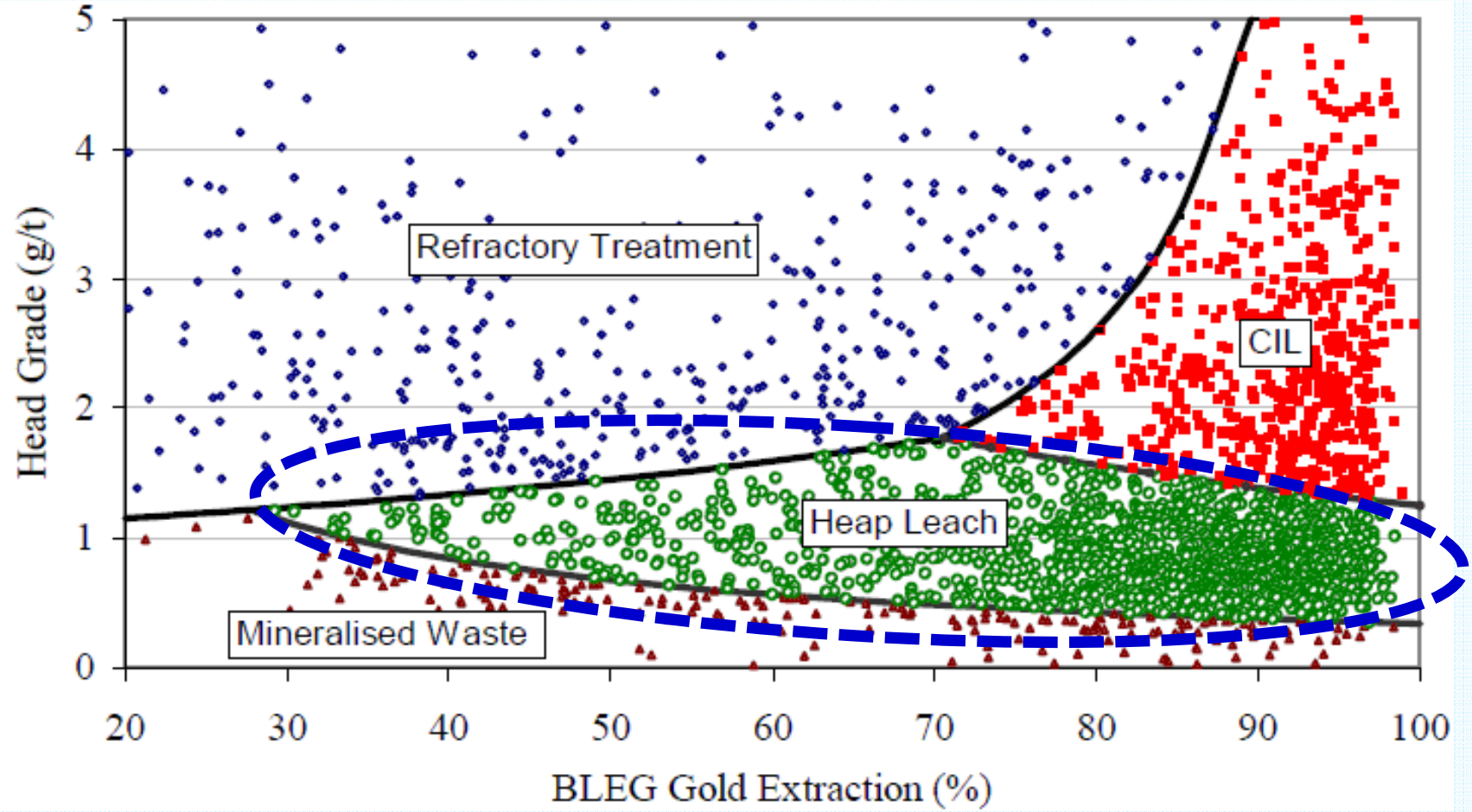
- the low grade base metal and precious metal ores *(<1% Cu, <1g/ton Au, <0.5% Ni)*
- *previously considered uneconomical*

became feasible with introduction of HEAP LEACH TECHNOLOGY.




*A generalized diagram of applicable LEACH-Type beneficiation technologies for oxide and sulphide ores versus ore grade*

# Applicable Process Categories
## *based on leach recovery versus gold ore grade*




*(McNab, B., 2006)*

**Bulk Leach Extractable Gold (BLEG)**

# LEACHING IN THE NATURE

Leaching is a physico-chemical process where minerals in rock masses **go through dissolution under percolating water** and anion/cation exchange reactions **to generate metal salts in solute/colloid phase that migrate and accumulate** under hydrological forces.

Depending on the presence of pyrite *(FeS)* and acidic/alkaline conditions, **biological process of sulphur oxidation** by certain natural bacteria may also be enhance the leaching process.

Lateritic ore deposits, the major resources of aluminum, nickel, platinum, cobalt and even gold, are clear evidence of ongoing **natural leaching process** through geological times.

***Similarly,***
leaching is also a major natural process that occurs at depths **in evolution of hydrothermal-origin ore deposits** which are the products of complex chemical interaction processes involving hydrothermal fluids and gases with the host rocks; namely, a "**natural high temperature and pressure leaching**" followed by a cooling process on a geologic time scale.

# Historical Leach Mining

- Soaking colored minerals and soils in water and decanting the colored liquid for clothing/rug fiber dying is likely the oldest practice of leaching process used by humans.

- The earliest written records of leaching as a mining technique can be found in **V. Biringuccio**'s book of "Pirotechnica" published in 1540 and **Georgius Agricola**'s book of "De Re Metallica" published in 1557 illustrating a heap leach for ***saltpeter*** *(caliche-sodium/potassium nitrate)* and ***alum*** (aluminium sulfate) recovery, respectively.

- In the 16th century, the extraction of copper by **dump/heap leaching** was known to be practiced in the Harz mountains area in Germany and in Rio Tinto mines in Spain.

- The first **uses of pressure leaching** of bauxite ores with $Na_2CO_3$ and Na(OH) were in France and St. Petersburgh in 1887 by L. LeChatelier and K.J. Bayer for recovery of $Al(OH)_3$ and $Al_2O_3$. The Bayer process is still used for Bauxite ore beneficiation. Pressure leaching has been in use since 1890's for recovery of numerous metallic ores with advances in hydrometallurgy.

- The first **use of cyanide for leaching** of gold and silver ores was in England in 1887 by J.S. MacArthur. Worldwide application of cyanidation process with heap and vat leaching and gold recovery processes increased greatly during the 1900-1920 period.

- **Heap leaching of gold ore** started to gain promenence in the late 1960's when it was applied on a large scale to low grade ores that were uneconomic to procees by conventional tank leach methods.

# LEACHING LIXIVIANTS USED IN MINING

**The primary objective of leaching processes applied in mining are:**

- **dissolution of metals of interest in ores,**
- **Segregation of the loaded (pregnant) solution from solids, and**
- **Recovery of available metals either:**
- **in metal compounds or**
- **in metallic forms**

***through further hydrometallurgical treatment.***

**Lixiviants** are chemical solutions used in leach mining to enhance dissolution of metals in ores.

- **Sulphuric acid** and
- **Cyanide salts**

*are the most common demonstrated lixiviants used in heap or vat (tank) leaching processes applied under atmospheric conditions.*

**Thiourea and thiosulphate** are also known lixiviants for copper and gold ores; *however, they are not used in world mining practice for their more complicated chemical management issues and environmental concerns.*

Currently, there is no demonstrated application with success on an industrial scale that can be considered within the context of Best Available Tecniques (BATs).

# LEACHING TECHNIQUES USED IN MINING

Techniques employed in modern leaching technologies **mimic the naturally occuring leaching processes under optimized operational conditions** for improved productivity.

**Dump Leaching:** is a technique used in historical and early modern times; where, generally run-of-mine sulfidic copper ore dumps are wetted with water and/or sulphuric acid as a lixiviant to leach copper salts.

**Heap Leaching:** is a technique where crushed (>5 mm) and/or agglomerated ores are stacked over an engineered impermable pad, wetted with lixiviant (solvent) chemicals under atmospheric conditions and leachate (metal loaded solutions) are collected for metal reovery processes.

**Tank leaching:** is a technique where ground ores are chemically treated in open tanks under atmospheric pressure conditions to extract metal salts from the ore in an accelerated rate.

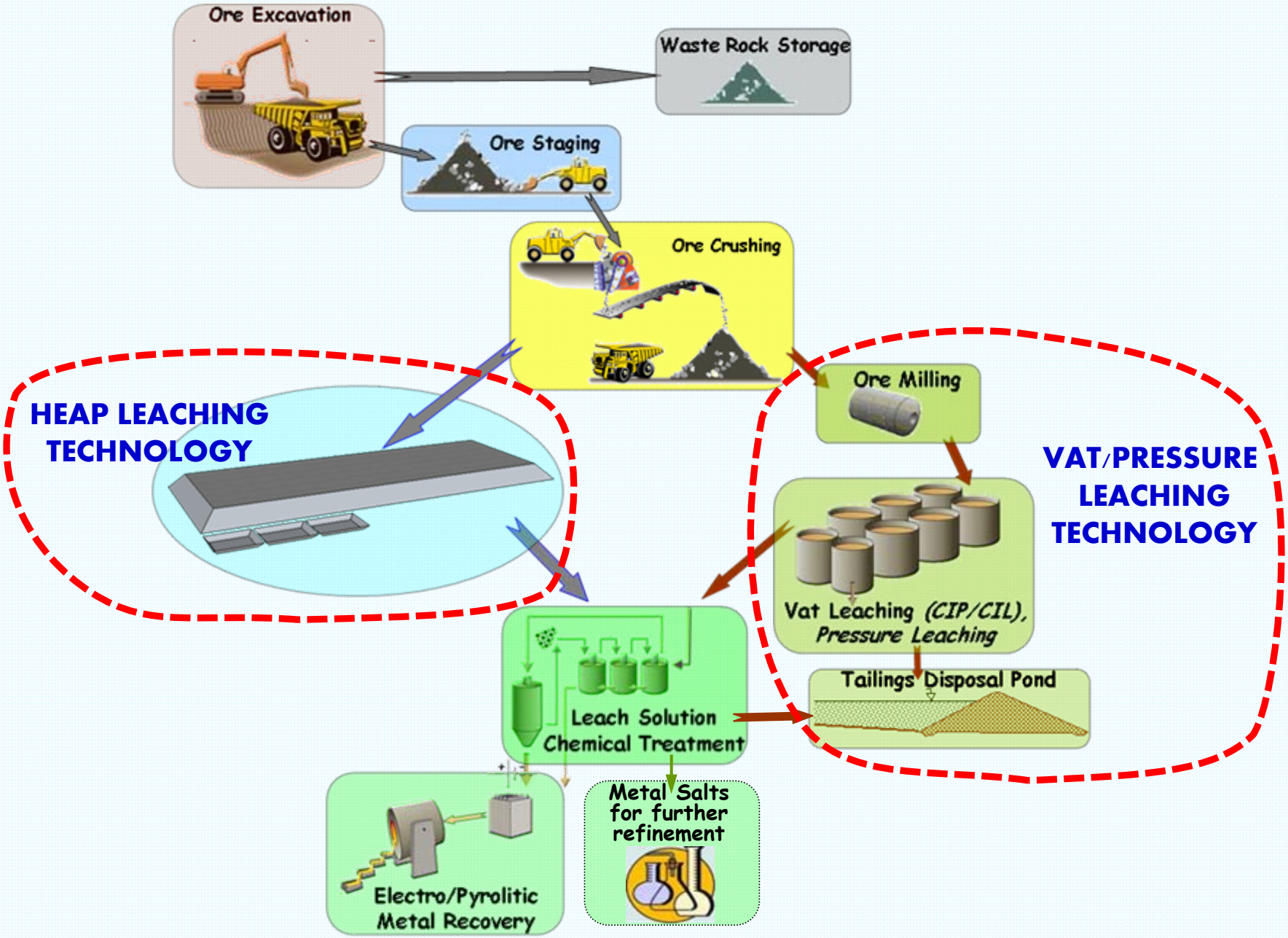
**Pressure Leaching:** is a technique where ground ores are chemically treated in reactors (otoclavs) under high pressure and temperature conditions to extract metal salts from the ore in an accelerated rate.

**In-Situ Leaching:** is a technique used recovery of salt/trona and uranium ores in appropriate hydrogeological settings.

Primary factors in selection of applicable/ appropriate leaching technique and lixiviant chemicals are:

- **mineralogical composition/matrix features of the ore**, and
- **economical feasibility** based on
- ***head grade and reserve*** of the ore deposit,
- ***forecasted commodity market prices*** and
- ***magnitude of capital investment required*** for the project.

# Operational units in a mine utilizing ORE LEACHING TECHNOLOGIES

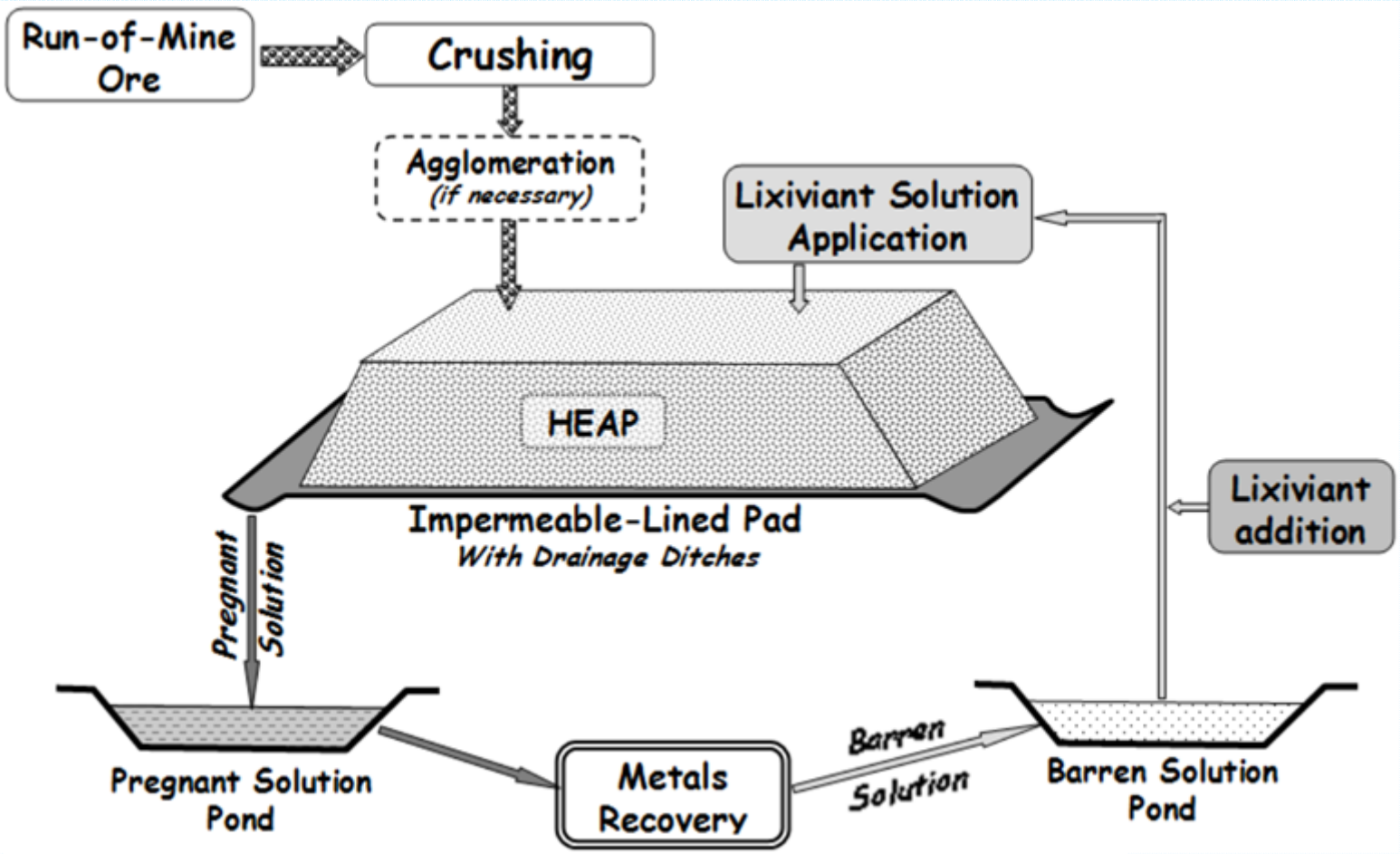


# DESIGN COMPONENTS OF A HEAP LEACH UNIT

The objective of "heap leaching process" is to chemically dissolve the metals out of:

- **gravel/pebble-size crushed ore**
  - ***stacked on an impermeable lined pad***
    - ***By applying lixiviant solutions onto the heaped ore***

into a solution ***where metals are recovered*** ***through further chemical processing.***



**IED Objectives for Mining Operations:**

- ACCIDENT MITIGATION
- ECONOMIC BENEFIT
- ENVIRONMENTAL PROTECTION

} BATs

Noise, Vibrations, Dust

1

Air Quality
Water Quality *(Surface/Groundwater-ARD)*
Soil Quality-Erosion *Protection/Prevention*

2


4

Economic Benefit
Social Responsibility

3

Site Rehabilitation

# REGULATORY DEFINITION OF "BEST AVAILABLE TECHNIQUES - BATs"

The Directive 2006/21/EC on **Management of Waste from Extractive Industries** ***(Mining Waste Directive)*** **requires that**

- *measures taken to achieve the objective of preventing or reducing environmental impacts* **are based,** ***inter alia*** **on,**
  - Best Available Techniques (BAT), **as defined by Directive 96/61/EC concerning integrated pollution prevention and control,** ***later codified by Directive 2008/1/EC (IPPC Directive).***

**As per the European Union Directive 2008/1/EC, emission limit values were to be based on the best available techniques, as described in item #18 stated as:**

*"whereas emission limit values, parameters or equivalent technical measures should be based on:*
- *the best available techniques,*
- *without prescribing the use of one specific technique or technology,*

*and taking into consideration:*
- *the technical characteristics of the installation concerned,*
- *its geographical location and*
- *local environmental conditions;*

*"whereas in all cases, the authorization conditions will lay down provisions on:*
- *minimizing long-distance or transfrontier pollution and*
- *ensure a high level of protection for the environment as a whole."*

# Framework Concept for Evaluation of a Technique in Consideration as a BAT:

**is to identify:**

- **available techniques** *that are developed*
  - **on a scale which allows implementation in the relevant industrial sector**
  - **under economically and technically viable conditions,**
    - **taking into consideration the costs and advantages,** *in order to:*
      - **to prevent or reduce emissions** *and*
      - **to prevent or mitigate accidents**

**in accordance with Section 6.3 of the EU Communication - COM(2000)664.**

The Directive 2008/1/EC includes a definition of best available techniques in article 2.12, where:

**"Best Available Techniques"** mean:

the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally ***to reduce emissions and the impact on the environment as a whole***:

- "**Techniques**" shall include both the technology used and the way in **which the installation is designed, built, maintained, operated and decommissioned**,
- "**available techniques**" means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, **whether or not the techniques are used or produced inside the Member State in question**, ***as long as they are reasonably accessible to the operator,***
- "**Best**" means most effective in ***achieving a high general level of protection of the environment as a whole.***

**EU Directive 2008/1/EC STATES:**

*.... "whereas emission limit values, parameters or equivalent technical measures should be based on:*

- *the best available techniques,*
- *without prescribing the use of one specific technique or technology,*

## 7.1 Annex IV of the Directive 2008/1/EC

Considerations to be taken into account generally or in specific cases when determining best available techniques, as defined in Article 2(12), bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention:

- *the use of low-waste technology;*
- *the use of less hazardous substances;*
- *the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;*
- *comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;*
- *technological advances and changes in scientific knowledge and understanding;*
- *the nature, effects and volume of the emissions concerned;*
- *the commissioning dates for new or existing installations;*
- *the length of time needed to introduce the best available technique;*
- *the consumption and nature of raw materials (including water) used in the process and energy efficiency;*
- *the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;*
- *the need to prevent accidents and to minimise the consequences for the environment;*
- *the information published by the Commission pursuant to Article 17(2), second subparagraph, or by international organisations.*

# BREF on Management of Tailings and Waste-Rock in Mining Activities

The IPPC Bureau, established under European Commission's Joint Research Centre (JRC), produces reference documents on Best Available Techniques (BATs), called **BREFs** which are the main reference documents used by competent authorities in Member States when issuing operating permits for the installations that represent a significant pollution potential in Europe.

According to article 4 par. 3 of the Mining Waste Directive,

- "emission limit values, parameters or equivalent technical measures should be based on *BAT*
- *without prescribing the use of one specific technique or technology*".

*THEREFORE,* the Mining Waste Directive and the BATs do not impose or ban any available technology.

# BREF on Management of Tailings and Waste-Rock in Mining Activities

EU Directive 2008/1/EC also states that, if there is a BAT described in the applicable BREF and the project or operation decides not to adopt it for technological reasons, then the project or operation will have to justify why the proposed choice of technology is BAT.

A revised BREF document on "Management of Tailings and Waste-Rock in Mining Activities" adopted in January 2009 provides information on mining techniques and mineral processing *relevant to tailings and waste rock management* including BATs for tank leaching techniques.

Heap leaching techniques were not explicitly covered in this version of the BREF document.

HOWEVER; if the Operational Activities of Heap Leaching are evaluated in terms of:

- prevention or reduction of emissions *and*
- prevention or mitigation of accidents

use of Heap Leaching Technology also fulfills the general intent of a BAT *as summarized in the following BREF criteria.*

# Framework BAT Criteria for Mining Operations in the Current IPPC-BREF Document

| BAT is to: | | BREF Section (*) | Criteria/Action Item | BREF Section (*) |
|---|---|---|---|---|
| • apply the general principles to assure that tailings and waste-rock management decisions are based on: | | Sect. 4.1 | • environmental performance,<br>• risk, *and*<br>• economic viability<br>*with risk being a site specific factor.* | |
| • apply a life cycle management approach | • *the design phase* | Sect.4.2.1 | • environmental baseline | Sect.4.2.1.1 |
| | | | • characterisation of tailings and waste-rock | Sect.4.2.1.2 |
| | | | • TMF studies and plans which cover the following aspects: | Sect.4.2.1.3 |
| | | | • site selection documentation | |
| | | | • environmental impact assessment | |
| | | | • risk assessment | |
| | | | • emergency preparedness plan | |
| | | | • deposition plan | |
| | | | • water balance and management plan | |
| | | | • decommissioning and closure plan | |
| | | | • TMF and associated structures design | Sect.4.2.1.4 |
| | | | • control and monitoring | Sect.4.2.1.5 |
| | • *the construction phase* | Sect.4.2.2 | • 'as built' drawings and 'actual' procedure and test work records are maintained,<br>• construction is supervised by an independent qualified engineering/geo-technical specialist | |
| | • *the operational phase* | Sect.4.2.3 | • OSM manuals | Sect.4.2.3.1 |
| | | | • auditing | Sect.4.2.3.2 |
| | • *the closure and after-care phase* | Sect.4.2.4 | • long-term closure objectives | Sect.4.2.4.1 |
| | | | • specific closure issues for heaps | Sect.4.2.4.2 |
| | | | • ponds, including: | |
| | | | • water covered ponds | |
| | | | • dewatered ponds | |
| | | | • water management facilities | |
| • reduce reagent consumption | | Sect. 4.3.2 | | |
| • prevent water erosion | | Sect. 4.3.3 | | |
| • prevent dusting | | Sect. 4.3.4 | | |
| • carry out a water balance | | Sect. 4.3.7 | • water management plan | Sect.4.2.1.3 |
| • apply free water management | | Sect. 4.3.9 | | |
| • monitor groundwater around all tailings and waste-rock | | Sect. 4.3.12 | | |

*(*) Numbers refer to the "Section Numbers" in the IPPC BREF Document on "Management of Tailings and Waste-Rock in Mining Activities" (European IPPC Bureau, 2009).*

# Specific Issues in Framework BAT Criteria *(as also Applicable to Heap Leach Mining)*

| Specific ISSUE: | | BAT is to: | BREF Section (*) |
|---|---|---|---|
| **Acid Rock Drainage (ARD) Management** The characterisation of tailings and waste-rock includes the determination of the acid-forming potential of tailings and/or waste-rock (Section 4.2.1.2 & Annex 4) | | If an acid-forming potential exists:<br>• to firstly prevent the generation of ARD | Sect. 4.3.1.2 |
| | | • If the generation of ARD cannot be prevented,<br>• to control ARD impact<br>• to apply treatment options | Sections 4.3.1.3, 4.3.1.4, 4.3.1.6 |
| | | Closure Plan to be developed for the site at the design stage of the operation deciding on the most suitable closure option. | Sect. 4.3.1.5 |
| **Seepage management** (Section 4.3.10): | | seepage needs to be:<br>• prevented, reduced and controlled | Sect. 4.3.10.1<br>Sect. 4.3.10.2 |
| **Emissions to water** | General: | • re-use process water | Sect. 4.3.11.1 |
| | | • mix process water with other effluents containing dissolved metals | Sect. 4.3.11.3 |
| | | • install sedimentation ponds to capture eroded fines | Sect. 4.3.11.4.1 |
| | | • remove suspended solids and dissolved metals prior to discharge of the effluent to receiving watercourses | Sect. 4.3.11.4 |
| | | • neutralise alkaline effluents with sulphuric acid or $CO_2$ | Sect. 4.3.11.6 |
| | | • remove As from mining effluents by the addition of ferric salts | Sect. 4.3.11.7 |
| | Treating acid effluents: | • active treatments:<br>• addition of limestone, hydrated lime or quicklime<br>• addition of caustic soda for ARD with a high Mg content<br>• passive treatment:<br>• constructed wetlands<br>• open limestone channels/anoxic limestone drains<br>• diversion wells. | Sect. 4.3.11.5 |
| **Noise emissions** | | • use continuous working systems (conveyor belts, pipelines)<br>• encapsulate belt drives in areas where noise is a local issue | Sect. 4.3.5 |
| **Tailings and waste-rock management facility operation** *In addition to the measures during the operational phase (Section 4.2.2) of any tailings and waste-rock management facility* | | • divert natural external run-off | Sect. 4.4.1 |
| | | • manage tailings or waste-rock in pits | Sect. 4.4.1 |
| | | • apply a safety factor of at least 1.3 to all heaps and dams during operation | Sect. 4.4.13.1 |
| | | • carry out progressive restoration/revegetation | Sect. 4.3.6 |
| **Monitoring stability** | | • monitor in a heap<br>• bench/slope geometry<br>• sub-tip drainage<br>• pore pressure | Sect. 4.4.14.2 |
| | | • in the case of a heap:<br>• visual inspections<br>• geotechnical reviews<br>• independent geotechnical audits | Sect. 4.2.3.2<br>Sect. 4.4.14.3 |
| **Mitigation of accidents** | | • carry out emergency planning | Sect. 4.6.1 |
| | | • evaluate and follow-up incidents | Sect. 4.6.2 |
| | | • monitor the pipelines | Sect. 4.6.3 |
| **Reduction of footprint** | | • if possible, prevent and/or reduce the generation of tailings/waste-rock | Sect. 4.1 |
| | | • backfill waste-rock, under the following conditions when:<br>• it can be backfilled within an underground mine<br>• mined-out open pits are nearby are available<br>• the open pit operation is carried out via backfilling the waste-rock without inhibiting the mining operation | Sect. 4.5.2 |
| | | • investigate possible uses of tailings and waste-rock | Sect. 4.5.3 |
| **Closure and after-care** *In addition to the measures described the closure and after-care phase (Section 4.2.4) of any tailings and waste-rock management facility* | | • develop closure and after-care plans during the planning phase, including cost estimates, and then update them over time. *However, the requirements for rehabilitation develop throughout the lifetime of an operation and can first be considered in precise detail in the closure phase of a TMF* | Sect. 4.2.4. |
| | | • apply a safety factor of at least 1.3 for dams and heaps after closure | Sect. 4.2.4 and 4.4.13.1 |
| | | • construct the dams so that they stay stable in the long term if a water cover solution is chosen for the closure. | Sect. 4.2.4.2. |

***(*)*** *Numbers refer to the "Section Numbers" in the IPPC BREF Document on "Management of Tailings and Waste-Rock in Mining Activities"*

# In Summary

**Heap leaching technology has been successfully applied to very low grade base metal (copper, zinc, nickel and cobalt) and precious metal (gold and silver) ores since 1969.**

Techniques developed in the world and in EU Member States during the last several decades demonstrated that **heap leaching is a viable process that can be applied in a manner**:

- **to address all of the regulatory issues identified in the BREF on "Management of Tailings and Waste-Rock in Mining Activities"** and
- **to ensure a high level of protection for the environment as a whole**

within the context of Best Available Techniques (BAT) identified in the EU Acquies.

**Kisladag and Copler gold mines in Turkey are current examples of**

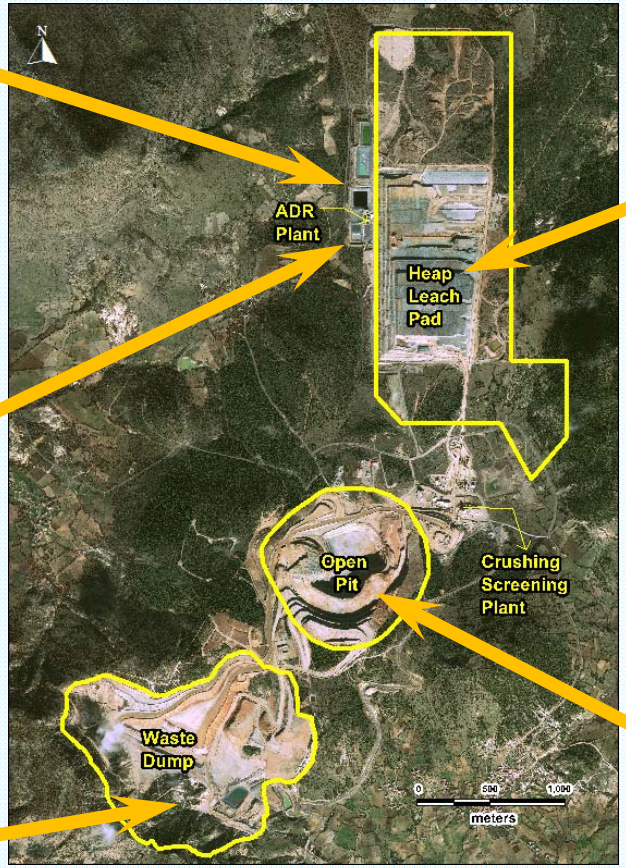
**environmentally sound,**

***operational* heap leach mining facilities in Europe.**

# KISLADAG Gold Mine, Turkey

*(Ref: Utkucu, H.N. and Sakiyan-Ates, J., 2011, Proc.WMC-2011, Vol. II, 771-777)*

**(In operation since 2006)**



# Alacer Gold - COPLER Mine, Turkey

*(http://www.anatoliaminerals.com/downloads/presentations/asr_p20110815.pdf/)*

**(In operation since 2010)**

# CONCLUSIONS

Currently, there are many copper, nickel and precious metal heap leach mining projects in design and permitting phase in Europe suffer from the fact that Heap Leaching Techniques were not explicitly described by the 2009 version of the BREF document on Management of Tailings and Waste-Rock in Mining Activities.

Therefore,

Inclusion of the **Heap Leach Mining Process** as a BAT in the next revision of the BREF document on "Management of Tailings and Waste-Rock in Mining Activities" would increase the consistency of the regulatory framework and ease the permitting of the current and upcoming EU mining projects planning to use the heap leach technology.

**Reference document is available at:**

**Zanbak, C. (2012). Heap Leaching Technique in Mining, Euromines, November, 33p.**
**http://euromines.org/ sites/default/ files/content/files/mining-techniques/**

# Thank you for your Attention..

## Caner ZANBAK, PhD.

Dr. Zanbak, is a 1971 graduate of Istanbul Technical University, has completed his Ph.D. at the University of Illinois, USA. His academic experience includes Istanbul Technical University until 1981, Kent State University, Ohio, South Dakota School of Mines, Rapid City, South Dakota as an associate professor until 1984 and at Illinois Institute of Technology, Chicago, Illinois as an adjunct full professor until 1994.

Dr. Zanbak has worked as a consultant to the USEPA and numerous industry facilities on hazardous waste management, remedial investigations, feasibility studies and remedial design for Superfund projects during the 1984-1994 period.

Dr. Zanbak is the principal author of "***Hazardous Waste Management***" section of the National Environmental Action Plan coordinated by the Turkish State Planning Organization and the "***Report on Environmental Non-Tariff Trade Barriers and an Action Plan for Turkey***" prepared for the Turkish Businessman's Association (TUSIAD). He has taken an actýve role in preparation of the "***Sustainable Development – Business Community and Industry***", Johannesburg (Rio+10) Conference Country Report for Turkey, prepared by the CEVKO Foundation. Currently, he serves on the TUSIAD's EU Environmental Acquis Harmonization Group.

Since 1994, Dr. Zanbak is the coordinator of the ***Responsible Care©*** Program of the Turkish Chemical Manufacturers Association and provides consultancy to the mining sector on geotechnical design, regulatory and environmental management issues. He regularly lectures on environmental management, industrial waste management and environmental policy topics at numerous universities in Turkey.

Currently, he is a standing member of the following organizations:

- ***Environmental Advisor,*** Turkish Chemical Manufacturers Association,
- ***Environmental Coordinator,*** Turkish Miners Association,
- ***Vice-Chairman, Environmental Affairs Commission*** of the Istanbul Chamber of Industry,
- ***Environment Working Group Member of*** the Turkish Businessman's Association (TUSIAD),
- ***ABET Accreditation Advisory Panel Member*** of ITU Faculty of Mines,
- ***Evaluator, Turkish Engineering Program Acrreditation Board*** (MUDEK),
- ***Advisory Board Member,*** TUBITAK-MAM,
- ***Vice-President*** of the Balkan Environmental Association (B.EN.A.),

e-mail : czanbak@tnn.net

# Heap leaching technique in mining within the context of best available techniques (BATs)

Caner Zanbak
*Environmental Coordinator, Turkish Miners Association*
*Environmental Advisor, Turkish Chemical Manufacturers Association, Turkey*

## ABSTRACT

The objective of the Directive 2006/21/EC on the management of waste from extractive industries is to prevent or reduce as far as possible any adverse effects on the environment or on human health brought about as a result of the management of waste from the extractive industries. It requires that measures taken to achieve its objective are based *inter alia* on Best Available Techniques (BAT), as defined by Directive 96/61/EC concerning integrated pollution prevention and control, later codified by Directive 2008/1/EC. Directive 2008/1/EC will be repealed in January 2014 by Directive 2010/75/EU which provides for a similar definition of BAT.
A revised Reference Document (BREF) on the "Management of Tailings and Waste-Rock in Mining Activities", published in January 2009, provides information on mining techniques and mineral processing relevant to tailings and waste rock management including BAT for tank leaching techniques. Heap leaching techniques are briefly addressed in this revised BREF document but not sufficiently described.
Heap leaching process has been successfully applied to very low grade base metal (copper, zinc, nickel and cobalt) and precious metal (gold and silver) ores since late 1960s. Techniques developed during the last decades demonstrated that it is a viable process which can be applied in a manner to address all the regulatory issues identified in the above-mentioned BREF and to ensure a high level of environmental protection.

The objective of this paper is to provide the relevant information to consider heap leaching in the context of BAT as defined under the regulatory framework of the European Union.

## 1. LOW-GRADE ORE BENEFICIATION METHODS IN MINING

Selection of an ore beneficiation technology is based on economic viability which is directly dependent on:

- ore type (*namely*, oxide or sulphide),
- mineral composition, matrix features of ore
- reserves and average grade *(based on the "cut-off grade")* of the ore.

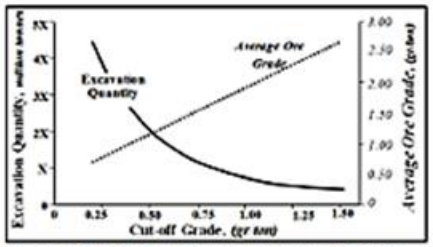



Figure 1. Relationship Between Excavation Quantity and Average Grade of Mined Ore as a function of "cut-off grade" (*modified from* McNab, 2006)

It should be borne in mind that lowering in cut-off grade of ores:

- increases asymptotically the quantity ore to be excavated and treated (Fig. 1),
- increases energy and chemical usage in pressure/tank leaching generating larger volumes of tailings to be managed,
- decreases profitability, making beneficiation process uneconomical below certain grades.

In response to global increases in metal commodity prices, the low grade base metal and precious metal ores *(<1% copper, <1g/ton gold, <0.5% nickel)* previously considered uneconomical, became feasible with introduction of heap leaching technologies (Marsden, 2009).
A generalized diagram showing applicable ore beneficiation technologies for oxide/sulphide ores versus ore grade is given in Figure.2.

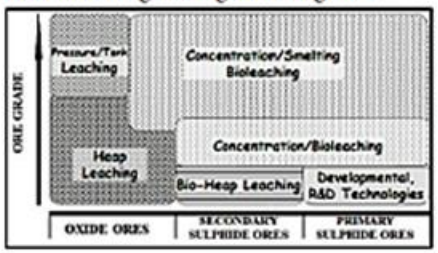



Figure 2. Applicable Ore Beneficiation Technologies as a Function of Ore Grade for Oxide and Sulphide Ores (*Modified from* Robertson et al, 2005).

A chart showing identified applicable process categories for gold ore recovery, based on a preliminary analysis of 2,832 bulk leach extractable gold (BLEG) results for shear-hosted Archean metasediment ores in Western Australia, is given in Figure 3 (McNab, 2006).

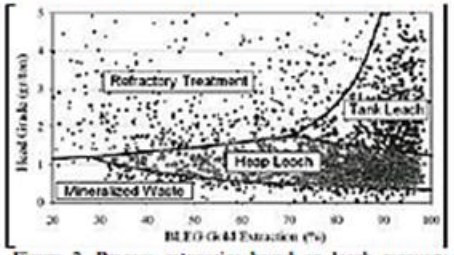



Figure 3. Process categories based on leach recovery versus gold ore grade (McNab, 2006)

## 2. LEACHING IN THE NATURE

Leaching is a physico-chemical process where minerals in rock masses go through dissolution under percolating water and anion/cation exchange reactions to generate metal salts in solute/colloid phase that migrate and accumulate under hydrological forces.

Depending on the presence of pyrite *(FeS)* and acidic/alkaline conditions, biological process of sulphur oxidation by certain natural bacteria may also be coupled in the leaching process.
Lateritic ore deposits, the major resources of aluminum, nickel, platinum, cobalt and even gold, are clear evidence of ongoing natural leaching process. Leaching is the second fundamental step following physical alteration in the rock-to-soil weathering cycle taking place in nature under atmospheric pressure conditions. Similarly, leaching is also a natural process that occurs at depths in evolution of hydrothermal-origin ore deposits which are the products of complex chemical interactions involving hydrothermal fluids and gases with the host rocks; namely, a "natural high temperature and pressure leaching" followed by a cooling process on a geologic time scale.

## 3. LEACH LIXIVIANTS IN MINING

The primary objective of leaching processes applied in mining is the dissolution of metals of interest in ores, segregate the loaded solution from solids and recover available metals either in metal compounds or in metallic forms through further hydrometallurgical treatment.
Lixiviants are chemical solutions used in leach mining to enhance dissolution of metals in ores. Sulphuric acid and cyanide salts are the most common demonstrated lixiviants used in heap or vat (tank) leaching processes applied under atmospheric conditions.
Thiourea and thiosulphate are also known lixiviants for copper and gold ores; however, they are not used in world mining practice for their more complicated chemical management issues and environmental concerns.

## 4. BASIC EFFICIENCY FACTORS IN HEAP LEACH PROCESS

Recovery rate of metals *(in percentage of the ore grade)* is an indicator of leaching effectiveness. In practice, recovery rate is characterised by the dissolution kinetics of metals, namely: percentage of metal of interest in ore transferred into the leach solution, and time required for metal dissolution.
Dissolutioning of metals in heap leaching process is controlled mainly by:

a. *Degree of mineral liberation – crushed ore particle size:* Ore is crushed to certain particle size prior to stacking. Certain portions of a "run-of-mine" ore material can be placed directly on the leach pad.

b. *Lixiviant contact with mineral grains:* Percolation rate of the fluids should be slow enough to provide good contact of the lixiviant to dissolve the metals. Therefore, achieving a uniform heap permeability is required for optimal flow of leach fluids. In cases where fine particles are present, agglomeration techniques are used for optimization of heap permeability.

c. *Dissolution potential of the metal/mineral composition – Leach Kinetics:* The major factors affecting the dissolution rate of metals of interest are lixiviant concentration, temperature, pH, dissolved oxygen, presence of other metals and ions in the solution. Leach recovery rates generally increase under higher lixiviant concentrations, temperature and dissolved oxygen and higher pH (>9) for cyanide leach and lower pH (<2) for acid leach conditions .
A comparative leach kinetics (dissolution rate) of oxide, secondary and primary copper sulphide ores and oxide, transitional and sulphide gold ores in heap leaching is presented in Figure 4 (Robertson et al. 2005) and Figure 5, respectively.

d. *Bacterial Activity on metal sulphides – Leach Kinetics:* Presence of metal sulphides (mostly, pyrite) in the ore heaps initiate bacterial activity, especially for copper, nickel and zinc sulphide minerals. Bacterial activity can be utilised to catalyse the oxidation of iron in sulfides (ferro to ferric state) which improve the leach kinetics.

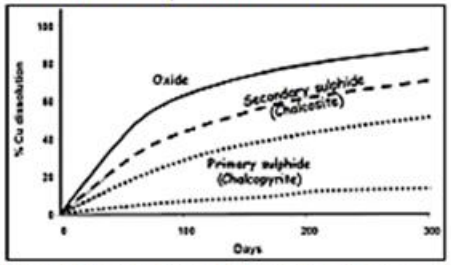



Figure 4. Comparative leach kinetics of oxide, secondary and primary copper sulphide ores in heap leaching *(Robertson et al. 2005).*

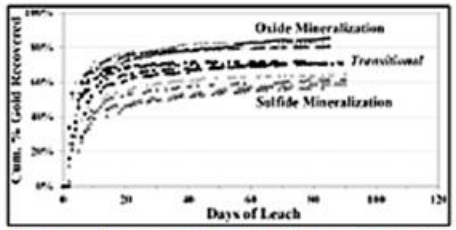



Figure 5. Comparative leach kinetics of transitional, oxide and sulphide gold ores in heap leaching *(Tuprag Gold Co., Kisladag Mine, Turkey)*

In all ore leaching processes the gangue *(undesired)* metals consume lixiviants along with the metals of interest; copper, zinc, iron in gold ore leaching; iron, manganese, calcium and potassium in copper and nickel ore leaching, to name a few. Also, pre-precipitation products of some of these gangue minerals *(gypsum, jarosite, silica)* have potential negative effects on leach permeability by plugging up of the pores in the heaps.

## 5. LEACHING TECHNIQUES IN MINING

Comprehension of the natural leaching mechanism has led the way to developments in the hydrometallurgy techniques for low-grade ores. Techniques employed in modern leaching technologies mimic the naturally occuring leaching processes under optimized operational conditions for improved productivity, namely:

- Dump Leaching: is a technique used in historical and early modern times; where, generally run-of-mine sulfidic copper ore dumps with no composite pad liner are wetted with water and/or sulphuric acid as a lixiviant to leach copper salts. Currently, the use of this technique is limited to a few sites due to environmental concerns and inefficiencies in copper solution recovery.
- Heap Leaching: is a technique where crushed (>5 mm) and/or agglomerated ores are stacked over an impermable pad, wetted with lixiviant chemicals under atmospheric conditions and leachate (metal loaded solutions) are collected for metal recovery. Because solutioning process is realized under atmospheric conditions by percolation of the lixiviant solution, completion of metal recovery requires longer time periods (weeks to months) for each pad loading sequence compared to tank leaching (hours to days). Upon completion of heap leaching, the barren ore stack is decommissioned in place; therefore, this technique does not require use of a tailings disposal facility.
- Tank Leaching: is a technique where ground ores are chemically treated in open tanks under atmospheric pressure conditions to extract metal salts from the ore in an accelerated rate. This technique, requires handling and grinding of all run-of-mine ores and disposal of treated materials in tailings ponds/dams.
- Pressure Leaching: is a technique where ground ores are chemically treated in reactors (otoclavs) under high pressure and temperature conditions to extract metal salts from the ore in an accelerated rate. This technique also requires grinding of all run-of-mine ores and disposal of treated materials (tailings) in tailings ponds/dams.
- In-Situ Leaching: is a technique used recovery of salt/trona and uranium ores in appropriate hydrogeological settings.

Primary factors in selection of applicable/ appropriate leaching technique and lixiviant chemicals are:

- mineralogical composition/matrix features of the ore, and
- economical feasibility based on head grade and reserve of the ore deposit, forecasted commodity market prices and magnitude of capital investment required for the project.

### *5.1 Historical Leach Mining*

The earliest written records of leaching as a technique can be found in V. Biringuccio's book of "Pirotechnica" published in 1540 describing leaching of saltpeter from decayed nitrified organic matter and in G. Agricola's "De Re Metallica" published in 1557 illustrating a heap leach to recover alum *(aluminium sulfate* (Habashi, 2005; Kappes, 2002).
In the 16th century, the extraction of copper by dump/heap leaching was known to be practiced in the Harz mountains area in Germany and in Rio Tinto mines in Spain.
The first uses of pressure leaching of bauxite ores were in France and St. Petersburgh in 1887 by L. LeChatelier and K.J. Bayer for recovery of alumina. The Bayer process is still used for Bauxite ore beneficiation (Habashi, 2005).
The first use of cyanide for leaching of gold and silver ores was in England by J.S. MacArthur in 1887. Worldwide application of cyanidation process with heap and vat leaching increased greatly during the 1900-1920 period. Heap leaching of gold ore started to gain promenence in the late 1960's when it was applied on a large scale to low grade ores that were uneconomic to procees by conventional tank leach methods.

### *5.2 Modern Day Leach Mining*

In mining operation flowsheets, leaching processes follows ore crushing, where:

- ore is directly stacked on leach pads - *Heap Leaching*,
- ore is further ground/milled and treated in vessels - *Pressure/Tank Leaching* (Fig. 6).

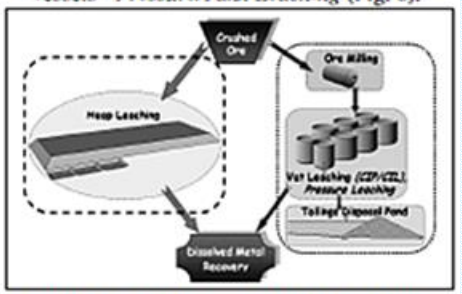



Figure 6. Leaching Processes in Mining Operations

There are two tank leaching processes where activated carbon is used for adsorbtion of cyanidized gold; namely, carbon in pulp (CIP) and carbon in leach (CIL). Another process, carbon in column (CIC), is used in gold recovery from heap leach solutions. Currently, 60-65% of world production of mined gold is realized using leaching techniques.
A special heap leaching technique is used on certain types of sulphidic copper ores where copper sulphides are converted into sulphates in a two-step leaching process with the help of natural iron oxidising bacteria with sulphuric acid(bio-heapleaching). Since 2000, application of the heap leaching technique, using sulphuric acid as the lixiviant, gained wide acceptance for recovery of nickel/cobalt from very low grade (< 0.5%) lateritic ores, where pressure leaching has not been feasible.

## 6. DESIGN COMPONENTS OF A HEAP LEACH UNIT

The objective of "heap leaching process" is to chemically dissolve the metals out of gravel/pebble-size crushed ore, stacked on an impermeable lined pad, into a solution where metals are recovered through further chemical processing (Fig. 7).

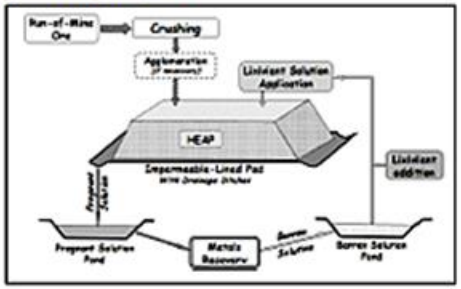



Figure 7. Generalized Flowsheet of a Heap Leach Unit

Basic components of a heap leaching unit are

- Leach pad and liner system,
- Heaped ore,
- Ponds,
- Lixiviant solution application

### *6.1 Leach Pads*

Leach pad is a general term for the overall foundation of the heap (ore stack). Design objectives of a leach pad are to provide:

- Stable foundation for the ore heap,
- Collection of leachate (pregnant solution),
- Environmental Protection *(soil and groundwater quality).*

Depending on land availability, the pads are constructed either on large, relatively flat surfaces or in topographical valleys (Fig. 8).

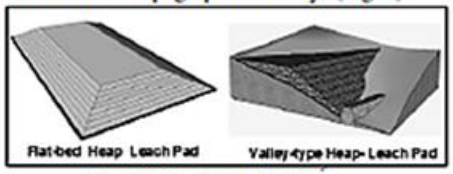



Figure 8. Heap Leach Pad Types

Typical components of a leach pad are contoured natural ground surface and overlying liner system (Fig. 9).

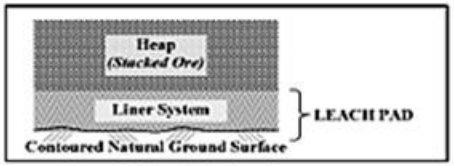



Figure 9. Generic leach pad components

Design objective of the leach pad liner is to contain and prevent the loss of solutions generated in the overlying ore that will be subject to leaching process for both economic and environmental reasons. In the current heap leach practice, the most preferred leach pad liner is the composite liner system. Composite liners are made up of a sequence of *(starting from bottom)*:

- compacted low permeability subgrade soil/clay liner (CCL) or a geosynthetic clay liner (GCL) over contoured ground surface,
- leak-detection/collection system,
- geomembrane liner *(with geotextile)*
- drain cover fill *(gravel and drain pipes)*

Geosynthetic clay liners (GCL) are also used in leach pad construction, in lieu of low permeability subgrade soil/clay liners (CCL).

### *6.3 Ponds*

Ponds are integral part of a heap leaching technology to collect and contain the leaching solutions. Ponds are sized to have sufficient capacities to optimize processing of pregnant solution and safely manage the liquids in cases of power outages and major rainstorm events. Common design practice is to have the following ponds, located downslope of the heap:

- Pregnant solution pond *(for heap leachate),*
- Barren solution pond *(for containment of processed pregnant solutions),*
- Intermediate solution pond *(for recycling of leachates from the older heaps to the newer heaps to build up the solution metal grade),*
- Overflow/Stormwater Pond *(standby for emergencies).*

Considering that the pregnant solution is ~~the~~ a valuable asset of the mine operation, current design practice for the process liquid ponds is to install double layer composite liner system fitted with leak detection pipes and pumps.

### *6.4 Ore Heap*

Crushed and/or agglomerated ore can be stacked on the heap leach pad by either truck dumping or via telescopic/grasshopper conveyor belts with travelling bridges in sequential lifts.

Segregation of fines from coarse material during ore stacking is a common problem observed in heaps creating excessive concentration of fines in the center causing different pockets of permeability. Therefore, special care is needed for even distribution of crushed/agglomerated ore in order to obtain uniform permeability in leach heaps.

Conveyor stacking, especially for agglomerated ore cases are commonly used for handling of crushed material for its ease/mobility, more homogeneous grain distribution in the heaps and its favorable economics (Kappes 2002).

Ore Stacking may proceed in the up or downslope direction provided the advacing face is stable. It is more usual to stack in upslope direction for increased slope stability *(top sketch in* Fig. 10).

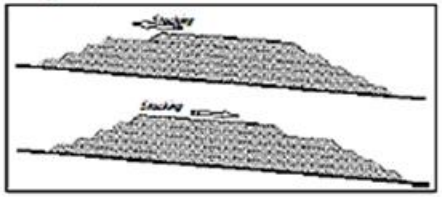


Figure 10. Ore Stacking Directions

From geotechnical point of view, stability mechanics of ore heaps are analogous to crushed rock piles stacked in lifts resting on a geomembrane layer. Circular or Block Failure stability analyses for soil slopes, available in geotechnical engineering practice, are applicable to the heap slopes where the geomembrane layer is a well-defined basal discontinuity with no cohesion and having a friction angle between 14-18°. Liquefaction potential should also be taken into consideration, especially in earthquake-prone regions (Thiel and Smith, 2003).

### *6.5 Lixiviant Solution Application and Pregnant Solution Collection*

The objective of lixiviant application is to achieve uniform and complete wetting of ore through continuous percolation of liquids between the ore particles. Lixiviant solutions are applied on the top surface of the heaps using either irrigational spraying or drip irrigation techniques. Selection of spraying or drip irrigation is generally based on the climatic conditions of the site taking into account the evaporation rate and freezing potential. Currently, drip irrigation is more commonly applied technique in mining practice.

Cyanide (generally NaCN) and sulphuric acid are the most commonly used lixiviant chemicals in gold/silver and copper/nickel leach mining, respectively. Lixiviant chemical concentrations in the leach solution and feed application rates on the heaps are dependent on site-specific factors of:

- permeability of the heap,
- chemical depletion rate *(chemical consumption by all metals in the heap)* and,
- climatic conditions *(evaporation, rain)*

which needs to be determined by bench/pilot-scale testworks on representative heap samples and optimized during the heap leach operations.

The pregnant solution is drained into the pregnant ponds for chemically stripping of dissolved metal salts in the pregnant solution, where resultant water is sent to barren pond and pumped to the lixiviant solution dosing unit for reuse in the leaching cycle.

### *6.6 Heap Rinsing and Pad Closure*

At the end of heap leaching cycle, the heap material is subjected to rinsing of lixiviant chemical with water circulation. During closure of pads, the solution management of heaps is conducted in three phases:

- residual metal recovery - where metal recovery continues via recirculation of solutions without the addition of lixiviants;
- inventory disposal - drained solution is evaporated and/or treated and discharged;
- draindown - where draindown of residual solutions continues passively.

Decisions for completion of heap rinsing process is based on depletion of free lixiviant chemical draining from the heap as demonstrated with continous monitoring of the return water. Excessive rinsing with water is to be avoided to prevent generation of acid mine drainage in the sulphidic ore heaps.

Upon application of a cover layer on the heap to stop potential for entry of rain water, the heap

material is left for gravitational draindown of residual water. Any water drained from the heap is treated with active or passive treatment methods prior to release into the receiving media. Protocols for monitoring and treating of drainage from closed heap pads are to be developed on a case-by-case basis for each pad.

## 7. REGULATORY DEFINITION OF "BEST AVAILABLE TECHNIQUES - BATs"

The Directive 2006/21/EC on the management of waste from extractive industries *(Mining Waste Directive)* requires that measures taken to achieve the above-mentioned objective of preventing or reducing environmental impacts are based *inter alia* on Best Available Techniques (BAT), as defined by Directive 96/61/EC concerning integrated pollution prevention and control, later codified by Directive 2008/1/EC. The Directive 2008/1/EC will be repealed in January 2014 by Directive 2010/75/EU providing for a similar definition of BAT, which reads as follows:

'BAT' *"means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole".*

'Techniques' *"includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned"*

'Available Techniques' *"means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator"*

'Best' *"means most effective in achieving a high general level of protection of the environment as a whole".*

### *7.1 BREF on Management of Tailings and Waste-Rock in Mining Activities*

The European IPPC Bureau, one of the scientific institutes of the European Commission's Joint Research Centre (JRC), produces reference documents on Best Available Techniques, called BREFs. These reference documents are used by competent authorities in Member States to issue operating permits for the relevant industrial installations.

It is important to note that, according to article 4 par. 3 of the Mining Waste Directive, *"emission limit values, parameters or equivalent technical measures should be based on BAT without prescribing the use of one specific technique or technology"*. Therefore, the Mining Waste Directive does not impose or ban the use of any available technology. As a consequence, if a project or operation decides not to adopt – for various reasons linked to technical characteristics or geographical location – a technology that is considered as BAT under the BREF document on "Management of Tailings and Waste-Rock in Mining Activities", *it will have to justify why the proposed technological choice is the most suitable technique to be implemented.* A revised BREF document on "Management of Tailings and Waste-Rock in Mining Activities" adopted in January 2009 provides information on mining techniques and mineral processing relevant to tailings and waste rock management including BAT for tank leaching techniques. Heap leaching techniques are briefly addressed in this revised BREF document but not sufficiently described.

### *7.1 Framework Concept for Evaluation of a Technique in Consideration as a BAT*

Framework concept of a BAT is to identify available techniques that are developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages in order to *prevent or reduce as far as possible any adverse effects on the environment and human health brought about as a result of the management of extractive waste*, as expressly provided by the Mining Waste Directive.

Heap Leaching is a worldwide demonstrated technique that fulfils the criteria for BAT as described in Chapter 4 of the Mining Waste BREF and the relevant environmental management issues as reviewed in a recent document supported by Euromines, which is available on Euromines' website (Zanbak, 2012).

## 8. CONCLUSIONS

In response to ever increasing prices of base metals, "heap leaching" has become a major beneficiation technique used for low grade ores which cannot be economically processed through tank leaching or any other available techniques.

Heap leaching process has been successfully applied to very low grade base metal (copper, zinc, nickel and cobalt) and precious metal (gold and silver) ores since 1969. Techniques developed in the world and in EU Member States during the last several decades demonstrated that heap leaching is a viable process that can be applied in a manner:

- to address all of the regulatory issues identified in the BREF on "Management of Tailings and Waste-Rock in Mining Activities" and
- to ensure a high level of demonstrated protection for the environment as a whole.

Currently, there are numerous copper, nickel and precious metal heap leach mining projects in operation in the world and in Europe. However, there are many projects in design and permitting phase in Europe that suffer from the fact that heap leaching techniques were not sufficiently described by the 2009 version of the BREF on Management of Tailings and Waste-Rock in Mining Activities. Therefore, it is the opinion of the author that inclusion of the heap leach mining process as a BAT in the next revision of the BREF document would increase the consistency of the regulatory framework and ease the permitting of current and upcoming EU responsible mining projects planning to use modern heap leach technology.


## ACKNOWLEDGEMENTS

This paper is a concise version of a document prepared by the Turkish Gold Miners Association and supported by Euromines, which has benefited from the contributions of Euromines' Members as well as of experts from several mining companies, both within Europe and abroad. The author would like to express his particular gratitude to the following experts for their valuable contributions to the document:

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- Miguel Diaz, Technical Director, AMEC Earth & Environmental, UK
- Larry Enloe, Manager, N. American Regional Business Unit, Barrick Gold, Utah, USA.
- Louise Grondin, Senior VP, Agnico-Eagle, Sweden
- Corina Hebestreit, Director, Euromines
- Robert Rose, CEO, Andina Minerals, Toronto, Ontaria, Canada *(formerly KCA, Reno, NV)*
- Marja Riekkola-Vanhanen, Sr. Biotechnology Advisor, Talvivaara Nickel Mine, Finland.


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———— European IPPC Bureau (2009), BREF Document on "Management of Tailings and Waste-Rock in Mining Activities", 511p.

*For current POPULARITY (!?!) of the Cyanide Ban Issue....*

**Back-up Info on status of CN ban issues in the EU....**

# YEAR 2005 - EU Commission's Response to an inquiry about "the use of Cyanide Leaching Technique in Gold Mining and Processing in the EU"

**There is no EU legislation explicitly allowing or prohibiting the use of this technique.**

16:35 DG ENV.A2 → 0025110450 NO. 571

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
ENVIRONMENT
Directorate G - Sustainable Development and Integration
ENV.G.4 - Sustainable Production & Consumption

Brussels, 28 -01- 2005
FP/jh D(2005)1602

Mr.
Councellor
Deputy Permanent Delegate
Permanent Delegation of Turkey to
the European Union
Rue Montoyer 4, B-1000 Brussels

By Fax:

Dear Mr.

Your fax of 6 January 2005 enquiring about the use of the cyanide leaching technique in gold extraction and processing in the EU was transmitted to my services.

There is no EU legislation explicitly allowing or prohibiting the use of this technique. The proposed directive on the management of waste from extractive industries (COM(2003) 319 final, 2.6.2003) contains provisions relating to the concentration limit values of cyanide in tailings ponds. This proposal is currently in the co-decision process.

The Commission does not keep a formal record of mining sites in the EU. However, relevant information can be found in a Study on the Costs of Improving the Management of Mining Waste, available at http://europa.eu.int/comm/environment/waste/mining/index.htm. Furthermore, the recently finalised Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities, available at http://eippcb.jrc.es/pages/FActivities.htm, lists a total of seven gold mining sites (see page 198 of the document).

Yours sincerely,

Marianne KLINGBEIL
Head of Unit

[illegible] Brussels / Bruxelles / Europese Commissie, B-1049 Brussel Belgium Telephone: (32-2) 299 11 11
[illegible] Telephone: direct line (32-2) 2983493. Fax: (32-2) 2983960.
[illegible] D:\MINING WASTE\3.1\Knowledge and analysis of policy needs (Mining Waste) WP\Correspondence\cyanide-TK.wpd

Your fax of 6 January 2005 enquiring about the use of the cyanide leaching technique in gold extraction and processing in the EU was transmitted to my services.

There is no EU legislation explicitly allowing or prohibiting the use of this technique. The proposed directive on the management of waste from extractive industries (COM(2003) 319 final, 2.6.2003) contains provisions relating to the concentration limit values of cyanide in tailings ponds. This proposal is currently in the co-decision process.

The Commission does not keep a formal record of mining sites in the EU. However, relevant information can be found in a Study on the Costs of Improving the Management of Mining Waste, available at http://europa.eu.int/comm/environment/waste/mining/index.htm. Furthermore, the recently finalised Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities, available at http://eippcb.jrc.es/pages/FActivities.htm, lists a total of seven gold mining sites (see page 198 of the document).

**Actually, there is NO PROHIBITION on USE of ANY CHEMICAL in ANY industrial process in the WORLD,**

***as long as the requirements of Human Health, Safety and Environmental Protection regulations are fulfilled !!***

# YEAR 2010 - EU Commission's Response to a Parliamentary Question on "Complete ban on the use of cyanide mining technologies in the EU"

**Parliamentary Question - 14 May 2010**
**WRITTEN QUESTION** by Csaba Sándor Tabajdi (S&D) to the Commission
**Subject: Complete ban on the use of cyanide mining technologies in the European Union**

## Answer given by Mr Potočnik on behalf of the Commission, 23 June 2010, P-3589/2010

The resolution of the Parliament calling for a general ban on the use of cyanide mining technologies in the European Union has received the full attention of the Commission.

***After an in depth analysis of the issue, the Commission considers that a general ban of cyanide in mining activities is not justified from environmental and health point of views.*** **Existing legislation notably on the management of extractive waste (Directive 2006/21/EC[1]) includes precise and strict requirements ensuring an appropriate safety level of the mining waste facilities.** The limit values for cyanide storage as defined in the directive are the most stringent possible and implies in practice a destruction step of cyanide used before its storage.

Due to the lack of better (in the sense of causing less impact on the environment) alternative technologies, a general ban on cyanide use would imply the closure of existing mines operating in safe conditions. This would be detrimental to employment without additional environmental and health added value.

**The Commission intends to continue to closely follow the possible technological developments in this sector in order to ensure that 'best available techniques' are applied in practice as required by the directive.**

In addition, the Commission considers that the priority should be set on ensuring full application of the directive by the Member States. As guardian of the Treaty, the Commission intends to take all necessary measures within its remit to ensure that the directive is fully and correctly applied in practice.

1) OJ L 102, 11.4.2006

*Reference: http://www.europarl.europa.eu/sides/getAllAnswers.do?reference=P-2010-3589&language=EN*