IIT(BHU) VARANASI

STUDENTS' NOTES

UNDERGROUND METALLIFEROUS MINING

TOPIC-SOLUTION MINING

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Solution Mining

- Solution mining is defined as the subclass of aqueous surface mining methods in which minerals are recovered by leaching dissolution, melting or slurrying processes.

- Gold, silver, copper, uranium, salt, magnesium, sulfur, lithium

- Borehole extraction systems
- Leaching methods
- Evaporites/ Evaporative procedure

Borehole extraction systems

- Mineral located under and earth
- Water and /or a lixiviant used

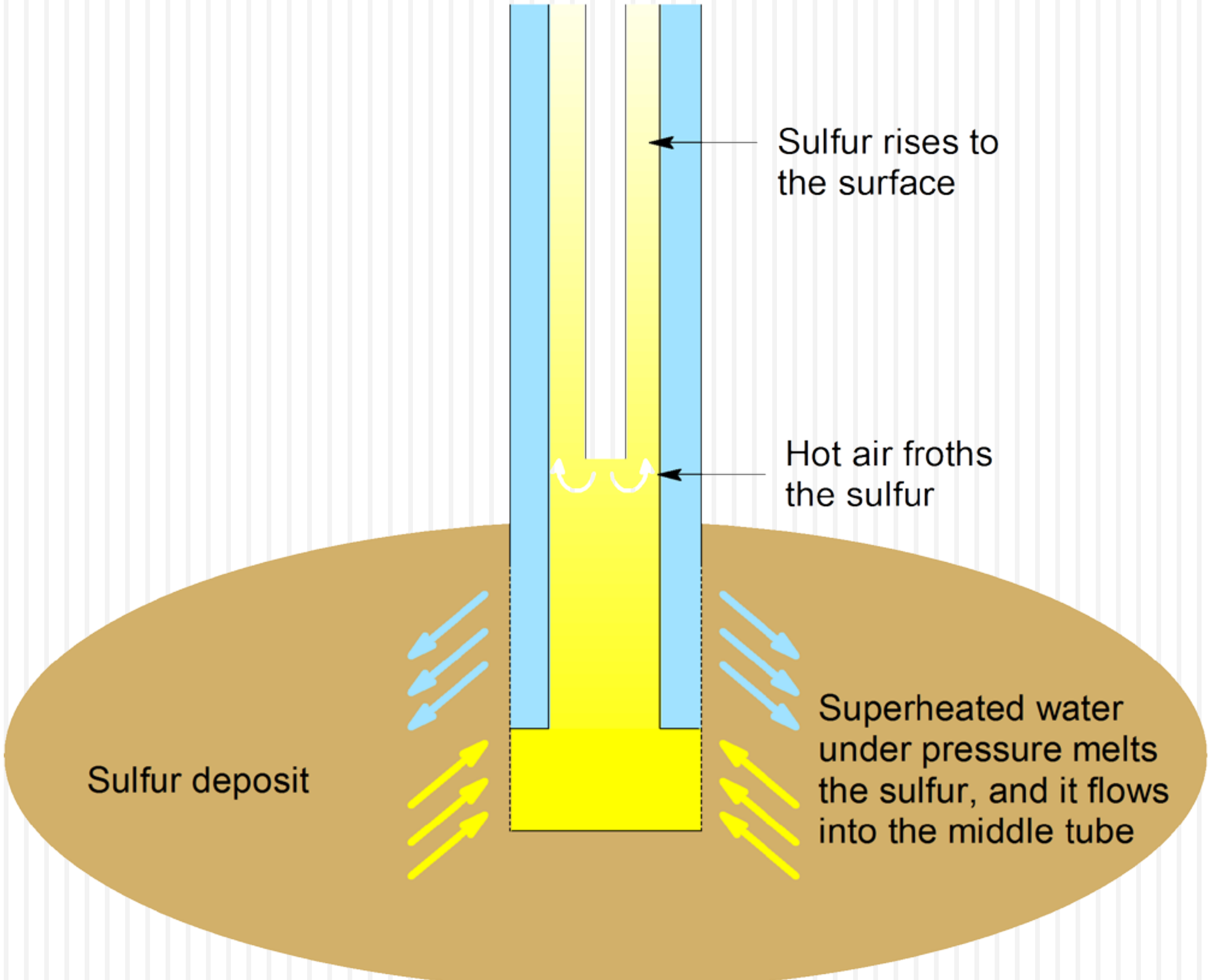
  - Melting of sulfur
  - Insitu leaching of uranium, copper, gold and silver
  - Dissolution of salt and potash
  - Slurrying of phosphate, kaolin, oil sands, coal, etc

lixiviant

- A lixiviant is a liquid medium used in hydrometallurgy to selectively extract the desired metal from the ore or mineral.
- It assists in rapid and complete leaching. The metal can be recovered from it in a concentrated form after leaching.
- Acidic lixiviants, such as sulfuric acid, are commonly used to leach base metals such as copper,
- Basic lixiviants such as a solution of sodium cyanide are used to leach precious metals.

Single well operation

- Metling, dissolution and slurrying are normally conducted using single bore hole
- It contains three concentric pipes.
- Outer pipes is used to inject superheated water into deposit to melt the sulfur
- The inner piper allows compressed air to flow to the bottom of the well
- It flow upward through between inner and middle pipes taking melted sulfur.

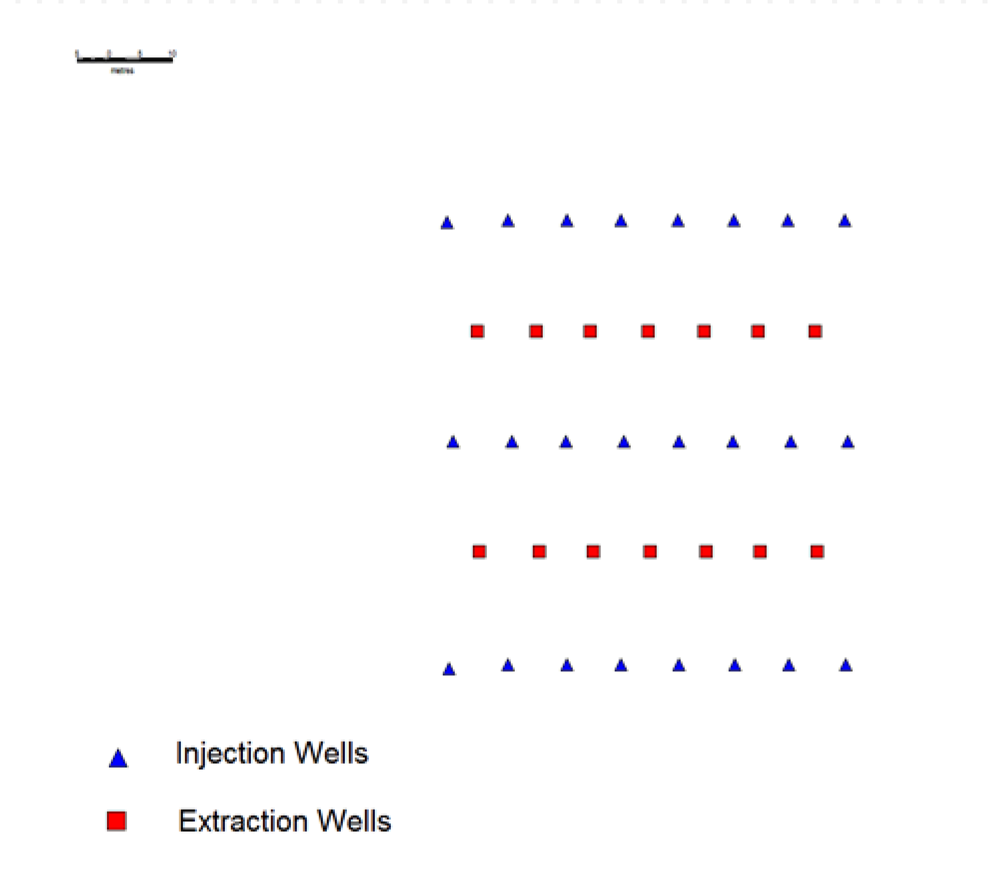

Sulfur rises to
the surface
Hot air froths
the sulfur
Superheated water
under pressure melts
the sulfur, and it flows
into the middle tube
Sulfur deposit

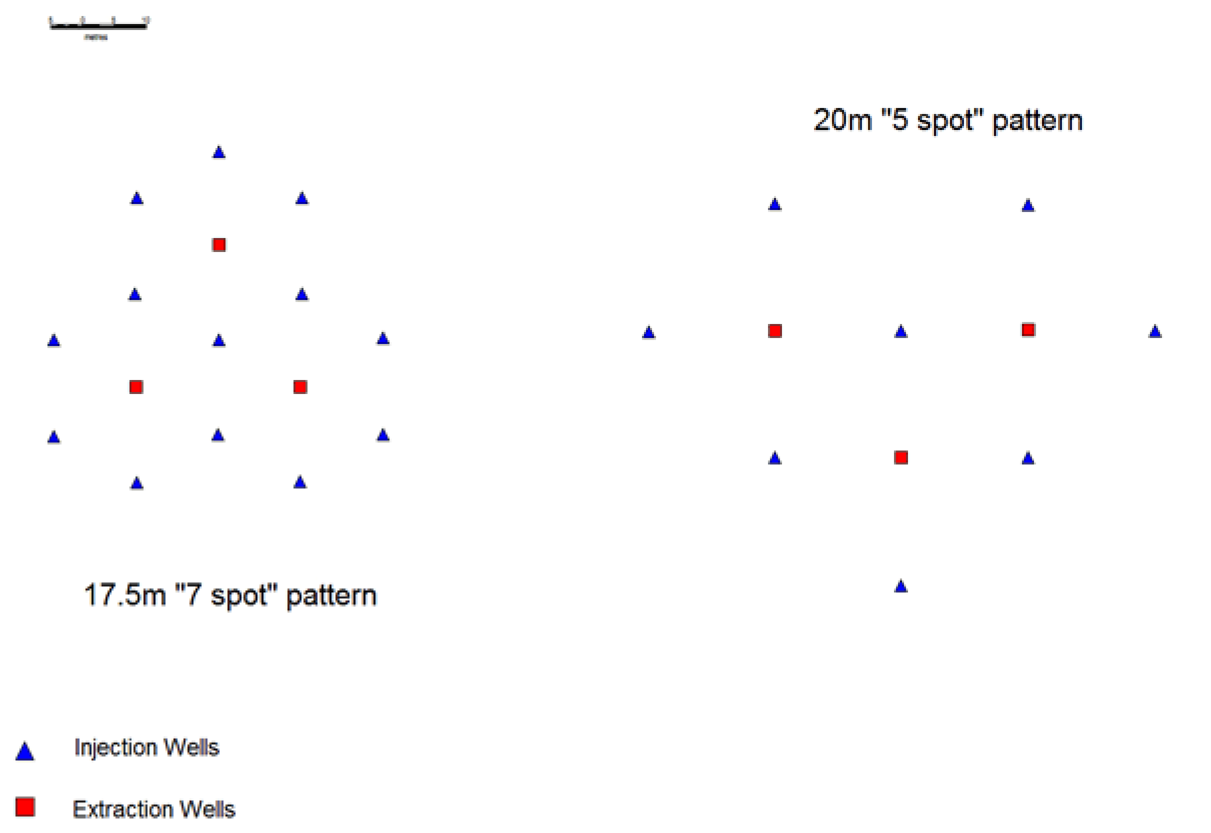
- Three concentric tubes are introduced into the sulfur deposit. Superheated water (165 °C, 2.5-3 MPa) is injected into the deposit via the outermost tube.
- Sulfur (m.p. 115 °C) melts and flows into the middle tube. Water pressure alone is unable to force the sulfur into the surface due to the molten sulfur's greater density.
- hot air is introduced via the innermost tube to froth the sulfur, making it less dense, and pushing it to the surface.

- Sulfur wells require following properties for economic operation.
- A large deposit > 5%
- An adequate and inexpensive supply of water
- A low cost source of fuel to heat the water.

Multi well operation

- Several wells work together to allow flow through deposit.
- Some of the wells are injection wells in which a fluid in flow into the ore zone
- Other are recovery wells through solution is extracted.
- The arrangement of the well have many design.


Injection Wells
Extraction Wells


20m "5 spot" pattern
17.5m "7 spot" pattern
Injection Wells
Extraction Wells

Cycle of operation

- Preparation the solution by heating or adding the proper lixiviant
- Pumping the solution into the deposit to bring the valuable mineral into solution (by melting , dissolution or slurrying)
- Raising the solution to the surface

Conditions

- Ore strength: competent, porous and permeable
- Rock strength: surrounding rock must be strong
- Deposit share: any, preferable tabular deposit
- Deposit dip: preferable flat or low
- Deposit size: moderate to large
- Ore grade: intermediate
- Ore uniformity: variable to uniform
- Depth: intermediate to high

Advantages

- High productivity
- Low capital cost
- Low mining cost
- Applicable to deep and low grade
- Reduce development time and cost
- Continuous operation
- Disturbs less surface area

Disadvantages

- Limited to deposits that dissolve, melt or slurry in water
- Moderate water requirement
- Unselective
- Recovery normally low to moderate
- Possible ground water contamination

Leaching methods

- Leaching is the chemical extraction of metals or minerals from the confines of a deposit or from material already mined.
- Percolation leaching
- Flooded leaching

- Chemical leaching
- Bacteriological leaching

- In situ : If the extraction is carried out on mineral in place, it is termed in situ leaching
- It can be preformed with the use of boreholes
- If it is preformed in previously mined dumps, tailings, or slag piles it is called heap (or dump) leaching and is accomplished by percolation of the lixiviant through broken ore mass.

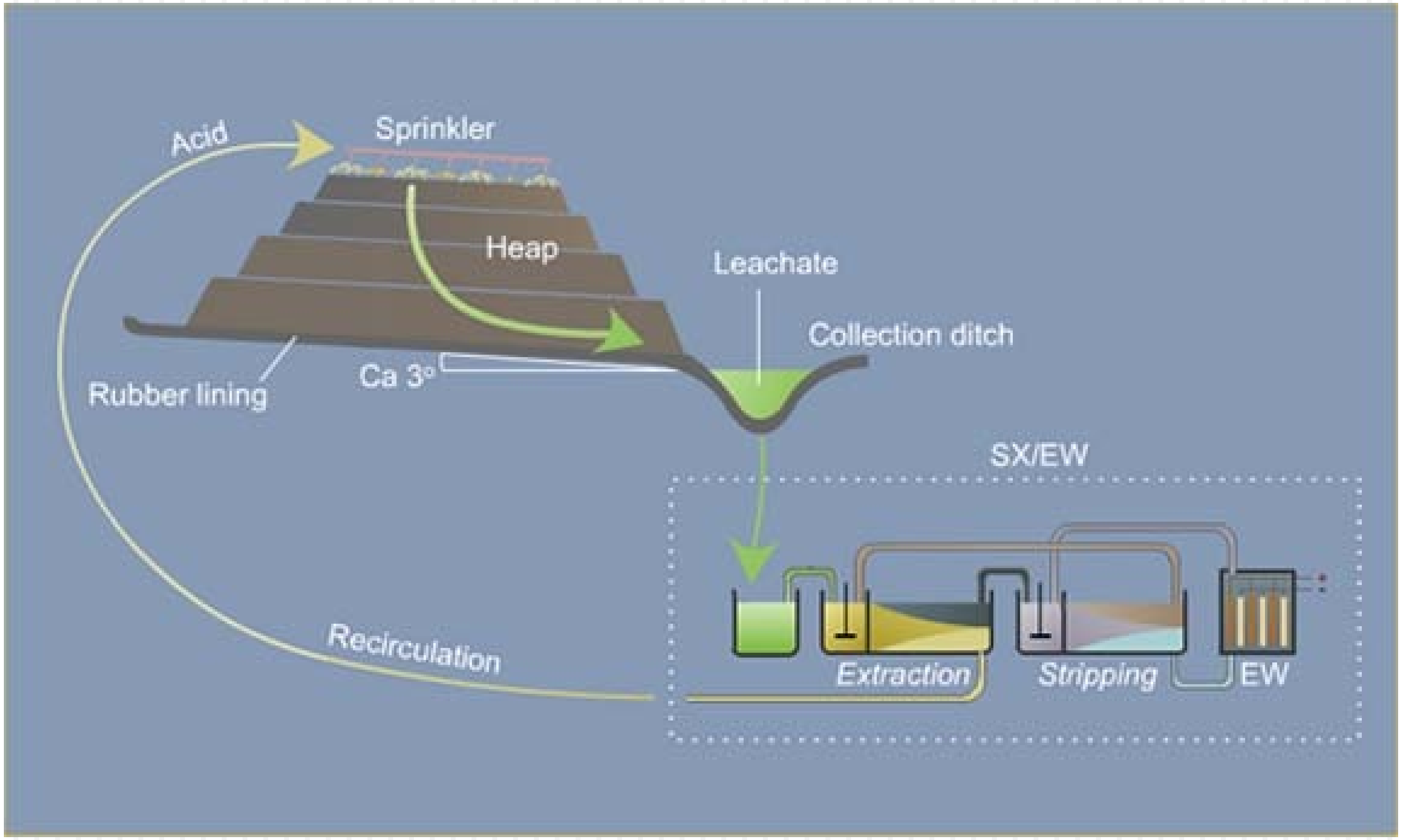
Methods for dump/ heap leaching

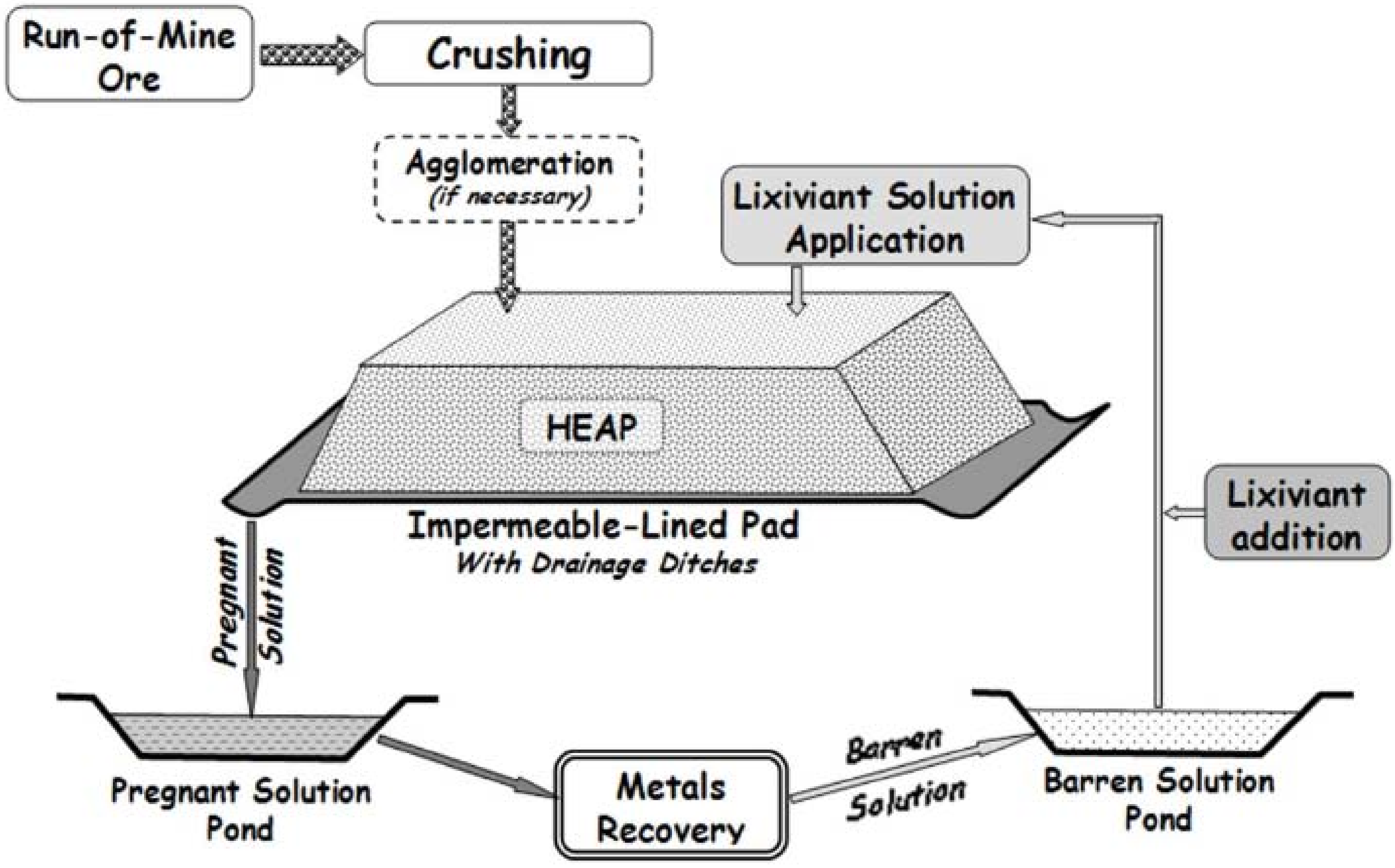
- The re usable pad method
- The expanding pad method
- The valley leach (multiple lift) method

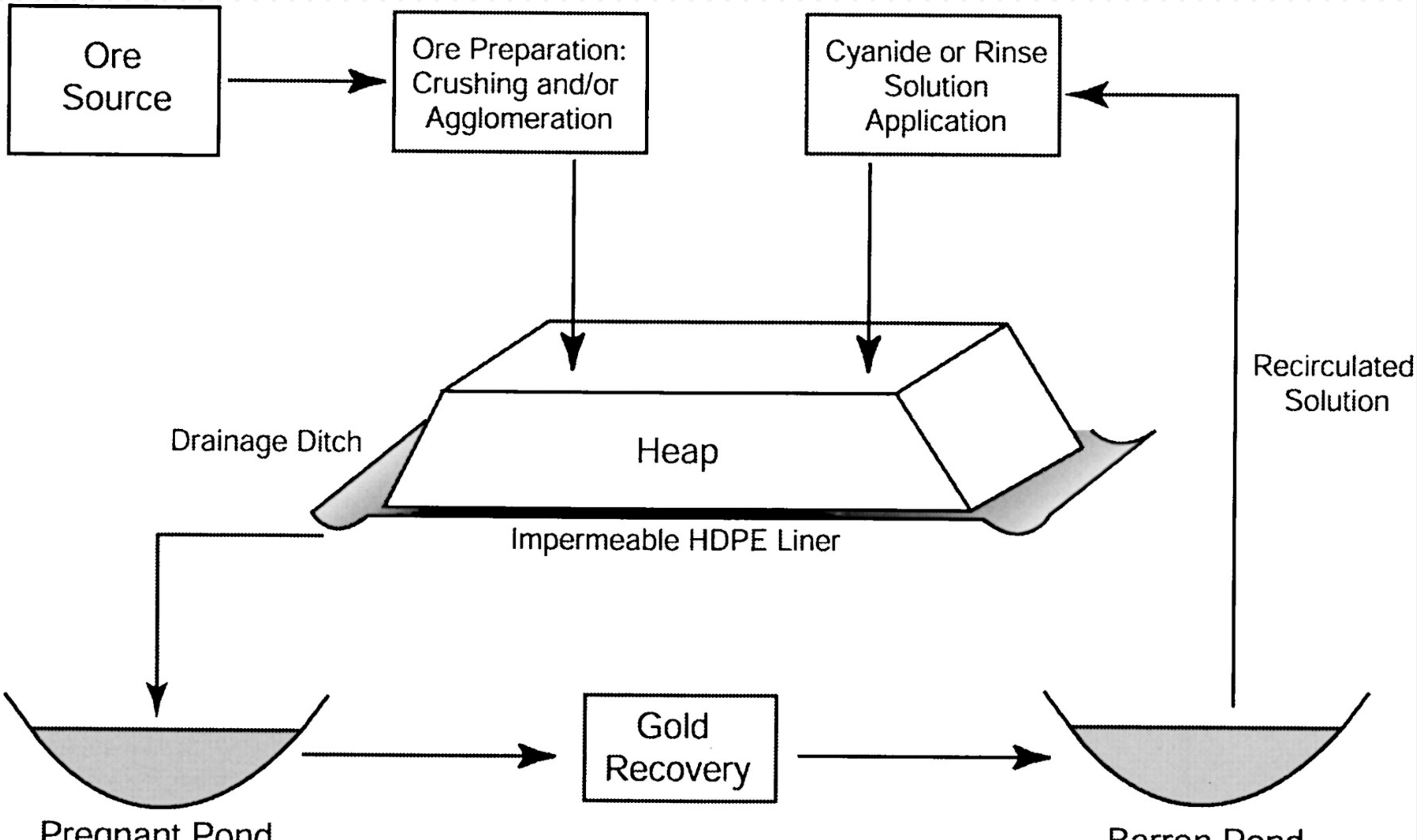
- Successful operation requires a pad that will reliably contain the liquids and a plan for maintaining water balance in the system.
- The physical layout of heap or dump depend on the methods of leaching
- The heaps are constructed using trucks, front end loader or conveyor stackers with proper permeability of dump/heap.

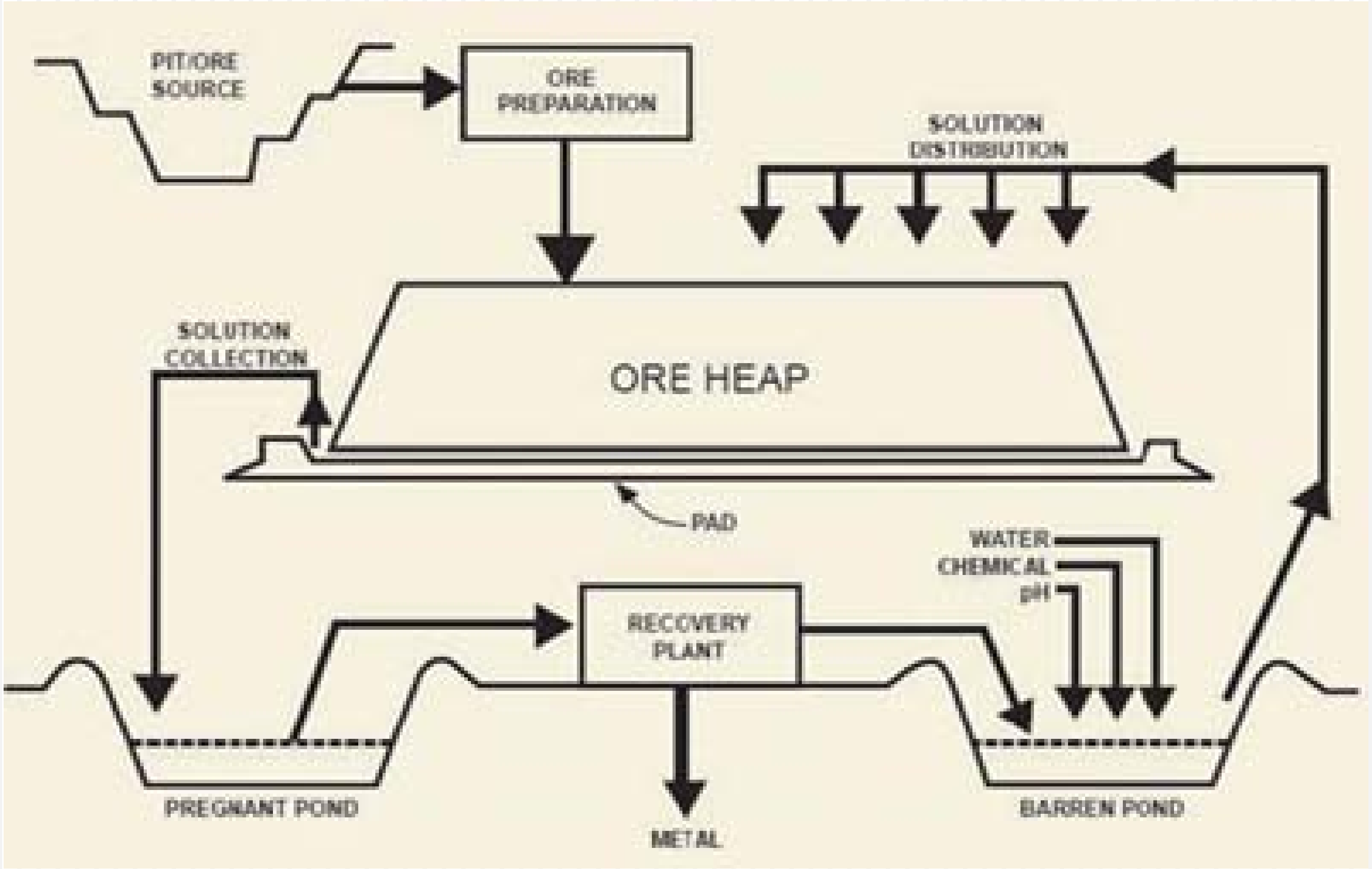
- Thickness (3m to 100m)
- Multilayer
- Solution applied from surface
- Sufficient perameability
- 0.002 to 0.005   l/sec/m2
- Control of leaching (environment)
- Asphalt pad, geomembrane liners
- Design consideration: rain fall and evaporation

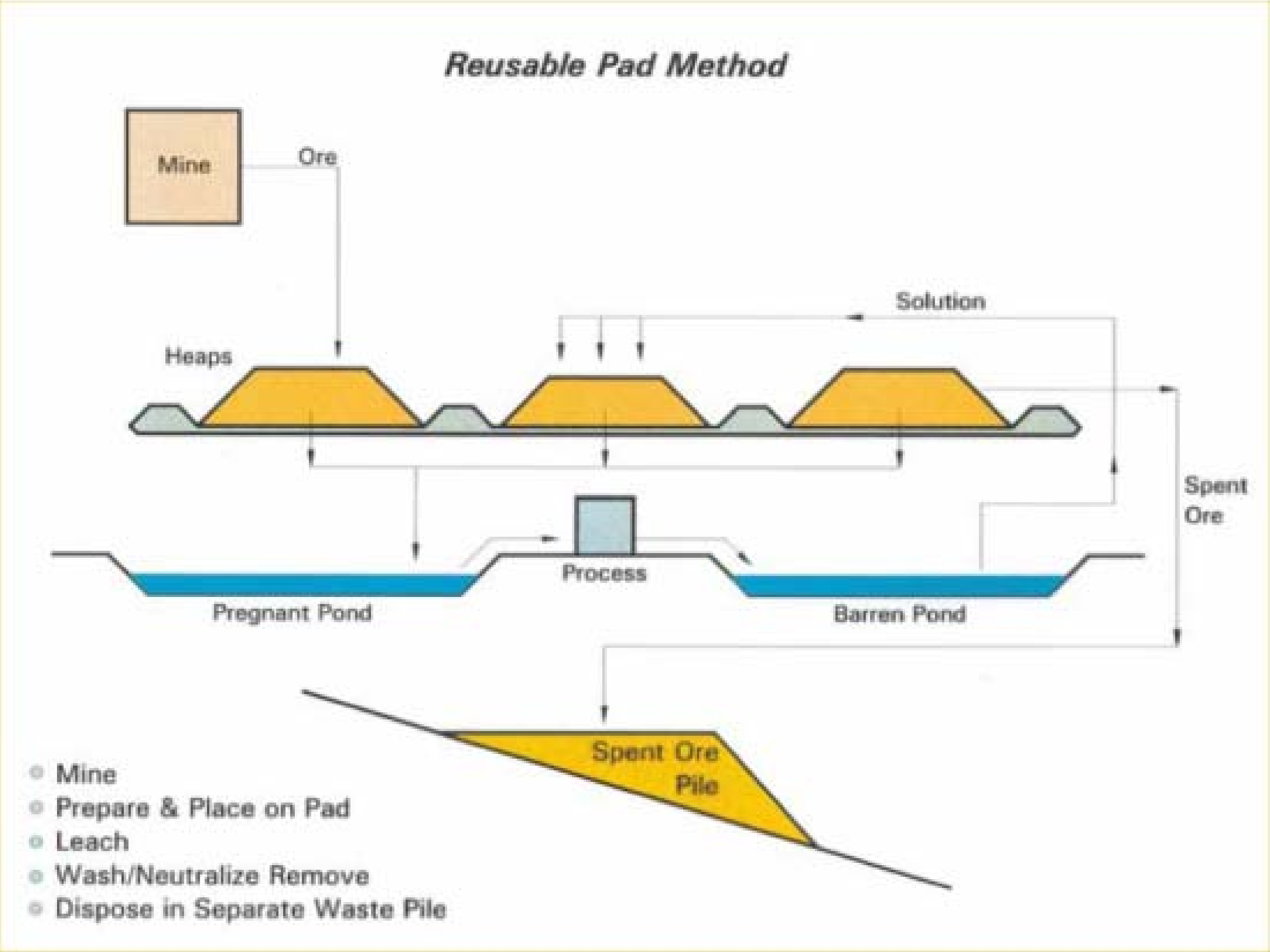
figure

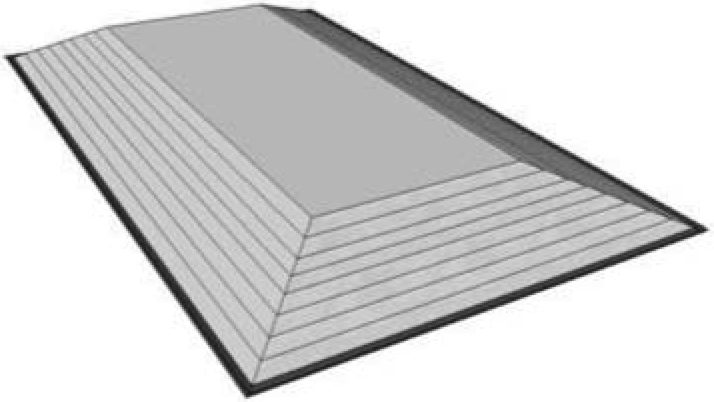

Acid
Sprinkler
Heap
Leachate
Collection ditch
Rubber lining
Ca 3°
SX/EW
Recirculation
Extraction
Stripping
EW

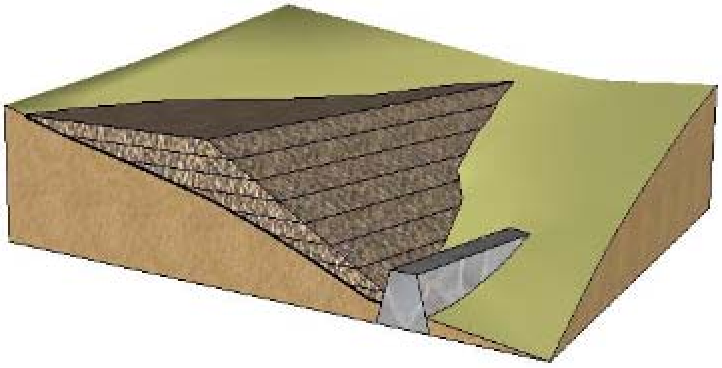

Run-of-Mine Ore
Crushing
Agglomeration (if necessary)
Lixiviant Solution Application
HEAP
Impermeable-Lined Pad
With Drainage Ditches
Pregnant Solution
Lixiviant addition
Pregnant Solution Pond
Metals Recovery
Barren Solution
Barren Solution Pond


Ore Source
Ore Preparation: Crushing and/or Agglomeration
Cyanide or Rinse Solution Application
Recirculated Solution
Drainage Ditch
Heap
Impermeable HDPE Liner
Gold Recovery
Pregnant Pond
Barren Pond

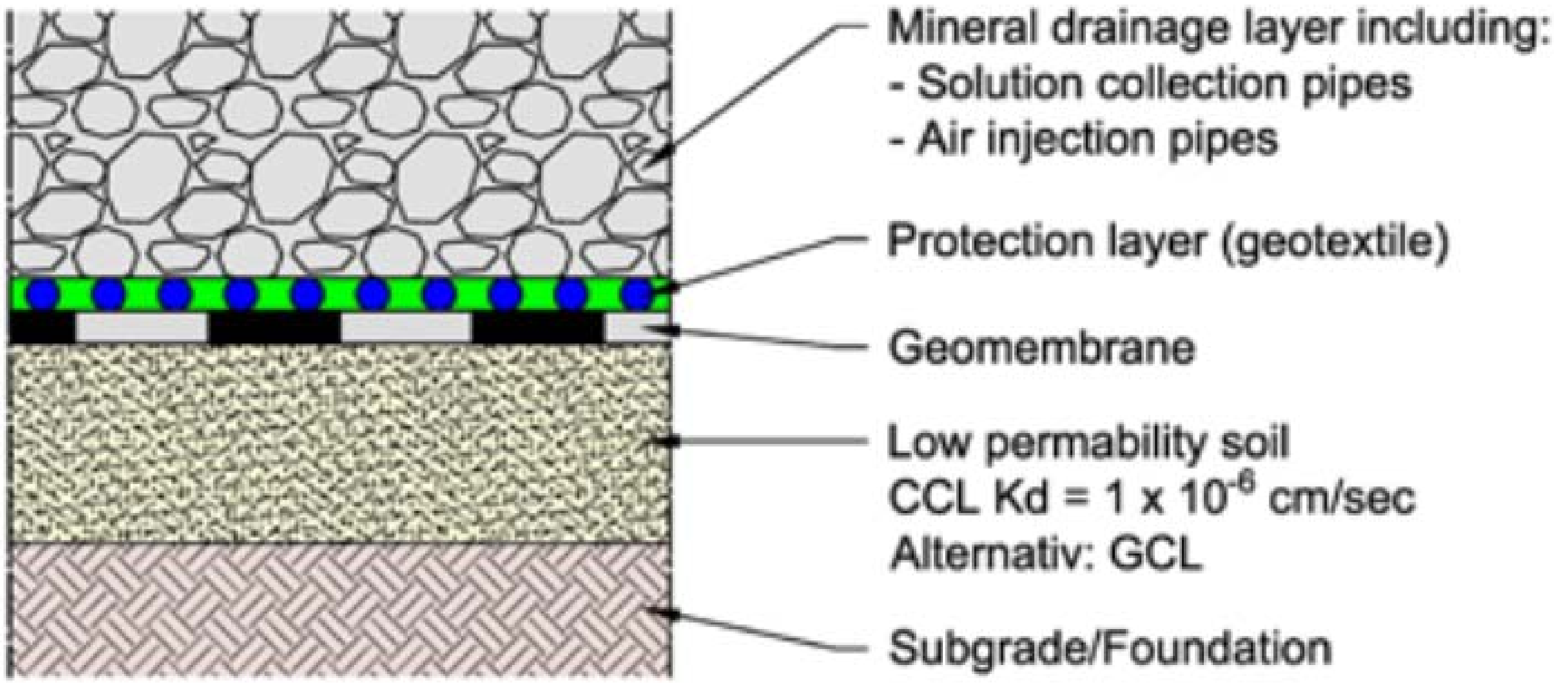

PIT/ORE SOURCE
ORE PREPARATION
SOLUTION DISTRIBUTION
SOLUTION COLLECTION
ORE HEAP
PAD
WATER
CHEMICAL
pH
RECOVERY PLANT
PREGNANT POND
METAL
BARREN POND


Reusable Pad Method
Mine
Ore
Solution
Heaps
Spent
Ore
Process
Pregnant Pond
Barren Pond
Spent Ore
Pile
Mine
Prepare & Place on Pad
Leach
Wash/Neutralize Remove
Dispose in Separate Waste Pile

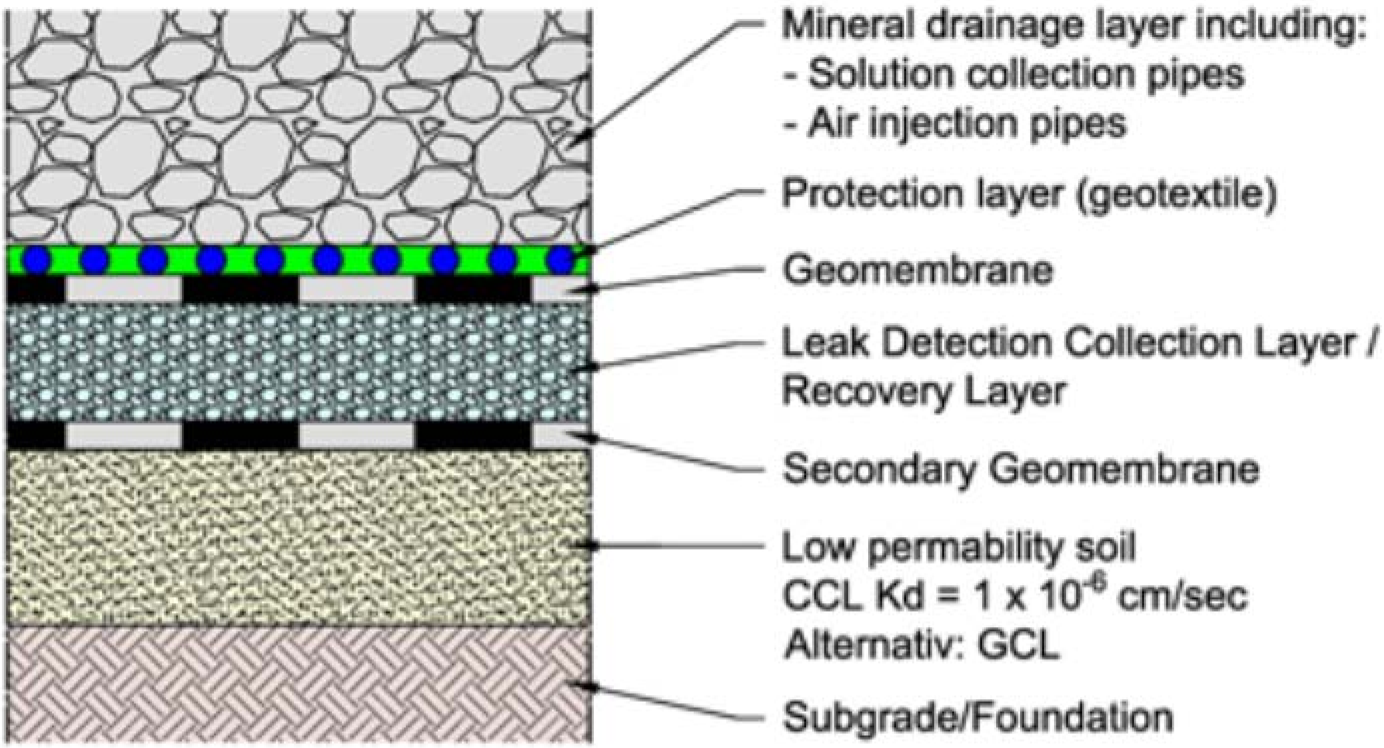




Single composite liner system



Double composite liner system



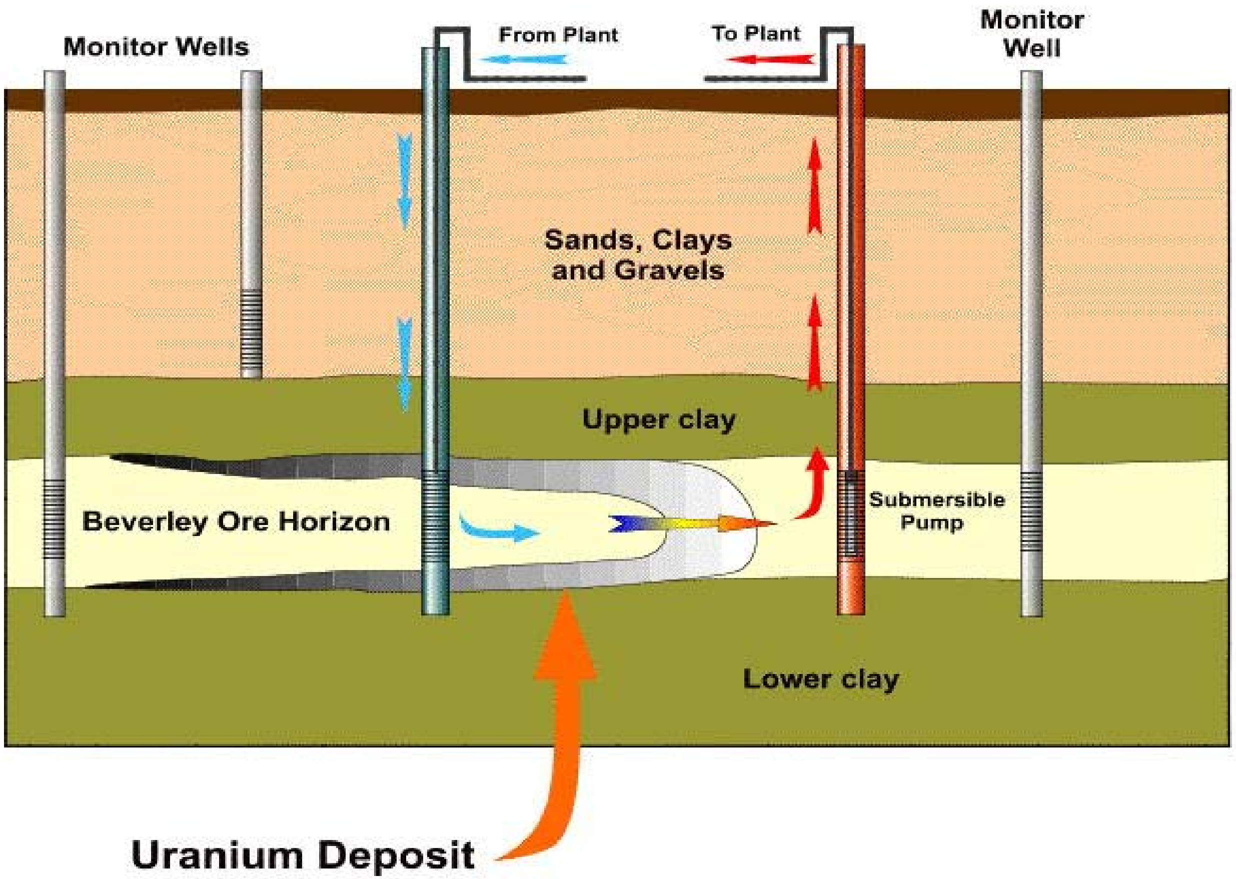
In situ leaching

Operation

- Leaching of the marginal remaining ore in an underground caving operation
- Leaching of a marginal near surface deposit after fragmentation of the ore body
- Leaching of open pit ore after blasting a portion of final high wall

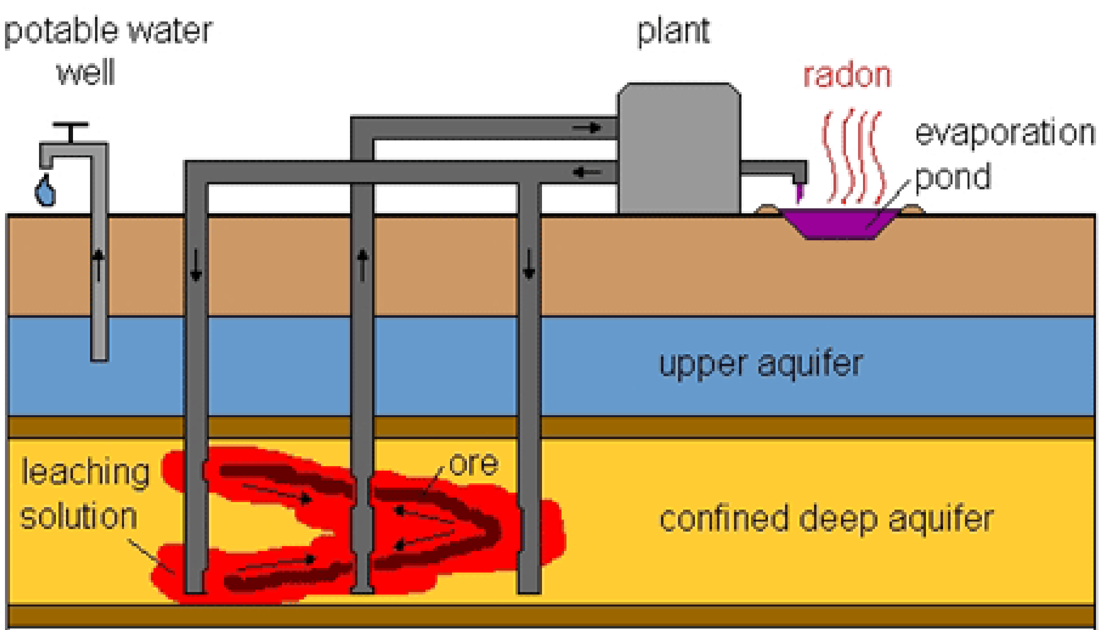
Sequence of development

- Remove vegetation from the area of the leach pad
- Create a slope of about 5% to facilitate pad drainage
- Construct an impervious pad and proper pad berm to control leaching fluid
- Construct a solution pond
- Mine, crush and remove fines from ore mineral
- Spread material in lifts (single or more)
- Rip the surface if necessary
- Install the irrigation system and initiate leaching


Monitor Wells
From Plant
To Plant
Monitor Well
Sands, Clays and Gravels
Upper clay
Beverley Ore Horizon
Submersible Pump
Lower clay
Uranium Deposit

IN SITU LEACHING

With the in situ leaching technology, a leaching liquid (e.g. ammonium-carbonate or sulfuric acid) is pumped through drill- holes into underground uranium deposits, and the uranium bearing liquid is pumped out from below. This technology can only be used for uranium deposits located in an aquifer in permeable rock, confined in non-permeable rock.



Cycle of operation

- Preparation of the material for leaching
- Application of the solvent
- Percolation of the solvent through the material
- Collection of solution
- Processing to recover mineral and regenerate solvent

conditions

- Ore strength: permeable and soft, loose
- Rock strength: can be weak, impervious to fluid transport
- Deposit share: massive to large
- Deposit dip: steep, if vein
- Deposit size: prefer large
- Ore grade: can be very low
- Ore uniformity: variable, mineral should accessible to the leach solution
- Depth: typically less then 300 m

Advantages

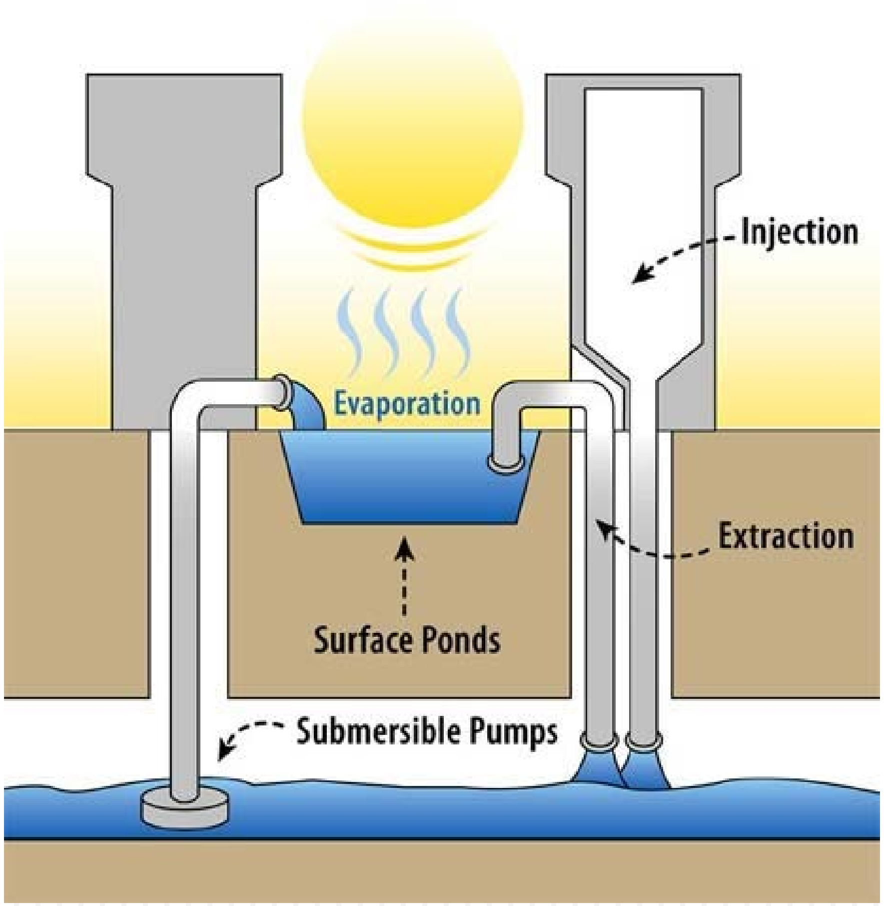
- Low mining cost
- Low labor requirement
- Applicable to low grade deposits
- Reduced development time and cost
- Good health and safety factor
- Biological science can enhance reaction and help with environment protection.

Disadvantages

- Limited to soluble minerals that can be chemically leached
- Moderate water requirements
- Large land areas required for leach dumps
- Can be unselective
- Recovery may be low in some cases
- Possible environmental hazards
- Ground water contamination
- Water problem
- Lixiviants may be dangerous b

Evaporites/ Evaporative procedure

- An evaporite is a sedimentary deposit composed primarily of minerals produced from a saline solution by evaporation in a close basin.
- Typical minerals: Halite ($NaCl$) and potash
- Recovery of the mineral is accomplished by water from brines in solar ponds.
- Saline solutions are pumped into large, shallow ponds to allow to evaporate.
- A warm, dry climate and level land are typically required


Injection
Evaporation
Extraction
Surface Ponds
Submersible Pumps

Sequence of development

- The extraction of an evaporites normally requires that mineral be located in solution in an inland sea or put into solution using in situ method
- Locate or produce large, nearly flat areas
- Lay down a layer of fine-grained material like sand or clay as a bed for geomembrane or other containment layer
- Initiate the flow of solution into the ponds

Cycle of operation

- Pump the solution into the ponds matching the inflow rate with the net evaporation rate
- Allow solar energy to concentrate and crystallize the mineral
- When a sufficient layer of minerals has been precipitated, allow the sun to evaporate all remaining water
- Harvest the mineral, ordinarily leaving a layer of salts to protect the lining of the pond
- Reinitiate the flow of solution into the pond

Condition

- Ore strength: evaporites deposit
- Rock strength: surrounding rock must be strong
- Deposit type: large
- Deposit dip: any
- Deposit size: moderate to large
- Ore grade: variable
- Ore uniformity: variable to uniform
- Depth: intermediate

Advantages

- Low cost
- Natural concentration often available
- Uses free solar energy
- Minerals relatively easily found
- Reduced development time and cost
- High recovery
- Good health and safety factors
- Low labor cost

Disadvantages

- Specialization method
- Moderate water requirements
- Requires large land areas for recovery
- Possible environment consequences