TOMSK
POLYTECHNIC
UNIVERSITY

Fundamentals of Nuclear Fuel Cycle

Lecturer
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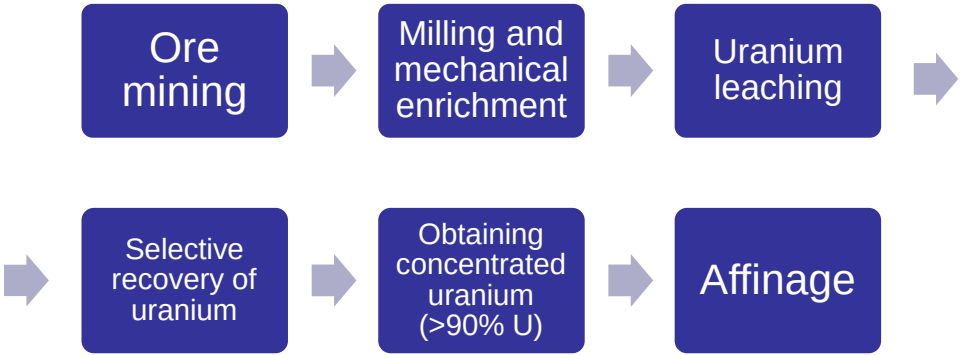
2016

Hydrometallurgical processing of uranium ore



Mining

- Open pit

drilling and blasting of ore body, ore excavation using loaders and dump trucks

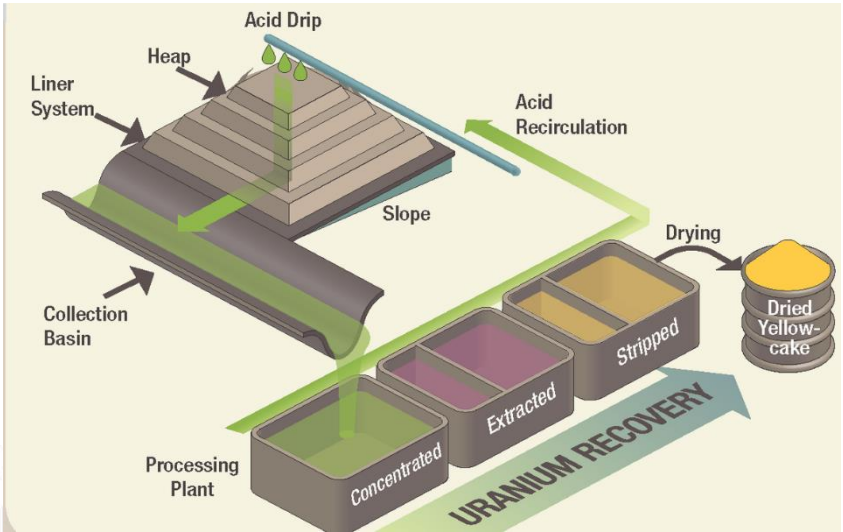
- Underground uranium mining

an analog of hard rock mining

Mining

- Heap leaching

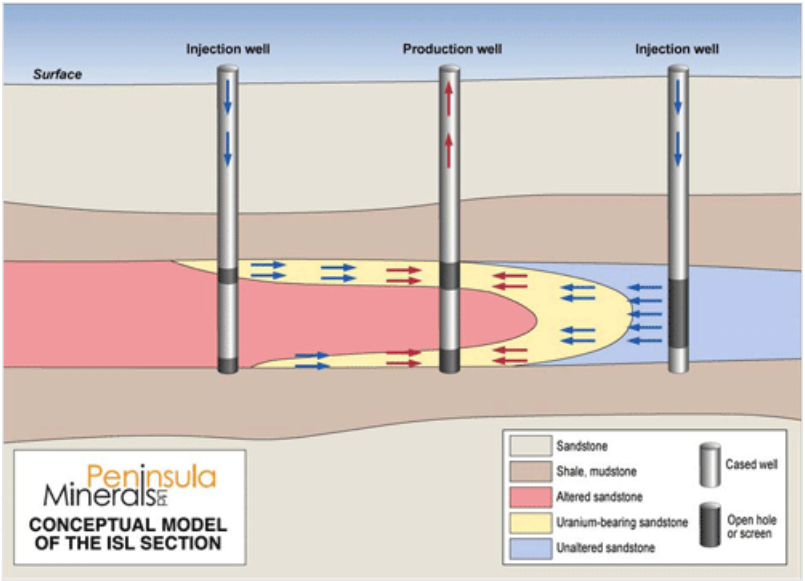
process to extract uranium from ore via a series of chemical reactions that absorb specific minerals and then re-separates them after their division from other earth materials



Mining

- In-situ leaching (ISL)

Leaching in the ground



Mechanical enrichment of uranium ore

- increasing concentration of U in mined ore

Why

different concentration of U in orebodies

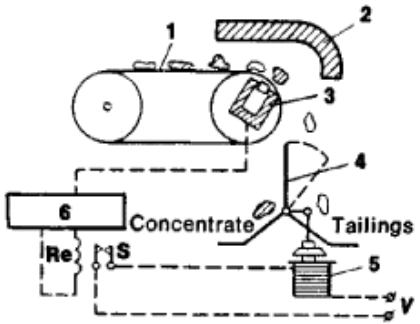
a large number of useless waste rock

Mechanical enrichment of uranium ore

1. Radiometric methods

Measurement of gamma-rays Intensity from ore pieces with future separations

Ore size 25-300 mm



Radiometric separator for naturally radioactive ores: (1) conveyor belt, (2) screen, (3) radiometer detector, (4) gate valve, (5) electromagnet, (6) radiometer, (Re, S) switch relay, and (V) power source

Mechanical enrichment of uranium ore

2. Gravity methods

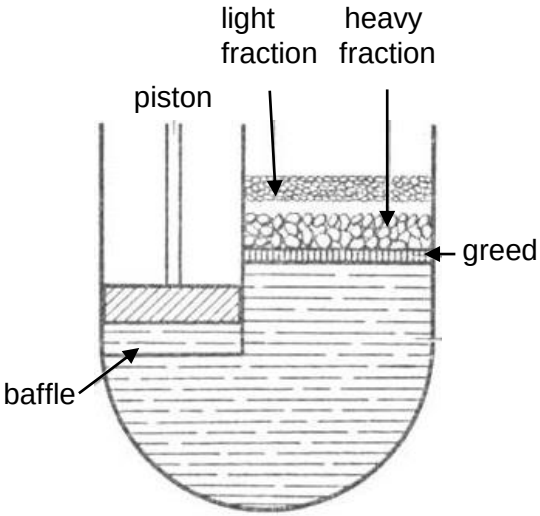
ρ(Uranium composition) = 6.5 -10.5 g/cm^3

ρ(Ore components) =2.5 – 2.7 g/cm^3

Ore size 0.07-0.1 mm

3. Flotation methods

Ore size 0.07-0.15 mm



Uranium leaching

Goal

Uranium extraction from enriched uranium ore by chemical reactions

- Acids
- Alkalis

t = 20-80 °C

T = 12-24 h

$UO_2(NO_3)_2$ uranyl nitrate

UO_2SO_4 uranyl sulfate

$UO_2H_2PO_4$ uranyl phosphate

UO_2Cl_2 uranyl chloride

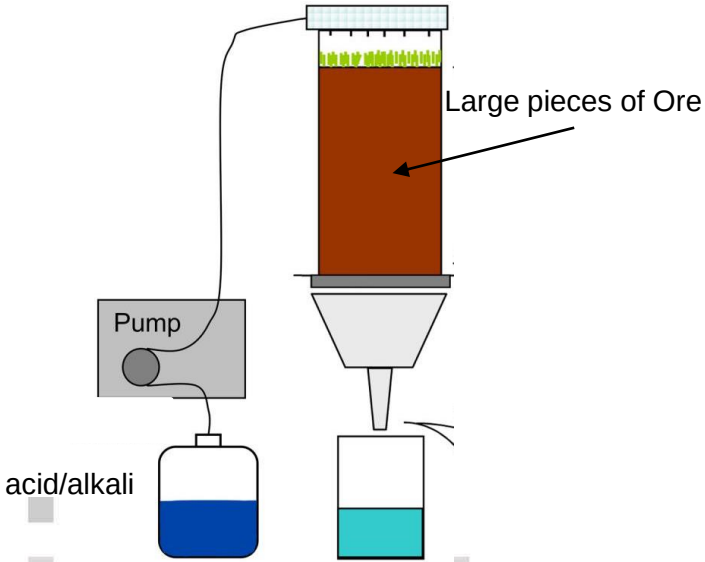
$Na_2UO_2(CO_3)_2$ sodium uranyl chloride

$Na_4UO_2(CO_3)_3$ sodium uranyl chloride

contaminants: Fe, Ca, P, V, As …..

Uranium leaching

1. Percolation leaching



2. Agitation leaching

Milled ore + acid/alkali

Leaching reagents

1. Sulfuric acid
2. Soda

cheap

3. Hydrochloric acid
4. Ammonium carbonate

expensive

5. Mixture of sulfuric and nitric acid
6. manganese oxide
7. sodium nitrate

high concentration Of U

8. Nitric acids

Recovery of uranium

- extraction of U from solutions

Methods

- Ion exchange sorption (IX)
- Organic Solvent extraction (SX)
- Chemical vapor deposition (CVD)

$NaOH/\ MgO/NH_4OH/H_2O_2$ + Pregnant liquor = UO_x *nH_2O

95-96 % concentrated uranium + impurities

Affinage

- is a process of uranium purification

"BAD" contaminants

Hf, B, Cd, Eu, Gd, Sm, Li, Mn, Ar, Na, Co, etc

Tributyl phosphate (TBP) $C_{12}H_{27}O_4P$

an organophosphorus compound
colourless
odorless
density 0.973 g/cm^3
15–40% (usually 30%) solution

Affinage

Steps $U_3O_8 + 8HNO_3 = {}_3UO_2(NO_3)_2 + 2NO_2 + 4H_2O$

$UO_2(NO_3)_2 + 2TBP = UO_2(NO_3)_2 * 2TBP$

heating to 60-70 °C $UO_2(NO_3)_2 * 2TBP$

chemical vapor deposition by H_2O_2

$UO_4 * 2H_2O$

heating to 400 – 500 °C

$UO_4 * 2H_2O = UO_3 + 2H_2O + 1\backslash 2\ O_2$

thermal decomposition 800-850 °C

UO_2 /U_3O_8 without additives

Affinage RU

Steps $U_3O_8 + 8HNO_3 = {}_3UO_2(NO_3)_2 + 2NO_2 + 4H_2O$

$UO_2(NO_3)_2$ + TBP+hydrocarbon

mix with NH_4HCO_3 for production $(NH_4)_4UO_2(CO_3)_3$

cooling to crystals

$(NH_4)_4UO_2(CO_3)_3 = UO_2 + 3CO_2+2NH_3+N_2+2H_2+3H_2O$

UO_2 dissolve in acids (HCl+HF)

UF_4*nH_2O

drying at 200-250 °C and calcination at 500 °C

UF_4

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U_3O_8 – Yellow cake