APPLICATION OF MEMBRANE DISTILLATION AND SOLVENT EXTRACTION FOR WATER AND ACID RECOVERY FROM MINING WASTE SOLUTIONS

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Presented by
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INTRODUCTION:

The Need of the Mining Industry

Mining and metallurgical processes generate effluents such as

- ✓ acidic waste solutions.
- ✓ acidic mine drainage (AMD).
- ✓ acidic process solutions.

The current practice of treatment of acid-containing effluents has been neutralisation

- ➢ Large amounts of neutralisation reagents consumed.
- ➢ Sludge containing unstable heavy metal compounds disposed, Causing environmental pollution.
- ➢ Large amount of water wasted

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INTRODUCTION:

The Need of the Mining Industry

Difficulties to recover water, acid and valuable metals

- Concentration of acid and metals are often too low to recover economically.
- Concentrating dilute acidic solutions through conventional evaporation is energy intensive.
- high cost for anti-corrosive materials needed for heating the waste solution.

Best approach:

- Membrane distillation (MD) to recover the water and to concentrate the waste solution
- Solvent extraction (SX) to recover the acid
- Solvent extraction (SX) to recover valuable metals

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INTRODUCTION:

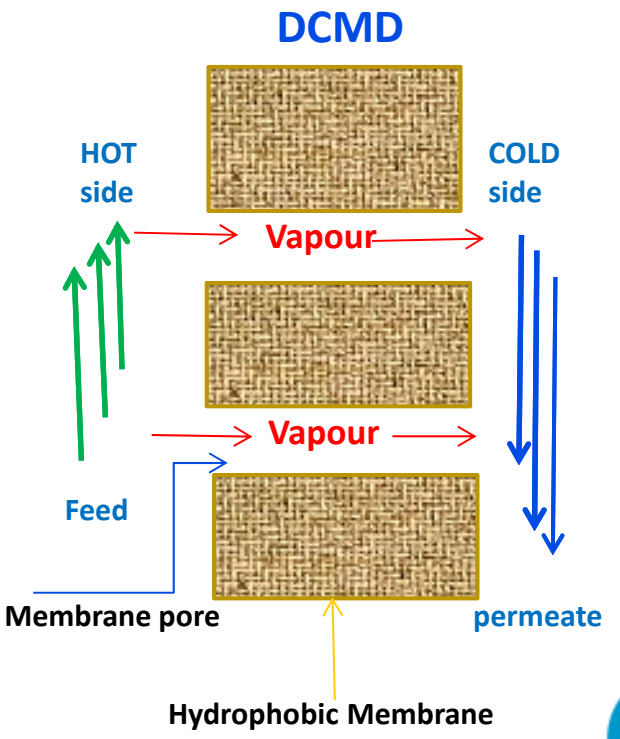
Membrane distillation (MD)

Membrane distillation is an emerging membrane process which may overcome some limitations of other membrane technology such as reverse osmosis (RO)

- **MD principle**
  - Small membrane is hydrophobic
  - Only vapour can pass through the pores
  - The driving force is the temperature difference

- **MD configuration**
  - Direct contact membrane distillation (DCMD)
  - Vacuum membrane distillation (VMD)
  - Air gap membrane distillation (AGMD)
  - Sweeping gas membrane distillation (SGMD)

- **Advantages of MD**
  - Lower operating temperatures than evaporation
  - Lower operating pressure than RO
  - 100% rejection of non volatiles



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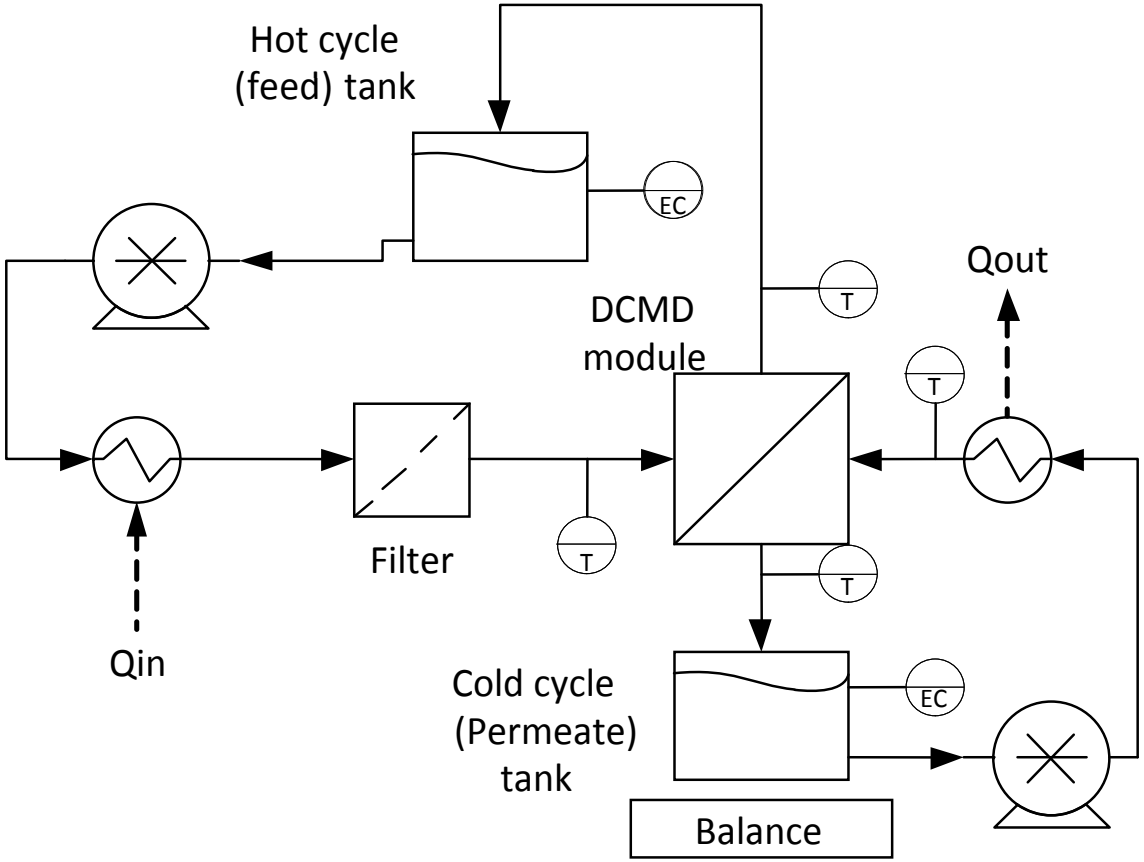
INTRODUCTION:

Membrane distillation (MD)



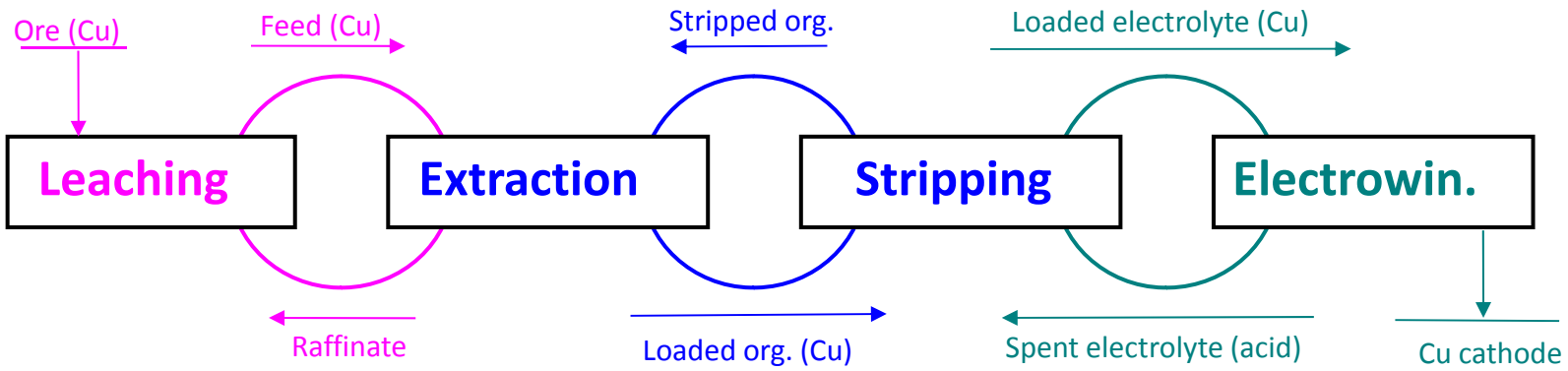
- Electrical conductivity (EC) in cold side tank to indicate membrane performance.
- A cartridge filter to capture salt precipitate at the highest temperature point in the hot cycle

Test rig of DCMD

INTRODUCTION:
Solvent Extraction (SX)

Solvent extraction (SX) is a widely applied technology in the mining industry

- ❑ **Mature technology**
- ❑ **High efficiency**
- ❑ **High selectivity**



An example of SX: Cu Leach-SX-EW process

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INTRODUCTION:
Outlines of this paper

MD for water recovery:

- Recovery of water by DCMD
- A comparison of MD and RO
- Economical consideration of MD

SX for acid recovery

- Effect of initial acid concentration on acid extraction
- Effect of temperature on acid extraction and tripping
- Successive extraction
- Extraction kinetics
- Stripping kinetics
- Acid extraction in the presence of metals
- Development of a conceptual process flowsheet

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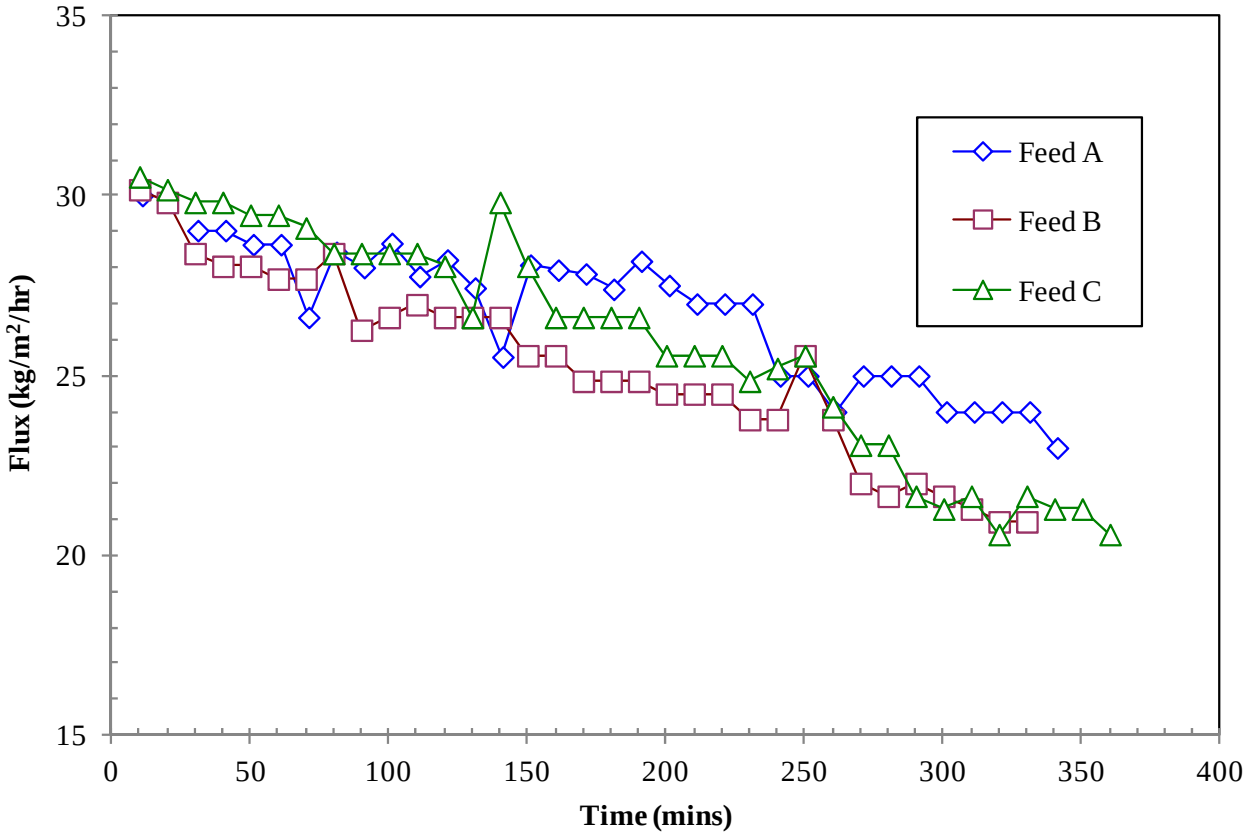
RECOVERY OF WATER BY DCMD



- Decrease in flux due to water reduction in feed tank

A: 0.5 M H_2SO_4
B: 0.5 M H_2SO_4/0.2 M NaCl
C: 0.5 M H_2SO_4/0.2 M NaCl/0.2 M Na_2SO_4

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RECOVERY OF WATER BY DCMD

Table 1: Chloride concentrations in feed and permeate

		Chloride concentration (mg/L)	
Feed	**Composition**	**Initial feed**	**Final permeate**
A	0.5 M H_2SO_4	120	45
B	0.5 M H_2SO_4/0.2 M NaCl	7,100	270
C	0.5 M H_2SO_4/0.2 M NaCl/0.2 M Na_2SO_4	7,300	500

- **The pH of the permeate in solution A was about 7 and no acid was detected in the permeate tank, indicating that H2SO4 cannot pass the MD to the permeate**
- **The pH in the permeate tank of solutions B and C was in the range of 2.0 – 2.5 and the Cl concentration largely increased, indicating that HCl vapour passes membrane to the permeate**
- **More Cl entered the permeate from solution C probably due to the higher Cl concentration and salt-out effect.**

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RECOVERY OF WATER BY DCMD

Table 2: Sulphate concentrations in feed and permeate

		Sulphate concentration (mg/L)	
Feed	**Composition**	**Initial feed**	**Final permeate**
A	0.5 M H_2SO_4	40,000	2
B	0.5 M H_2SO_4/0.2 M NaCl	45,000	1
C	0.5 M H_2SO_4/0.2 M NaCl/0.2 M Na_2SO_4	65,000	3

❖**Membrane exhibited high sulphate rejection (>99.99%) as demonstrated by low immigration of sulphate to the permeate**

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RECOVERY OF WATER BY DCMD

Table 3: Sodium concentrations in feed and permeate

		Sodium concentration (mg/L)	
Feed	**Composition**	**Initial feed**	**Final permeate**
A	0.5 M H_2SO_4	112	7
B	0.5 M H_2SO_4/0.2 M NaCl	4,600	7
C	0.5 M H_2SO_4/0.2 M NaCl/0.2 M Na_2SO_4	13,800	7

❖**Membrane exhibited high salt rejection (>99.99%) as demonstrated by low immigration of sodium to the permeate**

A COMPARISON OF MD AND RO

- MD has lower operating pressure compared to RO
- MD can deal with higher salt concentration compared to RO
- MD flux is less sensitive to feed and fouling compared to RO
- MD has 100% rejection of non-volatile components

- RO requires only electrical energy while MD requires both thermal and electrical energy
- RO is cheaper when waste heat is not available

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ECONOMICAL CONSIDERATION OF MD

- In comparison to conventional evaporators, MD requires more thermal energy per m^3 of water processed.
- MD can be operated at as low as 40°C with sufficient fluxes as long as ambient temperatures are around 20°C.
- The overall cost using MD with a low grade heat to desalinate waste water was US$0.49/$m^3$ at 60°C.
- MD is particularly economical when it is combined with SX to recover water, acid and valuable metals.

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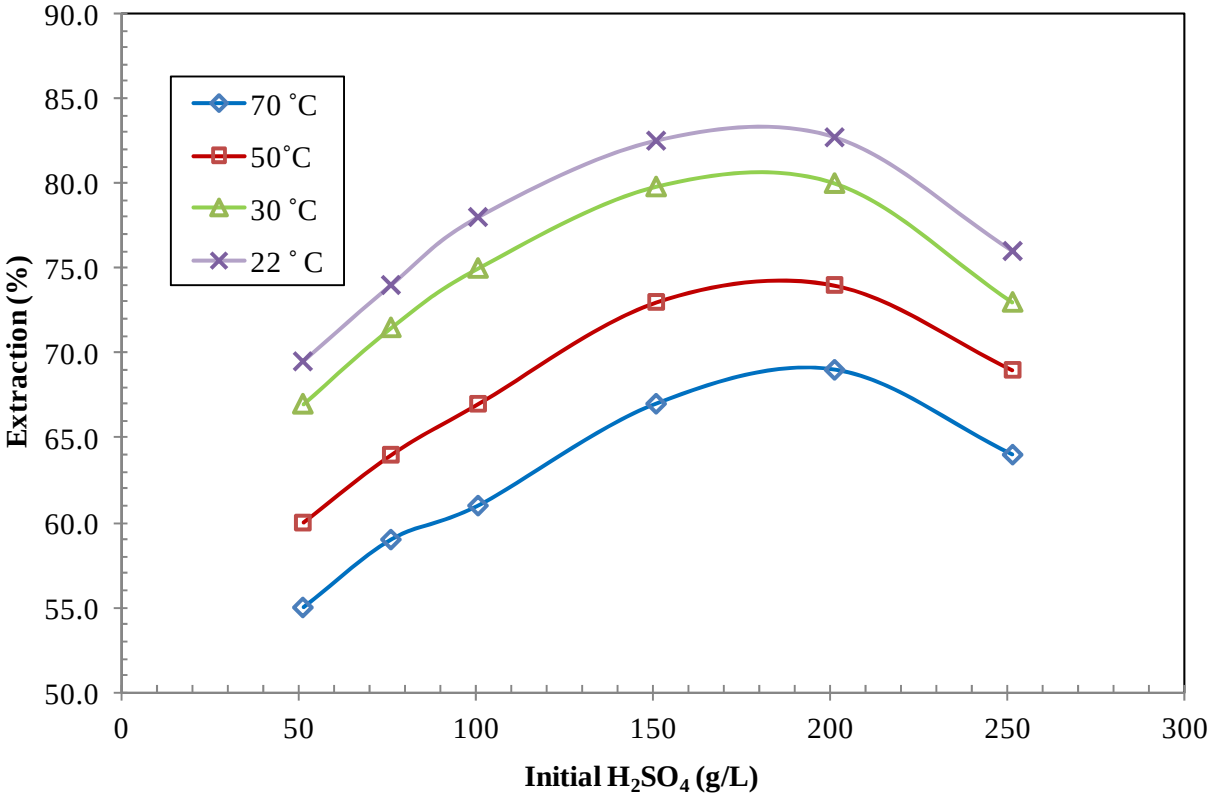
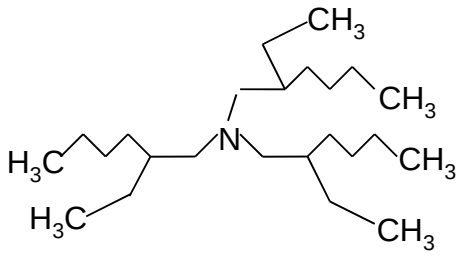
SOLVENT EXTRACTION OF ACID

Effect of initial acid concentration and temperature

- Optimised organic system: 50% TEHA/40% octanol/10% Shellsol A150
- Acid extraction increased with increase in initial acid concentrations
- Acid extraction increased with decrease in temperature
- Acid extraction reached maximum between 150 g/L and 200 g/L H_2SO_4.



TEHA:
tris-2-ethylhexylamine



Octanol: Alcohol with 8 Carbon atoms

Shellsol A150: kerosene

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SOLVENT EXTRACTION OF ACID

Successive Extraction

- ✓ The accumulative acid extraction after three extraction was 82.2%, 96.0% and 99.0%, respectively.
- ✓ Only 2 g/L H_2SO_4 left in the last raffinate.
- ✓ After three stages of extraction, almost all acid extracted.

Stage	Solution	Acid concentration (g/L)	Accumulative extraction (%)
	Feed	203.9	---
1	Raffinate 1	36.39	82.15
2	Raffinate 2	8.09	96.03
3	Raffinate 3	2.03	99.00

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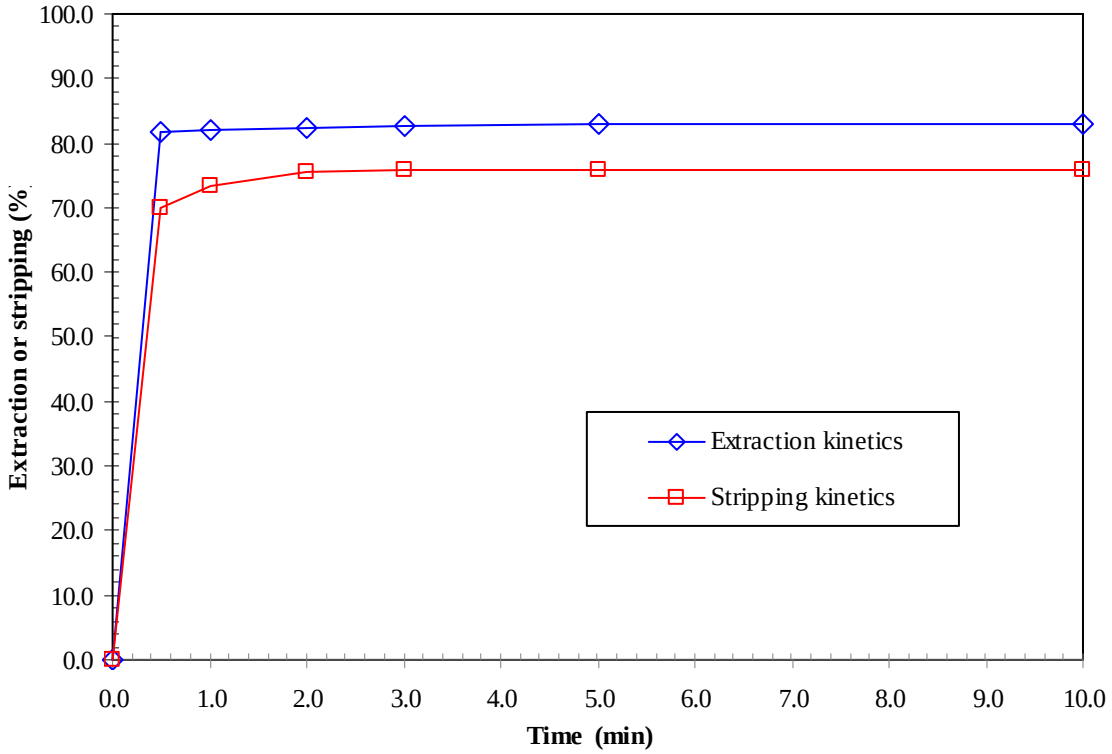
SOLVENT EXTRACTION OF ACID

Extraction and Stripping Kinetics

- Acid extraction reached 82% after 0.5 minute of mixing
- Acid extraction kinetics was very fast.
- Acid stripping reached 75% after 2 minutes of mixing
- Acid stripping kinetics was fast.



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SOLVENT EXTRACTION OF ACID

Acid extraction in the presence of metals

- The solution mimicked a process solution from a copper smelting plant after concentration by 10 times using MD.
- Very small amounts of metals entrained in the loaded organic solution
- A scrub stage at a high O/A ratio to remove the metals
- Metals in the low acidity raffinate can be recovered with SX

Solution	Acid	Fe	Cu	Ni	Zn	Mg	Co
	Concentration (g/L)						
Feed	206.0	10.166	0.994	0.200	0.189	0.118	0.216
Raffinate	35.77	9.636	0.952	0.192	0.187	0.114	0.205
Loaded organic	85.12	0.071	0.013	0.001	0.008	0.000	0.001
	Extraction (%)						
	82.64	1.40	2.55	0.97	8.61	0.00	0.98

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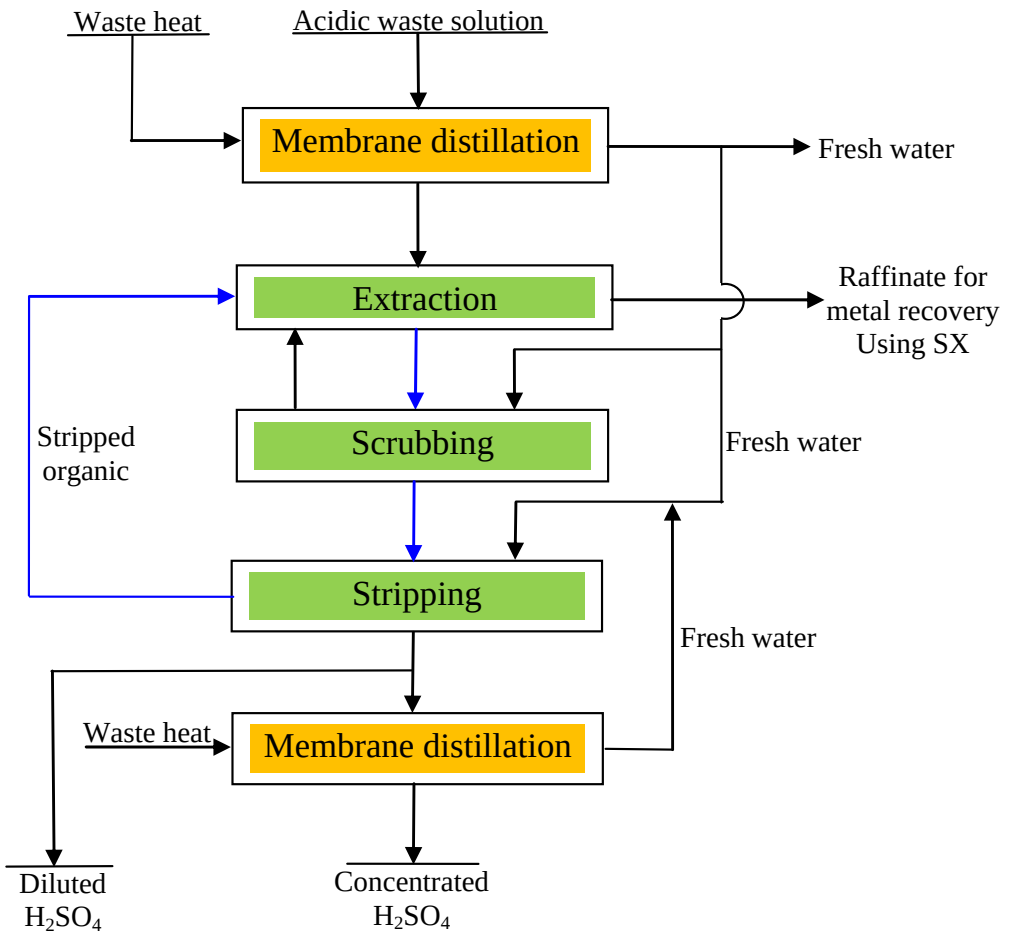
SOLVENT EXTRACTION OF ACID

Development of a Conceptual Process Flowsheet



A conceptual process flowsheet to recover water, acid and metals

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RECOVERY OF WATER AND ACID USING MD & SX

CONCLUSIONS

1. DCMD was successfully used to recover water and concentrate acidic solutions.
2. The final concentration of H_2SO_4 in the three solutions increased from 0.5 M to 2.45 M, 2.40 M and 2.95 M, respectively using MD.
3. The sulphate and sodium separation efficiencies were over 99.9% and the overall water recovery exceeded 80% using MD.
4. Using the optimized organic system and room temperature of 22 °C, over 80% H_2SO_4 was extracted after a single contact using SX.
5. After 3 stages of successive SX, nearly 99% of acid was extracted with only 2 g/L H_2SO_4 left in the raffinate.
6. Both acid extraction and stripping were fast and almost reached equilibrium within 0.5-2.0 min using SX
7. A conceptual flowsheet has been developed to recover water, acid and metal values from waste and process solutions using a combination of MD and SX.

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RECOVERY OF WATER AND ACID USING MD & SX

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