IPRO 302
Zero Liquid Discharge

Sponsored by:

Hydropure

Sargents & Lundy LLC
Overview

- Problem
- Project
- Goals
- Water Balance
- Options/Cases
- Final Costs
- Conclusion

Visit to Midwest Generation Plant
Our Problem

• Finding the most economical Zero Liquid Discharge system
  – It is difficult to obtain permits to discharge process waste water from facilities that generate electricity.
  – How can we eliminate the power plant’s waste water discharge stream?
Team Organization

Advisors: Don Chmielewski, Myron Gottlieb  Sponsor: Sargent & Lundy

Team Leader: William Pattermann

Preliminary Research Teams
1. Evaporation Pond
   - Angela Ng (L)
   - Alex Ong
   - Danny Beissinger
2. Deep Well
   - Will Pattermann (L)
   - James Lai
   - Mitchell Isoda
3. Brine Concentrator
   - Ray Ballard (L)
   - Sahar Ashrafi
   - Woo Sung Shin
4. Emerging Technology
   - Ross Hill (L)
   - Catherine Latour

Extensive Research Teams
1. Physical Team
   - Alex Ong (L)
   - Angela Ng
   - Woosung Shin
2. Regulatory Team
   - James Lai (L)
   - Danny Beissinger
3. Technological Team
   - Sahar Ashrafi (L)
   - Ray Ballard
   - Catherine Latour
4. Financial Team
   - Mitchell Isoda (L)
   - Ross Hill

Final Teams
1. Final Presentation Team
   - Ray Ballard (L)
   - Angela Ng
   - Will Pattermann
   - Ross Hill
2. Final Report Team
   - Sahar Ashrafi (L)
   - Mitchell Isoda
   - Catherine Latour
3. Poster Team
   - Danny Beissinger (L)
   - Woosung Shin
4. Brochure Team
   - Alex Ong (L)
   - James Lai
Project Challenges

• Fully understanding the problem given by Sargent & Lundy

• Difficulty finding extensive research

• Finding the time to do all research and presentations
Team Ethical Challenges

• How to deal with uncooperative team members

• Determining how in depth research should be distributed

• Communication among members
Our Goal

• Identify, evaluate, and prioritize technologies that can be used to eliminate waste water output
  – Water balance of power plant in Nevada
  – Finding options for reusing and treating discharge water
  – Size, capital cost and operating cost
• **Definition:** Man-made wells to inject fluid into the ground, either for disposal or to extract other material from the ground.

• **Goal:** Assess how a deep well could help reduce waste water discharge from a coal power plant.

• **Resolution:** Deep wells are not a feasible solution for zero discharge in Nevada --- all possible injection wells are prohibited by Nevada law.
Evaporation Pond

- **Definition:** Shallow dugout with very large surface areas to evaporate water by sunlight and exposure to ambient temperatures.

- **Pros:**
  - Relatively cheap compared to other technologies
  - Easy to maintain

- **Cons:**
  - Land consuming
  - Threaten wildlife
  - Low feasibility
  - Lining cost

[Image: http://tailings.info/images/pics/content/reclaimponds.jpg]
Brine Concentrator
(Vapor Recompression Evaporator)

- **Definition:** Takes waste water and separates it into outlet streams of clean water and sludge

- **Pros:**
  - Recovers 95% of plant wastewater

- **Cons:**
  - High capital Costs
  - High maintenance costs

Reverse Osmosis (RO)

- **Definition:** Membrane based filtration system used to separate waste system into clean water and concentrated sludge

- **Pros:**
  - Minimal maintenance
  - 40%–60% of water recovery per unit
  - Low risk of malfunction

- **Cons:**
  - High initial cost
  - Membrane clogging
Evaporation Pond

• Design equation
  – Amount of water entering/evaporation rate = \( A \)
  – Depth of pond = 3 ft = \( D \)
  – Total Area = \( 1.2A (1 + 0.155D) / \sqrt{A} \)

• Total Design Cost
  – land area
  – drainage pump and pipe
  – primary 80 mil, geonet, and secondary 60 mil liners
  – Bird netting; turtle & perimeter fencing

http://www.geosynthetic.co.uk/images/civil-engineering/large/Evaporation-lagoon-1.jpg
Brine Concentrator

- **Compressor & Evaporator**
  - Cost based on the flow needed

- **Design Constants**
  - Used to calculate other costs

- **Total Design Cost**
  - Capital Cost
  - Materials
  - Labor
  - Indirect Expenses
  - Construction Prices
  - Contractor Expenses

\[
C_b := e^{[7.2223 + 0.8(ln(PC))]} \\
C_s := 10,800*A^{[0.55]} \\
C_p := F_d*F_m*C_b
\]

Seider, Seader, Lewin *Product & Process Design Principles* 2e, 1999
Reverse Osmosis

• Based on flow needs

• Design equation
  – from Perry’s Chemical Engineers’ Handbook
  – \( E = (0.724 - 1000) \times (\Delta P )\)\(/\text{kWh})/(\text{CR})(\text{Ef})
  – \( A = (0.423)\)\(/\text{m}^2)/\text{CR–J–T}
  – Total operating cost = \( A + E \)

• Total Design Cost
  – Capital
  – Operating
  – Installation
  – Material/piping
Existing Evaporation Pond

Case Options 1

Case 1

Recycle/Reuse

New Evaporation Pond
Case Scenario 1

Case 1

Reverse Osmosis = $122,280,924

Brine concentrator = $175,442,083

Evaporation Pond = $0

Interest Rate: 12% APR, Life: 15 years
Case
Option 2

Existing Evaporation Pond

Case 2

Case 1

Recycle/Reuse

New Evaporation Pond
Case Scenario 2

Case 2
Reverse Osmosis = $86,480,045
Brine concentrator = $133,239,424
Evaporation Pond = $0

Interest Rate: 12% APR, Life: 15 years
Case Scenario 3

Case 3
Reverse Osmosis = $69,218,907
Brine concentrator = $111,652,263
Evaporation Pond = $2,292,282

1191 gpm through Recycle System
297 gpm to New Evap. Pond
616 gpm to existing Evap. Pond

Interest Rate: 12% APR, Life: 15 years
Existing Evaporation Pond

Case Option 4

Case 1

Case 2

Case 3

Case 4

Recycle/Reuse

New Evaporation Pond
Case Scenario 4

Case 4
Reverse Osmosis = $75,533,803
Evaporation Pond = $1,841,824

Brine concentrator = $119,689,985

1300 gpm through Recycle System
616 gpm to existing Evap. Pond
188 gpm to New Evap. Pond

Interest Rate: 12% APR, Life: 15 years
Conclusion

• Best cost case scenario is Case 3
  – Use a Reverse Osmosis recycle system to recycle 1191 gpm of wastewater
  – Use the original evaporation pond of 616 gpm and create an additional evaporation pond for 297 gpm of wastewater

Total Cost: $71,511,189
Our IPRO Family

• Expectations

• IPRO Experience

• What We Learned
Any Questions?