2019 WERC Design Contest

TASK 4

Recovery of Water and Salt from Hyper-Saline Mine Water using Freeze Crystallization

Background Information

Hyper-saline brines may be present in mine waters. These brines are problematic to treat because they have salt concentrations higher than treatable through conventional water treatment. Currently, evaporation ponds are most often used to dispose of hyper-saline bines. This practice is not sustainable because the water is not reused but is lost through evaporation. Additionally, the salt byproduct may require disposal as hazardous waste. Due to concerns of water scarcity and environmental sustainability in the region of the desert southwest, Freeport-McMoRan, a mining company based in Arizona, wishes to treat and reuse hyper-saline mine waters.

There are two common methods for the separation and recovery of pure salts from hyper-saline mine waters. The first option for brine management is the use of evaporation ponds. This method is only viable in arid regions where evaporation is much higher than precipitation. The second method is Evaporative Crystallization which entails heating the saline bine until enough water has evaporated for salt crystals to form. This option is the only commercial option available in areas where solar evaporation is not available. However, this method uses a large amount of energy and the crystalized salt product is often not pure enough for reuse or resale but instead must be disposed of as waste. Freeze Crystallization is another method a method that has been investigated for separating pure crystalline salt products from hyper-saline bines. Currently, there are no commercial operations using this method. In this process the brine is slowly cooled until it reaches a temperature where ice crystals form excluding the salt from their crystal structure. The pure ice crystals are separated from the brine and water is recovered by melting the ice. As the brine concentrates dissolved salts may start to precipitate out of solution in the form of pure crystalline salts. Freeze Crystallization is claimed to be much more energy efficient than Evaporative Crystallization. Furthermore, the pure water and salt products are recovered for reuse using Freeze Crystallization.

Problem Statement

Your team must develop a Freeze Crystallization system to separate salt form hyper-saline mine waters to recover at least 50% of the process water.

Design Condition

Your teams design must produce the following outcomes

Utilize Freeze Crystallization to separate water from a synthetic hyper-saline brine containing about 100,000 mg/L total dissolved salts. They hypersaline brines from mining typically contain a mix of sulfate salts, primarily aluminum and magnesium sulfate. For this competition your team will be given 1 gallon/3.78 litters of a synthetic water with the following formulation:

Ingredient	Quantity
MgSO4.7H2O	50 grams
Al2(SO4)3	50 grams
Distilled Water	Make up to 1 liter

Evacuation Criteria

Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. Please visit the WERC website: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/ for a copy of the Public Involvement Plan and Participation Guide and other important resources. Additionally, your team will be evaluated based on the following:

- 50% of the process water must be recovered as a liquid
- Final conductivity of the treated water must be less than 1000 mS/cm/ to reach the EPA standard for healthy freshwater ecosystems and safe drinking water [1].
- Any water used to a wash step must be incorporated in the process must be accounted in the overall mass of water treated.
- If salts are recovered they should be in a pure usable crystalline form
- Your process must be scalable to 100 gallons per minute for large-scale mining operations and include the following in the design report
    - Equipment necessary to freeze the water
    - Method to intermittently or continuously harvest ice
    - Method to intermittently or continuously harvest salt
    - Energy balance compared to non-solar evaporation system.
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- Your design should be as energy efficient as possible (i.e. recycle heat from chilling to ice melting).

Other specific evaluation criteria may be provided at a later date.

Past Works

Fernandez-Torrez et al [2] studied compared the energy usage of Evaporative Crystallization and Eutectic Freeze Crystallization for saline water treatment. They found that Eutectic Freeze Crystallization used 6-7 times less energy than Evaporative Crystallization.

Lewis et al [3] used Eutectic Freeze Crystallization to remove several different salts from hyper-saline solutions to produce pure Sodium Sulfate crystals using seeding techniques.

Randall et al [4] used Eutectic Freeze Crystallization to treat waste water from a reverse osmosis plant. They were able to recover 97% of the waste water in the form of pure water. They also recovered calcium sulfate at 98% purity and sodium sulfate at 96.4% purity.

References

[1] Environmental Protection Agency, "Salinity," 5 April 2015. [Online]. Available: https://www.epa.sa.gov.au/environmental_info/water_quality/threats/salinity. [Accessed 22 June 2018].

[2] M. J. Fernández-Torres, D. G. Randall, R. Melamu and H. Von Blottnitz, " A comparative life cycle assessment of eutectic freeze crystallisation and evaporative crystallisation for the treatment of saline wastewater," Desalination, vol. 306, pp. 17-23, 2012.

[3] A. E. Lewis, D. Randall, T. Reddy, R. Jinvanji and Nathoo, "Worth Its Salt–How Eutectic Freeze Crystallisation Can be Used to Recover Water and Salt From Hypersaline Mine Waters".

[4] D. G. Randall, J. Nathoo and A. E. Lewis, "A case study for treating a reverse osmosis brine using Eutectic Freeze Crystallization—Approaching a zero waste process," Desalination, vol. 266, no. 1-3, pp. 256-262, 2011.