Water Treatment using Electrocoagulation

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1.0 Issues and their Importance

The most important issue in this project was to treat brine coming out from the process called High Efficiency Reverse Osmosis (HERO™). Semiconductor industrial waste water amounts to approximately $10^5 – 10^6$ gal/day water [(1)]. Such a large amount of water corresponds to almost daily water use of a small town with 1000 to 10,000 people. A process called HERO™ within these industries produces large amounts of brine amounting to almost 10^3- 10^4 gal/day water. The difference between conventional Reverse Osmosis (RO) and HERO™ lies in the recovery. HERO™ can help achieve >95 % recovery [(2)]. Hence, the brine produced from this process is relatively less and extremely concentrated in silica (~ 1000 ppm or 16.67 mM) at a high pH of 12[2]. Figure 1 shows a simple schematic of HERO™.

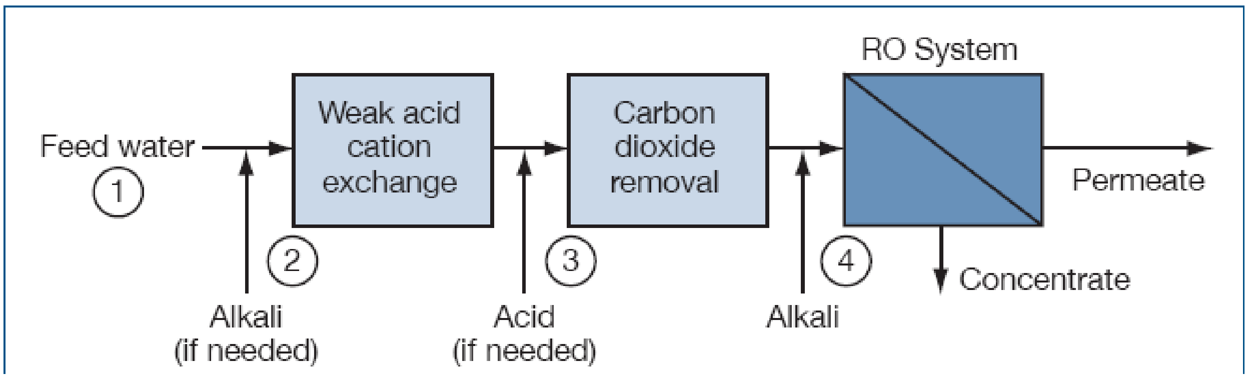

Figure 1 – Schematic of HERO™ system[2].

Even though the brine is very concentrated (~1000 ppm silica), the silica content in water still amounts to about 1 g of silica per kilogram of water assuming density of water is 1 kg/L or (~1 g silica/1 kg water). Therefore, reclaiming the brine will save large amounts of water. The study will show an effective means to remove most of the silica from the brine. Figure 2 shows how the system will work if Electrocoagulation (EC) technology is used along with HERO™ to treat the brine.

Another study was done to treat arsenic and hardness from water using the EC technology. Arsenic in potable water leads to serious toxic consequences. Because of its wide range health issues, World Health Organization has set a standard of 10 parts per billion in drinking water[3]. Arsenic disrupts ATP production through various mechanisms. Prolonged exposure to this substance is also known to have chronic consequences[3].

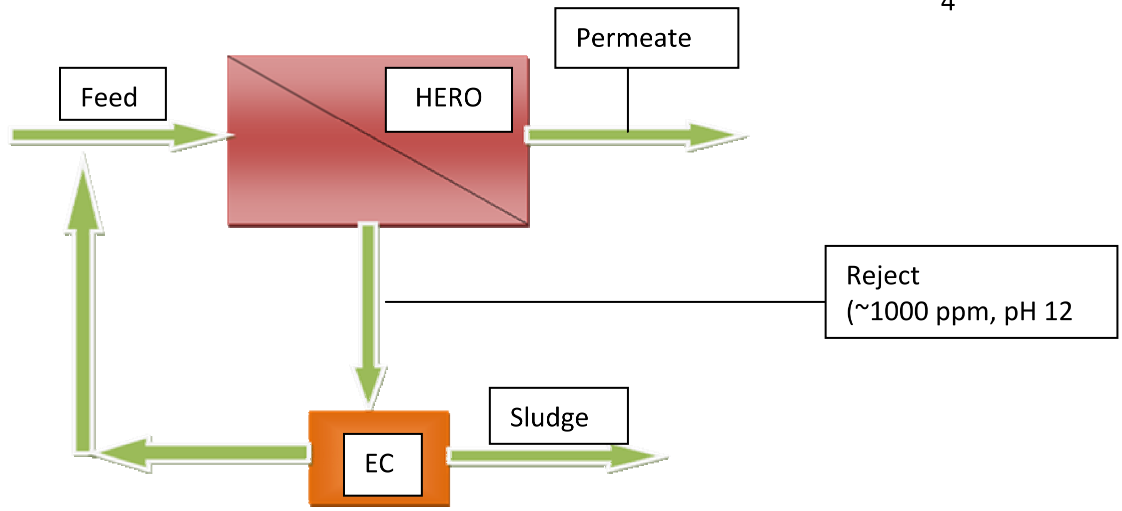

Figure 2- Illustration of the incorporation of EC technology in treating brine from HERO™

2.0 Methods

a) Treatment of brine from HERO™:

All chemicals used in this study were of analytic grade. Deionized water was used to prepare solutions. 6 L of 1000 ppm silica water at pH 12 was prepared using sodium meta- silicate.10 samples, 500 mL each with pH values ranging from 2 to 12 were prepared from the 6 L solution using sulfuric acid or sodium hydroxide. pH measurements were made using pH paper. 100 mL of the original sample from the prepared 6 L solution was also saved in a separate container. All samples were well stirred.

Electrocoagulation in a batch system: Iron anode (34 cm long, 3.2 cm wide and 0.32 cm thick) and hollow cylindrical ebonex cathode were placed in each of the 500 mL sample jars while still continuing the stirring. The power supply was then set to deliver 0.322 Amps for 10 minutes to deliver 2 mM Fe dose. Samples were then filtered using 0.1 µm filter paper and analyzed for final silica concentration. For 4 mM Fe dose, the samples were supplied with 0.322 Amps for 20 minutes instead of 10 minutes.

b) Arsenic and hardness removal:

Two 20 L jars were filled with DI water. The desired initial concentrations of arsenic, magnesium, calcium, and silica were then dissolved in each of the two jars using orthoarsenate, magnesium chloride hexahydrate, sodium meta-silicate and calcium chloride dihydrate respectively. The pH was always adjusted to 7 using an acid or a base. After stirring the jars for 24 hours, a desired iron or aluminum dose was given using the EC. All experiments were done in a parallel configuration using aluminum or iron electrodes. The residence time for the system was decided to be 2, and samples were taken at steady state (steady voltage). The following is the calculation for Total Anodic Current (TAC):

i. Al:

$$TAC = Dose\ (M\text{-}Al^{3+}) \times 3\ (mol\ e^{-}) \times 96484\ (C) \times q\ (L/s)$$

ii. Fe:

$$TAC = Dose\ (M\text{-}Fe^{2+}) \times 2\ (mol\ e^{-}) \times 96484\ (C) \times q\ (L/s)$$

The power supply was then set to deliver current equivalent to dividing TAC by 4 due to parallel configuration. After samples were taken at different doses of iron or aluminum, they were stirred for 24 hours. Samples were then filtered using 0.47 µm filter paper and analyzed for final silica, arsenic, magnesium, and calcium concentration.

3.0 Results

HERO™: figure 3 illustrates removal of silica in the pH range 2 – 12 at 2 mM and 4 mM Fe dose. A relationship between pH and removal of silica is also illustrated in figure 3. According to the illustration, there is a range of pH values at which Si gets removed (pH values ranging from 5 to 9). Clearly, more Si gets removed at a 4 mM dose. This is probably due to formation of more precipitates at high Fe dose.

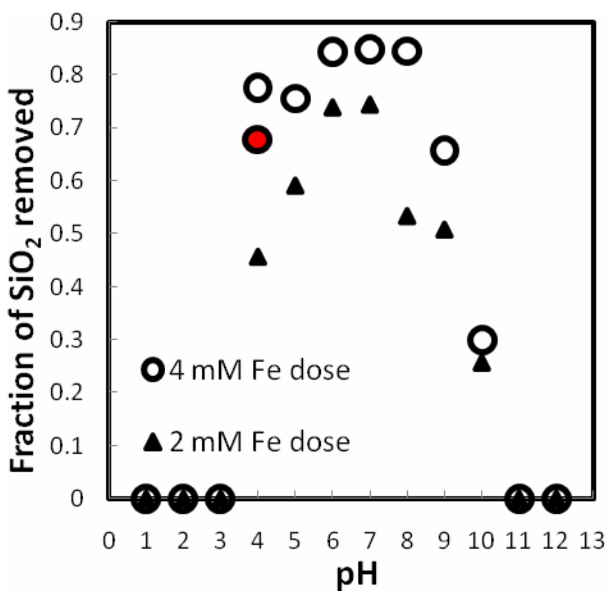

Figure 3- Fraction of SiO_2 removed vs. pH at 2 mM and 4 mM target Fe dose. The red mark is for the solution filtered with 0.47 µm filter paper, while the rest of the solutions were filtered using 0.1 µm filter paper. Initial concentration of silica is 1000 ppm.

On one hand, at very low pH values, iron does not form any precipitates. This is probably because iron becomes very soluble at low pH values, and is unable to bind with dissolved silica salt to form solid precipitates. On the other hand, extremely high pH values (>10), possibly pacifies the iron electrode due to which no iron is able to dissolve into the solution to form any precipitates. Therefore, it is postulated that there is an optimum range for the removal of silica when electrocoagulation using iron electrodes is used.

Arsenic and hardness removal using EC: the results for this study are illustrated in figures 4 and 5.

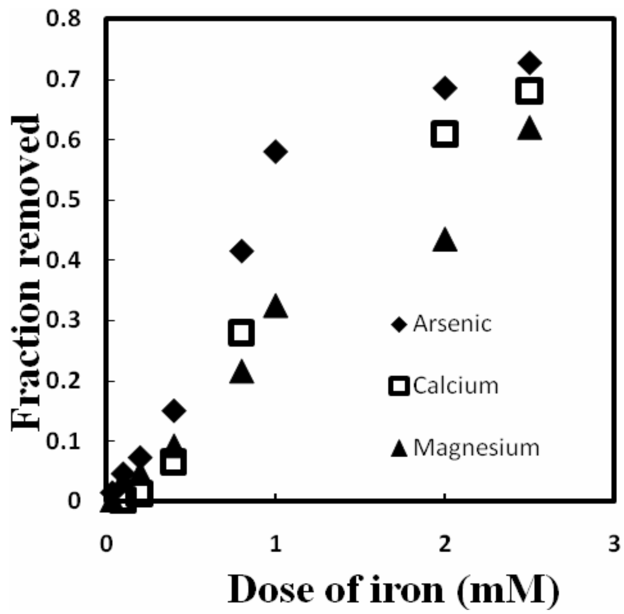

Figure 4- fraction of initial arsenic removed at 1.8 mM, calcium at 1.112 mM, and magnesium at 0.494 mM by iron blades as a function of coagulant dose at pH 7.

Figure 4 illustrates an increase in the removal of arsenic, calcium, and magnesium as the dose of iron is increased. Presence of arsenic also promotes the removal of hardness because in the absence of arsenic a maximum of about 15 % hardness removal is achieved. That graph has not been shown in this report. Similar results as figure 4 are obtained when aluminum is used as the dose. The results of this study can be seen in figure 5. Figure 5 also shows an exponential increase in removal as the anodic dose is increased.

4.0 Conclusions

HERO™ reject: 1000 ppm silica, pH 12 can be treated by EC using iron anodes. The optimal conditions for the removal of silica lies in the pH range 5 to 9. Approximately 3 -6 moles of silica re removed for every 1 mole of iron dose.

Arsenic removal: for every one mole of iron or aluminum dose, 0.5 moles of arsenic are removed. Presence of arsenic in water also promotes removal of hardness (calcium and magnesium) from 10 % to 65 %.

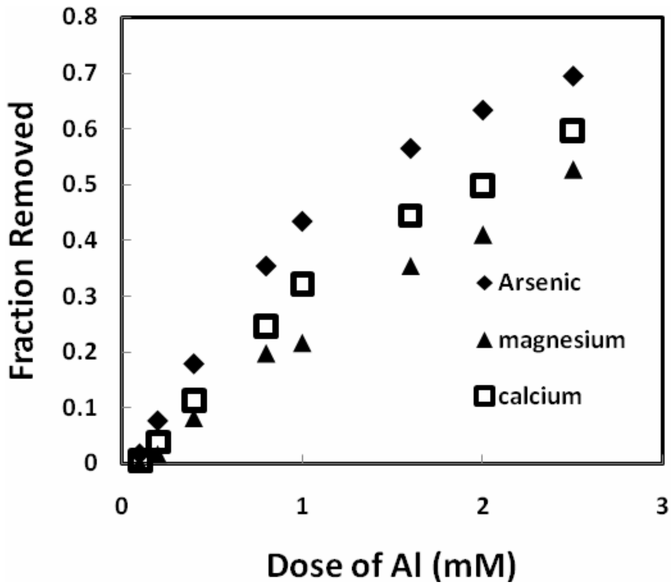

Figure 5- fraction of initial arsenic removed at 1.8 mM, calcium at 1.112 mM, and magnesium at 0.494 mM by aluminum blades as a function of coagulant dose at pH 7.

5.0 References

1. Shah, A., & Ploeser, J. (1999). Reusing rinse wastewater at a semiconductor plant. *Journal American Water Works Association , 91* (8), 58-65.

2. Saving Energy,Water, and Money with Efficient Water Treatment Techologies. (n.d.). Retrieved April 2009, from www1.eere.energy.gov: http://www1.eere.energy.gov/femp/pdfs/hero_tf.pdf

3. *New Limits Established for Arsenic in Drinking Water* . (n.d.). Retrieved April 2009, from http://www.agiweb.org/gap/legis107/tpg_arsenic.html