The Effect of Initial Irrigation Conditions on Heap Leaching Efficiency - Preliminary Results

THE UNIVERSITY OF ARIZONA

GSA GeoSystems Analysis, Inc. Innovative Solutions

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ABSTRACT

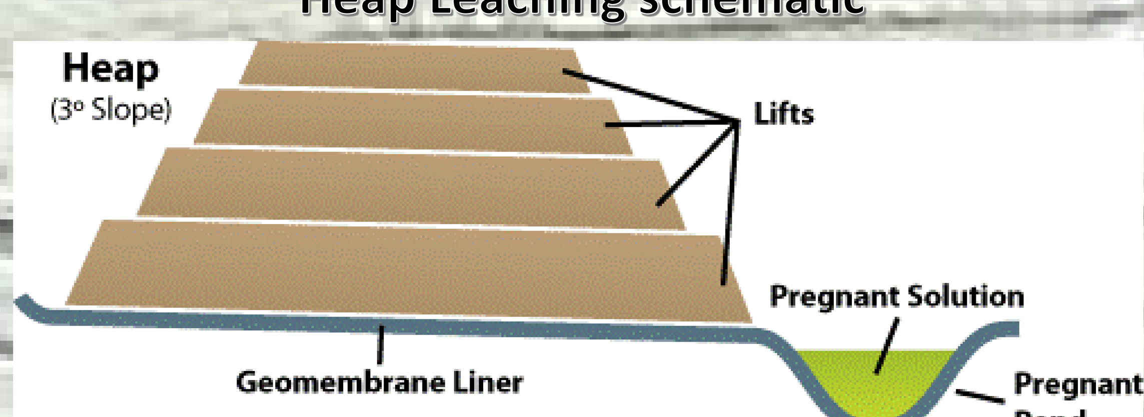
Many mine operators believe that slow initial irrigation and ramp up irrigation schemes can help minimize heap leach ore permeability loss and increase metal recovery. However, the mechanisms and solution flow processes are not well understood and have not been studied in detail. Laboratory saturated and unsaturated hydraulic conductivity tests and large column irrigation tests are being conducted on copper ore to better understand the flow mechanisms of different heap leach irrigation rates.

The objective of the study is to test if lower initial irrigation rates and ramp up irrigation schemes can improve leaching efficiency. The results could then be used to optimize heap leach operations.

BACKGROUND

Heap leaching is a metal recovery process where a lixiviant is added to crushed rock (ore) to dissolve the target minerals and the solution is collected for extraction processing. Heap leaching needs unsaturated conditions to maximize metal recovery. Heterogeneities and other factors such as pore size distribution within the stacked ore can lead to uneven wetting and the formation of preferential flow pathways, which can reduce solution contact and lower metal recovery. Furthermore, mineral dissolution and "decrepitation" can cause alteration of the porous media structure, changing the ore's physical and hydraulic properties, in particular, the loss of permeability and increase in solution holding capacity (Milczarek, et al. 2013)

Heap Leaching schematic



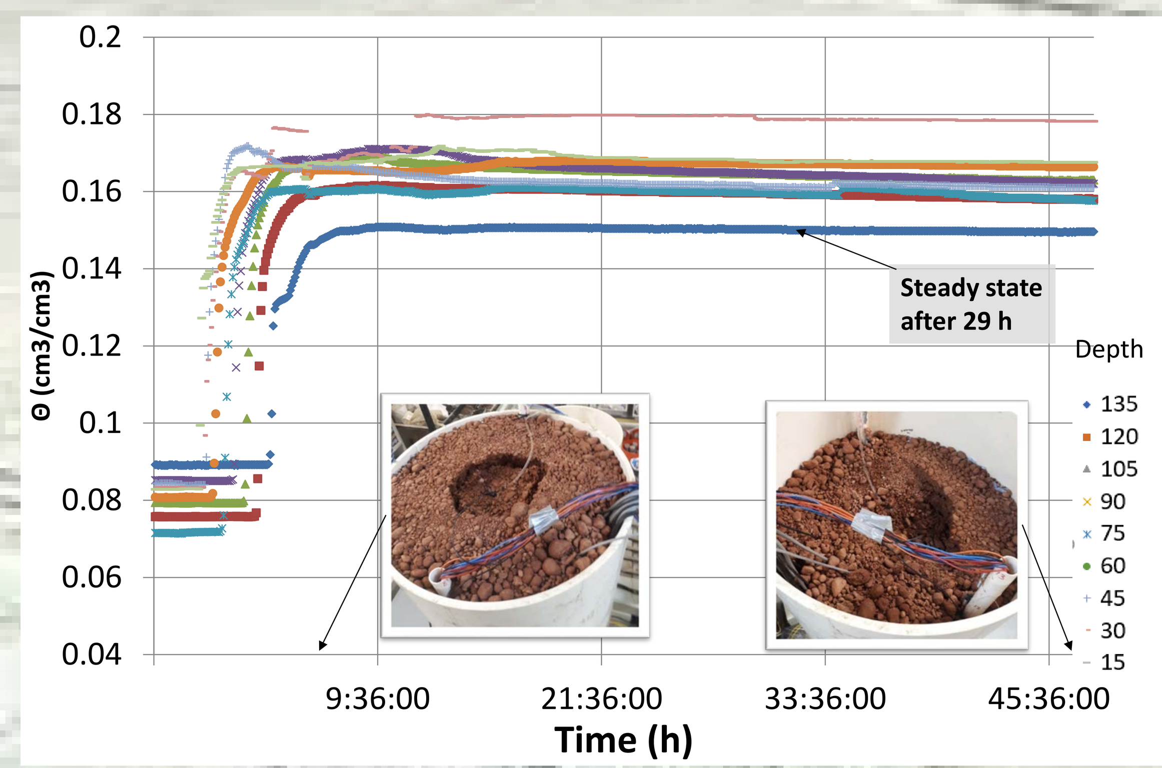
METHODS

- **Sample Preparation:** Prepare 1600 kgs of ½-inch crushed copper ore for copper leaching tests. Cured with sulfuric acid (6kg acid/ton of ore) and agglomerated with raffinate (7% moisture).
- **Hydraulic Properties:** 6-inch diameter flexible-wall flow cells were used to test ore saturated hydraulic conductivity (Ksat) and unsaturated hydraulic conductivity (Kunsat) properties at various confining pressures (Dane & Topp, 2002, Milczarek, et. al., 2013).
- **Large Column Preparation:**
  - 1.5 m high, 50 cm in diameter columns for irrigation tests
  - Moisture sensors every 15 cm in center of column
  - Electrical resistivity probes every 7 cm at 13 locations on the edge of the column, and 1 at the top and 1 at bottom
  - Prepare dye (1g FD&C Blue/L and 100mg B/L tracer solutions with raffinate.
- **Column Procedures:**
  - Controlled inflow and outflow monitoring
  - Moisture content and ER sensor monitoring every 5 minutes
  - Neutron probe measurements from four different directions
  - Conduct tracer test after steady state conditions achieved
- **TEST 1: Baseline test**
  - Irrigation rate: 9.1 L/m²/hr (38 mL/min (21.9 cm/day)
- **TEST 2: Ramp up scheme** – at ratios of baseline irrigation rate (on going)
  - 1/16th: 0.5 hrs on, 7.5 hrs off.
  - 1/8th : 0.5 hrs on, 3.5 hrs off.
  - 1/4th : 1hrs on, 3 hrs off.
  - ½ :2 hrs on, 2 hrs, off.
  - Full rate (38 L/min)
- **TEST 3: Ramp up scheme** - Start with 1/8th of baseline rate (next test)

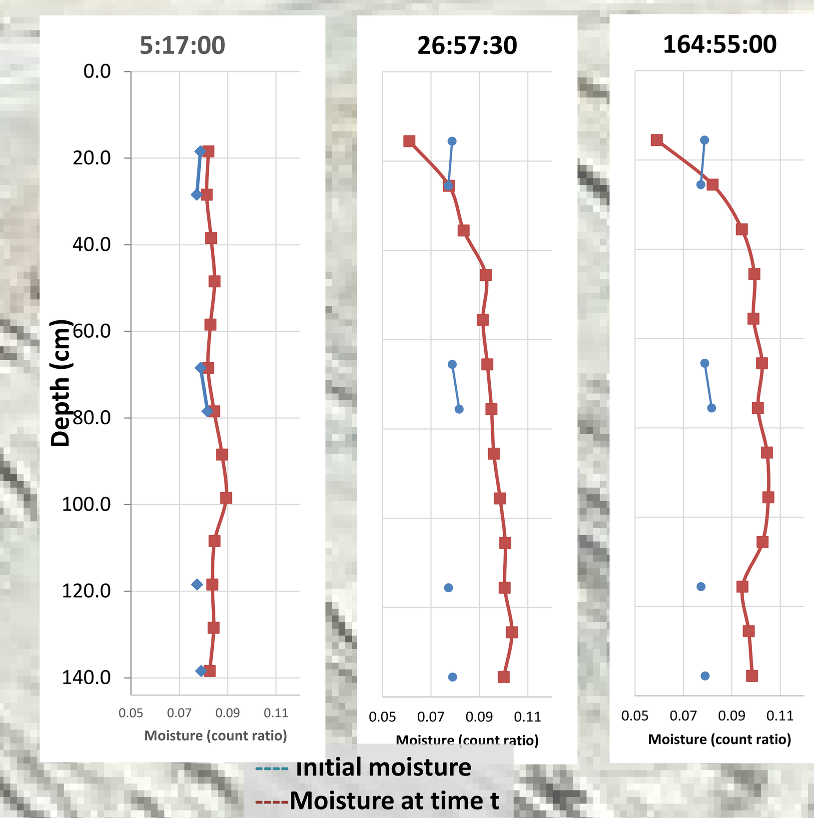
RESULTS

BASELINE TEST

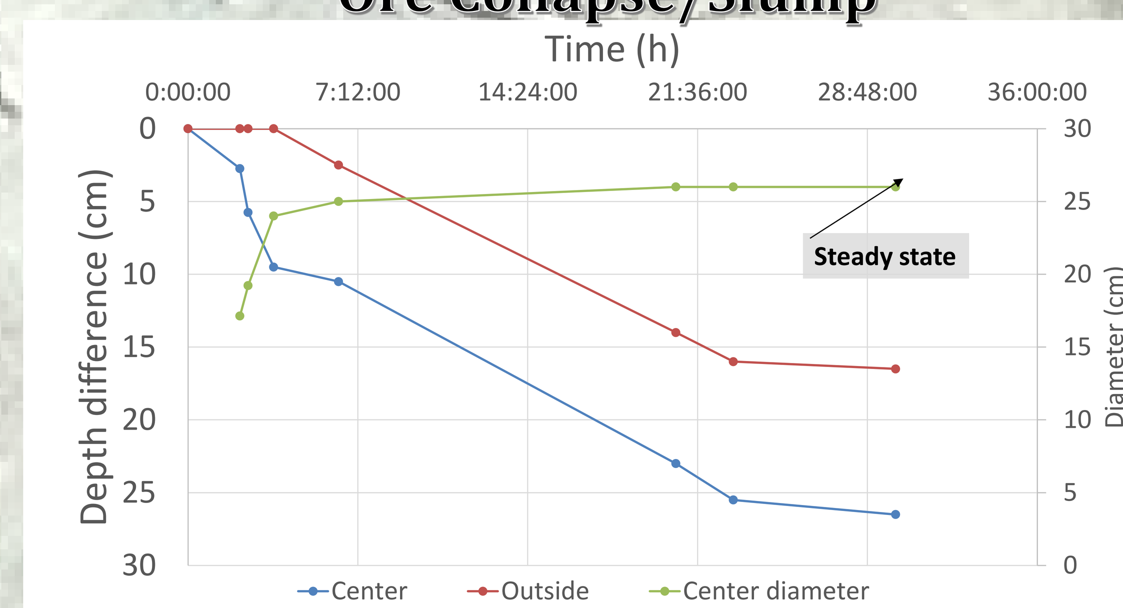
Solution Content over Time



Neutron probe measurements

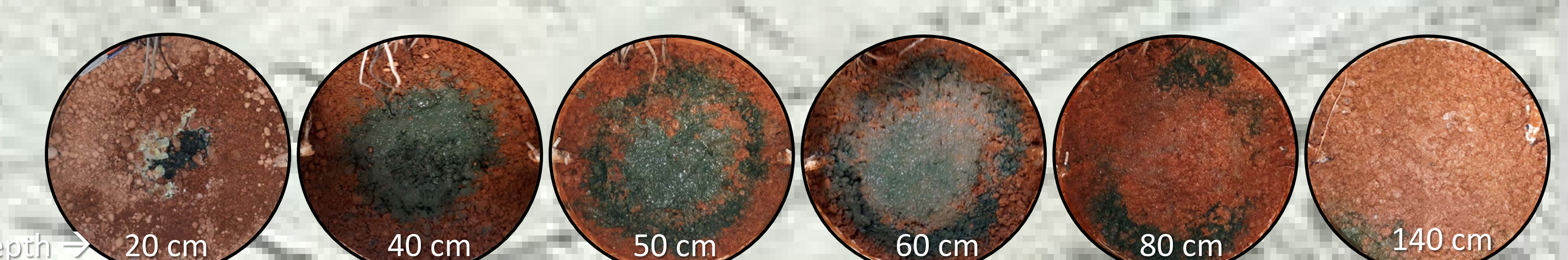


Ore Collapse/Slump



Results of baseline test

- Fastest collapse occurs in the first 4 h, from then it all collapses at the same rate until 29 h
- For inside the wetting area, initial solution content 7%, Steady state water content 16%
- Bulk solution content 0.098 cm³/cm³ (mass balance)
- Lateral spreading captured by neutron probe at height 95 and below

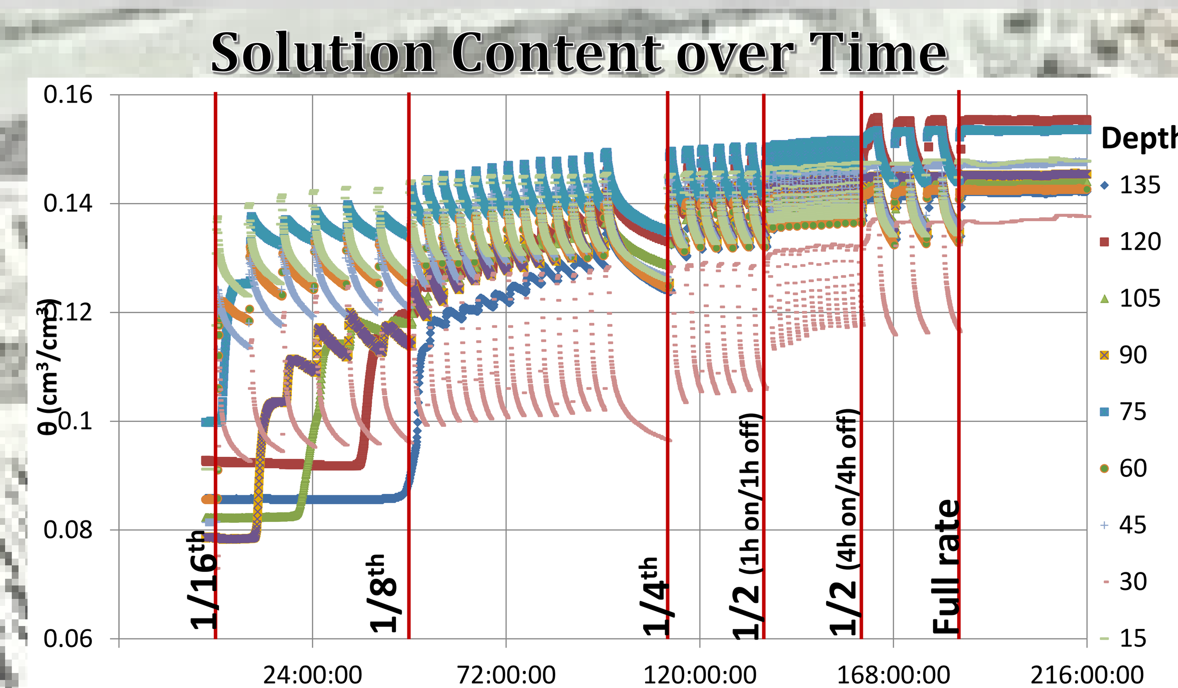


Dye test

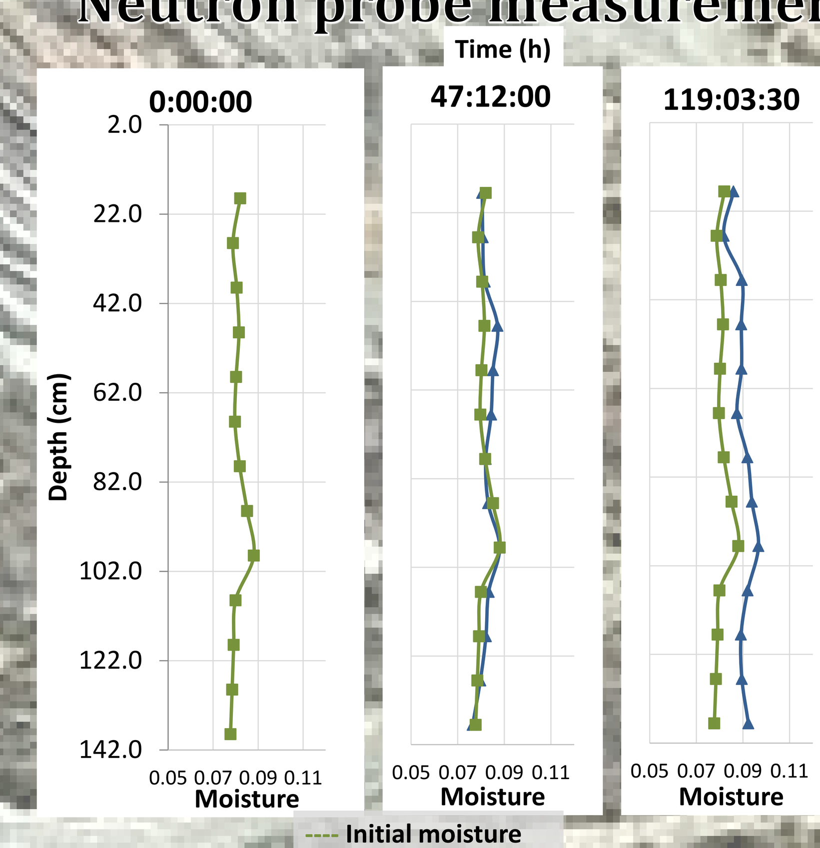
- Outer ring suggests lower permeability near the center ring after steady state (more agglomeration failure and lost permeability at the center)
- Most flow occurs at edge when it arrives at the bottom of the column

TEST 2: RAMP-UP

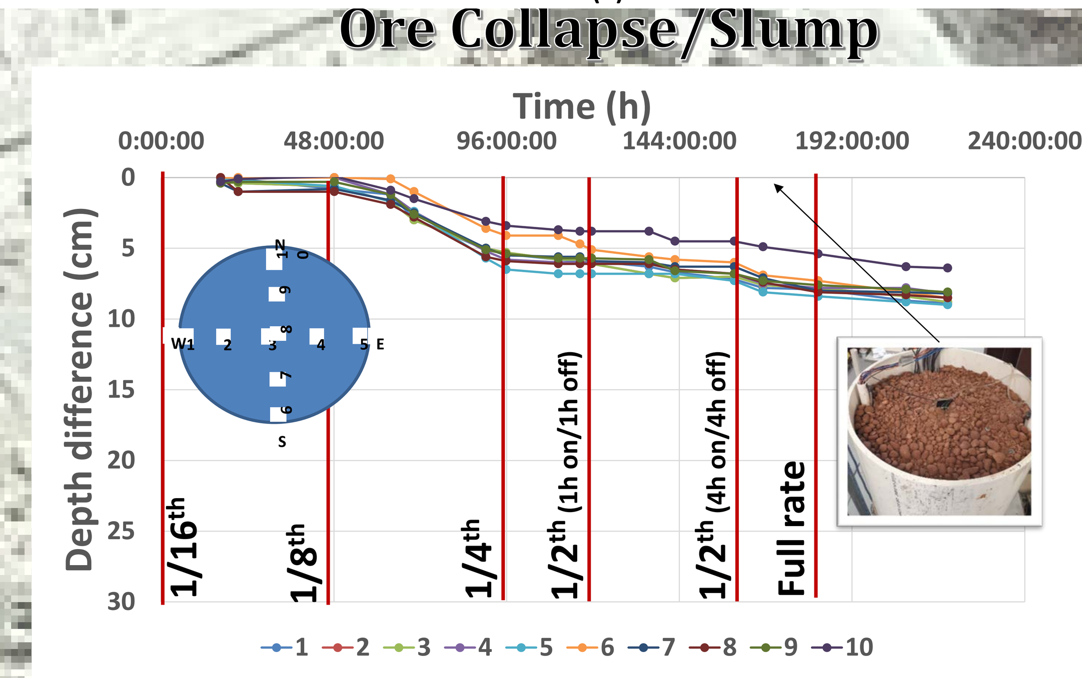
Solution Content over Time



Neutron probe measurements



Ore Collapse/Slump



Results of ramp-up test

- Major collapse occurred during 1/8th scheme with much smaller slumping compared to baseline test
- Bulk solution content at ½ scheme = 0.060 cm³/cm³ (mass balance)
- Bulk solution content at full rate scheme = 0.074 cm³/cm³ (mass balance)
- Lateral spreading captured when 1/8th scheme was set, during major collapse/slump

INITIAL RESULTS

- **Hydraulic Properties:**
  - Significant increase in fines (decrepitation) for acid addition and agglomeration of ores
  - Kunsat tests show incompetent ore hydraulic behavior under high irrigation rates and marginal behavior under low irrigation rates.
- **Large Column Studies:**
  - Fast solution advance in baseline test (less than 6h) due to possible preferential flow.
  - Observed ore collapse/slump and dye test in baseline test suggest broken down agglomeration, ore compaction, and possibly decrepitation and subsequent downward fine particles migration, causing loss of permeability.
  - Less ore collapse in ramp-up test suggest that ore structure and permeability are less affected with slow irrigation ramp up.
  - Neutron probe measurements show lateral spreading occurs from height 95 cm after 165 hrs in baseline test, but only detected when 1/8th of final rate is set in ramp-up test.

NEXT...

- Third test starting at 1/8th of baseline rate
- Electrical resistivity tomography data processing and analysis
- Tracer (Boron) test analysis
- Complete calibration of neutron probe

REFERENCES

- J. H. Dane, C. G. Topp, editors, 2002. Methods of Soil Analysis: Part 4 Physical Methods. SSSA Book Ser. 5.4. SSSA, Madison, WI
- Milczarek, M., Yao, T. Y., Banerjee, M., & Keller, J. (2013). Ore permeability methods of evaluation and application to heap leach optimization. In *Heap Leach* (pp. 403–415). Vancouver.

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