The Engineering of Truly Passive Mine Water Treatment Systems using Recycled Concrete Aggregate

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The opportunity – Gold King Mine (August 15, 2015)

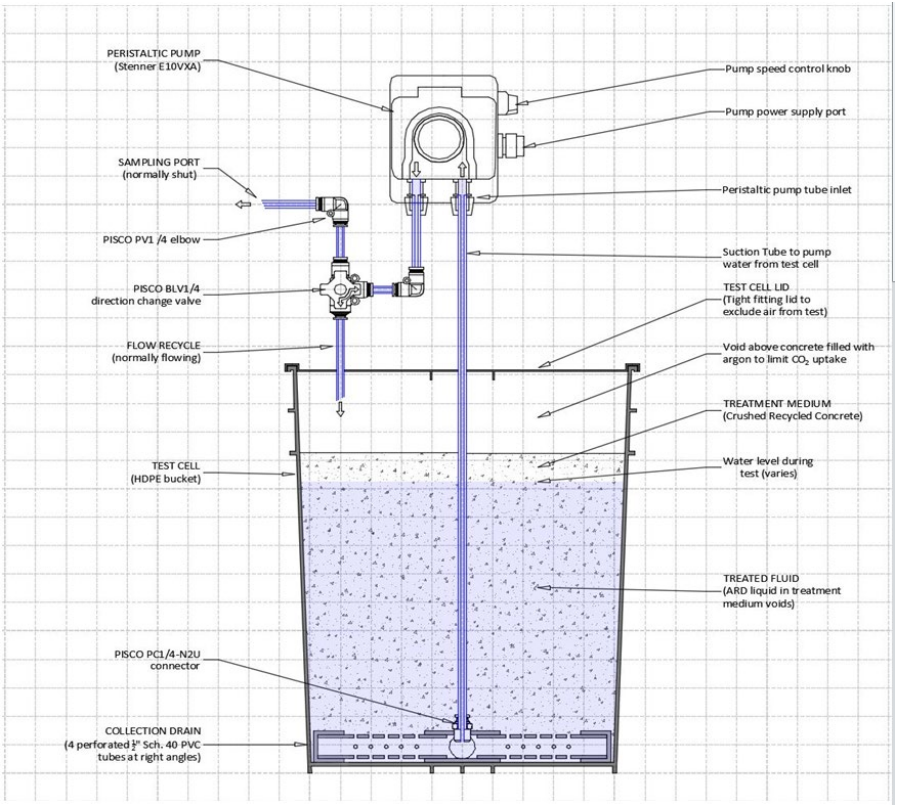
Gold King Mine portal, post-blowout

Animas River downstream of Gold King Mine, post-blowout

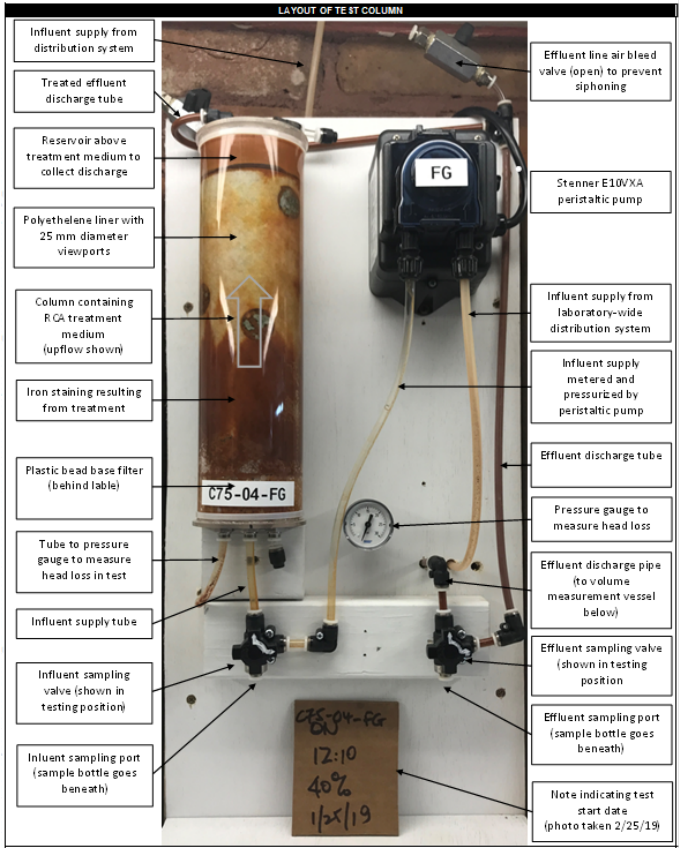
The need, the solution, the difficulty, and the plan

- The Need – Truly passive AMD treatment
  - A treatment method for Acid and Metalliferous Drainage (AMD) that is passive, simple, long-term, cheap, and sustainable
- The Solution - Recycled Concrete Aggregate (RCA)
  - Passive: timed release of the alkalinity in old concrete
  - Simple: pass AMD through RCA
  - Long-term: slow leach rate gives long life
  - Cheap: low cost and local short haul
  - Sustainable: recycled material with no waste
- The Difficulty - Feasibility
  - Nobody has made it work long-term
- The Plan – Learn how to make it work
  - Run actual AMD through actual RCA
  - Vary treatment rate and method till it works long-term

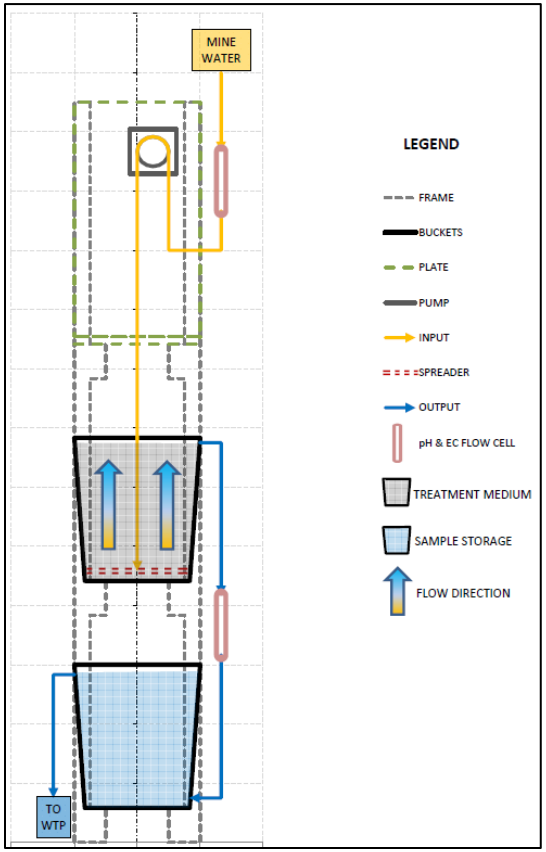
Method #1 – Batch Testing

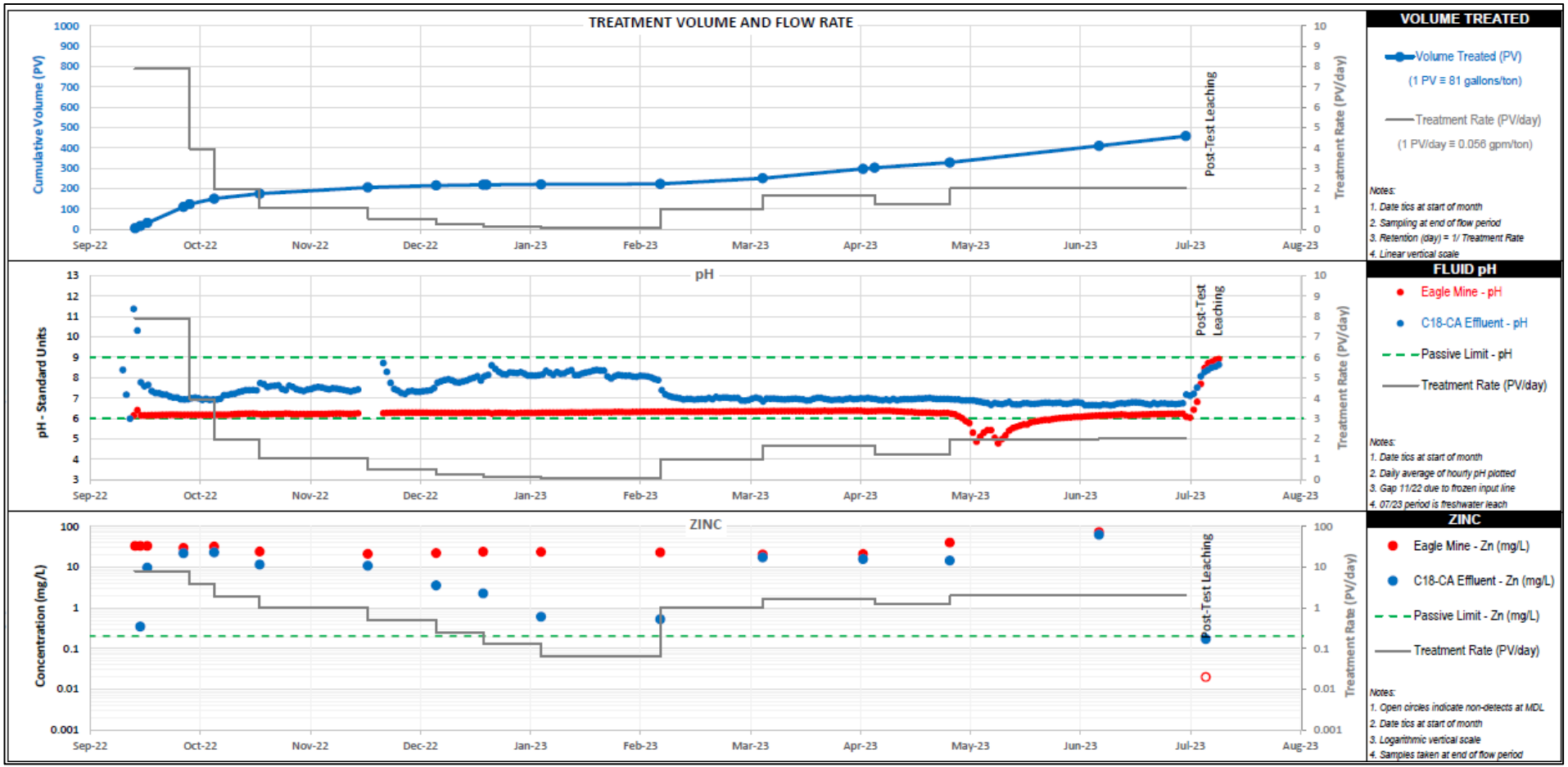


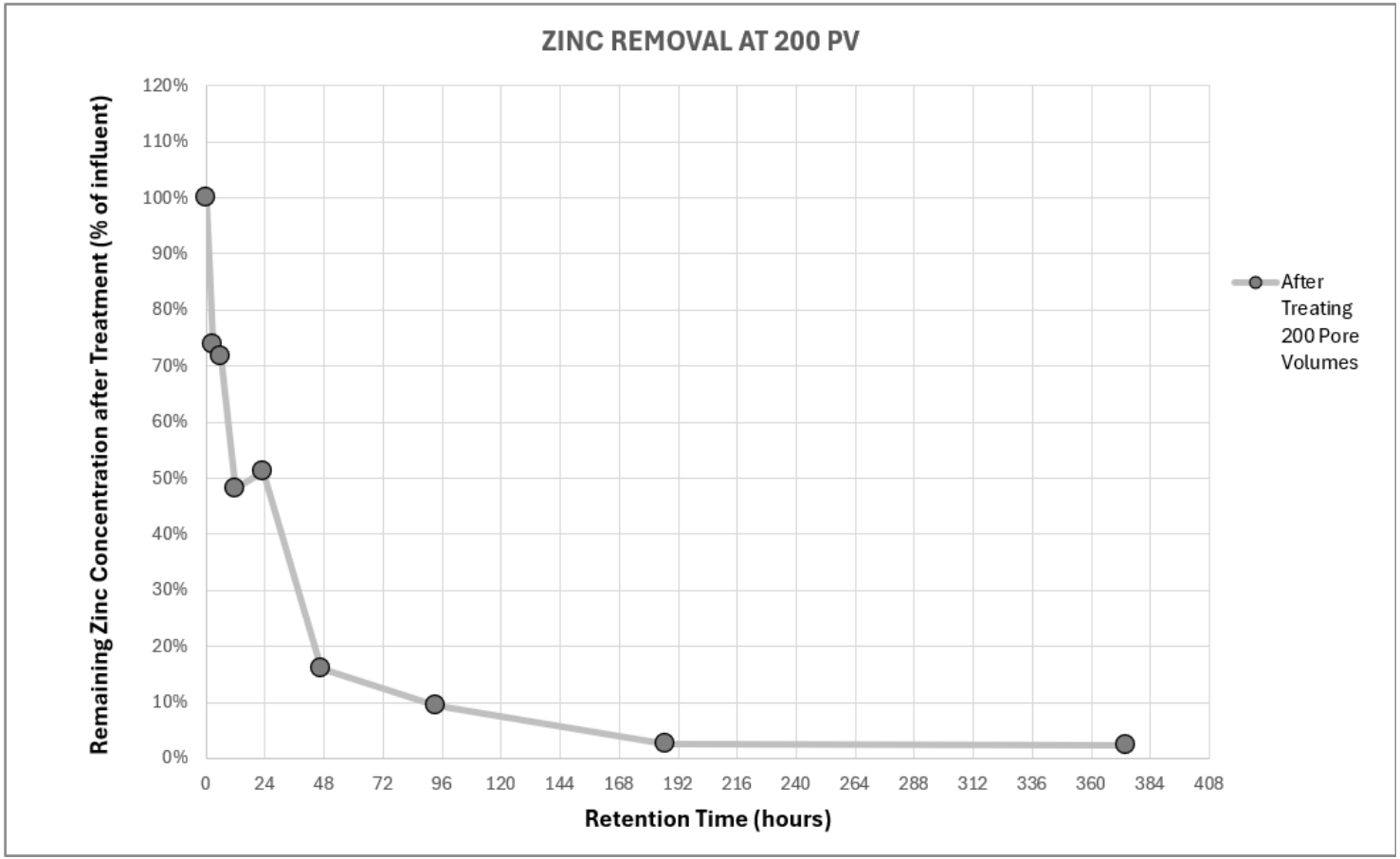
Method #2 – Column Testing



Method #3 – Field Testing

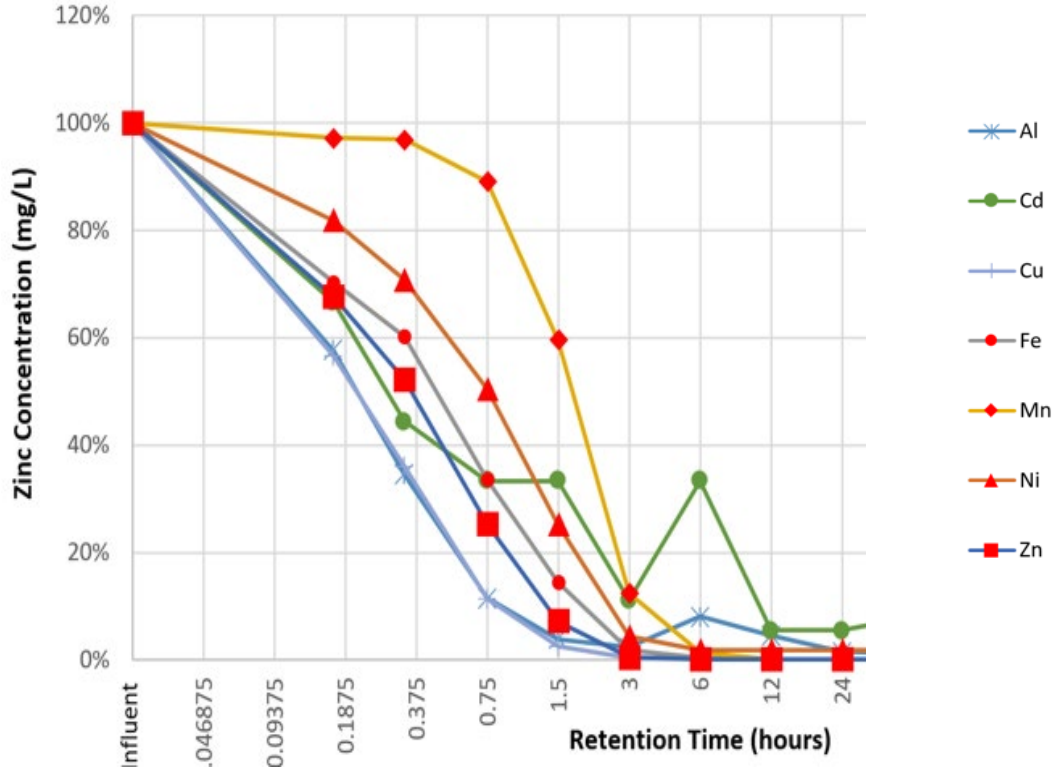



TREATMENT VOLUME AND FLOW RATE
Cumulative Volume (PV)
Treatment Rate (PV/day)
Post-Test Leaching
Sep-22
Oct-22
Nov-22
Dec-22
Jan-23
Feb-23
Mar-23
Apr-23
May-23
Jun-23
Jul-23
Aug-23
VOLUME TREATED
Volume Treated (PV)
(1 PV = 81 gallons/ton)
Treatment Rate (PV/day)
(1 PV/day = 0.056 gpm/ton)
Notes:
1. Date tics at start of month
2. Sampling at end of flow period
3. Retention (day) = 1/ Treatment Rate
4. Linear vertical scale
pH
pH - Standard Units
Post-Test Leaching
FLUID pH
Eagle Mine - pH
C18-CA Effluent - pH
Passive Limit - pH
Treatment Rate (PV/day)
Notes:
1. Date tics at start of month
2. Daily average of hourly pH plotted
3. Gap 11/22 due to frozen input line
4. 07/23 period is freshwater leach
ZINC
Concentration (mg/L)
Post-Test Leaching
ZINC
Eagle Mine - Zn (mg/L)
C18-CA Effluent - Zn (mg/L)
Passive Limit - Zn (mg/L)
Treatment Rate (PV/day)
Notes:
1. Open circles indicate non-detects at MDL
2. Date tics at start of month
3. Logarithmic vertical scale
4. Samples taken at end of flow period


ZINC REMOVAL AT 200 PV
Remaining Zinc Concentration after Treatment (% of influent)
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
360
384
408
Retention Time (hours)
After Treating 200 Pore Volumes

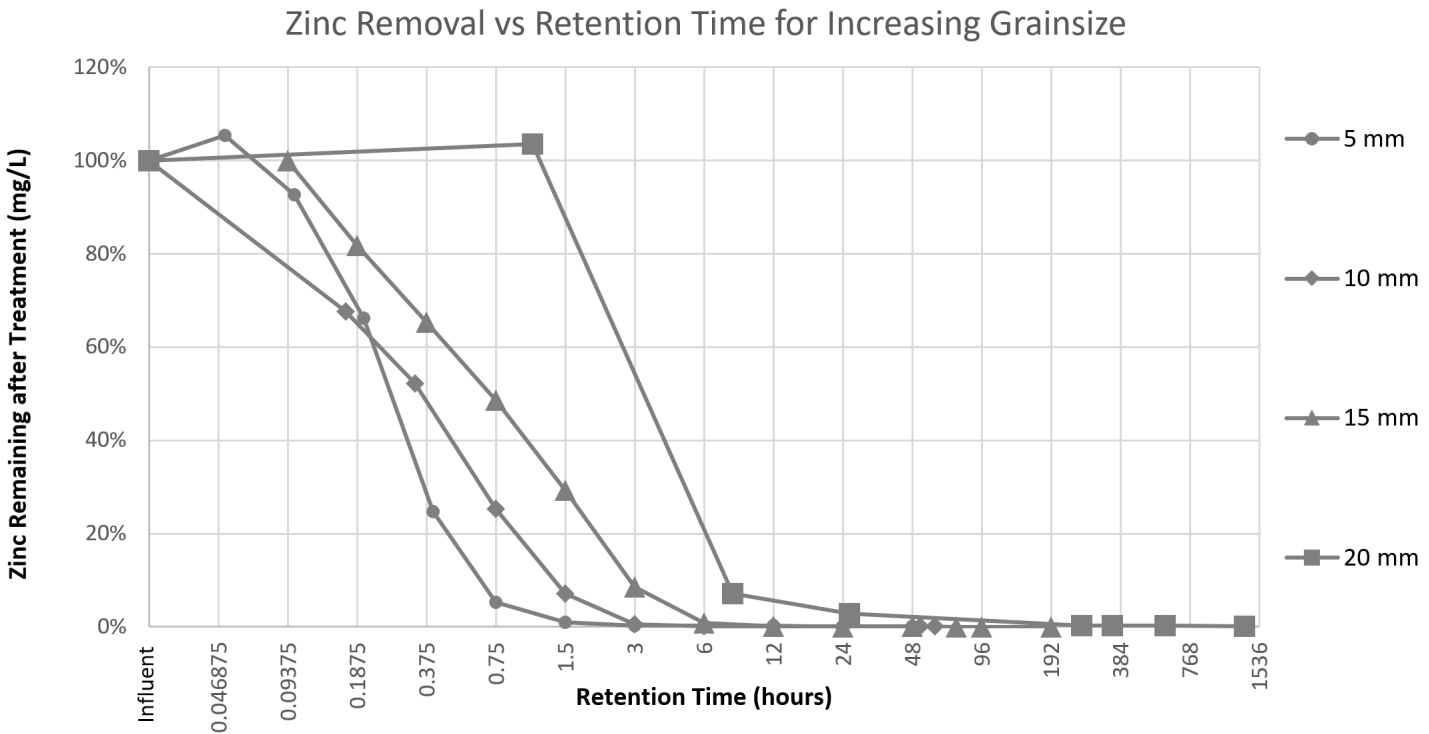
Observation #1

RCA successfully removes MOCs from AMD.

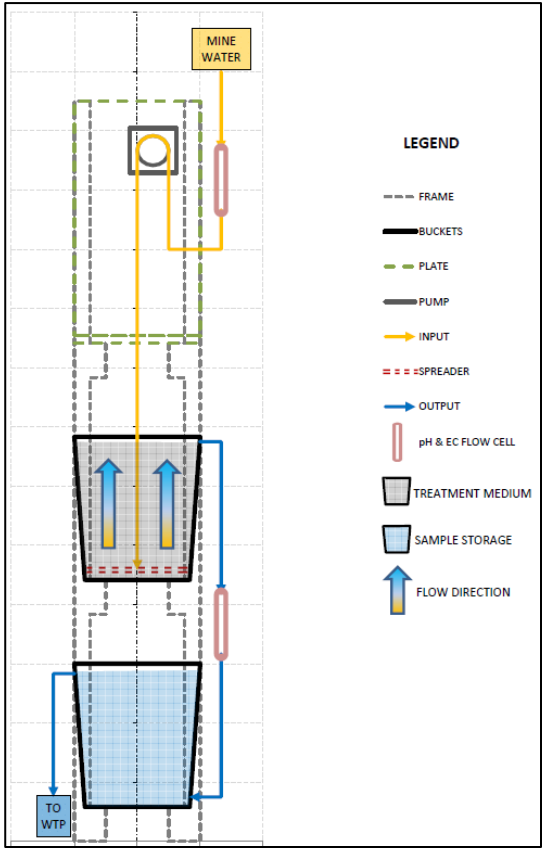


Observation #2

AMD treatment requires small particles of RCA



Observation #3



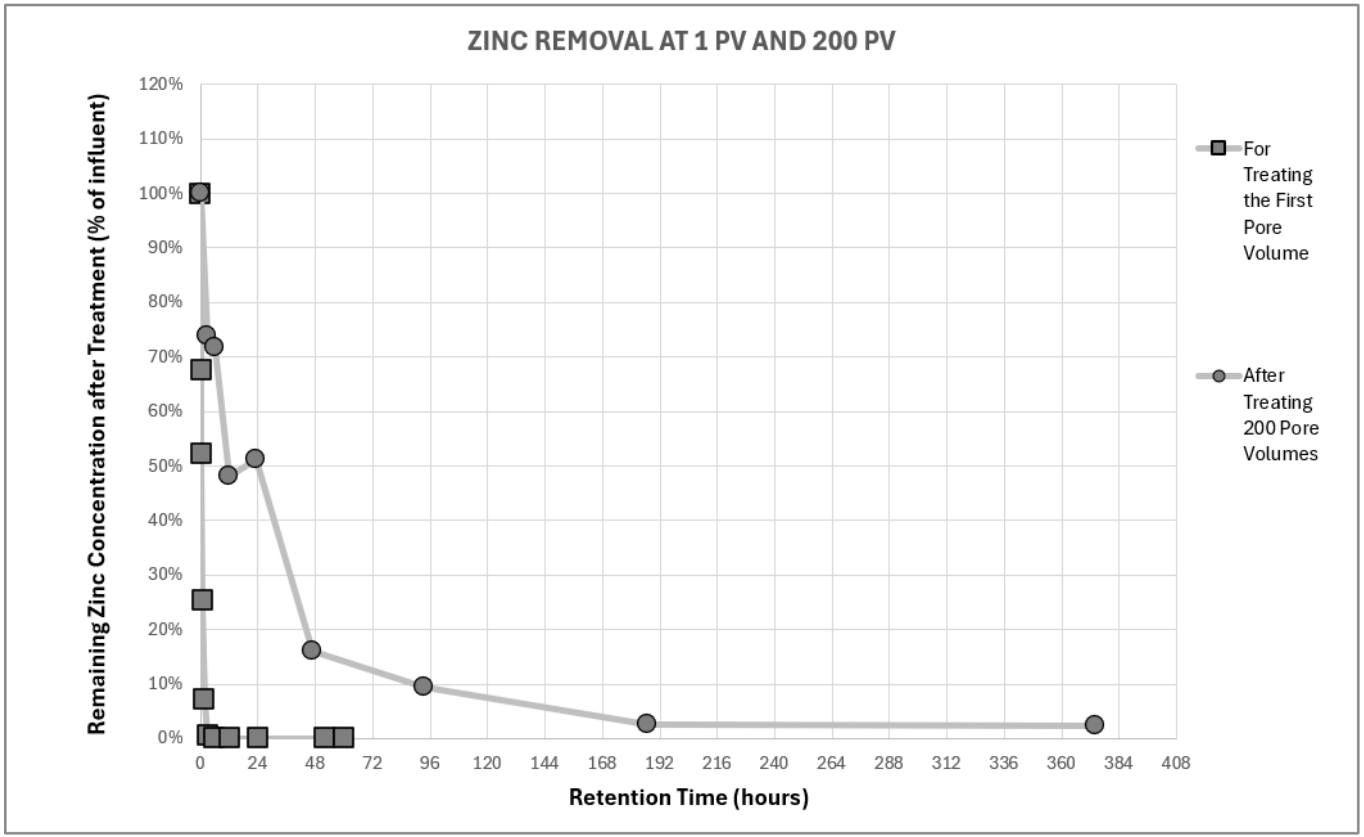
AMD treatment best with upflow through the RCA

Observation #4

RCA treatment of AMD does not clog the RCA medium.

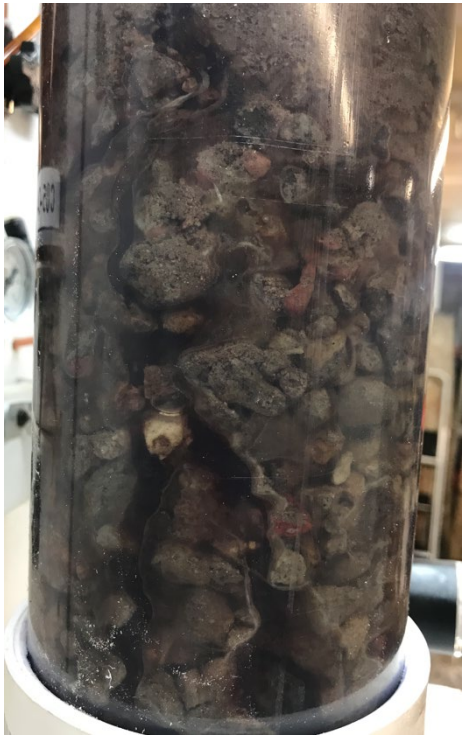
Observation #5

AMD treatment does not blind the RCA



Observation #6

RCA treatment does not create deleterious short-circuits

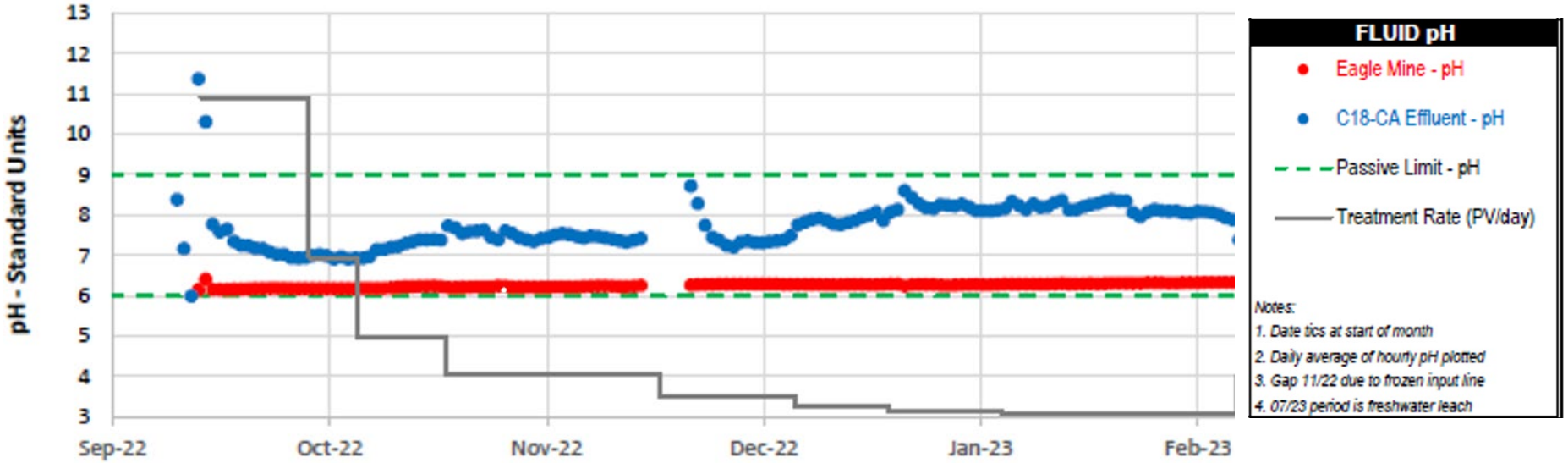


Observation #7

RCA treatment of AMD retains treatment products

Observation #8

RCA treatment of AMD produces alkaline discharge



Observation #9

RCA treatment of AMD permanently sequesters MOCs

ELEMENT	PRE-TEST	POST-TEST
	mg/kg	mg/kg
Al	49,600	60,300
As	<1,020	<202
Cd	<41	<40
Ca	71,100	42,100
Cu	<51	<51
Fe	17,800	17,700
Pb	384	<152
Mg	2,690	6,620
Mn	393	654
K	32,200	29,500
Na	15,300	18,200
S	2,530	2,060
Zn	<102	1,580

Observation #10

RCA does not add MOCs to the treated fluid.

ANALYTE		Influent	Effluent
pH		6.2	8.1
Al	mg/L	0.09	<0.05
As	mg/L	0.298	<0.04
Cd	mg/L	0.0469	<0.008
Cu	mg/L	0.164	<0.01
Fe	mg/L	47.5	1.58
Pb	mg/L	<0.03	<0.03
Mn	mg/L	15.5	3.78
S	mg/L	566	517
Zn	mg/L	23.8	0.608

Quantity of RCA Required for AMD Treatment System

1. Determine AMD flow rate (Q) requiring treatment; sample and analyze.
2. Determine RCA to be used for passive treatment; sample and analyze.
3. Perform batch or (better) field tests to determine:
   a. Retention time (t) for your RCA to treat your AMD to remove MOCs.
   b. Porosity (n) of your RCA from volume of AMD to flood the RCA.
   c. Dry density (ρ) of your RCA by dividing mass by volume of test solids.
4. Calculate the amount of RCA that is required for your passive treatment system using the data that you have just obtained:

$$Total\ volume\ of\ RCA\ (V) = \frac{Treatment\ flow\ rate\ (Q) \times Retention\ time\ (t)}{Porosity\ of\ RCA\ (n)}$$

- Based on testing as described above, a treatment system might the following characteristics:
  - Treatment Flow Rate (Q) ~1,000 m^3/day (~200 USgpm)
  - Critical Retention Time (t) ~ 4 days
  - Porosity of RCA (n) ~ 45%
- The critical volume of RCA required to treat this AMD is computed using the above equation:
- $$Critical\ volume\ of\ RCA \approx \frac{1000\ (m^3/day) \times 4\ (days)}{45\ (\%)} \approx 9{,}000\ (m^3)$$

Conclusion

Long-term truly passive treatment of acid and metalliferous drainage (AMD) by treatment systems using recycled concrete aggregate (RCA) is feasible, provided the following guidelines are adopted:

1. *Small RCA particle size* (2 - 20 mm).
2. *Large RCA mass (thousands of tonnes)*.
3. *Long contact between the AMD and the RCA* (1 to 15 days).
4. *Minimal contact of AMD with the atmosphere (upflow)*.
5. *Simple treatment system hydraulics (no pipes)*.

FOR MORE INFORMATION CONTACT:

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