Passive Treatment of Sulfate from Mine-Influenced Water

B.T. Thomas/CH2M
Jim Bays/CH2M

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Passive Treatment Overview

- Biochemical reactor (BCR) units are common in PTS design, especially where sulfate reduction is desired as the removal mechanism for trace metals.
- The BCR media is designed to support high levels of anaerobic microbial activity over an extended timeframe (>10 years)
- Metal removal is through both biological and abiotic removal mechanisms (mainly sulfide precipitation)
- Downstream APC units are typically installed to re-oxidize the BCR effluent and remove any excess sulfide before discharge to the environment.

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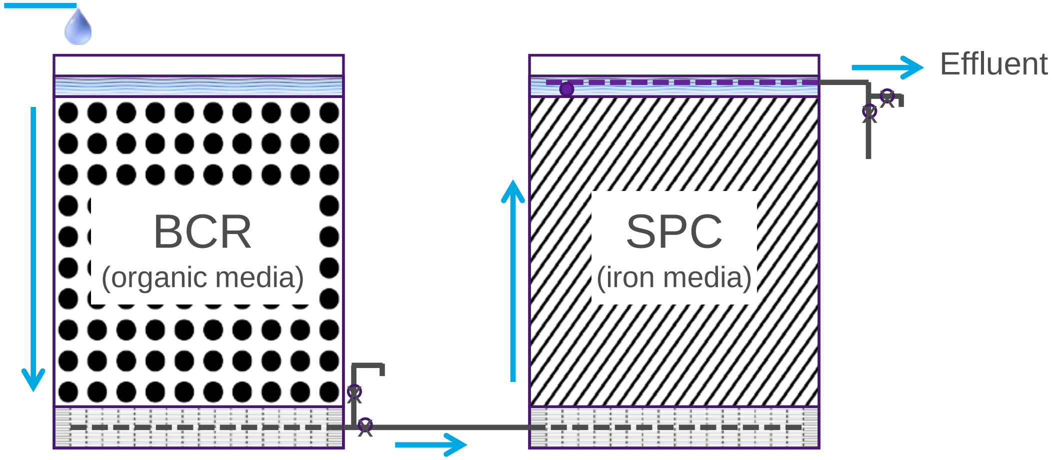
Introduction

- Biochemical Reactors designed around sulfate reduction
  - 300 mmole sulfate reduced per cubic meter of substrate per day
- Focused on metal removal; not sulfate removal
- High rates of sulfate reduction achieved through BCR
- Net change in sulfate through entire PTS is generally low due to APC; not enough metals in solution to precipitate all of the sulfide generated

Sulfide Precipitation Cell (SPC)

- Metal deficiency in BCR influent
- Require “capture” metal to retain sulfide as solid precipitate (FeS)
- Creates “consumable” substrate; shorter predicted life than BCR
- Employ separate process unit to isolate potential maintenance issues
- Clean sand matrix supporting low concentrations of distributed iron media to minimize cementation
- downflow BCR hydrologically connected to upflow SPC reactor to prevent oxidation of sulfide between units



Pilot Study

Background

- Former mine site with WRD seepage
  - Sulfate concentration 1,000 – 1,600 mg/L
  - Iron concentration 75 – 135 mg/L
  - Low-level zinc (<1 mg/L)
  - Predicted flow rate (post capping) ~10 gpm
- Treatment goal of 250 – 500 mg/L sulfate
- Pilot-testing multi-stage seep capture system
  - BCR/SPC/APC

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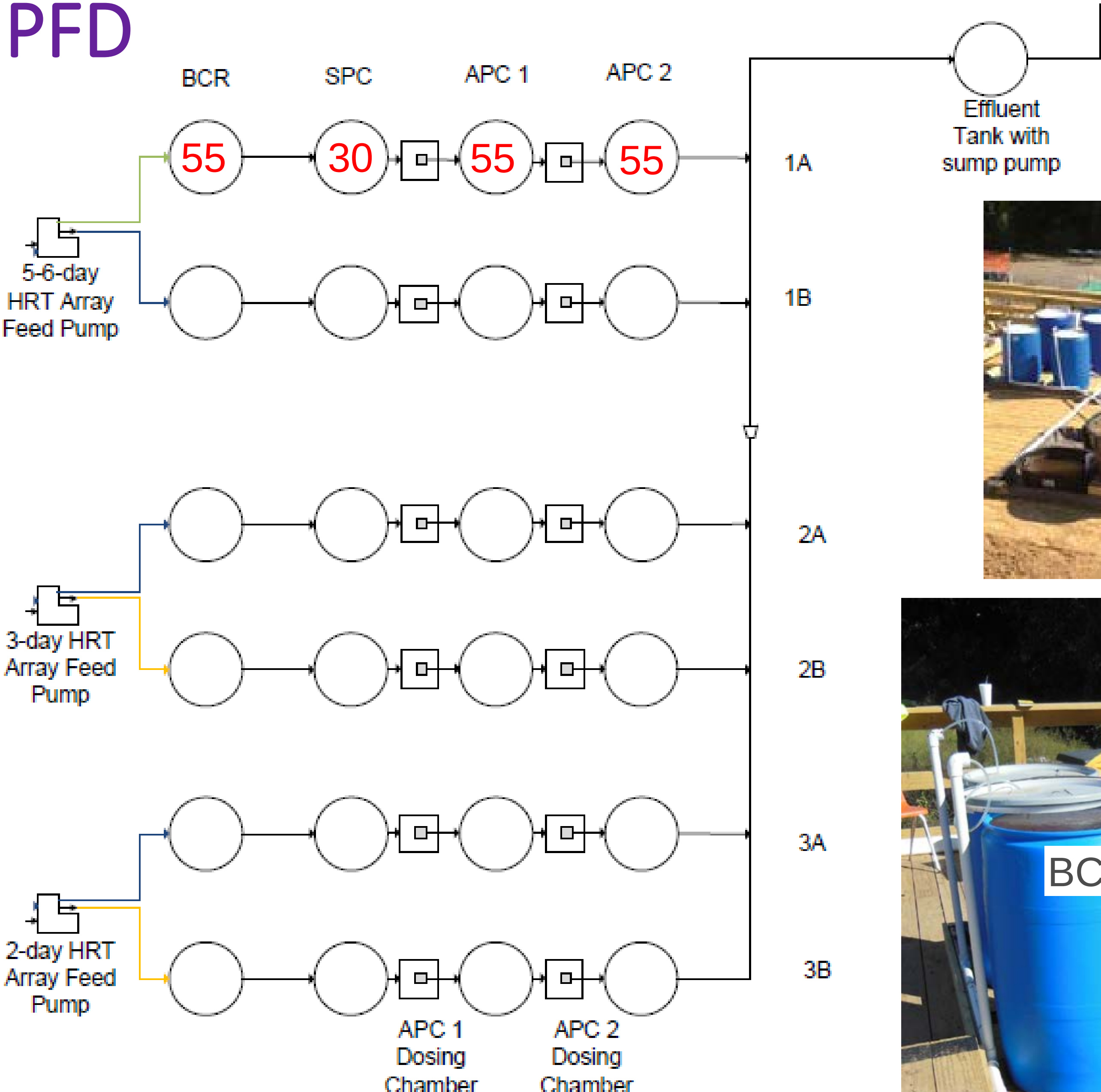
Experimental Design

- Six (6) test arrays
  - BCR → SPC → APC1 → APC2
- 3 (slight) variations of BCR media recipe
  - "Typical"
  - "Labile" (begasse-based)
  - "Enhanced" (carbon feed)
- Evaluated multiple HRTs
  - 3, 6, 9, 12-day HRT
- Tested five SPC media substrates
  - ZVI
  - waste rock from a magnetite mine in Missouri
  - low-grade magnetite ore from Utah
  - iron carbonate (siderite) from a mine in east Texas
  - magnetite fines from the Alabama Pigments Company.

PFD


BCR
SPC
APC 1
APC 2
55
30
55
55
5-6-day HRT Array Feed Pump
3-day HRT Array Feed Pump
2-day HRT Array Feed Pump
1A
1B
2A
2B
3A
3B
Effluent Tank with sump pump
APC 1 Dosing Chamber
APC 2 Dosing Chamber


BCR
SPC

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Substrate Recipes

- BCR
  - "Typical" (woodchips, sawdust, hay, limestone sand, SMC, peat)
  - "Labile" (typical-BCR substrate interlayered with Hay and SCB)
  - "Enhanced" (typical-BCR fed various forms of lactate/lactic acid)
- SPC
  - Two phases of testing
    - "HRT Testing" in 30 gallon drums
    - "Optimization Testing" in 17 gallon drums

Phase	1A	1B	2A	2B	3A	3B
HRT Testing	MO Mansand (33% Mag: 66% Sand)	AL Pigments (40% Mag: 60% sand	MO Mansand (50% Mag: 50% Sand)	100% Siderite	33% ZVI:66% Sand	Comstock Lean Ore (40% Mag: 60% Sand)
Optimization Testing	15% ZVI: 85% Sand	15% ZVI: 75% Sand: 10% hay/bagasse	90% ZVI: 10% hay/bagasse	100% Siderite	100% MO Mag Mansand	100% MO Mag Mansand

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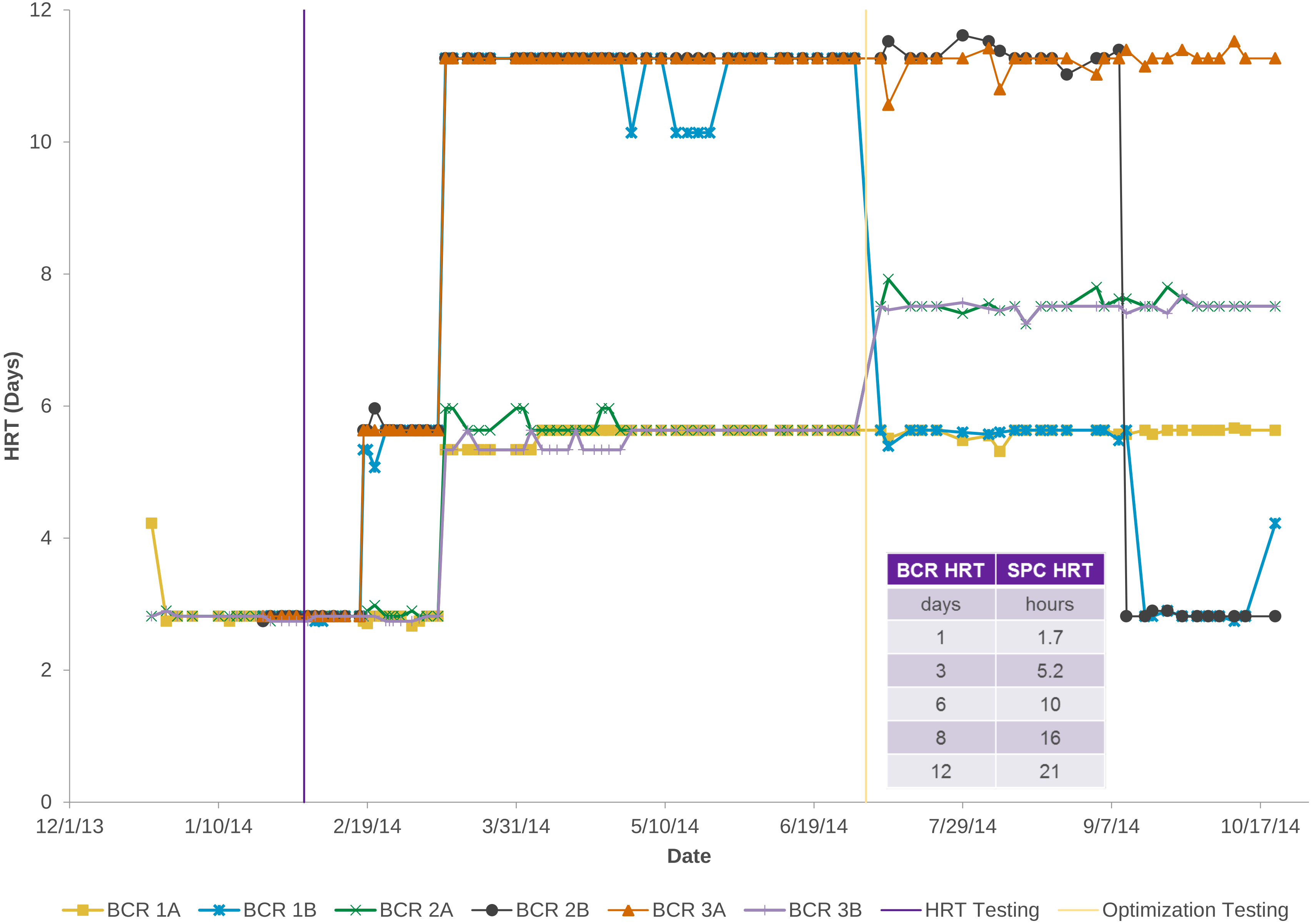
Hydraulic Residence Time



BCR HRT	SPC HRT
days	hours
1	1.7
3	5.2
6	10
8	16
12	21

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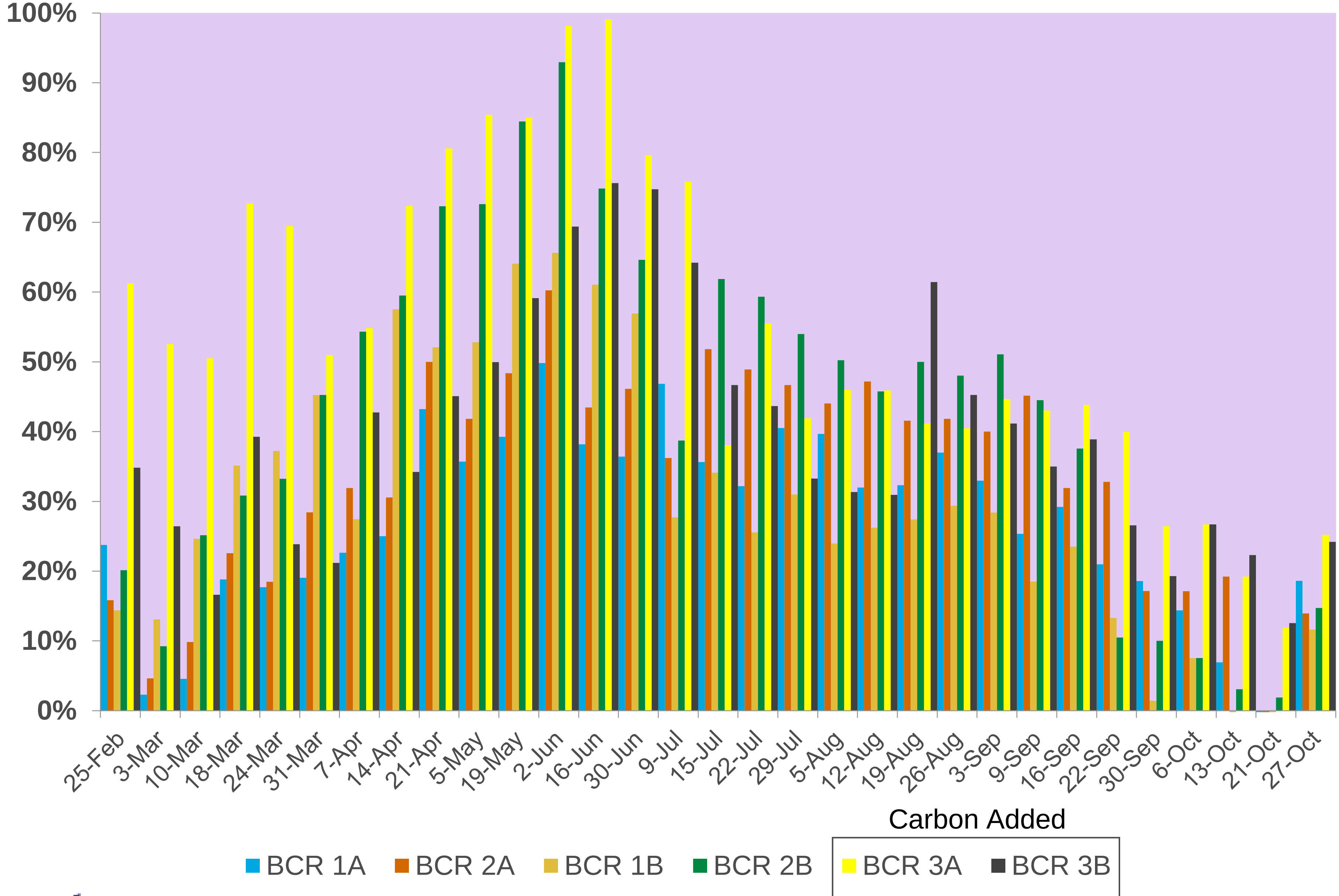
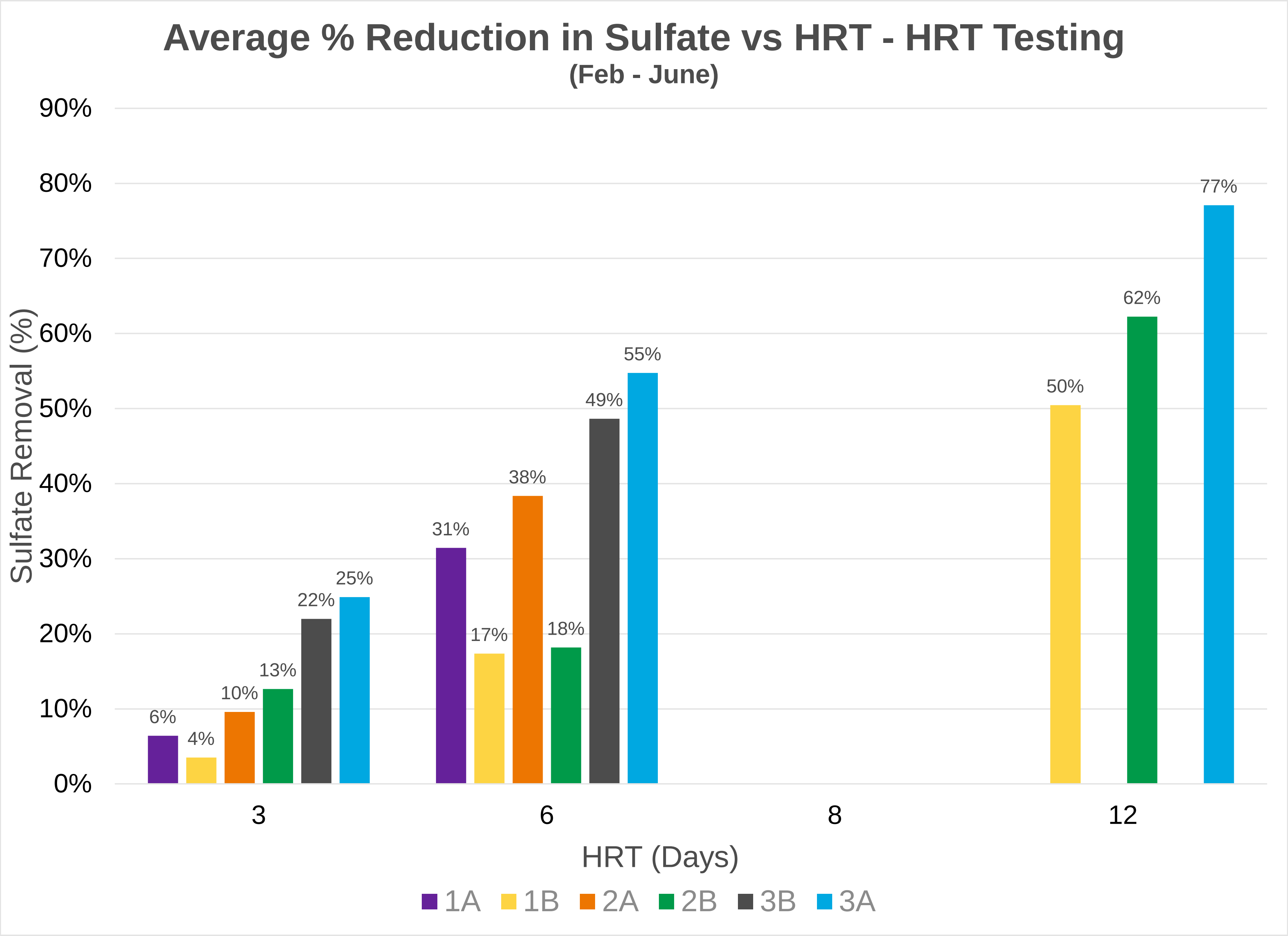
Results - BCR

% Sulfate removal in BCR barrels





Average % Reduction in Sulfate vs HRT - HRT Testing
(Feb - June)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Sulfate Removal (%)
6%
4%
10%
13%
22%
25%
31%
17%
38%
18%
49%
55%
50%
62%
77%
3
6
8
12
HRT (Days)
1A
1B
2A
2B
3B
3A

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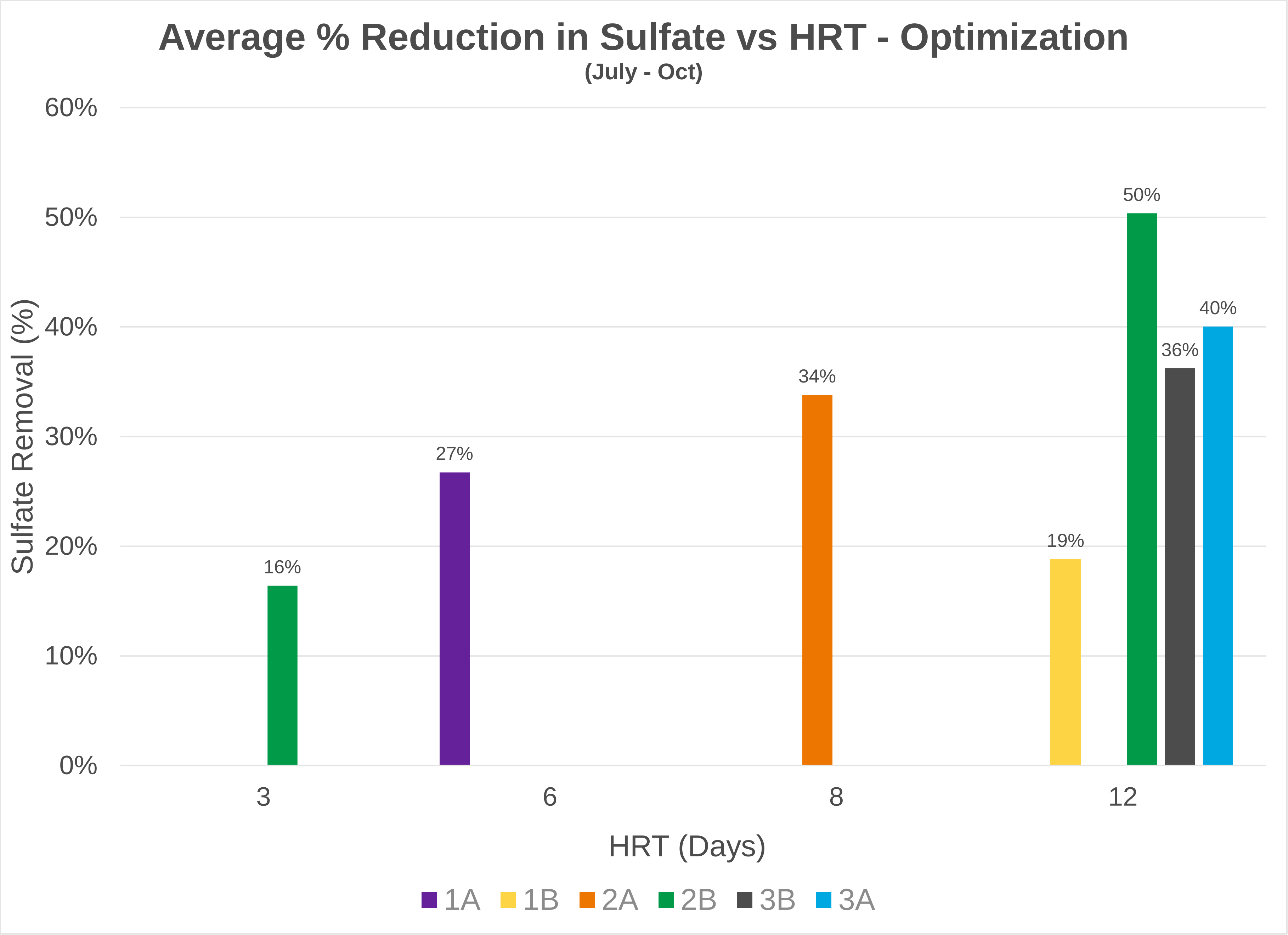
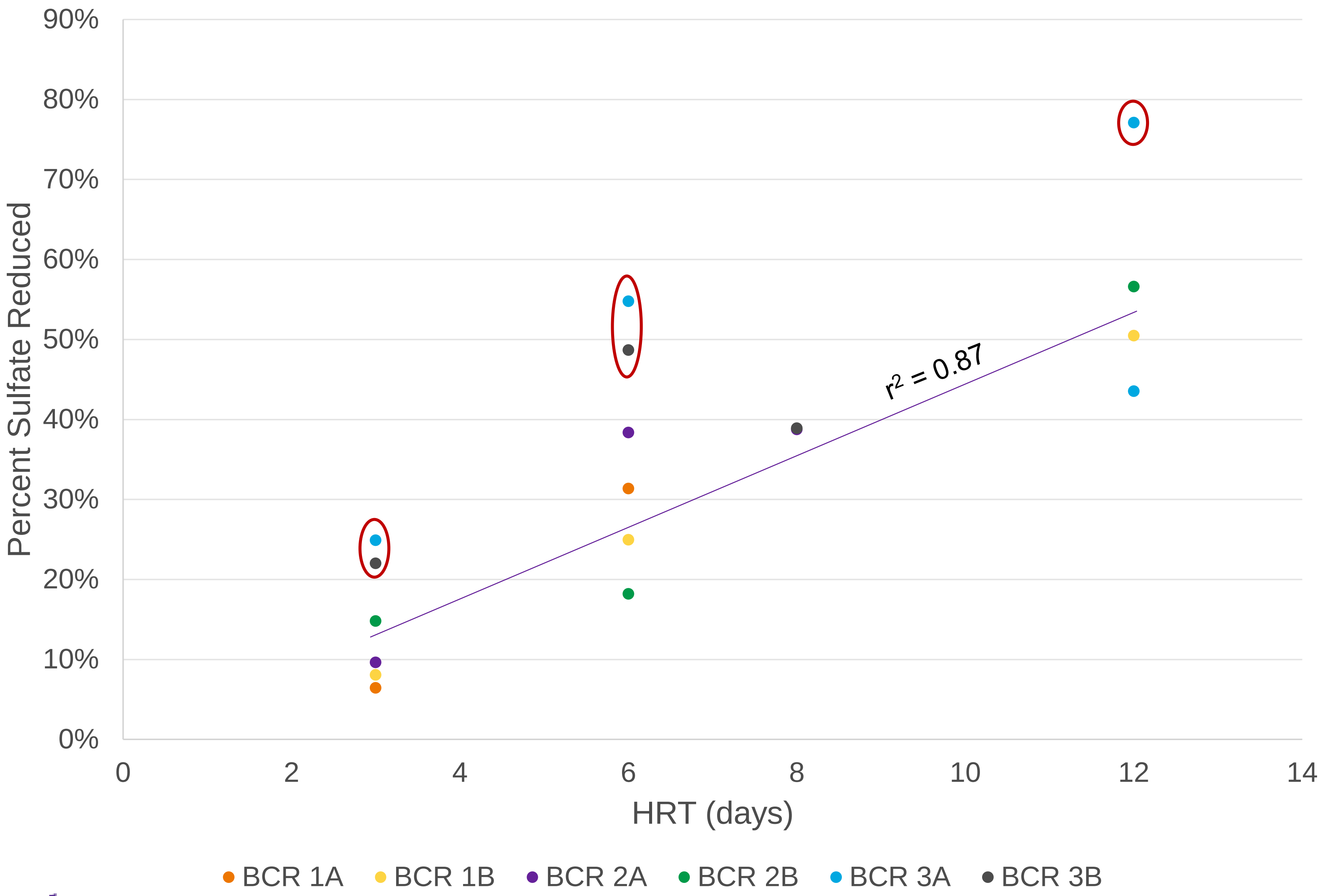
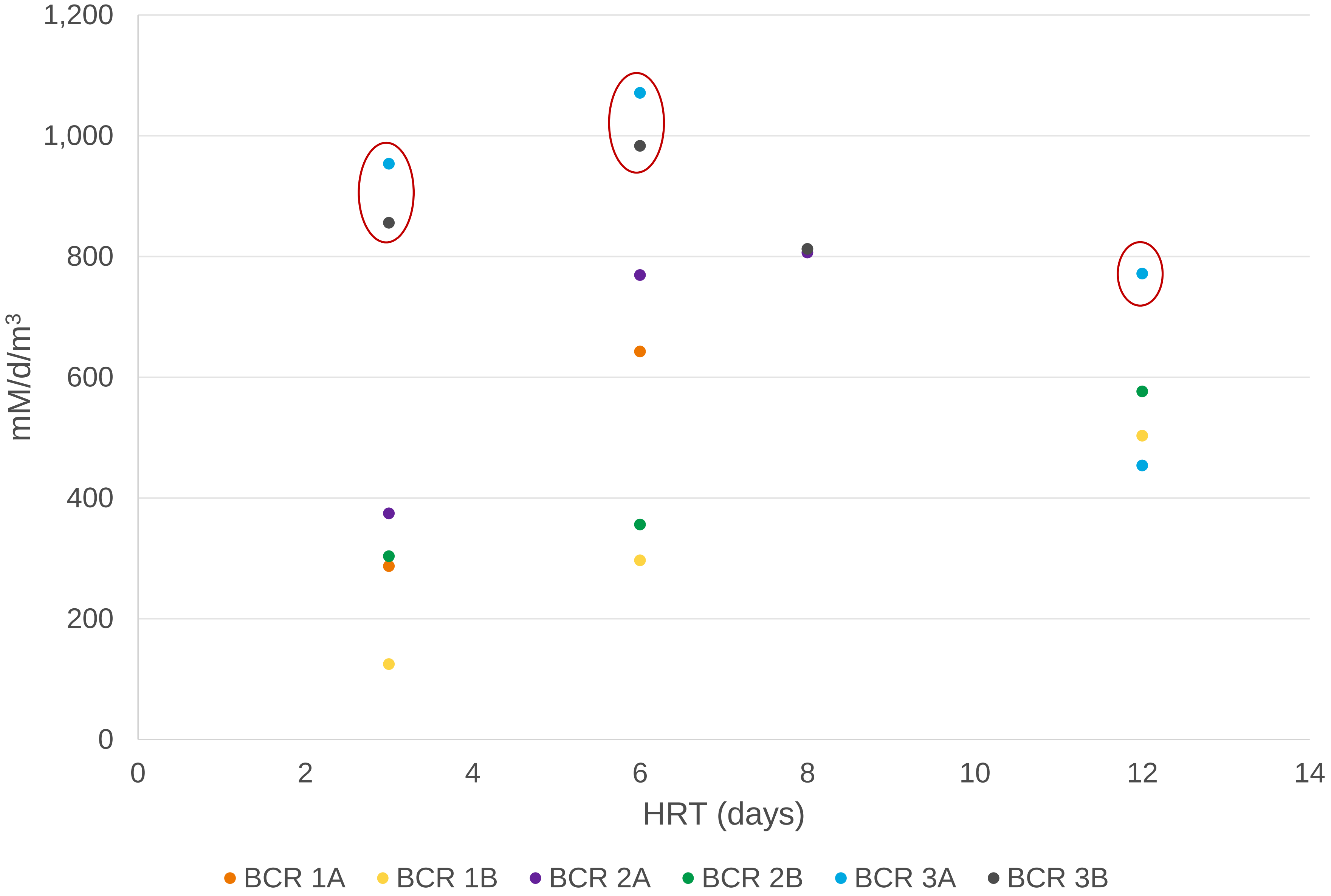

Average % Reduction in Sulfate vs HRT - Optimization
(July - Oct)
60%
50%
40%
30%
20%
10%
0%
Sulfate Removal (%)
16%
27%
34%
19%
50%
36%
40%
3
6
8
12
HRT (Days)
1A
1B
2A
2B
3B
3A

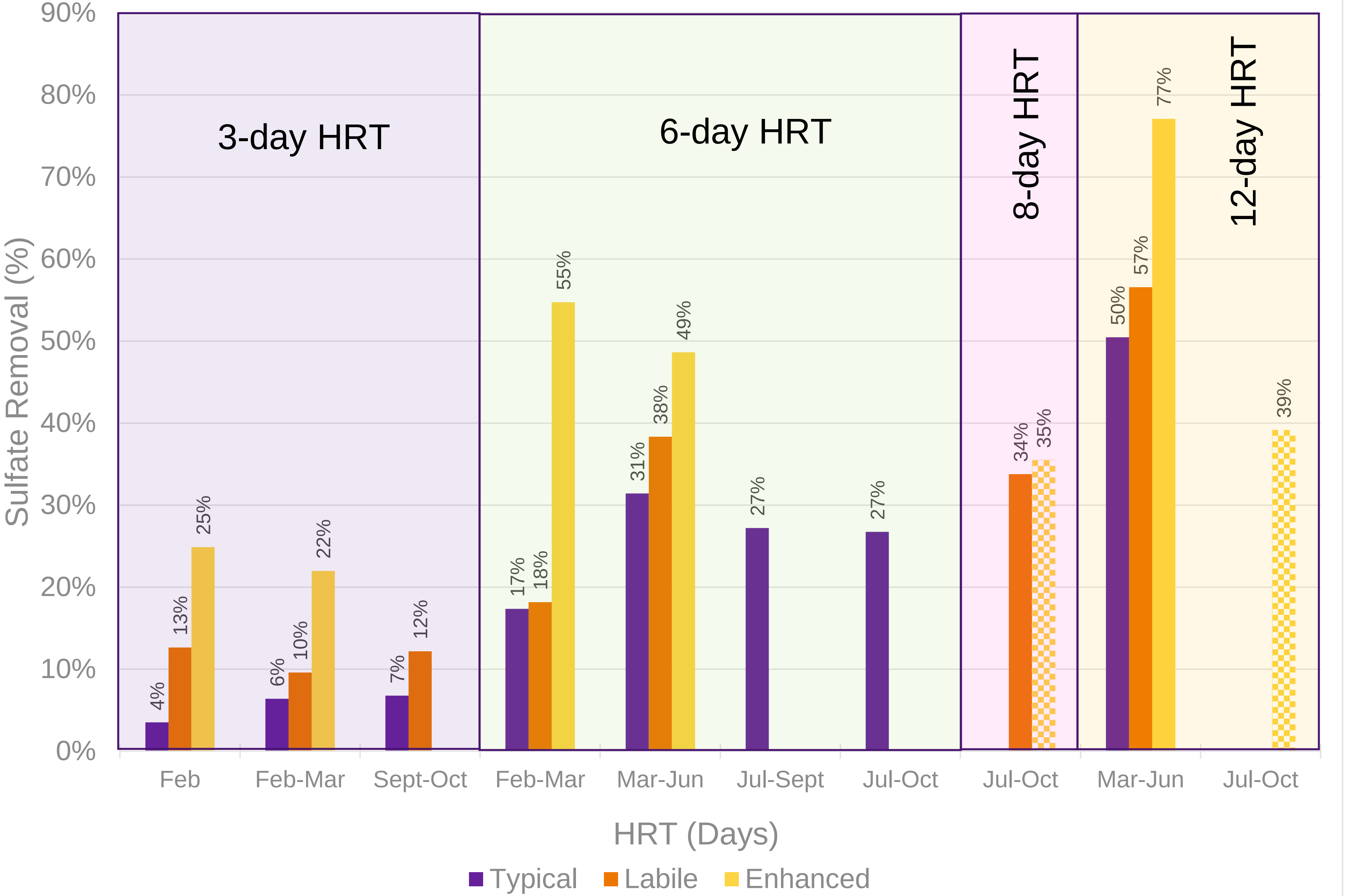
Percent Sulfate Reduced versus HRT



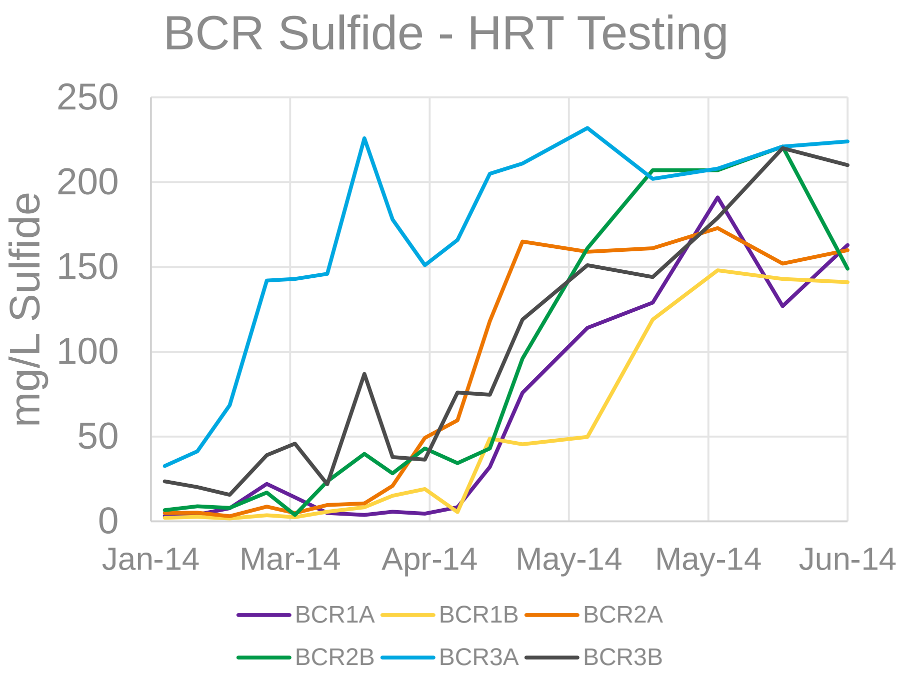
Volumetric Reduction Rate versus HRT

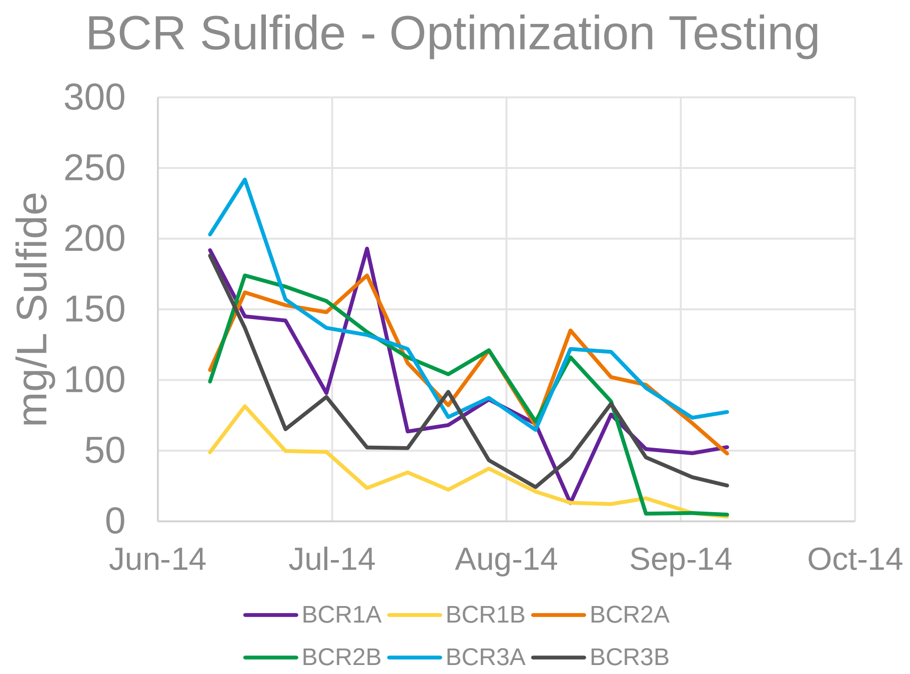


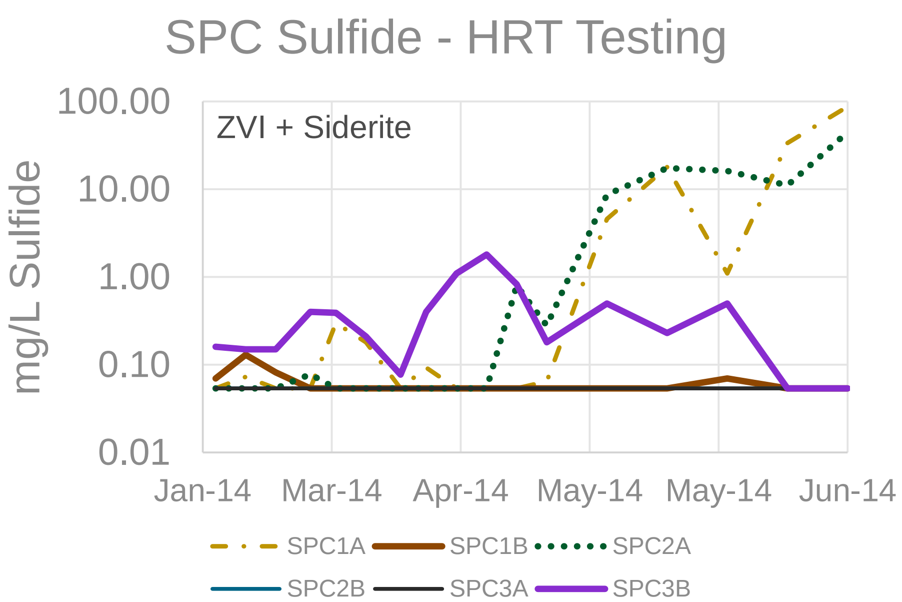
Comparison of Substrate Recipe Performance

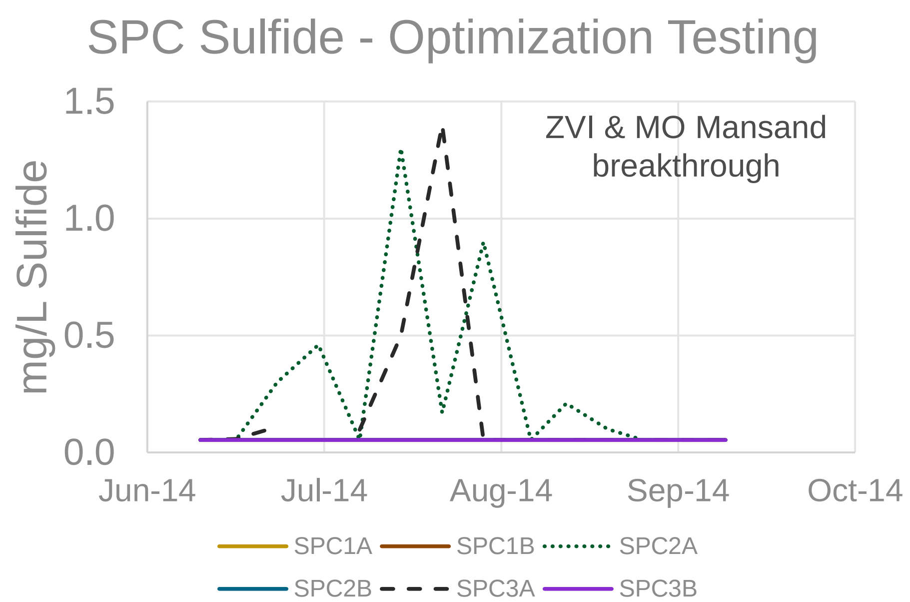


Results - SPC


BCR Sulfide - HRT Testing
mg/L Sulfide
250
200
150
100
50
0
Jan-14
Mar-14
Apr-14
May-14
May-14
Jun-14
BCR1A
BCR1B
BCR2A
BCR2B
BCR3A
BCR3B


BCR Sulfide - Optimization Testing
mg/L Sulfide
300
250
200
150
100
50
0
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
BCR1A
BCR1B
BCR2A
BCR2B
BCR3A
BCR3B


SPC Sulfide - HRT Testing
ZVI + Siderite
mg/L Sulfide
100.00
10.00
1.00
0.10
0.01
Jan-14
Mar-14
Apr-14
May-14
May-14
Jun-14
SPC1A
SPC1B
SPC2A
SPC2B
SPC3A
SPC3B


SPC Sulfide - Optimization Testing
ZVI & MO Mansand breakthrough
mg/L Sulfide
1.5
1.0
0.5
0.0
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
SPC1A
SPC1B
SPC2A
SPC2B
SPC3A
SPC3B

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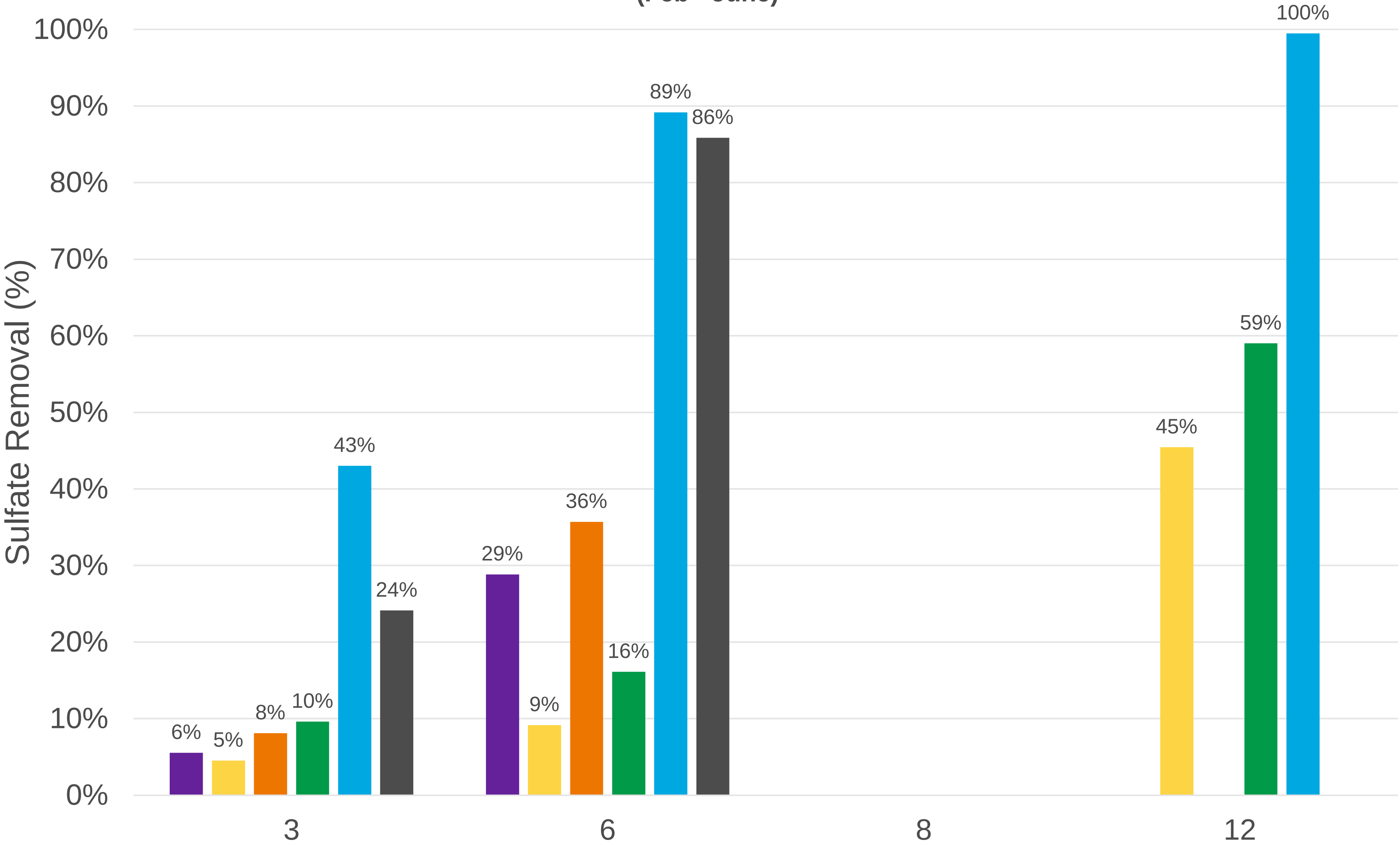
SPC Average % Reduction in Sulfate vs HRT - HRT Testing
(Feb - June)



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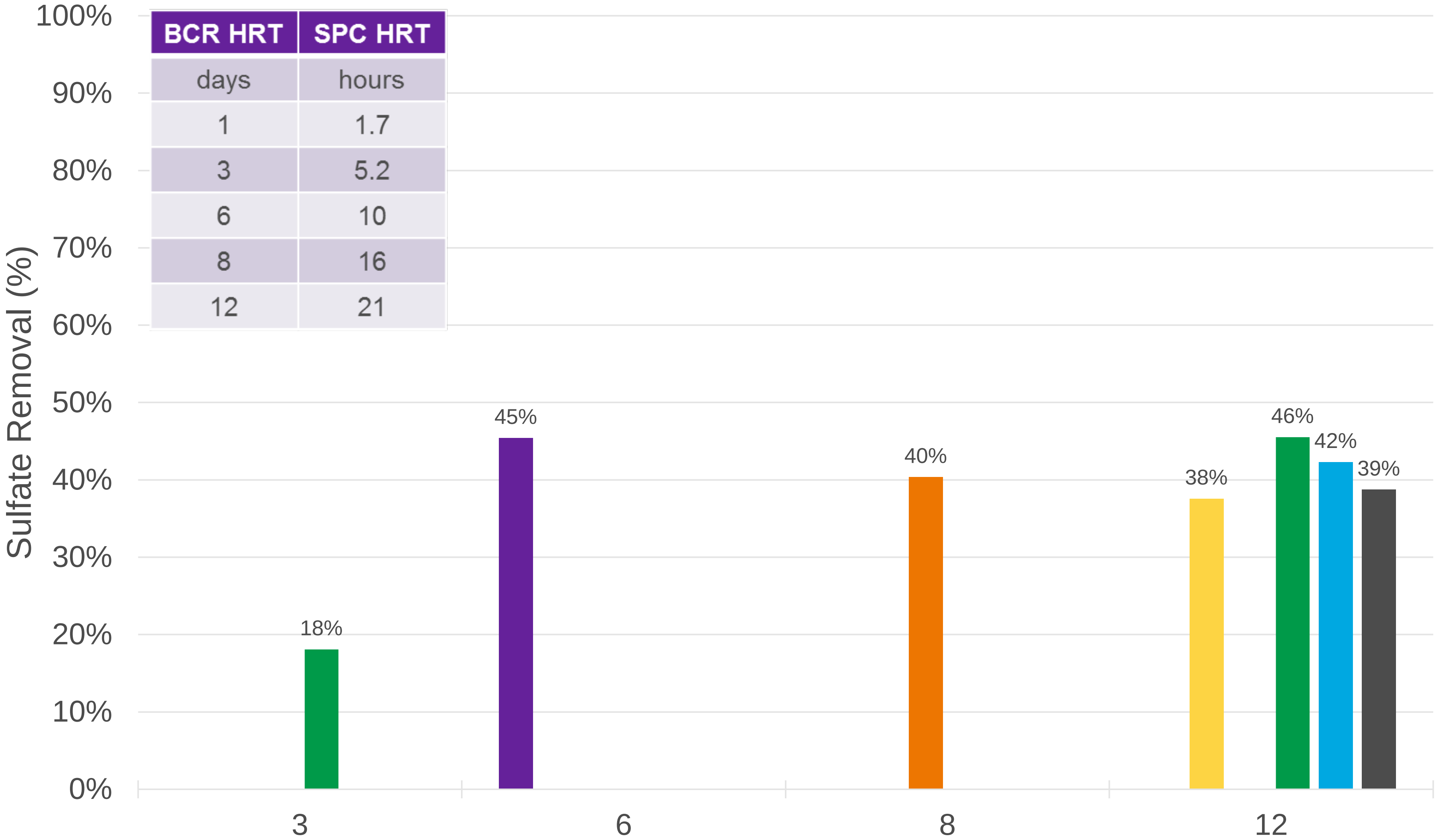
SPC Average % Reduction in Sulfate vs HRT - Optimization

(July - Oct)



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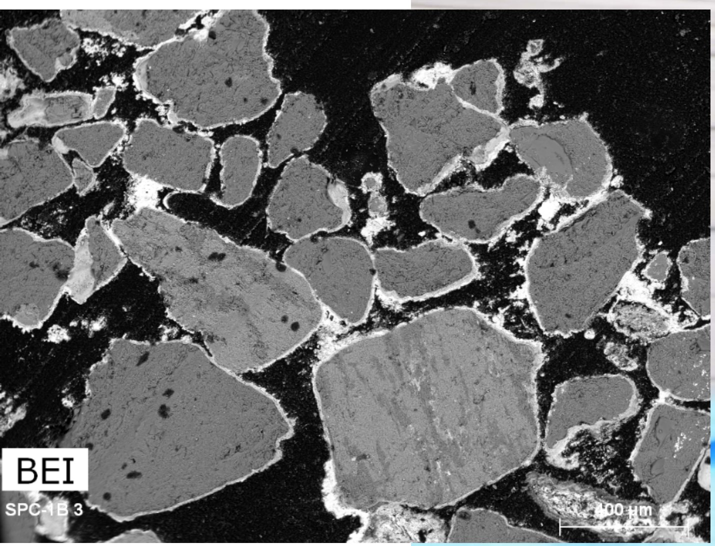
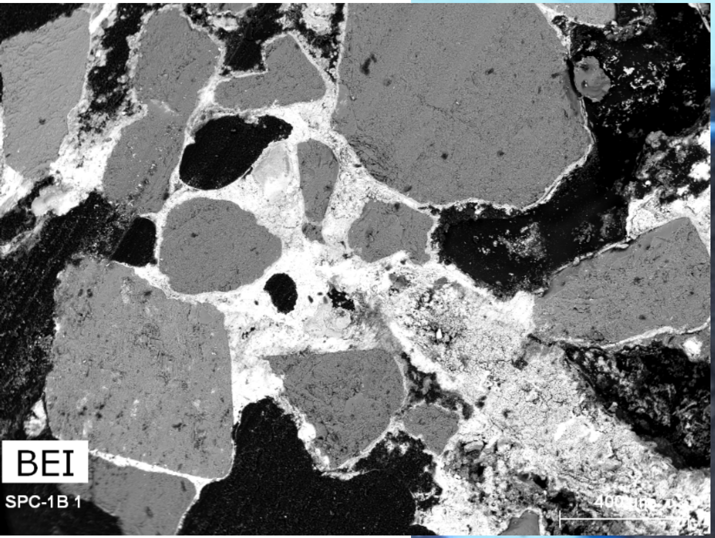
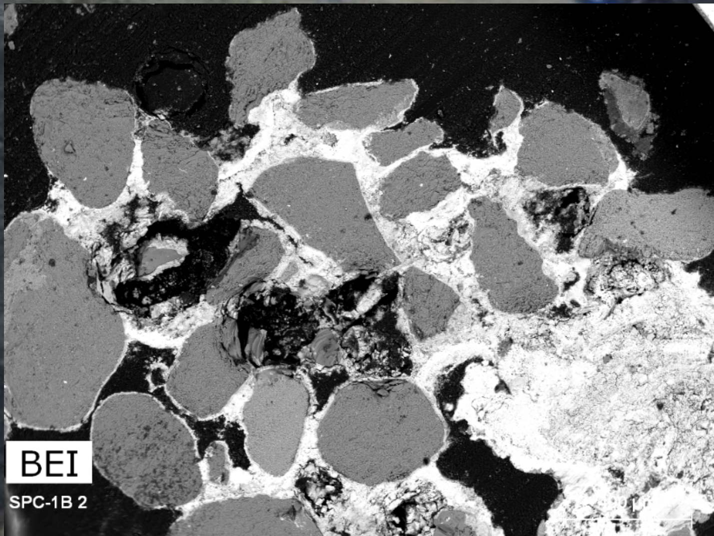
1A	1B	2A	2B	3A	3B
15% ZVI: 85% Sand	15% ZVI: 75% Sand: 10% hay/bagasse	90% ZVI: 10% hay/bagasse	100% Siderite	100% MO Mag Mansand	100% MO Mag Mansand

Results – Substrate Autopsy

ZVI







Missouri Mag Mansand

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Siderite

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Thank You