Sulfate Reduction in Bench and Pilot-Scale Passive Treatment Systems

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Sulfate Reduction in
Bench and Pilot-Scale
Passive Treatment Systems

Agenda

1. Case Studies Background
2. Sulfate Biochemical Reactions
3. Experimental Setups
4. Tests Results
5. Path Forward

Case Studies Location and Site Problems

Parameters	Bench Test 1	Bench Test 2	Pilot Test
Location	United States	Armenia	United Kingdom
Leachate	From a waste rock dump	From a waste rock dump	From an old landfill
pH	~7	~3.6	~7
Sulfate (mg/L)	~3000	~150	~900
Sulfate Discharge Limit (mg/L)	*250*	*16*	*450*
Metals Concentration	Low	Low	Low

Sulfate Biochemical Reactions

sulfate reducing bacteria

$SO_4^{-2} + 2\ CH_2O \rightarrow HS^- + 2\ HCO_3^- + H^+$

When metals are present:

$Me^{+2} + HS^- \rightarrow MeS + H^+$

When metals are NOT present:

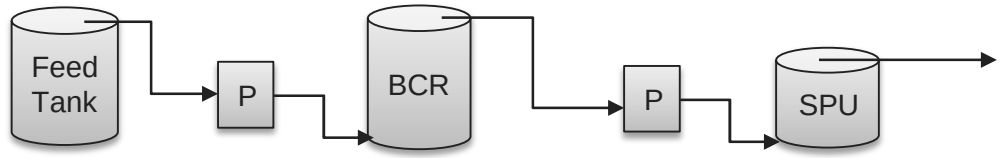
$CO_2 + 4\ H_2S + O_2 \rightarrow CH_2O + 4\ S^0 + 3\ H_2O$

Photosynthetic bacteria

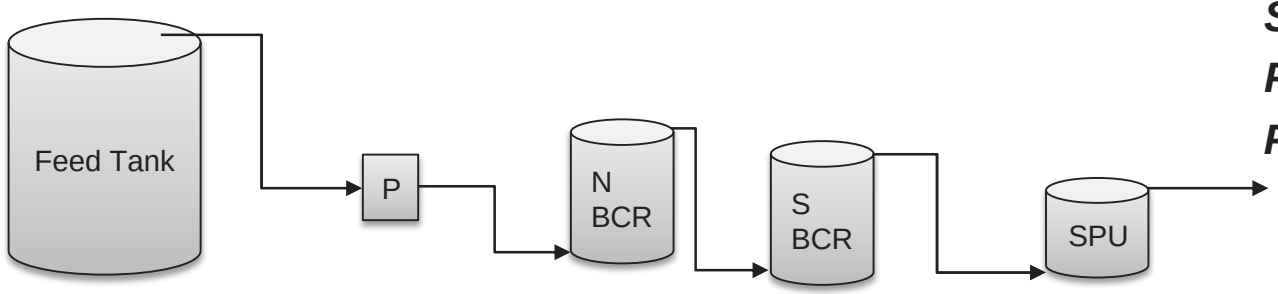
$2S^0 + H_2O + 3O_2 \rightarrow 2H^+ + SO_4^{-2}$

Bench and Pilot Scale Setup Schematic

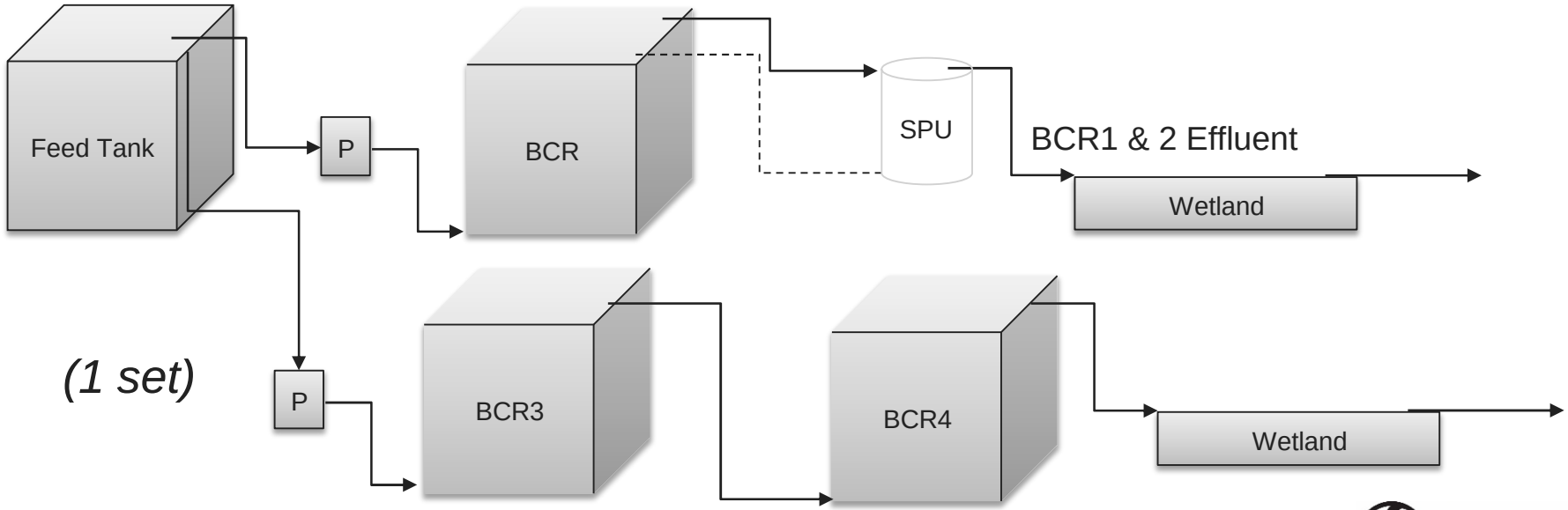
- **Bench Test 1**
  (3 PT trains)



- **Bench Test 2**
  (3 PT trians)



- **Pilot Test**
  (2 PT trains)



***BCR**: Biochemical Reactor*
***NBCR**: Nitrate BCR*
***SBCR**: Sulfate BCR*
***SPU**: Sulfide Polishing Units*
***P**: Pump*
***PT**: Passive Treatment*

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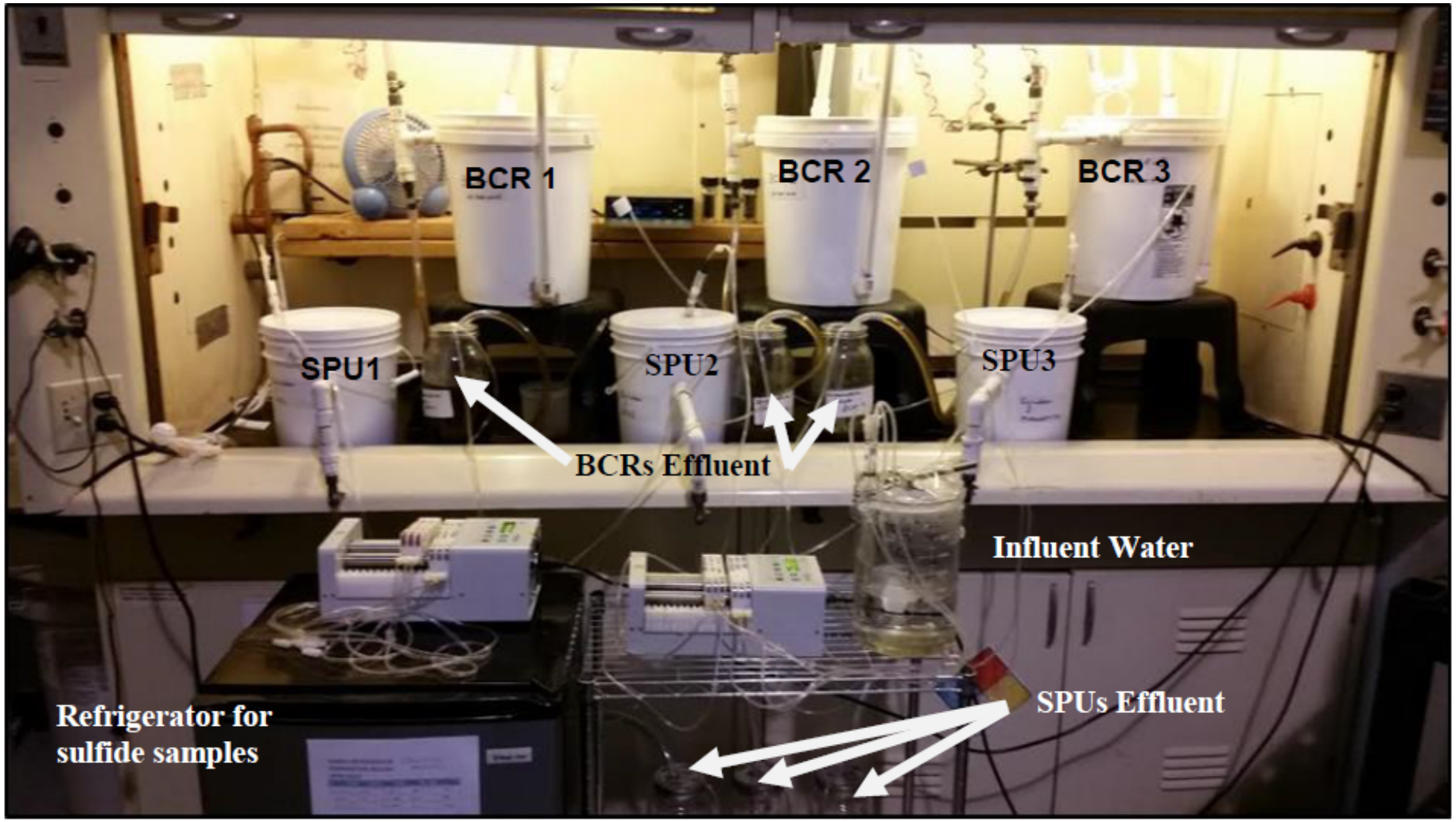
Bench Test 1 - US



Fattore, et al., *Journal American Society of Mining and Reclamation, 2017*

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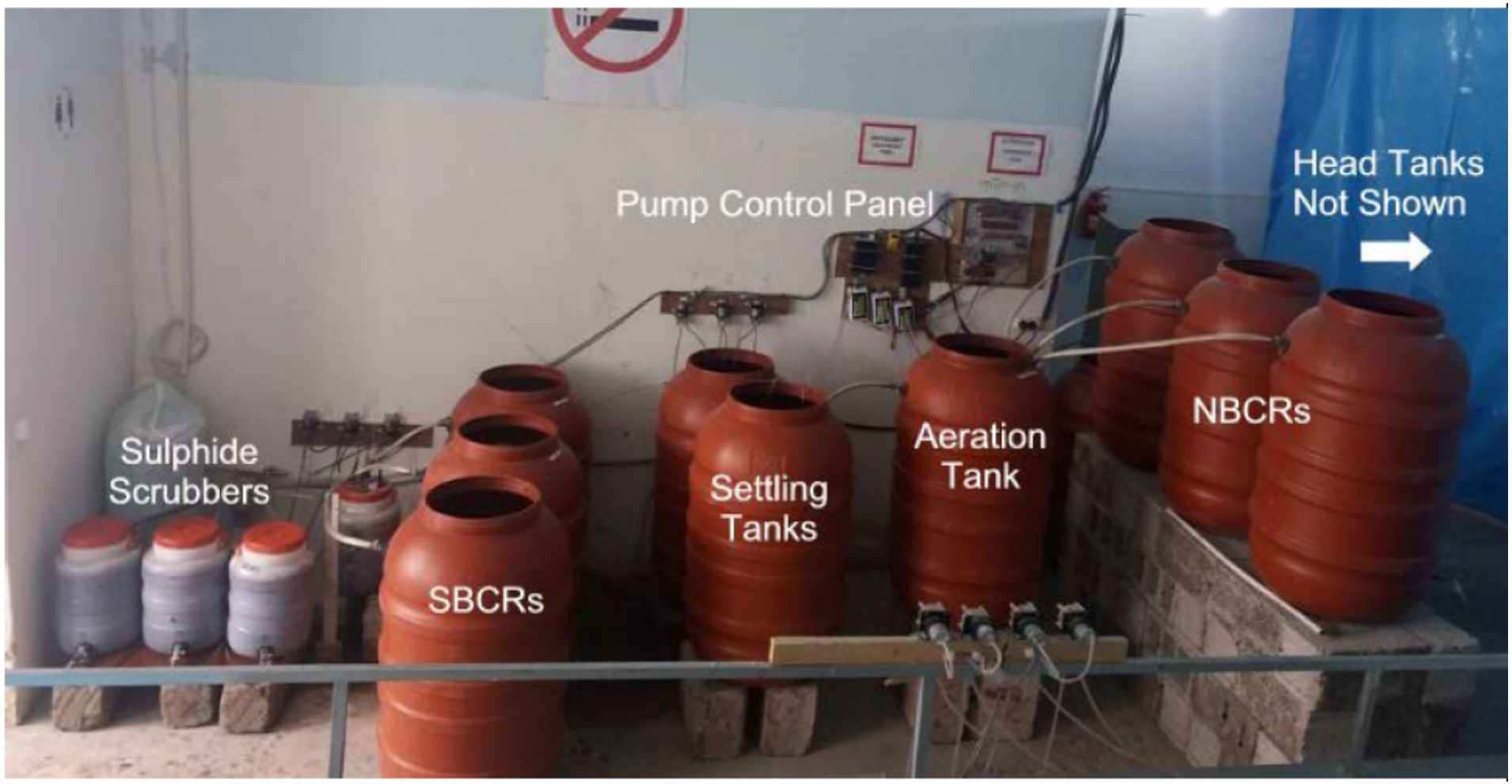
Bench Test 2 - Armenia



Gusek, et al., *Tailings and Mine Waste 2018*

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Pilot Test - UK

J Robinson, et al., *Australian Centre for Geomechanics, 2022*

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Biochemical Reactors (BCRs) Substrate

Material	BCR1	BCR2	BCR3
Wood Chips	Bench Test 2, Pilot	Bench Test 2, Pilot	Bench Test 2, Pilot
Wood Pellets	--	Bench Test 1	Bench Test 1
Grapes Pressings	Bench Test 2	Bench Test 2	Bench Test 2
Straw	All Tests	All Tests	All Tests
Limestone	All Tests	All Tests	All Tests
Biochar	Bench Test 2 Pilot	Bench Test 2, Pilot	All Tests
Animal Manure	All Tests	All Tests	All Tests

Sulfide Polishing Units (SPUs) Materials

Material	BCR1/SPU1	BCR2/SPU2	BCR3/SPU3
Soil/Rock	Bench Test 1		
Scarp Metal		Bench Test 1	
Magnetite			Bench Test 1
Iron Oxide/Sand	Bench Test 2		
Scrap Metal/Sand		Bench Test 2	
Upper Volcanic Rock			Bench Test 2
Scrap Metal	Pilot		
Wire Wool		Pilot	
Sand (filter)	Pilot	Pilot	

Operational Parameters

Parameters	Bench Test 1	Bench Test 2	Pilot Test
Flow Rate *(ml/min)*	0.1 – 0.86	12 -24	500 *(BCR1 & 2)* 1000 *(BCR3/BCR4)*
HRT @ *(day)*	75 - 5	9 – 4.5 each BCR	25
Duration of Testing *(week)*	20	26	28+
Volume of substrate *(m^3)*	0.015	0.15 each BCR	18

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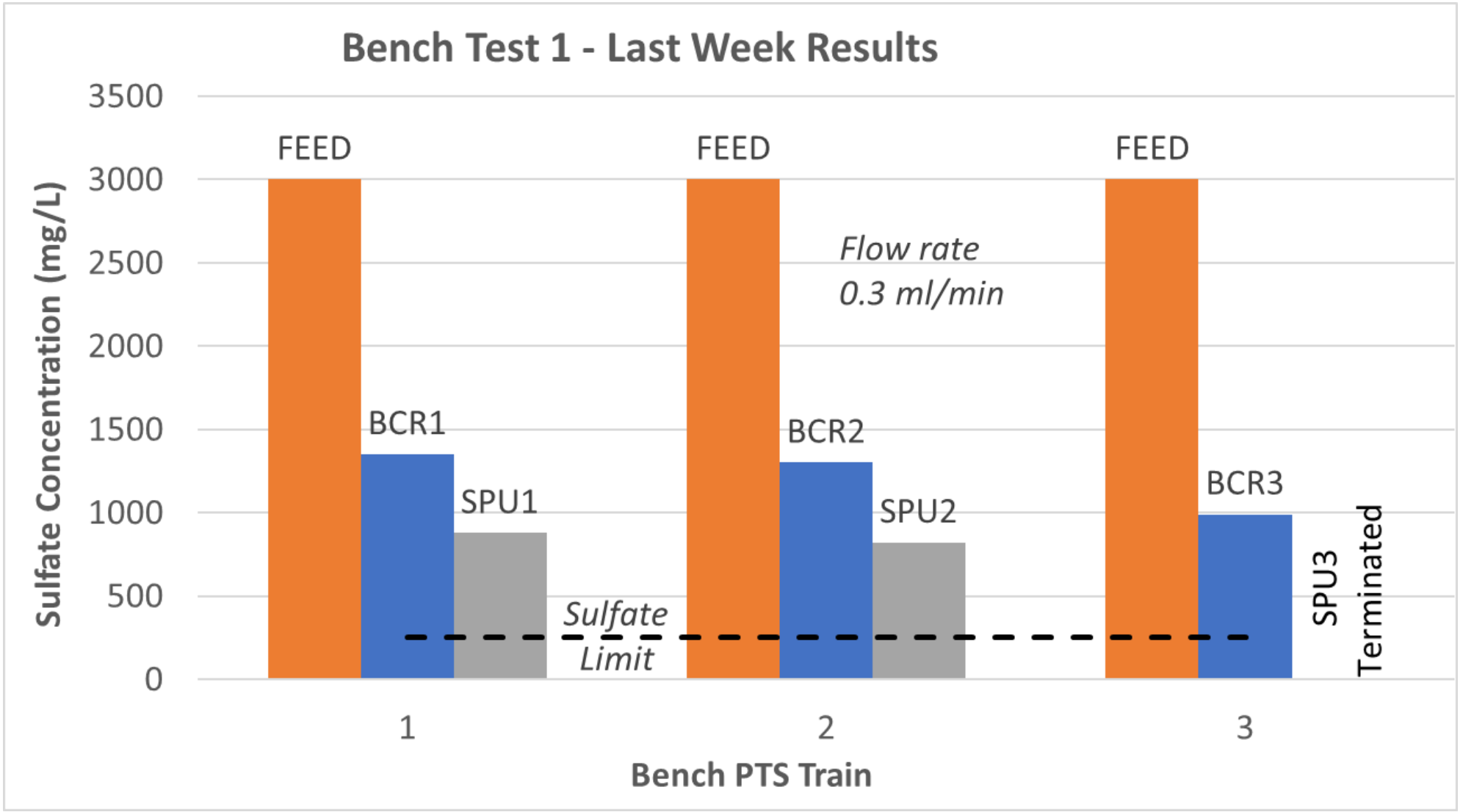
Results



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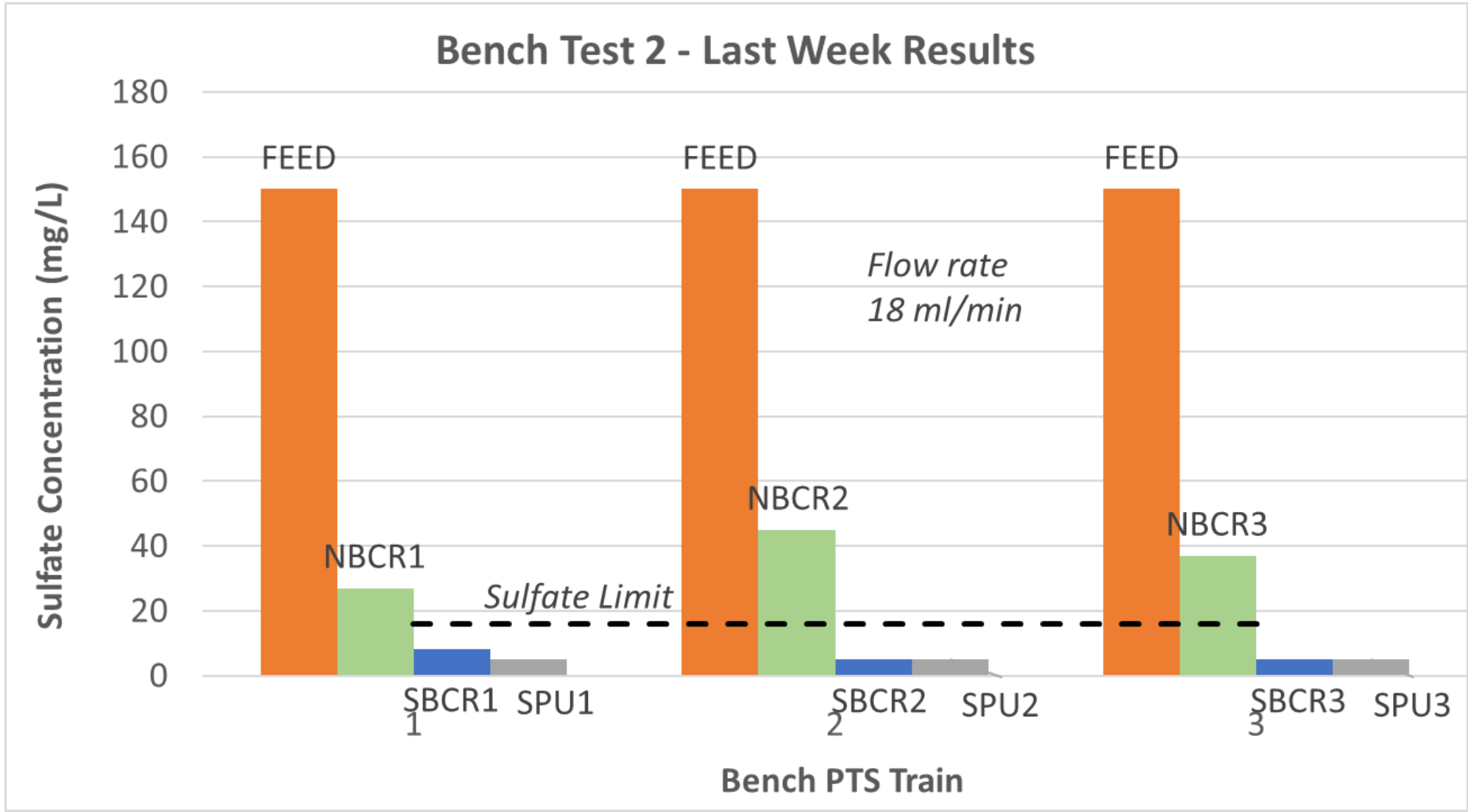
Results



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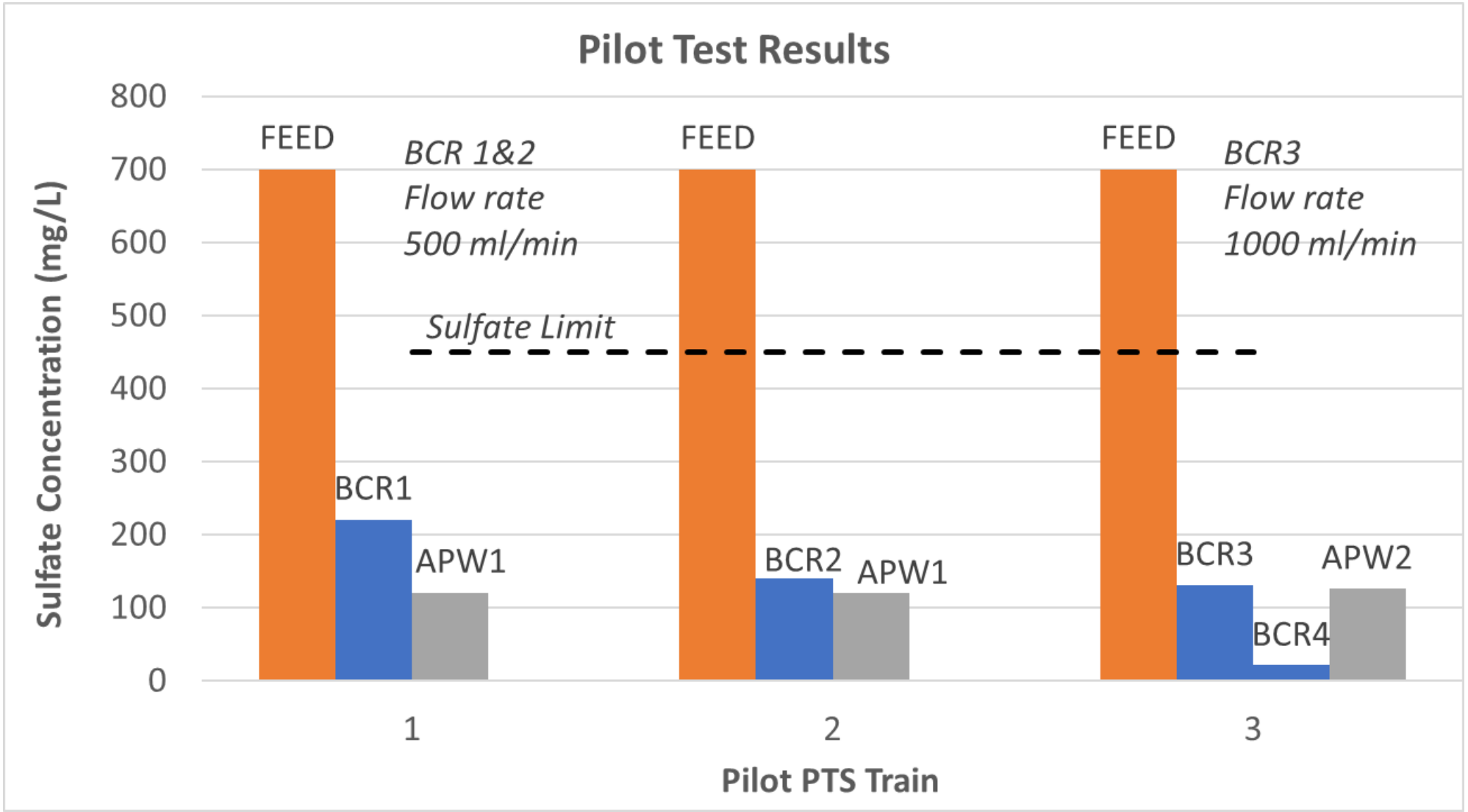
Results



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Bench Test 1 Conclusions

- Bench Test 1 passive treatment system was successful at reducing sulfate levels but not enough to meet the limit value
- Microbial data supports that the BCRs were still maturing after 20 weeks and had not shown their full potential.
- Sulfate was removed as elemental sulfur.
- SPU 1 and 2 were designed to remove hydrogen sulfide but they removed sulfate too.
- Local Soil/Rock (SPU1) material performed slightly better than the scrap metal (SPU2)

Bench Test 2 Conclusions

- Bench Test 2 passive treatment system was successful at reducing sulfate levels down to the strict Armenian limit (16 mg/L).
- The combined two NBCRs and SBCRs in series were able to provide the required HRT.
- Pilot plant design was going to include one single BCR unit with a retention time similar to the NBCR/SBCR combination.
- Iron Oxide and ZVI sulfide scrubbing media performed better than the upper volcanic rock formation from the site

Pilot Test Conclusions

- Pilot Test passive treatment system was successful at reducing sulfate levels down to the limit value for 28 weeks
- Sulfate was removed as elemental sulfur in the BCRs
- Scrap metal and wire wool were not able to remove elemental sulfur.
- Elemental sulfur was converted back to sulfate in the APWs
- Sand filters were added for the removal of elemental sulfur and successfully removed it.

Path Forward

- **Bench Test 1** results were used to select the full-scale substrate recipe and quantities
  - Full scale passive treatment system was designed, constructed and monitored by others
  - It was able to remove sulfate, but not enough to meet the limit.

- **Bench Test 2** results were going to be used to design a pilot test, but the project was placed on hold

- **Pilot test** results were used to design the full-scale passive treatment that will be constructed this summer of 2023.

Without change there is no innovation, creativity, or incentive for improvement. Those who initiate change will have a better opportunity to manage the change that is inevitable.

William Pollard

Questions?

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