Generating Rare Earth Element and Critical Mineral hydraulic pre-concentrate from Acid Mine Drainage at remote sites: a case study at Fola Job 5, Clay County, WV

Iuri Santos[1], Nathan Depriest[2], David Hoffman[2], Caitlin Glascock[2], Michael King[3], John Quaranta[3], Paul Ziemkiewicz[2]

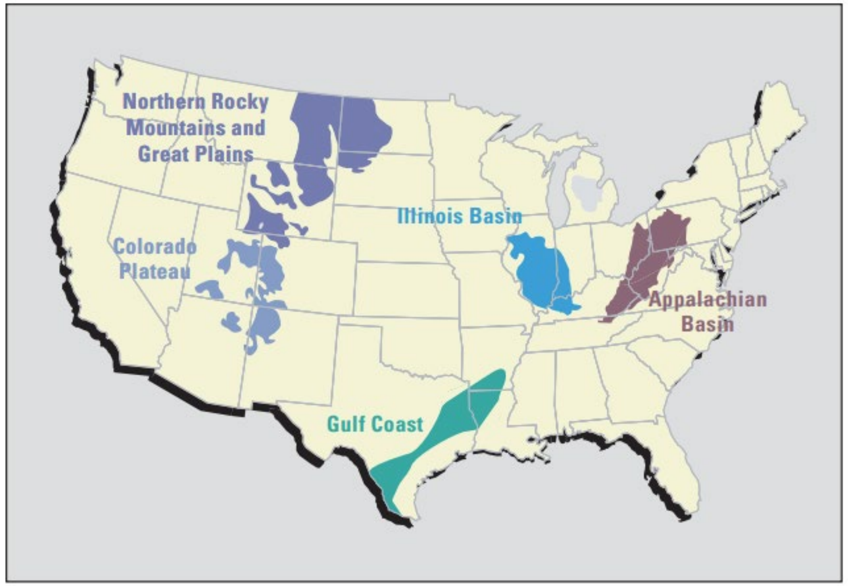
[1]Slippery Rock University, Slippery Rock, USA, iuri.santos@sru.edu, ORCID 0000-0002-4559-0193

[2]West Virginia Water Research Institute, Morgantown, USA

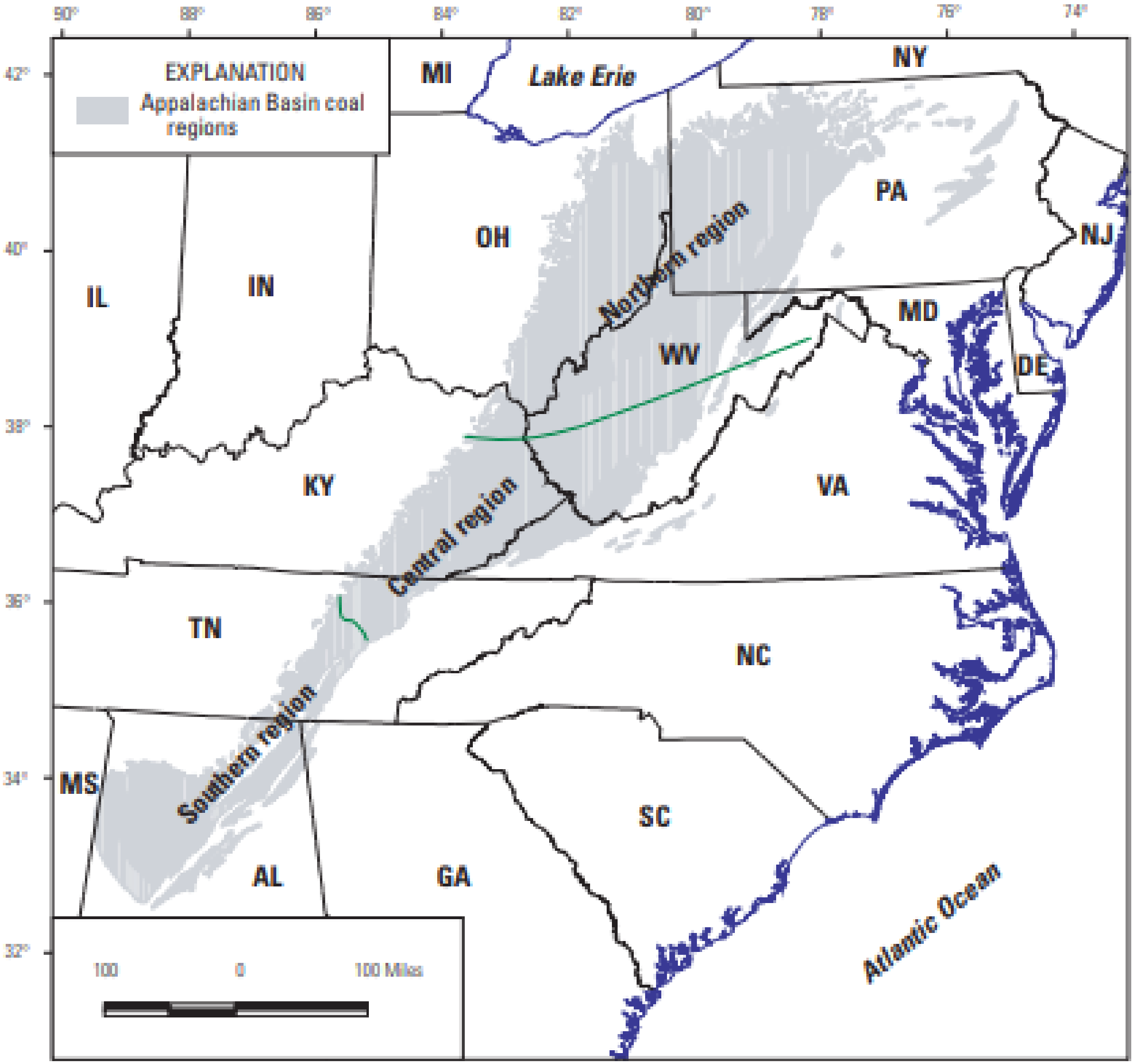
[3]West Virginia University, Morgantown, USA

Background

Coal mining



USGS's 2000 National Coal Resource Assessment.
Ruppert and Rice, 2000.



The Appalachian Basin extends from New York to Alabama. Ruppert and Rice, 2000.

Background

The problem: Acid Mine Drainage (AMD)

$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe_2+ + 4\ SO_4^{2-} + 4\ H^+$
$4\ Fe_2^+ + O_2 + 4\ H^+ \rightarrow 4\ Fe_3^+ + 2\ H_2O$
$4\ Fe^{3+} + 12\ H_2O \rightarrow 4\ Fe(OH)_{3(s)} + 12\ H^+$
$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4{}^{2-} + 16\ H^+$

Background

The opportunity: REE and CM in Acid Mine Drainage (AMD)

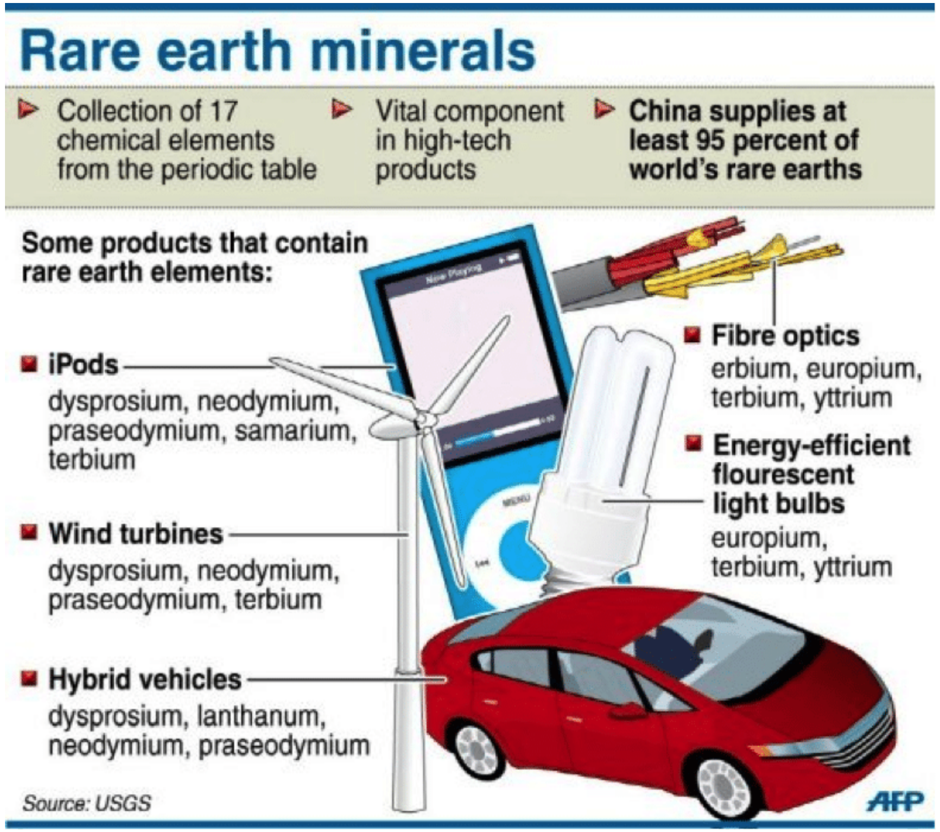
"the REE concentrations of the precipitates varied from 29 to 1,286 ppm with an average of 517 ppm among the sampled sites" Vass et al., 2019a.

Critical minerals (Co, Mn, Ni, and Zn)
REE (Lanthanides, Y, and Sc)

Background

The opportunity: REE and CM in Acid Mine Drainage (AMD)

The use of Rare Earth Elements is broad with applications in technology development such as cell phones, TVs, electric vehicles, clean energy resources like batteries and solar photovoltaic panels, and on defense applications including missile guidance systems, antimissile defense, and communication systems to space [Humphries, 2010; USGS, 2021].



https://jcdream.org/rare-earths-applications/

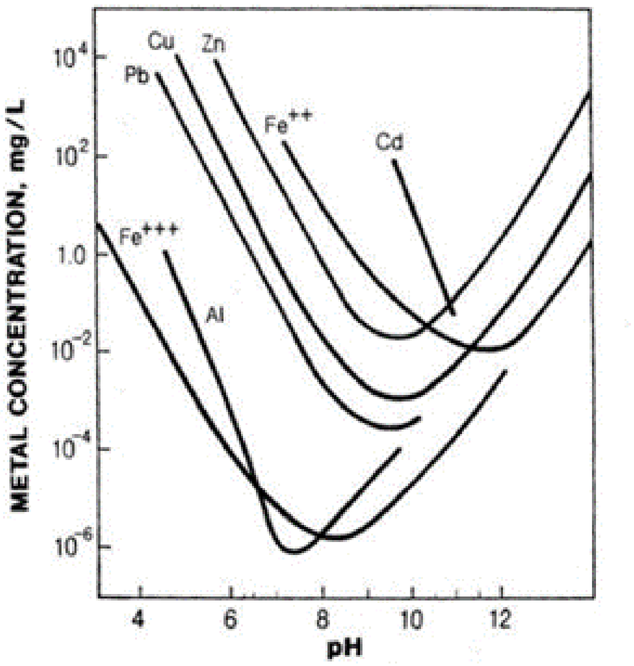
Background

A challenge: Limited Feedstock Supply

“724 g/tonne (precipitate) of REEs” Vass 2019b

Background

Solution: Acid Mine Drainage (AMD) – Selective precipitation

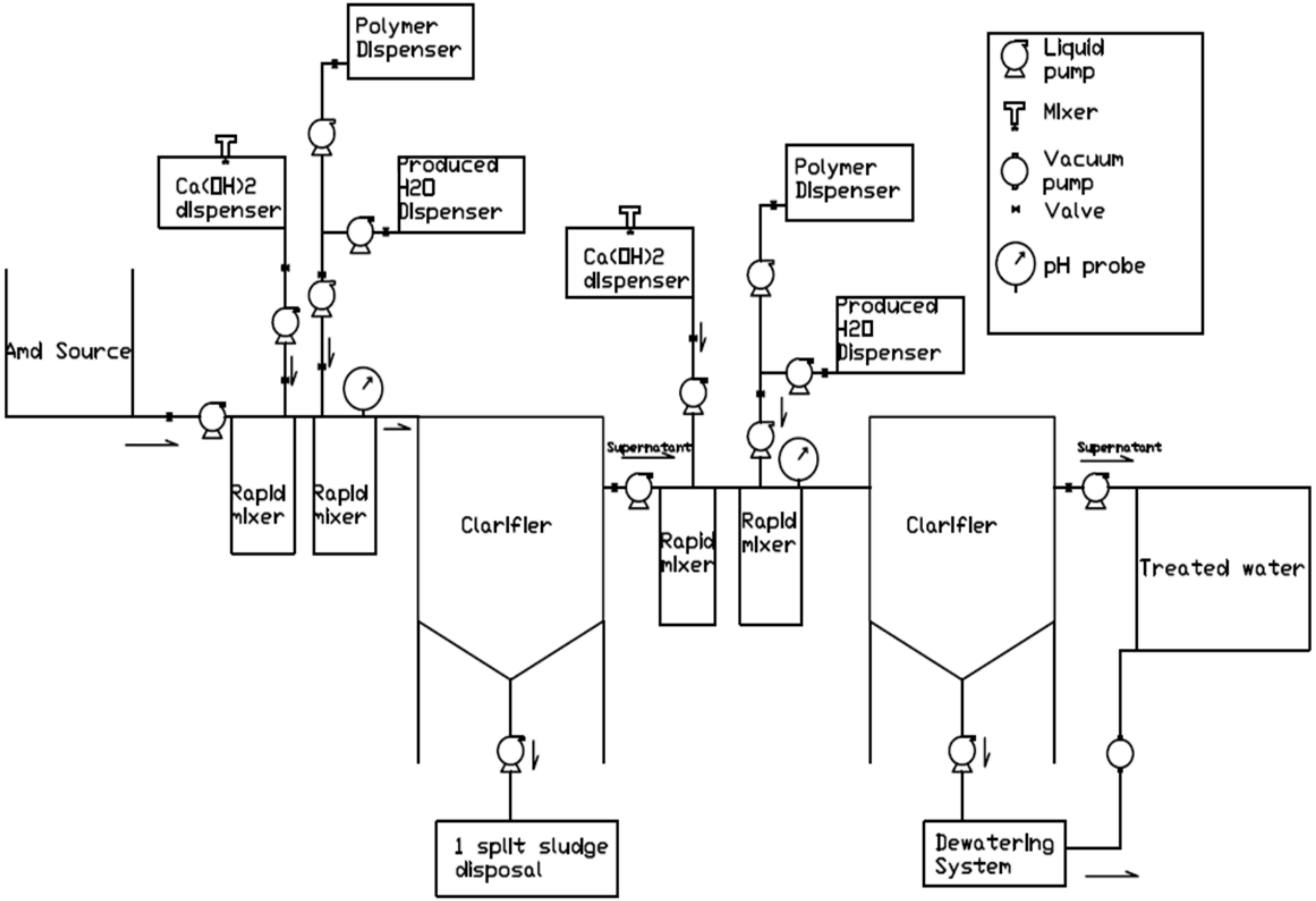


Solubility curve for AMD metals.
Zinck, 2005

pH & Flocculation

The process

Adapted from Ziemkiewicz et al. (2021) U.S. Patent No.: US 10,954,582 B2



Purpose

The approach: Major sites: clarifiers and power;

Remote sites: how to?

Thus, develop a solution for remote sites

- Easy to implement
- Low maintenance

Objectives

- Implement a treatment station on a remote site using the patented process to generate HPC
- Monitor system efficiency based on recovery rates

The site

- Remote (no power)
- Drainage area: 154.8 acres (0.63 km2)
- In-situ flow: >50 GPM (190 L/min), pH ~3.61.
- REE feed: $0.5\ \mathrm{mg/L}$

Treatment results – Raw water characteristics

The total concentration of Rare Earth Elements (REE) for the site measures 0.5 mg/L

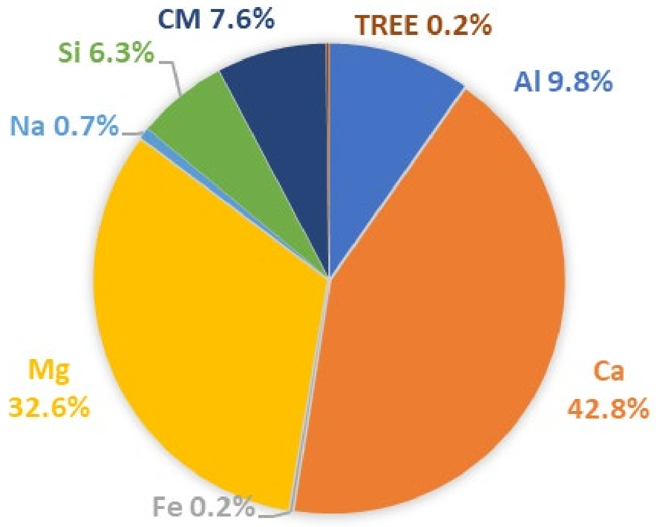


Figure 1 *Metal concentration in AMD feedstock at FOLA Job 5. Critical Materials (CM) account for 7.6% of the total solution concentration while Total Rare Earth Elements (TREE) account for 0.2%. Note this chart only accounts for cationic species.*

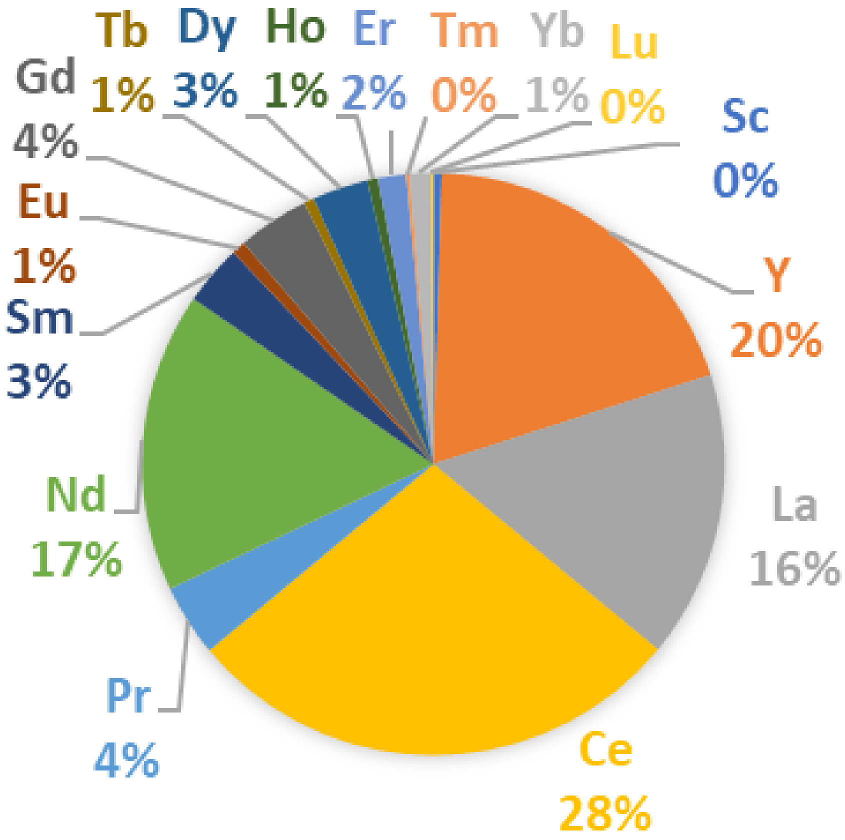
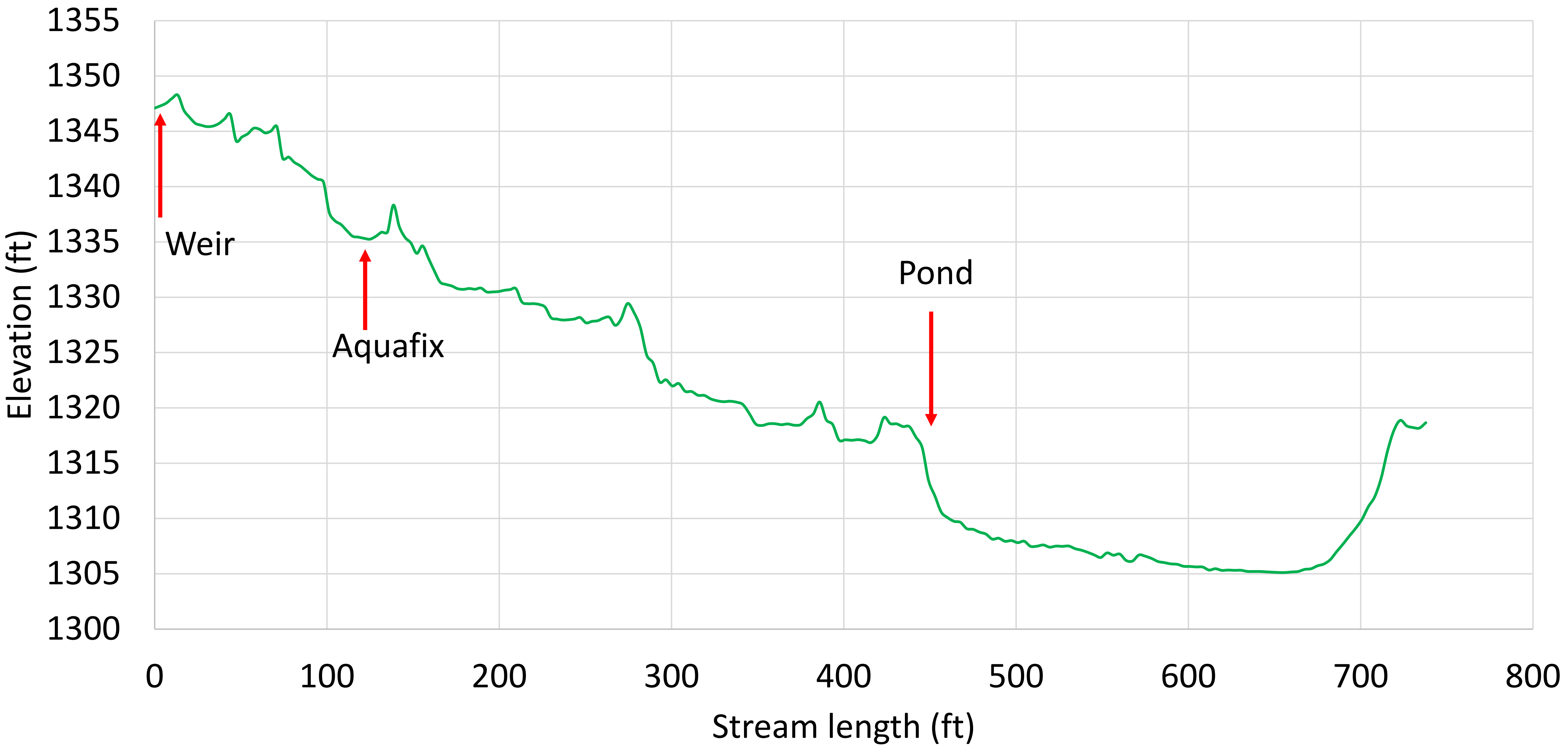


Figure 2 *TREE distribution – Fola Job 5 feedstock*

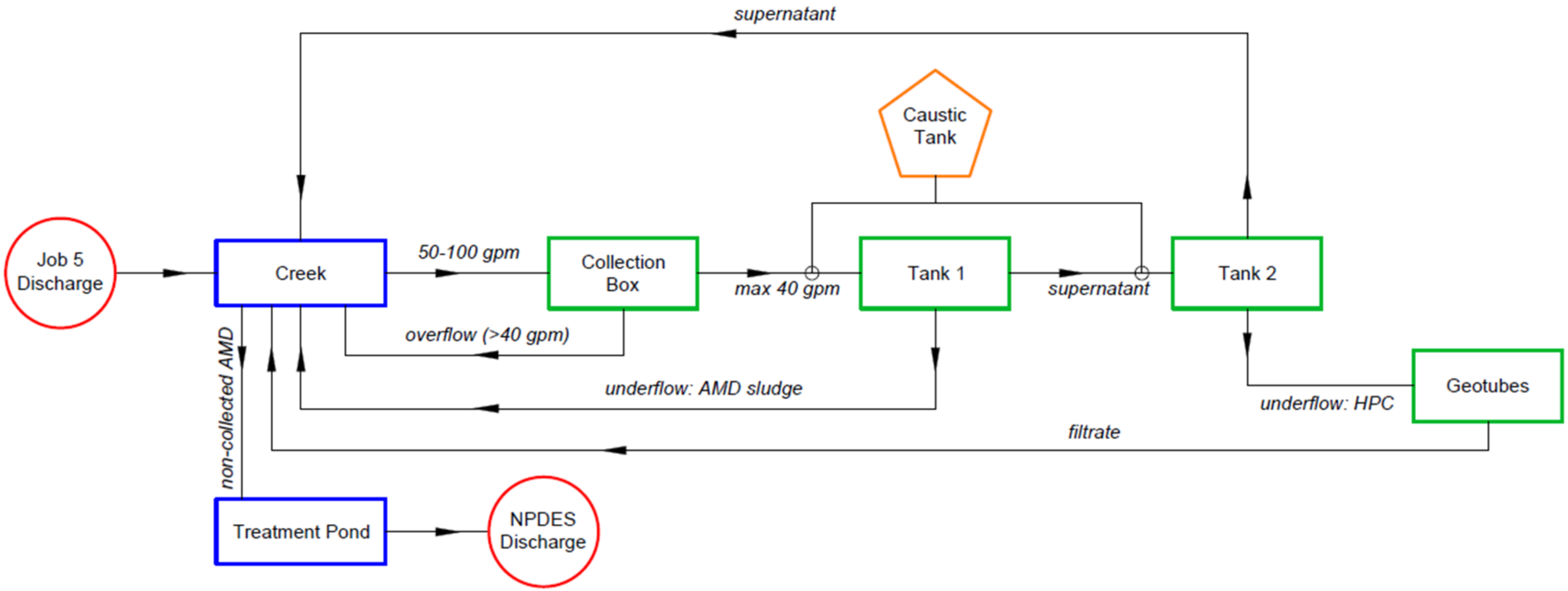
The site

Existing stream profile

Existing Stream Profile



Remote Small-Scale Coal AMD REE/CM Feedstock Production
Fola Process Flow Diagram



Box weir – water collection

Pipe transport

Caustic application system

Caustic tank

Gravity feed caustic control

Caustic pump

Caustic injection

Static mixer

Sample port

Cleanout port

Water treatment – settling tank 1

Water treatment – settling tank 2

Dosing station/flushing valve

Project Performance

Remote Small-Scale Coal AMD REE/CM Feedstock Production

Fola System Photos

Supernatant discharge

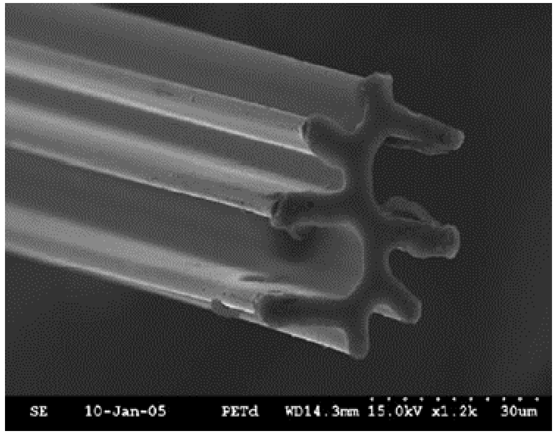
Tank 2 to geotubes

Power/control panel

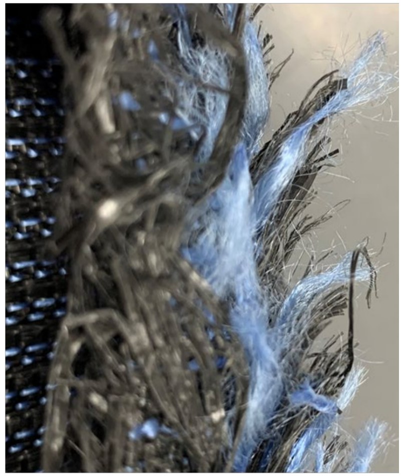
Geotube manifold

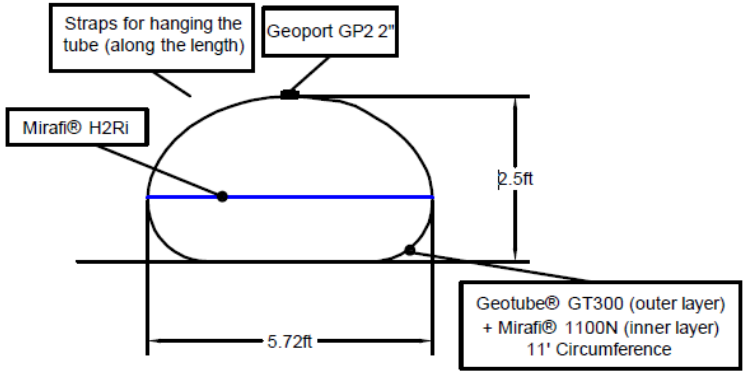
Floc log

Automated valve

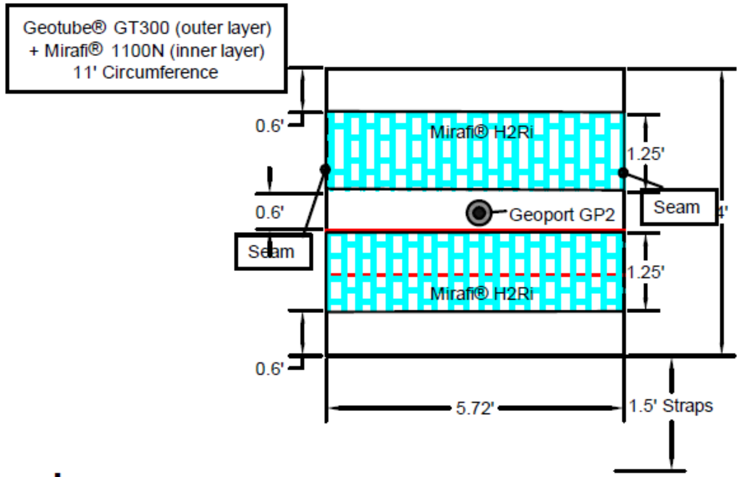


Stanelle et al., 2005.



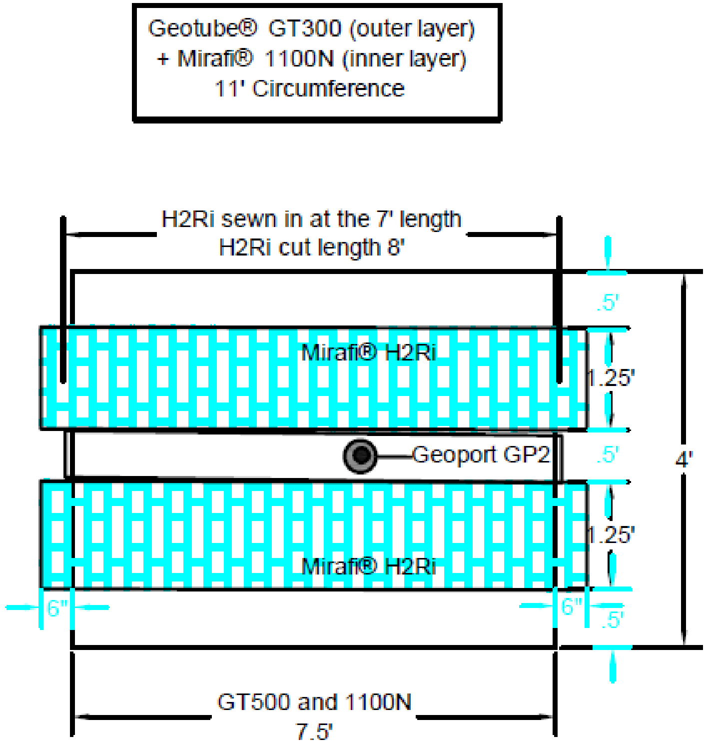


CROSS SECTION

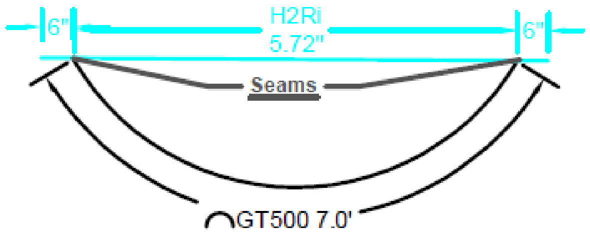


val :

PLAN VIEW



FABRICATION VIEW



Filtration system – Solmax Geotube ® enhanced with capillary channel fibers

After treatment

Element	Concentration per treatment stage: Raw Job 5 AMD mg/L	First Split mg/L	Second Split mg/L	% Recovery to Solid First Split	% Recovery to Solid Second Split
Al	27.3	24.9	1.3	9%	86%
Ca	119.4	110.1	107.5	8%	2%
Co	0.4	0.4	ND	15%	85%
Fe	0.5	0.6	ND	-33%	100%
Mg	91.0	82.4	69.7	9%	14%
Mn	19.2	16.4	5.4	14%	58%
Ni	0.5	0.4	ND	12%	88%
Si	17.5	17.8	ND	-2%	100%
Zn	1.1	1.4	ND	-28%	100%
TMM	276.8	254.3	183.8	8%	25%
Sc	0.00	0.0	0.0	0%	97%
Y	0.10	0.1	0.0	13%	87%
La	0.08	0.1	0.0	18%	81%
Ce	0.15	0.1	0.0	13%	86%
Pr	0.02	0.0	0.0	16%	84%
Nd	0.09	0.1	0.0	14%	86%
Sm	0.02	0.0	ND	14%	86%
Eu	0.00	0.0	ND	16%	84%
Gd	0.02	0.0	ND	15%	85%
Tb	0.00	0.0	ND	16%	84%
Dy	0.02	0.0	0.0	14%	86%
Ho	0.00	0.0	ND	13%	87%
Er	0.01	0.0	0.0	11%	89%
Tm	0.00	0.0	ND	12%	88%
Yb	0.01	0.0	ND	9%	91%
Lu	0.00	0.0	ND	11%	89%
TREE	0.5	0.5	0.0	14%	85%

Conclusions and future work

- A remote site (Fola Job 5) in Clay County, WV was evaluated for REE/CM feedstock, and an AMD treatment system was designed, deployed, and operated. The system utilized selective precipitation to generate REE/CM enriched precipitate (HPC). The following conclusions are made from this project:

•Feedstock investigation demonstrated REE/CM contents at 7.8% of the solution, indicating potential for profitable operation.

Conclusions and future work

- The system was designed, deployed, and operated over an 8-week period, achieving a successful steady-state flow of 40 GPM (151 L/min) with very stable pH control (+/-0.1) on the first split through the operation. A moderately stable (+0.5/-1.5) second pH split was achieved over isolated periods. These operational results indicate that a passive system to generate REE/CM preconcentrate can overcome remote site constraints.
- Analytical Data from the aqueous pH splits indicates an acceptable recovery of TREE to the HPC solid phase.

References

Humphries, M. (2010). Rare Earth Elements: The Global Supply Chain. Congressional Research Service report R41347.

Rupert, L.F., Rice, C.L. 2000. Resource Assessment of selected coal beds and zones in the northern and central Appalachian basin coal regions. U.S. Geological Survey professional paper 1625-C

Stanelle, R., Sander, L., Marcus, R. (2005). Hydrodynamic flow in capillary-channel fiber columns for liquid chromatography. Journal of Chromatography A, 1100: 68-75.

Vass, C.R., Noble, A. and Ziemkiewicz, P.F. 2019a. The occurrence and concentration of rare earth elements in acid mine drainage and treatment by-products: Part 1-Initial survey of the Northern Appalachian Coal Basin. Mining, Metallurgy & Exploration. HTTPS://doi.org/10.1007/s42461-019-0097-z.

Vass, C.R., Noble, A. and Ziemkiewicz, P.F. 2019b. The occurrence and concentration of rare earth elements in acid mine drainage and treatment by-products: Part 2: Regional Survey of Northern and Central Appalachian Coal Basins. Mining, Metallurgy & Exploration. HTTPS://doi.org/10.1007/s42461-019-00112-9.

Zinck, J. (2005). Review of Disposal, Reprocessing, and Reuse Options for Acidic Drainage Treatment Sludge. CANMET Report 04-007 CR prepared for MEND (Report 3.42.3).

Contact

iuri.santos@sru.edu

LinkedIn: Iuri Santos