Revisiting ABA and Calculation Procedures Due to High pH from Alkaline Amendment

Experiences at Leer Mine Refuse Area in Taylor County

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Coarse Refuse Amending – Active Longwall Mine with Slurry Cell Impoundment

- Leer Mine Overview
- AMD and ABA Overview at Coarse Refuse facilities
- Challenges/Successes incurred during Amending Coarse Refuse
    - Increased pH at outlet below coarse refuse facility
    - Methods for testing pyritic sulfur in coarse refuse
- Tracking Amendment of Coarse Refuse Amending at Leer Mine
- How Amending is done while Mine is in Operation
- Forecasting Required Amendment Rates
- Summary/Conclusion

Leer Mine and Impoundment

- Leer Mine
  - Located near Grafton, WV
  - Underground Longwall mine
  - 4MM+ tons per year
  - High Vol-A metallurgical coal
  - 1400 TPH coal preparation facility

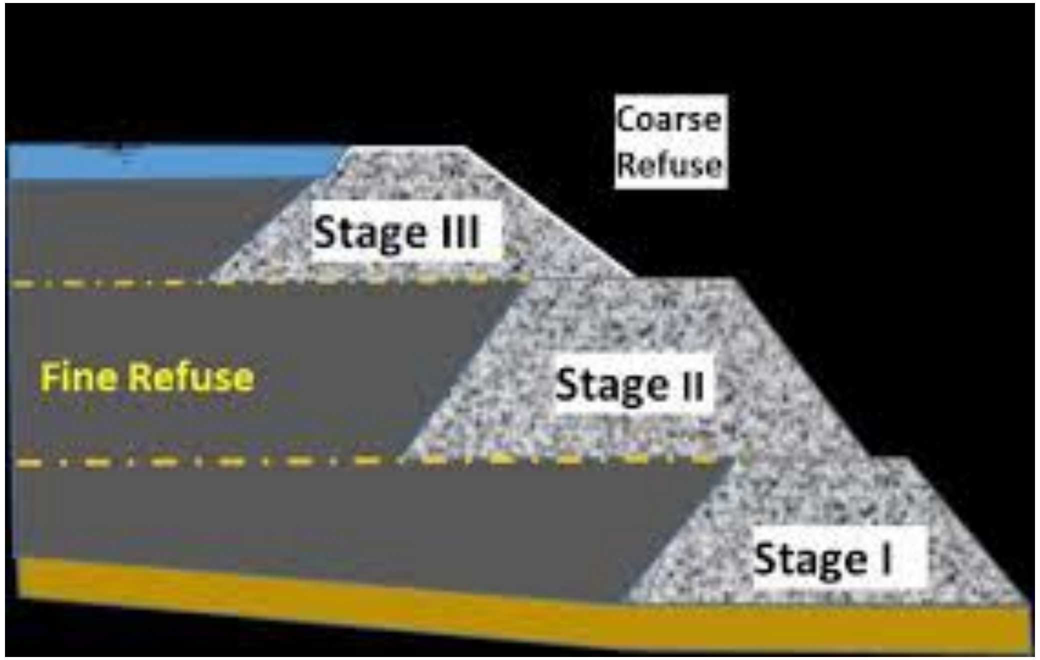
- Leer Impoundment
  - Began placing coarse refuse in 2012
  - Upstream construction Slurry Cell Design
  - Approximately 340 feet from the low point on the crest to the toe of the main embankment.
  - Placed nearly 26m CY of coarse refuse since construction began.

Leer Complex – Taylor County, WV

Conditions Needed for Formation of AMD

This evaluation focuses on Coarse Refuse Embankment construction due to the regulatory limitations placed on those structures:

- Specified lift thickness, ranging from 1 to 2 feet, reducing voids and allowing air and water infiltration.
- Compaction requirements, typically 95% Standard Proctor Density, further reducing void for air and water entrapment.
- Alkaline Amendment Requirements to Neutralize Potential Acid Production.
- Requirements to minimize pooled water in the embankment construction area.



Challenges and Successes of Amending at Leer

- Elevated pH at downstream Outlet
  - At Outlet 006 (downstream of coarse refuse facility), the median pH increased to 8.08 S.U.
  - The higher pH was managed using acetic acid to lower the pH when necessary to comply with effluent limitations, as aluminum can resolubilize at elevated pH.
  - In addition, the use of limestone sand increases the hardness and conductivity of the effluent.
  - Prior to 2016, alkaline amendment rates at the facility ranged from 5-7%.
- Methods for testing pyritic sulfur in coarse refuse:
  - These concerns led to a more in-depth review of the Acid- Base Accounting techniques, laboratory practices, and operating practices.

Conditions Needed for Formation of Acid Mine Drainage (AMD)

Three factors are needed for formation of AMD:

- Pyritic Sulfur
- Water and
- Oxygen

Normal Formation of AMD

$$FeS_2 + {}^{7}/_{2}\,O_2 + H_2O \longrightarrow Fe^{+2} + 2SO4^{-2} + 2H^{+}$$

(pyrite)

$$4Fe^{+2} + O_2 + 4H^{+} \longrightarrow 4Fe^{+3} + 2H_2O$$

$$Fe^{+3} + 3H_2O \longrightarrow Fe(OH)_{3(s)} + 3H^{+}$$

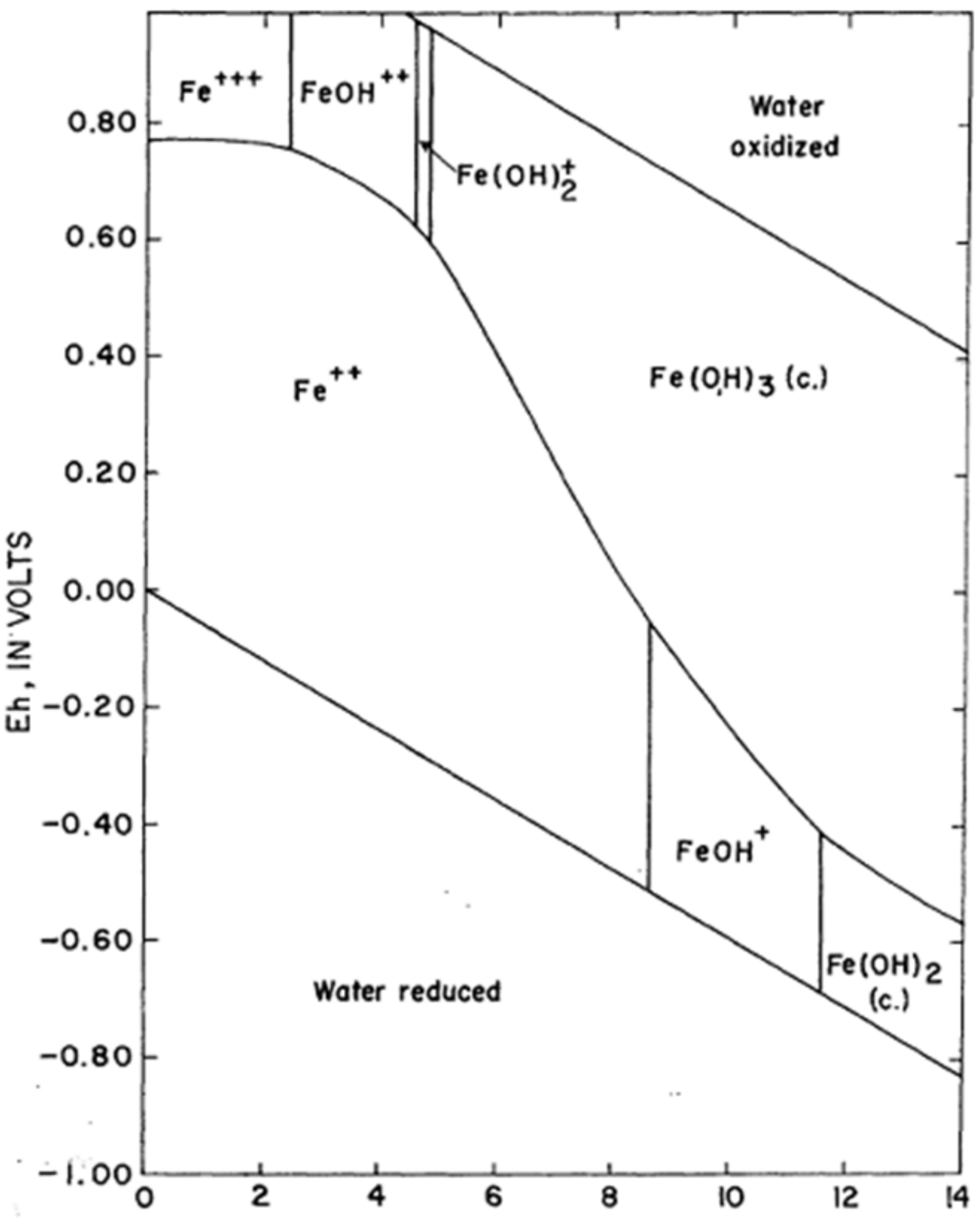
(yellow boy)

$$FeS_2 + 14Fe^{+3} + 8H_2O \longrightarrow 15Fe^{+2} + 2SO4^{-2} + 16H^{+}$$

Elimination or reduction of one of these factors reduces the potential for the creation of Acid Mine Drainage.

Too much of a good thing?

- If pH becomes too high, this expected chemistry may not occur, especially in a low eH environment.
- We would expect reducing conditions in places with limited air supplies, such as within a fill. This is evident in the solubility curve for iron.



Typically Accepted WVDEP Formula For Determining Alkaline Amendment Rates

The amendment rate will be calculated in accordance with the procedure described in the paper entitled “Amending Coal Refuse with Alkaline Materials” presented by WVDEP geologist George Jenkins at the 1999 West Virginia Acid Mine Drainage Task Force Symposium in Morgantown, West Virginia:

$$\text{Amendment \% by weight} = \frac{\text{\% Pyritic Sulfur} \times 3.125 \times 0.75}{\text{\% } CaCO_3 \text{ equivalent of amending material}}$$

- Amendment is applied at a higher rate (factor of 1.1 rather than 0.75) within the zone from original ground to 20’vertically above the main underdrain in Stage 2A.
- Preparation of a sample for ABA testing **requires that materials being analyzed be crushed to pass a 0.25 mm (60 mesh or 0.1 in.) sieve. The actual size of refuse ranges up to 6”,** so the test procedure will always expose much more pyrites than will occur in reality.

Why Acid Base Accounting?

The objectives of Acid-Base Accounting are to provide a simple, relatively inexpensive, and consistent procedure for:

1. Identifying toxic or potentially acid-producing materials;
2. Identifying non-acid or calcareous materials that can be mixed with acid-producing material to neutralize the acid, and
3. Identifying an alternative material in the overburden for placement on the surface for revegetation

ASTM 2492
Standard Test Method for Forms of Sulfur in Coal

The procedure specifies two different methods for determining the pyritic sulfur in a sample:

Method 1 - (Quickie Method) Sample is mixed with nitric acid and brought to a boil for 15 minutes.

Method 2 - Sample is mixed with water and allowed to digest overnight for a period of 16 hours

This test method applies to the determination of sulfate sulfur and pyritic sulfur in coal and calculates organic sulfur by difference. This test method is not applicable to coke or other carbonaceous materials.

Which method best represents actual condition in the environment?

- Method 1 is easier on the labs. However, it tends to over report pyritic sulfur concentrations significantly.
- This is important because in the ABA process, the maximum needed to neutralize the acid from pyrite is calculated by the **% Pyrite times 31.25 tons/1000 Tons of material**

2016 Study of ABA Sulfur Extraction Methods

Method 1: Quickie Sulfur Fractionation

Method 2: Overnight/16 Hour Digestion Sulfur Fractionation

Daily Pyritic Sulfur Quickie Method		
% Pyritic Sulfur	% Total Sulfur	Pyritic as % of Total
3.49	4.47	78.1%
2.26	2.55	88.7%
2.51	3.01	83.3%
1.39	1.81	76.9%
2.46	2.72	90.5%
1.75	1.83	95.8%
1.72	1.97	87.1%
1.33	1.47	90.5%
3.23	3.45	93.6%
1.61	1.97	81.7%
1.95	2.31	84.4%
1.16	1.43	81.1%
2.07	2.42	85.98%

ASTM Pyritic Sulfur Method		
% Pyritic Sulfur	% Total Sulfur	Pyritic as % of Total
1.56	4.47	34.9%
1.02	2.55	40.1%
1.35	3.01	44.8%
0.78	1.81	43.2%
2.64	2.72	97.2%
1.83	1.83	99.7%
1.62	1.97	82.1%
1.27	1.47	86.4%
1.97	3.45	57.1%
0.92	1.97	46.8%
1.28	2.31	55.4%
0.56	1.43	38.9%
1.40	2.42	60.54%

Tracking Amending Rates

- Raw samples of coarse refuse are collected for a range of parameters.
- Data is combined with CCE analysis provided by lime supplier.
  - Typical CCE ranges between 80-85.
- Post-amendment samples are collected and tested as well; this provides a snapshot of ABA analysis.
- Monthly reports are submitted to WVDEP.

Sample ID	% MOISTURE		FIZZ	COLOR	% TOTAL SULFUR	(MAX) POTIENTIAL ACIDITY	Neutralization Potential	MAX CCE NEEDED TO pH 7	Excess CCE	Paste pH
A	5.23		1	2.5Y 3/1	2.01	62.81	22.98	39.83		8.6
B	3.92		1	2.5Y 3/1	1.66	51.88	20.65	31.23		8.8
C	5.10		1	2.5Y 3/1	1.73	54.06	21.70	32.36		8.7
AVERAGE	4.75		1	2.5Y 3/1	1.80	56.25	21.78	34.47		8.7

	% MOISTURE		FIZZ	COLOR	% PYRITIC SULFUR	(MIN) POTIENTIAL ACIDITY	Neutralization Potential	MAX CCE NEEDED TO pH 7	Excess CCE	Paste pH
A	5.23		1	2.5Y 3/1	1.33	41.56	22.98	18.58		8.6
B	3.92		1	2.5Y 3/1	.908	28.38	20.65	7.73		8.8
C	5.10		1	2.5Y 3/1	1.01	31.56	21.70	9.86		8.7
AVERAGE	4.75		1	2.5Y 3/1	1.08	33.83	21.78	12.06		8.7

Sieve/Test	Tests	Average	Min	Max	Range	St Dev
CaCO3	21	80.25	78.12	82.49	4.37	1.210
CCE	21	84.52	82.97	86.23	3.26	0.891
MgCO3	21	3.58	2.98	4.71	1.73	0.442
Total Moisture	20	1.61	1.14	2.28	1.14	0.349

Coarse Amending Process

Coarse Amending Process

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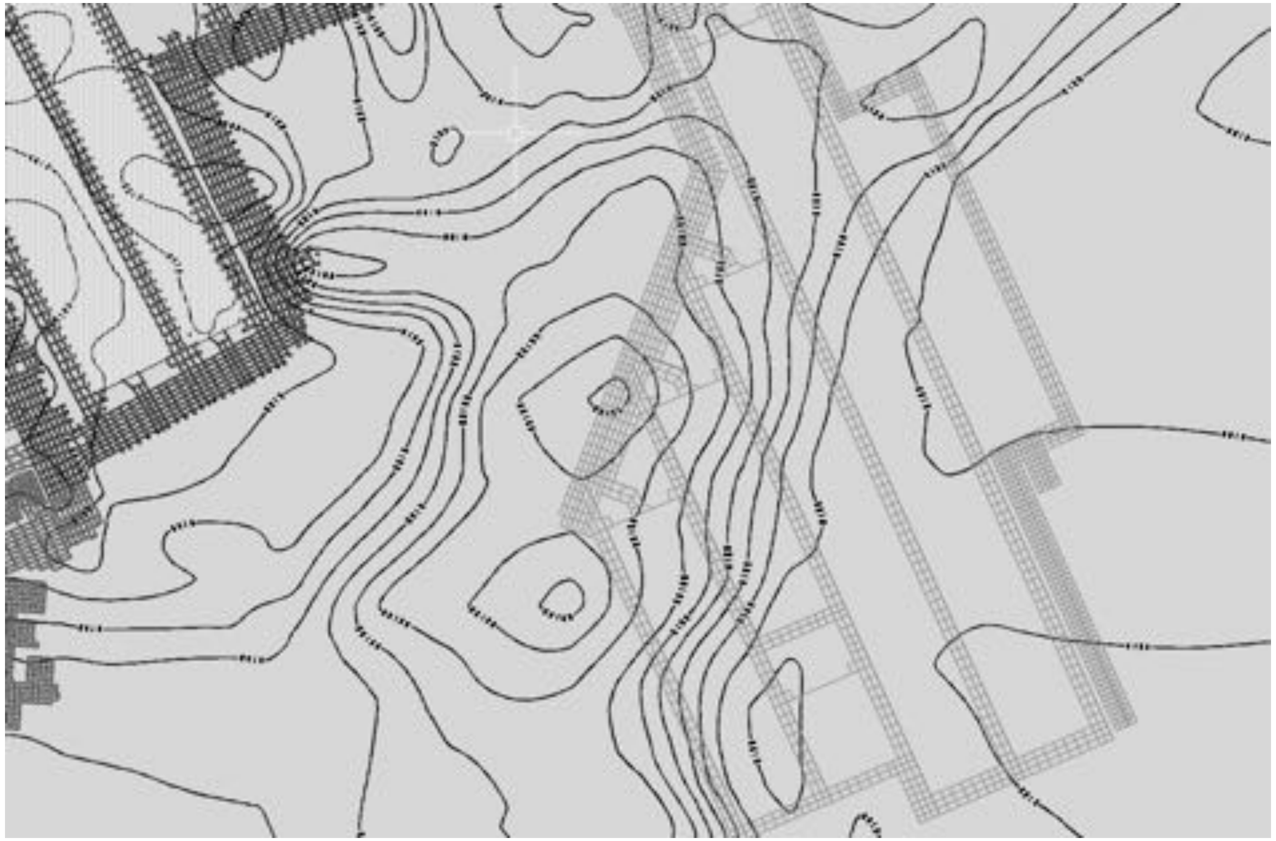
Forecasting Amending Rates

- Forecast grids have been developed to identify the amending requirements of future panels.
- Using a formula based on a recovery grid at 1.6 SG float, % pyritic of the refuse can be estimated.
- Forecasting is used to identify ramp-ups in amendment rates to ensure neutralization, as well as budget requirements.



Conclusion and Looking Forward

Leer has continued incorporating lime to neutralize AMD since slurry cell construction commenced in 2012.

- Continuing to look for ways to optimize amending to neutralize AMD within the slurry cell.
- Further analysis of proposed mining areas to identify elevated areas of pyritic sulfur.