Rare earth elements (REE) in West Virginia coal mine drainage; an analysis of CMD discharges from various coal seams

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Maiden Mine Discharge into Robinson Run in Monongalia Co, WV (E. Siefert, WVWRI)



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Background

Coal mine drainage in WV

- Pyrite oxidizes to form sulfuric acid, releases metals
- AML's are government responsibility to treat
- There are over 12,000 miles of streams and rivers affected by CMD in the United States
 - 2,500 stream mi impacted by CMD in WV

AML – abandoned mine lands (prior to 1977) CMD – coal mine drainage



AML discharge into Glade Run in Grant Co, WV (M. Shafer, WVWRI)



Rare earth elements

- 17 elements considered rare earth elements (REE)
- Currently, most of world's REE are mined in China
- WVWRI found that REEs exist in raw CMD in all sites sampled (>300)
- In WV, those who treat CMD get the economic benefit of any byproducts
 - HB 4003



Obtained from sciencenotes.org

Sample Distribution

		Major Coal Beds		
	Dunkard	Washington		
ian	Group	Waynesburg		
		Uniontown		
an		Sewickley		
<u>ک</u>	Monongahela	Redstone		
ns	Group	Pittsburgh		Pittsburgh
en		Little Pittsburgh		0
r P		Elk Lick		• Elk Lick
be	Conemaugh	Harlem		
d	Outcindugii	Bakerstown		Bakerstown
	Group	Brush Creek		
		Mahoning		
		Upper Freeport		Upper Freeport
		Upper Kittanning		
	Allegheny	Middle Kittanning		Middle Kittanning
	Group	Lower Kittanning (No. 6 block)		l ower Kittanning
	oroup	No 5 Block	,	
		Stockton		
		Coalburg		
		Winifrede		
an		Clinton		
ni		Fire Clay		
lva		Cedar Grove		
syl		Williamson		
u u		Peerless		
Pe	Kanawika	No 2 Gas		
e		Powellton		
pp	Kanawna	Eagle		
Ξ	Formation	Little Eagle		
		Matewan		
		Upper War Eagle		
		Ben's Creek		
		Lower War Eagle		
		Glenalum Tunnel		
		Gilbert		
		Douglas		
		l ower Douglas		

221 CMD Locations Sampled Since 2021

Locations relative to AMLs





Pittsburgh Coal

oper ylvanian	Dunkard Group	
	Monongahela Group	<
Denns	Conemaugh Group	
E	Allegheny Group	
Middle Pennsylvanian	Kanawha Formation	
ennsylvanian	New River Formation	
Lower P	Pocahontas Formation	

Pittsburgh Coal



TREE Concentrations in CMD associated with Pittsburgh coal



Pittsburgh Coal

Locations	# of sites	32
	# of samples	101
рН	Range	2.2-8.1
	Average	3.3
Total REE	Range	4-1754
(ug/L)	Average	319

- Lowest TREE concentrations variable between watersheds
- Highest TREE concentrations into Cheat River and Monongahela River



Surface mine discharge into Crafts Run in Monongalia Co, WV (E. Siefert, WVWRI)

Elk Lick Coal

an	Dunkard Group	
lpper sylvani	Monongahela Group	
Denns	Conemaugh Group	
2	Allegheny Group	
Middle Pennsylvania	Kanawha Formation	
ennsylvanian	New River Formation	
Lower P	Pocahontas Formation	

Elk Lick Coal



TREE Concentrations in CMD associated with Elk Lick coal



Elk Lick Coal

Locations	# of sites	3
	# of samples	4
рН	Range	2.7-3.4
	Average	3.2
Total REE	Range	16-107
(ug/L)	Average	66

- Abram Creek of North Branch of Potomac
- Lowest TREE from AML into Emory Creek
- Highest TREE from AML into Glade Run during low flow



Surface mine discharge into Little Creek in Grant Co, WV (E. Siefert, WVWRI)

Bakerstown Coal

an	Dunkard Group	
pper ylvani	Monongahela Group	
U Penns	Conemaugh Group	
	Allegheny Group	
Middle Pennsylvanian	Kanawha Formation	
ennsylvanian	New River Formation	
Lower Po	Pocahontas Formation	

Bakerstown Coal



TREE Concentrations in CMD associated with Bakerstown coal



Bakerstown Coal

Locations	# of sites	8
	# of samples	8
рН	Range	3.0-6.7
	Average	4.1
Total REE	Range	20-193
(ug/L)	Average	76

- Lowest TREE was pH 6.68
- Highest TREE into OSR treatment with pH 4.4



Discharge into FOC treatment system in Preston Co, WV (G. Richardson, FOC)

Upper Freeport Coal

an	Dunkard Group	
pper ylvani	Monongahela Group	
n Denns	Conemaugh Group	
u	Allegheny Group	
Middle Pennsylvania	Kanawha Formation	
ennsylvanian	New River Formation	
Lower P	Pocahontas Formation	

Upper Freeport Coal



TREE Concentrations in CMD associated with Upper Freeport coal

Upper Freeport Coal

Locations	# of sites	139
	# of samples	230
рН	Range	2.2 - 7.1
	Average	3.3
Total REE	Range	0.1 - 1289
(ug/L)	Average	217

- Lowest TREE concentrations variable among watersheds
- Highest TREE concentrations into Cheat River



AML discharge into Lick Run in Preston Co, WV (M. Shafer, WVWRI)

Middle Kittanning Coal

an	Dunkard Group	
pper ylvani	Monongahela Group	
Denns	Conemaugh Group	
и	Allegheny Group	
Middle Pennsylvania	Kanawha Formation	
ennsylvanian	New River Formation	
Lower P	Pocahontas Formation	

Middle Kittanning Coal



Middle Kittanning Coal

Locations	# of sites	29
	# of samples	33
рН	Range	2.8-6.6
	Average	3.8
Total REE	Range	0.01-454
(ug/L)	Average	70



Discharge from Kittle Flats in Randolph Co, WV (R. Spirnak, WVWRI)

- Lowest TREE in Roaring Creek with pH >3.6
- Highest TREE in Kittle Flats (Cassity Fork) with pH < 2.9

Lower Kittanning Coal

an	Dunkard Group	
Upper Pennsylvani	Monongahela Group	
	Conemaugh Group	
u	Allegheny Group	
Middle Pennsylvania	Kanawha Formation	
ennsylvanian	New River Formation	
Lower P	Pocahontas Formation	

Lower Kittanning Coal



TREE Concentrations in CMD associated with Lower Kittanning





Lower Kittanning Coal

Locations	# of sites	10
	# of samples	11
рН	Range	2.7-5.6
	Average	3.6
Total REE (ug/L)	Range	7-388
	Average	148

- Samples from OSR site tying into active treatment
- No major differences between samples with varying concentrations



OSR treatment system influent CMD in Upshur Co, WV (R. Spirnak, WVWRI)

Summary

Pittsburgh and Upper Freeport coal mines released the most TREEs, respectively



The Middle Kittanning, Elk Lick, Bakerstown, and Lower Kittanning coal mines released the least TREEs, respectively



In general, low pH CMD contain higher TREE concentrations



Conclusions

- CMD associated with Pittsburgh coal mining had highest recorded TREE concentration
 - Overall highest concentrations
- Middle Kittanning coal had lowest recorded TREE (of the formations included)
- Low pH CMDs had highest TREE across all associated coals

Going Forward

- Continue monthly trace and major metal sampling at select sites
- Watershed scale restoration efforts
- Comparison with other published CMD REE data
 - ex: Cravotta, 2008 (Parts 1 and 2)
- Evaluate data for DIC, NPOC, CO₂ analysis



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