

AMD and REE: Watershed Scale Restoration

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AMD and REE



Atomic Number → 1

Symbol ← H

Name → Hydrogen

Atomic Weight ← 1.008

REE's

What are the 17 elements of rare earth?

The rare earth metals are a group of 17 elements - lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, yttrium - that appear in small concentrations in the ground.

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Periodic Table of the Elements

1 IA H Hydrogen 1.008																	13 IIIA B Boron 10.81	14 IVA C Carbon 12.011	15 VA N Nitrogen 14.007	16 VIA O Oxygen 15.999	17 VIIA F Fluorine 18.998	18 VIIIA Ne Neon 20.180																																																																																																													
2 IIA Li Lithium 6.941	3 IIIA Be Beryllium 9.012																	5 IIIA Al Aluminium 26.9815385	6 IVA Si Silicon 28.085	7 VA P Phosphorus 30.973761998	8 VIA S Sulfur 32.06	9 VIIA Cl Chlorine 35.45	10 VIIIA Ar Argon 39.948																																																																																																												
4 IIA Na Sodium 22.98976928	5 IIIA Mg Magnesium 24.305	6 VIB Cr Chromium 51.9961	7 VIIB Mn Manganese 54.938044	8 VIIB Fe Iron 55.845	9 VIIB Co Cobalt 58.933194	10 VIIB Ni Nickel 58.6934	11 IB Cu Copper 63.546	12 IIB Zn Zinc 65.38	13 IIIA Ga Gallium 69.723	14 IVA Ge Germanium 72.630	15 VA As Arsenic 74.921595	16 VIA Se Selenium 78.971	17 VIIA Br Bromine 79.904	18 VIIIA Kr Krypton 83.798	19 IIA K Potassium 39.0983	20 IIA Ca Calcium 40.078	21 IIIB Sc Scandium 44.955908	22 IIIB Ti Titanium 47.88	23 IIIB V Vanadium 50.9415	24 IIIB Cr Chromium 51.9961	25 IIIB Mn Manganese 54.938044	26 IIIB Fe Iron 55.845	27 IIIB Co Cobalt 58.933194	28 IIIB Ni Nickel 58.6934	29 IIIB Cu Copper 63.546	30 IIIB Zn Zinc 65.38	31 IIIB Ga Gallium 69.723	32 IIIB Ge Germanium 72.630	33 IIIB As Arsenic 74.921595	34 IIIB Se Selenium 78.971	35 IIIB Br Bromine 79.904	36 IIIB Kr Krypton 83.798	37 IA Rb Rubidium 85.4678	38 IIA Sr Strontium 87.62	39 IIIB Y Yttrium 88.90584	40 IIIB Zr Zirconium 91.224	41 IIIB Nb Niobium 92.90638	42 IIIB Mo Molybdenum 95.94	43 IIIB Tc Technetium 98.9062	44 IIIB Ru Ruthenium 101.07	45 IIIB Rh Rhodium 102.90550	46 IIIB Pd Palladium 106.42	47 IIIB Ag Silver 107.8682	48 IIIB Cd Cadmium 112.414	49 IIIB In Indium 114.818	50 IIIB Sn Tin 118.710	51 IIIB Sb Antimony 121.760	52 IIIB Te Tellurium 127.60	53 IIIB I Iodine 126.90547	54 IIIB Xe Xenon 131.29																																																																																	
55 IA Cs Caesium 132.90545196	56 IIA Ba Barium 137.327	57 IIIB La Lanthanum 138.90547	58 IIIB Ce Cerium 140.116	59 IIIB Pr Praseodymium 140.90766	60 IIIB Nd Neodymium 144.242	61 IIIB Pm Promethium 145	62 IIIB Sm Samarium 150.36	63 IIIB Eu Europium 151.964	64 IIIB Gd Gadolinium 157.25	65 IIIB Tb Terbium 158.92535	66 IIIB Dy Dysprosium 162.500	67 IIIB Ho Holmium 164.93033	68 IIIB Er Erbium 167.259	69 IIIB Tm Thulium 168.93422	70 IIIB Yb Ytterbium 173.045	71 IIIB Lu Lutetium 174.967	72 IIIB Hf Hafnium 178.49	73 IIIB Ta Tantalum 180.94788	74 IIIB W Tungsten 183.84	75 IIIB Re Rhenium 186.207	76 IIIB Os Osmium 190.23	77 IIIB Ir Iridium 192.222	78 IIIB Pt Platinum 195.084	79 IIIB Au Gold 196.966569	80 IIIB Hg Mercury 200.592	81 IIIB Tl Thallium 204.38	82 IIIB Pb Lead 207.2	83 IIIB Bi Bismuth 208.98040	84 IIIB Po Polonium (209)	85 IIIB At Astatine (210)	86 IIIB Rn Radon (222)	87 IA Fr Francium (223)	88 IIA Ra Radium (226)	89 IIIB Ac Actinium (227)	90 IIIB Th Thorium 232.0377	91 IIIB Pa Protactinium 231.03588	92 IIIB U Uranium 238.02891	93 IIIB Np Neptunium (237)	94 IIIB Pu Plutonium (244)	95 IIIB Am Americium (243)	96 IIIB Cm Curium (247)	97 IIIB Bk Berkelium (247)	98 IIIB Cf Californium (251)	99 IIIB Es Einsteinium (252)	100 IIIB Fm Fermium (257)	101 IIIB Md Mendelevium (258)	102 IIIB No Nobelium (259)	103 IIIB Lr Lawrencium (260)	104 IIIB Rf Rutherfordium (261)	105 IIIB Db Dubnium (262)	106 IIIB Sg Seaborgium (266)	107 IIIB Bh Bohrium (264)	108 IIIB Hs Hassium (277)	109 IIIB Mt Meitnerium (276)	110 IIIB Ds Darmstadtium (281)	111 IIIB Rg Roentgenium (282)	112 IIIB Cn Copernicium (285)	113 IIIB Nh Nihonium (286)	114 IIIB Fl Flerovium (289)	115 IIIB Mc Moscovium (289)	116 IIIB Lv Livermorium (293)	117 IIIB Ts Tennessine (294)	118 IIIB Og Oganesson (294)																																																																				
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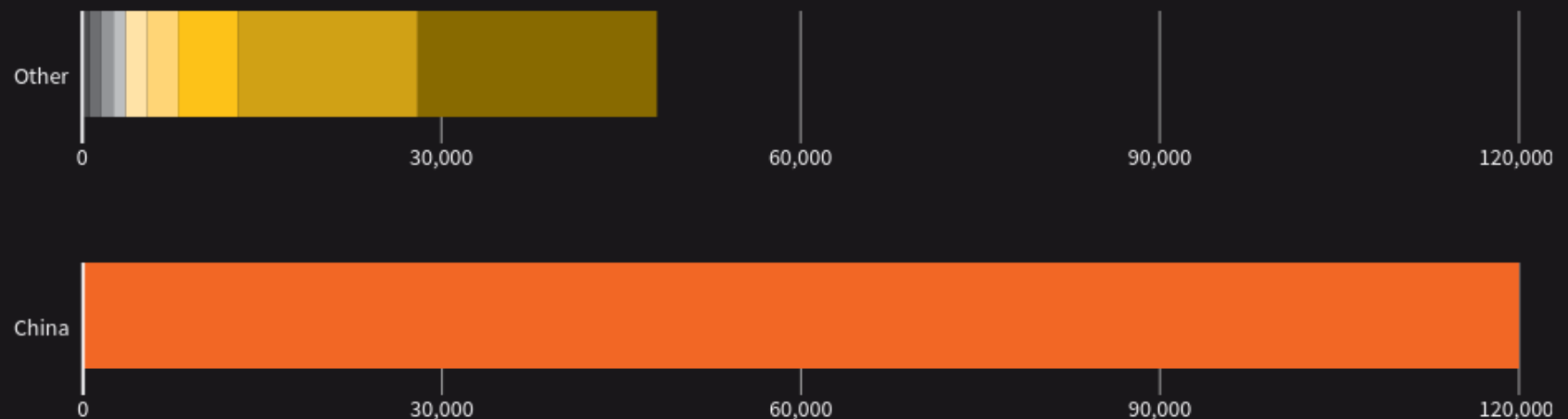
Rare earth production

China accounts for around 80% of U.S. rare earths supply, materials used in many high-tech goods, ranging from consumer items like electric cars all the way to cutting-edge weapons and communications systems.

MINE PRODUCTION IN 2018

In tons

■ Malaysia ■ Vietnam ■ Burundi ■ Thailand ■ Brazil ■ India ■ Russia ■ Burma ■ US ■ Australia



Source: U.S. Geological Survey
Christian Inton | REUTERS GRAPHICS

How do REE/CM's Relate to WV Watersheds-First a look at WV watersheds

7 Major basins within West Virginia

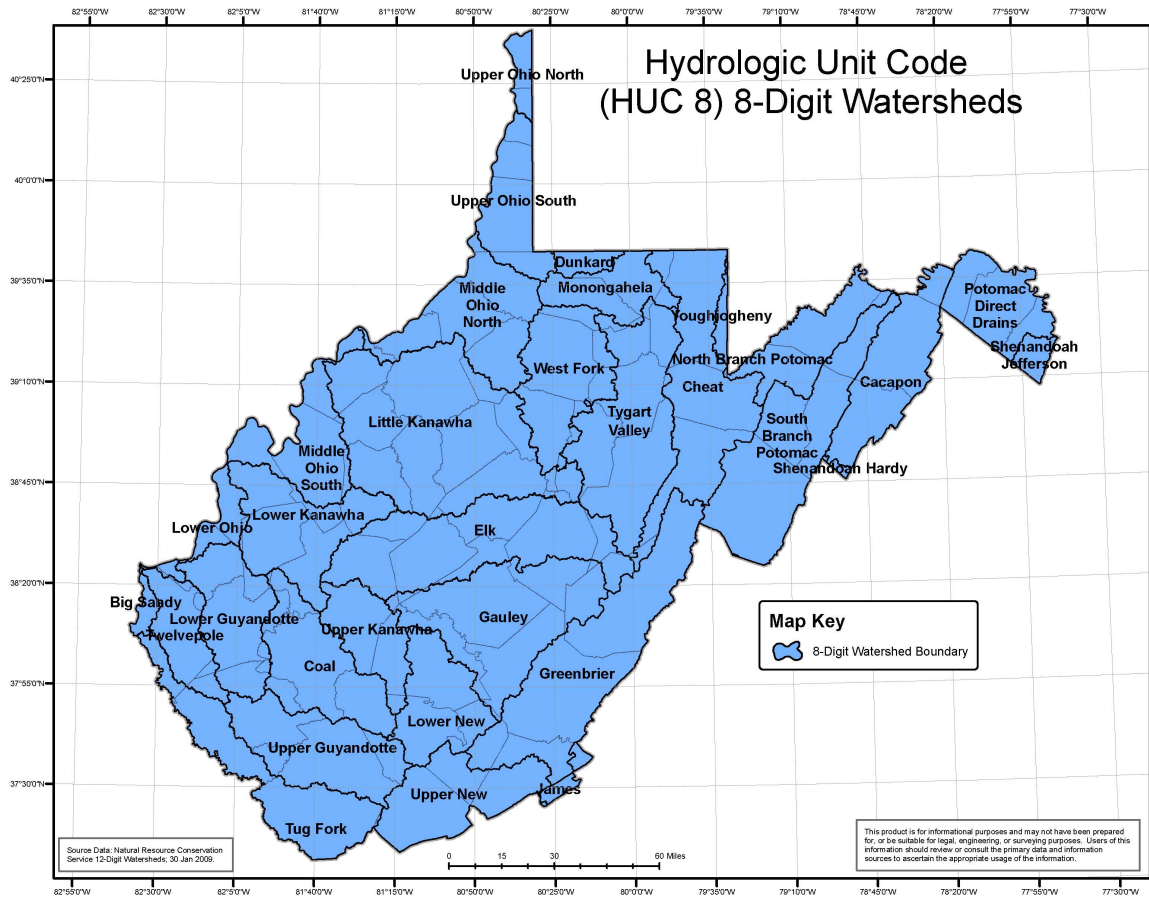
32 watersheds divided according to hydrologic unit codes (HUC-8) that contribute to the Chesapeake Bay and the Gulf of Mexico

The waters west of the eastern continental divide flow into the Ohio River

The eastern continental divide also changes the course of five of our eastern rivers towards the Potomac River

A few streams in the southeastern corner of the state flow towards the James River

Multiple smaller subbasins within WV have severe degradation due to AMD (HUC 10,12,14)



- WV HUC 8 Watersheds

National Mine Land Reclamation Center

Objectives

In 1988 Congress recognized the need for an organization to specifically address the outstanding reclamation problems and authorized formation of the National Mine Land Reclamation Center (NMLRC).

The NMLRC has become an internationally-recognized leader in the area of acid mine drainage (AMD). Among technologies initiated, refined or demonstrated by the NMLRC, the following are now in practice within the industry, state and federal agencies:

- Alkaline amendment *Quantitative AMD prediction method
- Pneumatic and slurry placement of alkaline coal ash in underground mines
 - Selective spoil handling * Remining
- Passive AMD treatment systems for watershed restoration
 - Use of coal ash and steel slag barriers

The NMLRC has worked with numerous groups throughout WV to address AMD and install passive treatment systems

Slide photo is of the North Portal at the Mars Portals site; this heavily polluted AMD water is now treated as part of the Mars Portal Passive Treatment project



Watershed Scale Restoration

- Multiple subbasins within WV that have severe degradation due to AMD (HUC 10,12,14)
- Historically we have treated single sources of AMD due to funding restrictions
- Recently we've been able to tackle a few projects that are on a larger scale and take entire watersheds into consideration
- Now, with BIL funding, these projects are more of a reality than a vision

Muddy Creek Treatment Facility



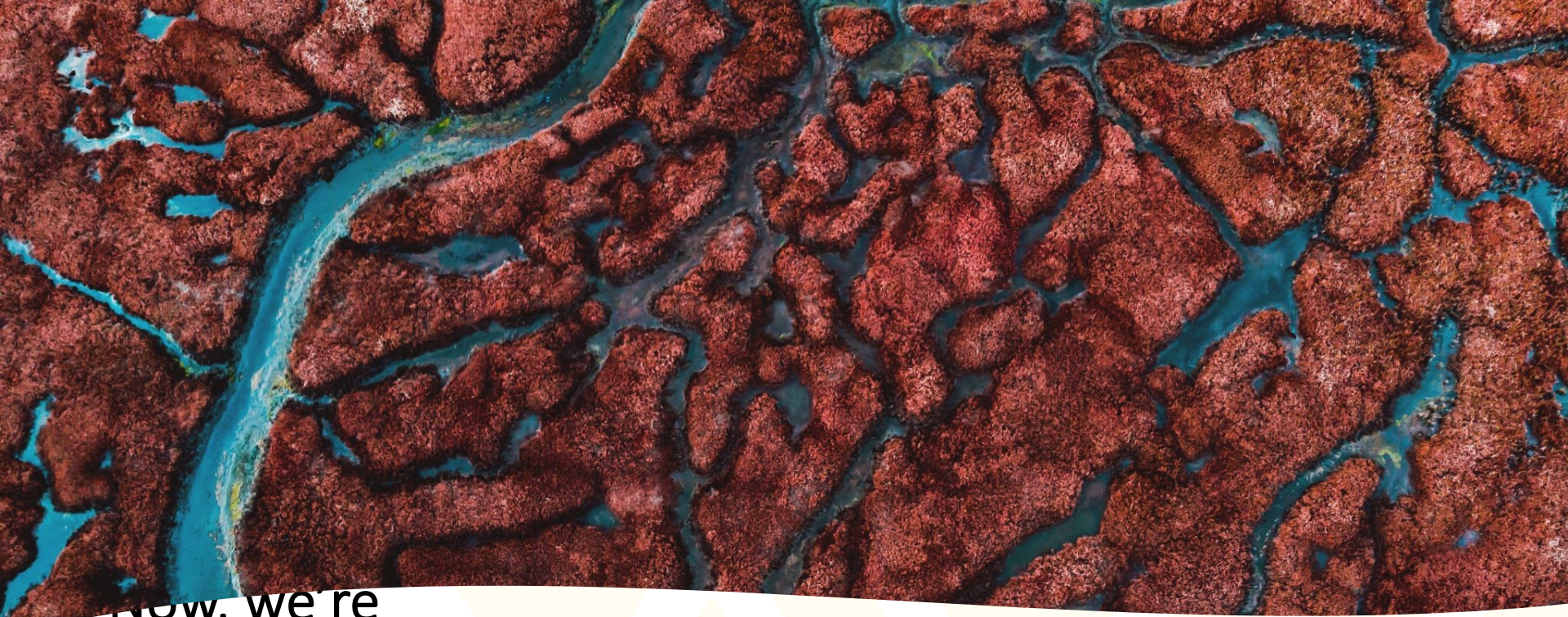
Watershed Scale Restoration and REE/CM Production

Historically AMD treatment in WV has resulted in sludge handling and disposal issues

This has been viewed as a highly **negative by-product** of AMD treatment

Do we bury it, move it off-site, or landfill it?





Now, we're
starting to
recognize
AMD by-
products as
an
opportunity!

- The Critical Materials and Rare Earth Element team at WVU have developed methods to extract these materials out of AMD
- Instead of an unwanted by-product, our sludge now has the opportunity to be transformed into something of value

However, there are some Disadvantages of Sourcing REE/CM from AMD

- Low concentrations
- Requires collection from many sites
- Need to manage upstream supply chain
- Quality control: moisture, grade



Yet, there are Numerous Advantages

Often already
permitted sites, no
delays due to
permitting

Easy to quantify
yield, minimal
exploration cost

Environmentally
beneficial, the
byproduct is clean
water

Solid wastes are
non-hazardous

Distributes jobs and
benefits across
broad areas

Incentivizes
treatment of legacy
AMD discharges

Uniform feedstock,
across mines and
sectors

Attractive
economics – offset
of treatment cost

Now, it's an opportunity!

- The NMLRC has identified multiple watersheds in WV that would benefit from large-scale restoration projects
 - Many of these projects have the potential for REE/CM production
- Watershed scale AMD treatment strategies are efficient
 - Lower cost
 - High watershed benefit-TMDL compliance
 - Large, consolidated AMD treatment plants are better for REE/CM recovery
 - Feedstock and product quality control
 - Logistics, infrastructure



Conclusions

- Countless WV watersheds have been negatively impacted by legacy coal mining issues; these issues persist despite efforts from industry, state, higher education, and grassroots groups
- Historically there has only been an opportunity to treat AMD discharges as a single source due to funding constraints
- With the additional \$140 million per year invested in the AML program, WV now has an opportunity to treat AMD via large-scale centralized systems
- REE/CM extraction can be built into the design plans for these large systems; offsetting costs and reducing negative by-products