NAXOS 2018, 6th International Conference on Sustainable Solid Waste Management

Feasibility of Utilizing Acid Mine Drainage Sludge in an Innovative Iron-based Wastewater Treatment Process

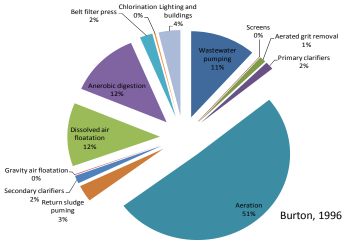
Rifat Anwar, Musfique Ahmed, Paul Ziemkiewicz, and Lian-Shin Lin
Civil and Environmental Engineering
West Virginia University
June 15, 2018

WestVirginiaUniversity

Mining, Wastewater Treatment, and Opportunities

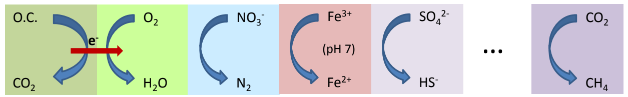
Municipal Wastewater Treatment

- Aeration: > 50% electricity utilization
- Activated sludge related treatment units: 12 – 17%
- Nutrients discharge to surface waters
- CO_2 emission



Burton, 1996

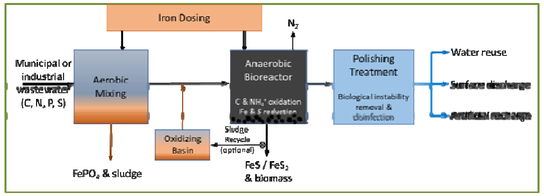
Microbial metabolism

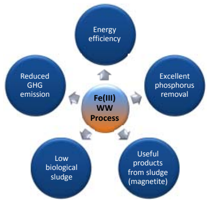


	Aerobic	Denitrifiers	Iron Reducing Bacteria	Sulfate Reducing Bacteria	Methanogenic Microbes
Max. degrad. rate μ (d^{-1})	8.4 – 13.2	4	??	0.5	0.3
Yield Y (kg VSS/kg COD)	0.42 - 0.49	0.25	??	0.057	0.035

Organic C as e^- donor, Rittmann and McCarty (2001)

Innovative Fe(III)-dosed Wastewater Treatment Technology

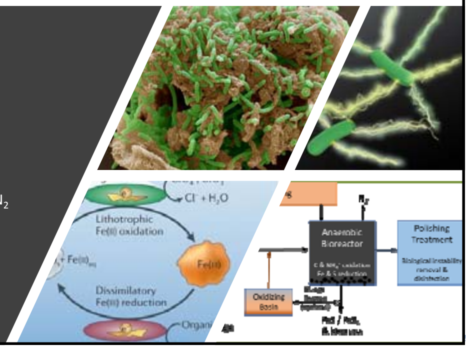




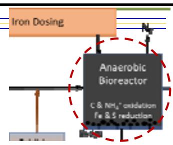
Deng and Lin, 2017; Ahmed and Lin, 2017; Deng et al., 2018

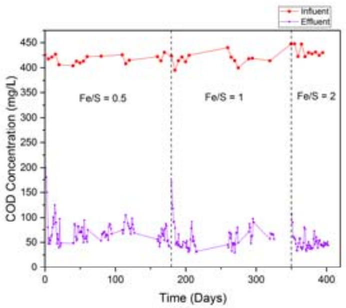
Main biogeochemical reactions

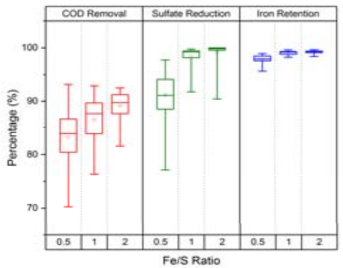
- Chemoheterotrophs
  - Iron reducing bacteria (IRB)
    Fe^{3+} + organics → $Fe^{2+} + HCO_3^- + CO_2 + H^+$
  - Sulfate reducing bacteria (SRB)
    SO_4^{2-} + organics → $HS^- + CO_2$
- Possible chemoautotroph
  Feammox (Yang et al., 2012)
  $3Fe(OH)_3 + 5H^+ + NH_4^+ \rightarrow 3Fe^{2+} + 9H_2O + 0.5N_2$
- Chemical precipitation
  $Fe^{2+} + HS^- \rightarrow FeS_{(s)} + H^+$



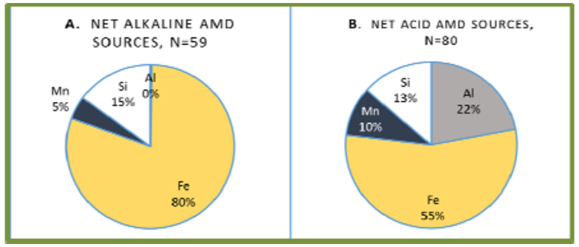
Fe(III)-dosed wastewater treatment



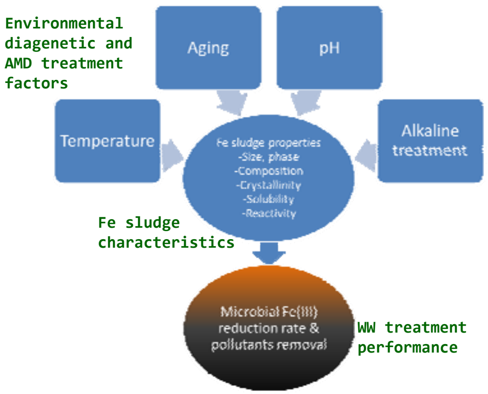




Acid Mine Drainage Sludge



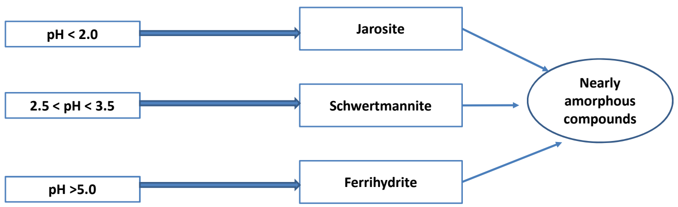
Distribution of major chemical elements in the AMD sludge based on a field survey on 138 AMD sludge cells in Maryland, Pennsylvania, Ohio, and West Virginia. Concentrations are based on the dry weight basis.



Effects of pH Neutralizer on Sludge Composition

Hydrated lime ($Ca(OH)_2$) neutralization	Ferric hydroxide and gypsum
Magnesium oxide (MgO) neutralization	Ferric sulfate and undissolved magnesium oxide
Lime (CaO) neutralization	Iron and higher calcium content
Limestone ($CaCO_3$) neutralization	Iron and lower calcium content
Ammonia neutralization	Iron and aluminum

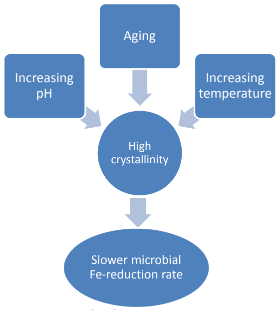
pH Dependent Ferric Mineral Formation



Mineral Phases of AMD Sludge

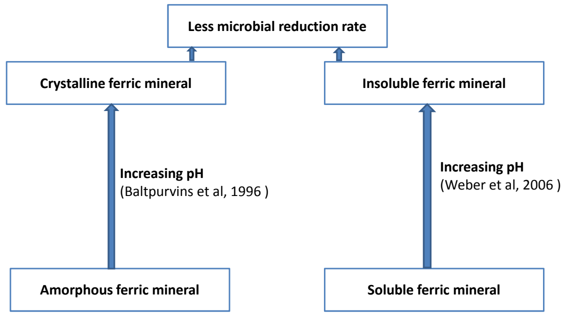
Treatment	Major mineral phases	Reference
Multi-step passive remediation	Schwertmannite, $Fe_8O_8(OH)_6(SO_4)\cdot nH_2O$ Hydrozincite, $Zn_5(CO_3)_2(OH)_6$	Macias et al. 2012
Passive pond-based abiotic treatment	Goethite, FeO(OH) Lepidocrocite, γ-FeO(OH) Hematite, Fe_2O_3	Kirby et al. 1999
Passive lime bed treatment	Lepidocrocite, γ-FeO(OH)	Aube et al. 1999
Passive vertical flow reactor	Schwertmannite, $Fe_8O_8(OH)_6(SO_4)\cdot nH_2O$ Goethite, FeO(OH)	Florence et al. 2016
NaOH and NH_4OH neutralization	Magnetite, Fe_3O_4 Hematite, Fe_2O_3 Hausmannite, Mn_2O_4	Kefeni et al. 2015
Limestone bed treatment	Goethite, FeO(OH) Calcite, $CaCO_3$	Cui et al. 2012

Crystallinity & Microbial Fe-reduction Rate

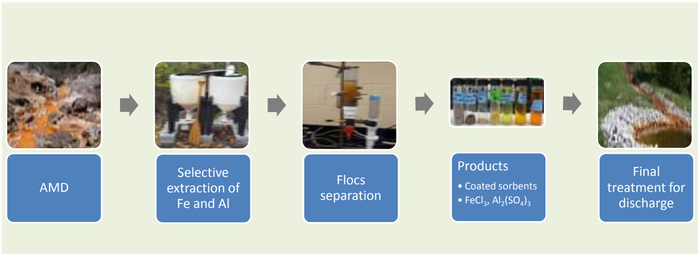


$FePO_4.4H_2O > Fe(OH)_3 > \gamma\text{-}FeOH > \alpha\text{-}FeOH > Fe_2O_3$

pH Effects

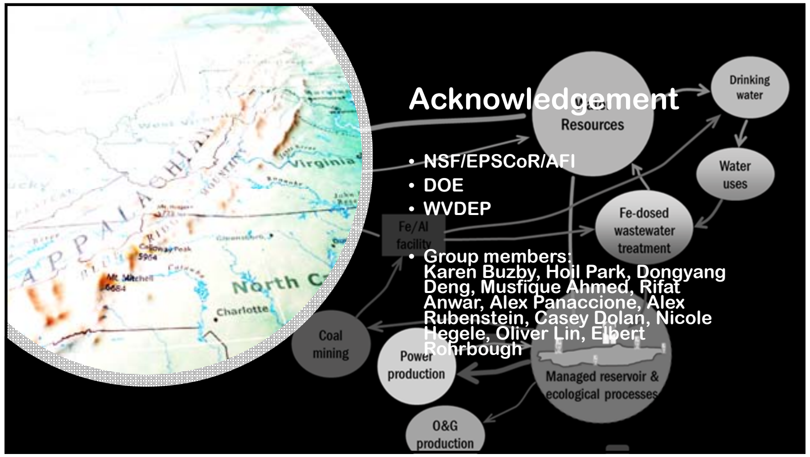


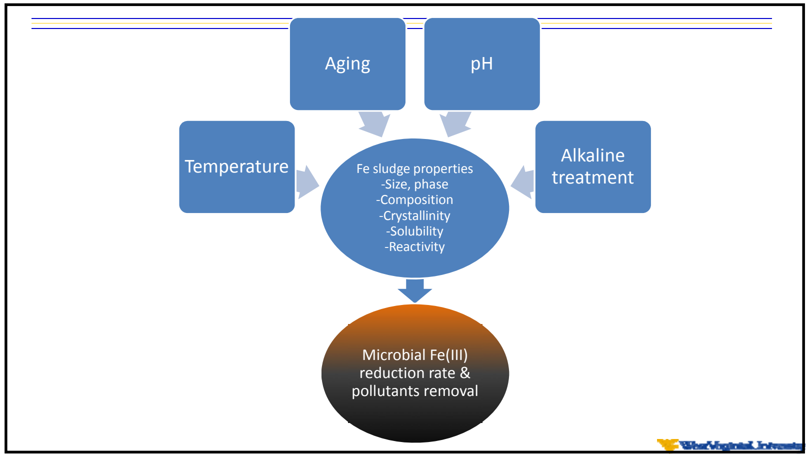
Fe/Al Products from AMD - Treatment steps



Conclusions & Current Status of Technology

- AMD can be a source of ferric iron for the innovative Fe-dosed wastewater treatment technology
- Tremendous opportunities exist for using Fe-containing wastes for beneficial uses that improve food-energy-water nexus efficiencies
- Environmental, diagenetic, and AMD treatment are important factors for Fe sludge characteristics
- Technical feasibility of the treatment concept proven
- Pilot testing to start this summer


Acknowledgement
• NSF/EPSCoR/AFI
• DOE
• WVDEP
• Group members:
Karen Buzby, Hoil Park, Dongyang Deng, Musfique Ahmed, Rifat Anwar, Alex Panaccione, Alex Rubenstein, Casey Dolan, Nicole Hegele, Oliver Lin, Elbert Rohrbough
Resources
Drinking water
Water uses
Fe-dosed wastewater treatment
Fe/Al facility
Coal mining
Power production
Managed reservoir & ecological processes
O&G production
North C
Charlotte


Aging
pH
Temperature
Alkaline treatment
Fe sludge properties
-Size, phase
-Composition
-Crystallinity
-Solubility
-Reactivity
Microbial Fe(III) reduction rate & pollutants removal