Investigation of acid mine drainage remediation by co-treatment with municipal wastewater using the activated sludge process

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Research funded by the Irish Research Council for Science, Engineering, and Technology Embark Initiative

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Overview

1. Principles of research
2. Irish context
3. Major studies
4. Key conclusions

1. Principles of research

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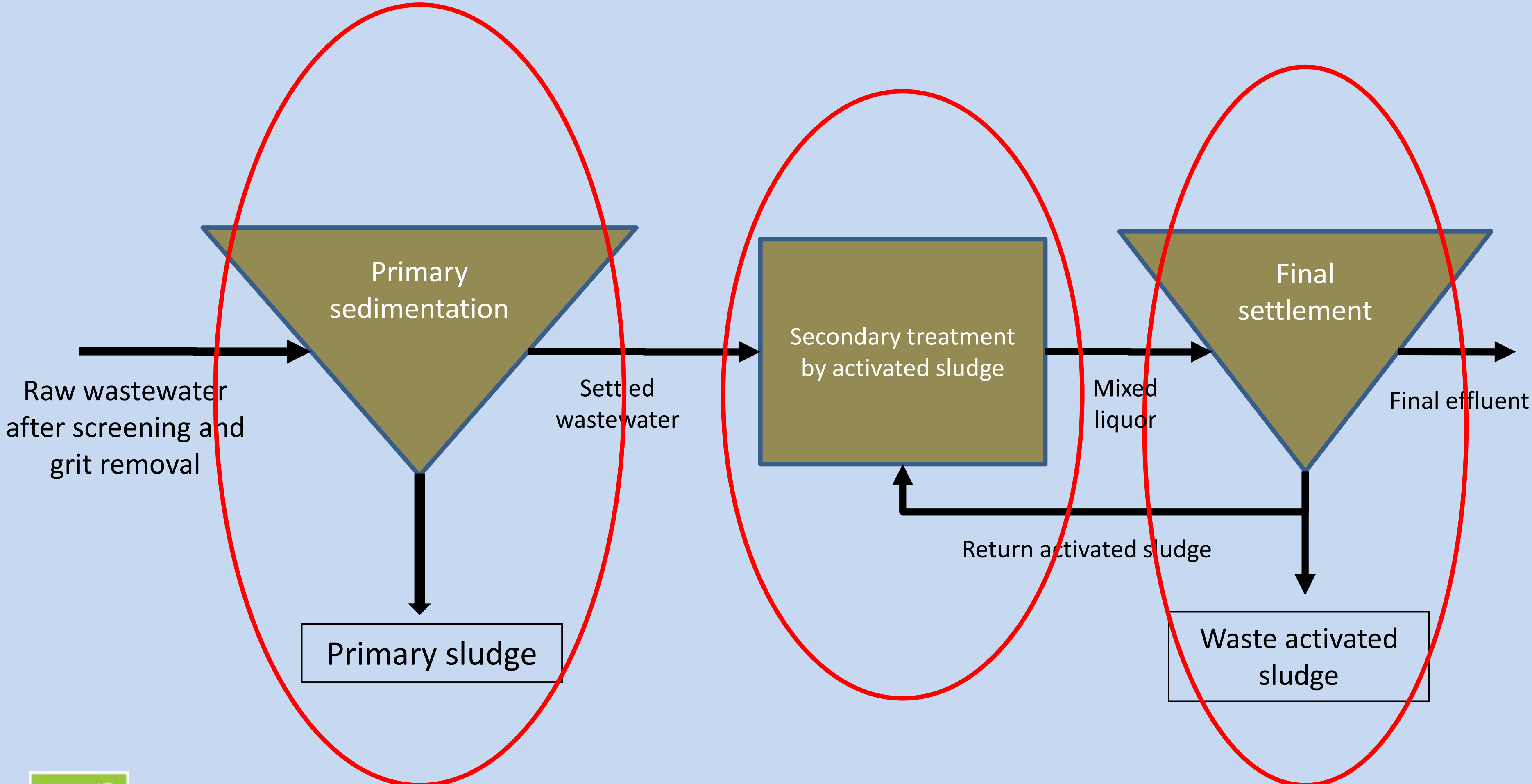
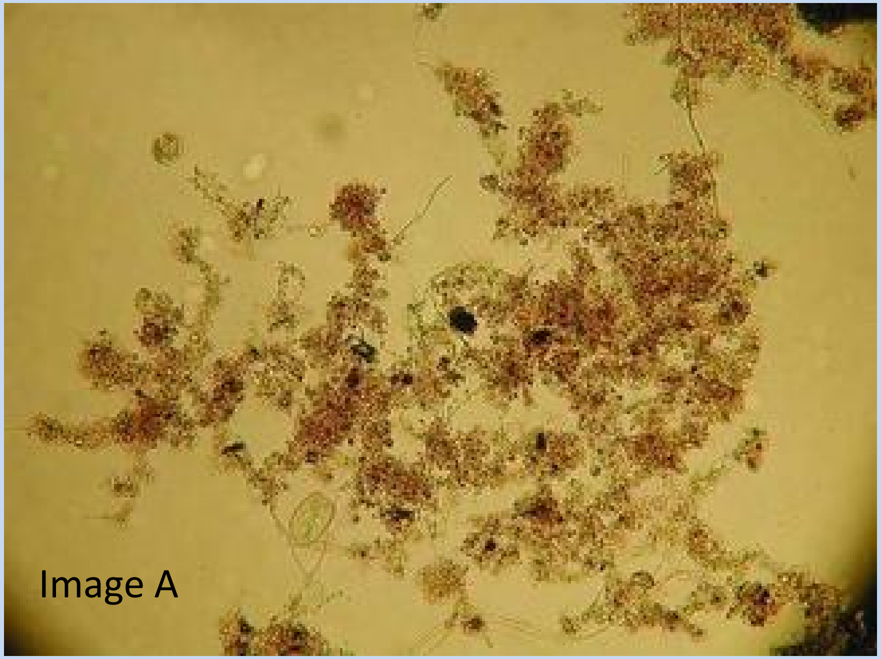
Municipal wastewater

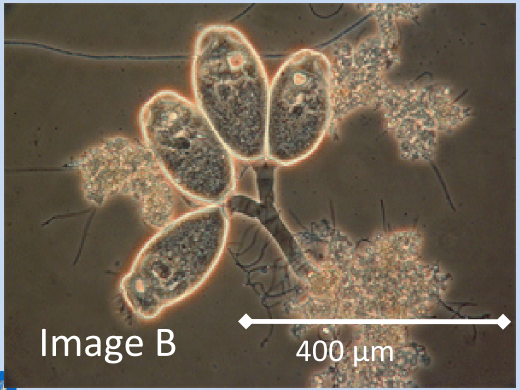
- Mixture of domestic and industrial wastewaters
- Net-alkaline (typical range 50-200 mg L^{-1} as $CaCO_3$)
- Low metal concentrations

Activated sludge process



Activated sludge





- Solids concentration 3-4 g L^{-1}
- Flocculation controls settleability and solids removal

Principles of process and supporting evidence

- Municipal wastewater net-alkaline
- Activated sludge biomass forms flocs
- Iron oxyhydroxide precipitates form (enhanced by presence of suspended solids in wastewater) (Johnson and Younger, 2006)
- Ferric iron at high concentrations
- Passive co-treatment of municipal wastewater and AMD

- Mix AMD and WW, pH increases, metal solubility decreases
- Metals adsorbed/precipitated and enmeshed in floc matrix, removed with solids fraction (Brown and Lester, 1979; Santos and Judd, 2010)
- Phosphate removed by sorption onto iron precipitates (Sibrell et al., 2009; Wei et al., 2008)
- AMD can replace commercial coagulants (Rao et al., 1992)
- Metals removed, net-alkaline effluent (Strosnider et al., 2011a)
- High BOD and nutrient removal efficiency (Strosnider et al., 2011b)
- Enhanced coagulation, sedimentation, and pathogen removal (Neto et al., 2010; Winfrey et al., 2010)

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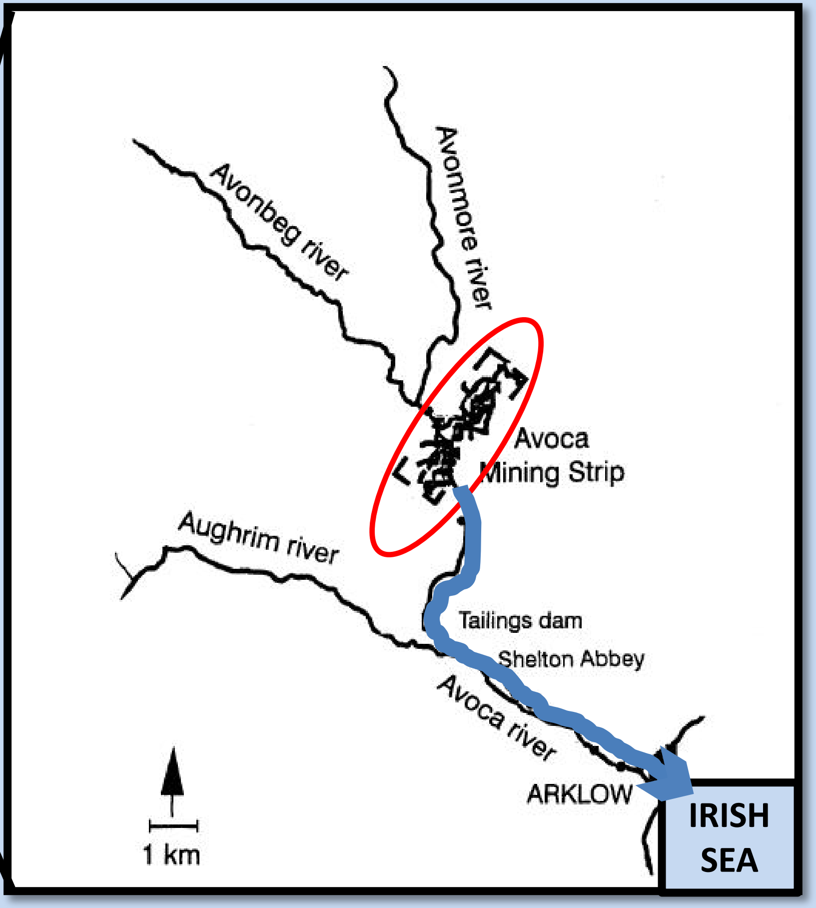
Avoca: Site


DONEGAL
DERRY
ANTRIM
TYRONE
FERMANAGH
MONAGHAN
ARMAGH
DOWN
SLIGO
LEITRIM
CAVAN
MAYO
ROSCOMMON
LONGFORD
LOUTH
MEATH
WESTMEATH
DUBLIN
GALWAY
OFFALY
KILDARE
WICKLOW
LAOIS
CLARE
CARLOW
TIPPERARY
KILKENNY
LIMERICK
WEXFORD
WATERFORD
KERRY
CORK


Avonbeg river
Avonmore river
Avoca
Mining Strip
Aughrim river
Tailings dam
Shelton Abbey
Avoca river
ARKLOW
1 km
IRISH
SEA

Avoca: Mining legacy

- Approx. 9 Mt ore mined
- Approx. 960,000 m^3 mine spoils

- Total site area: 0.63 km^2
- Open pits, waste piles, sparse vegetation

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Avoca: Current Status

Ballymurtagh Adit (W side Avoca River)

- Monthly mean flow: 8 L s^{-1} (summer) – 35 L s^{-1} (winter)
- Acidity: approx. 700 mg L^{-1} as $CaCO_3$ eq
- Fe: 81.4 mg L^{-1}
- Al: 14 mg L^{-1}
- Cu: 0.3 mg L^{-1}
- Zn: 8.2 mg L^{-1}
- Pb: 0.3 mg L^{-1}
- Mn: 6.0 mg L^{-1}
- Cd 0.02 mg L^{-1}

Deep Adit (E side Avoca River)

- Monthly mean flow: 10 L s^{-1} (summer) – 70 L s^{-1} (winter)
- Acidity: approx. 600 mg L^{-1} as $CaCO_3$ eq
- Fe: 83.6 mg L^{-1}
- Al 100 mg L^{-1}
- Cu: 0.4 mg L^{-1}
- Zn: 54.6 mg L^{-1}
- Pb: 1.6 mg L^{-1}
- Mn: 3.7 mg L^{-1}
- Cd 0.1 mg L^{-1}

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Avoca: Current Status

- Avoca AMD untreated
- EU Water Framework Directive
- Budget limitations
    - ➢Sustainable solution needed
    - ➢Research grant from IRCSET

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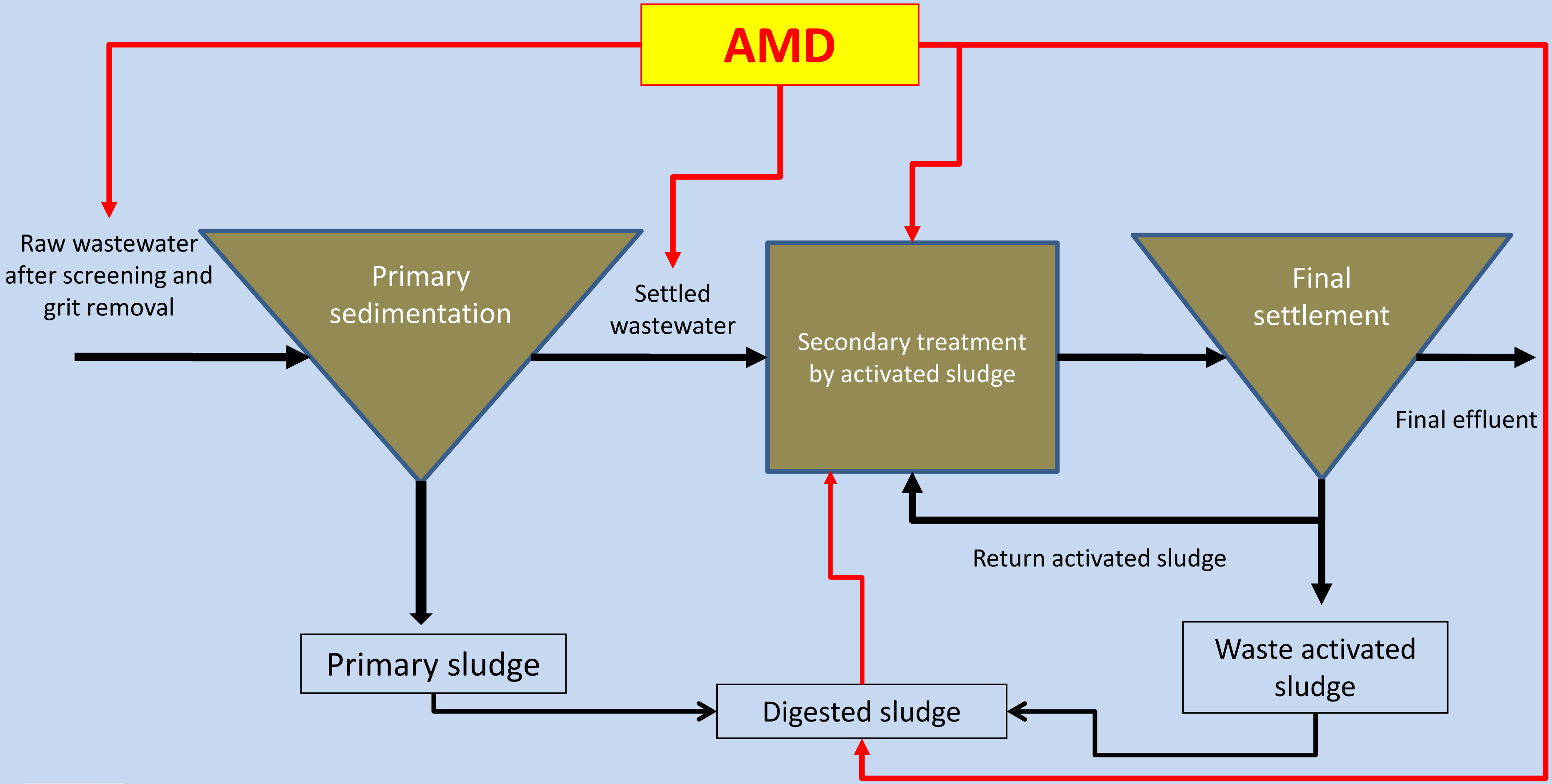
Process design



Key questions and studies

- Toxicity of AMD to microorganisms?
- Metal removal efficiency of sludge and wastewaters?
- Neutralization capacity?
- Impacts on wastewater treatment?

➢ Treatability studies

➢ Metal removal and neutralization studies

➢ Performance evaluation

Treatability studies

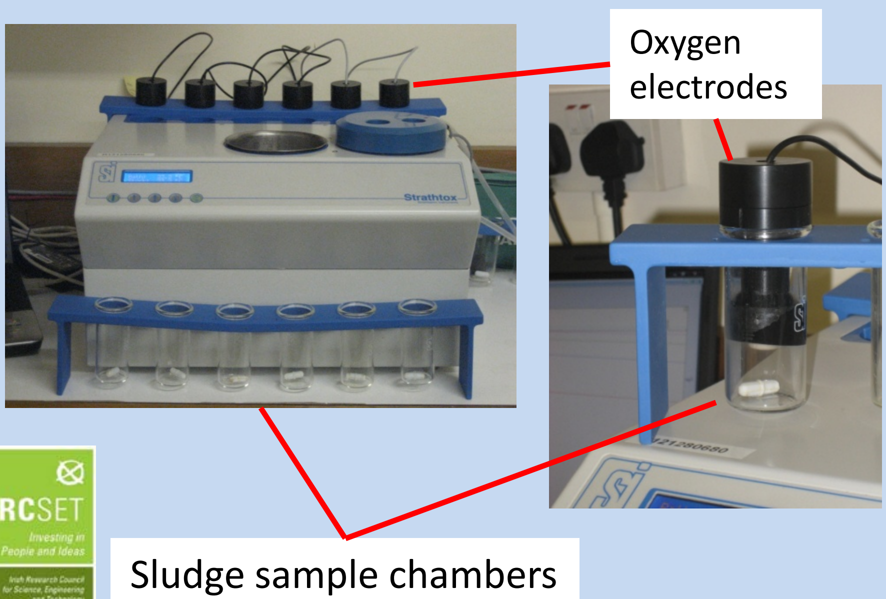
(Hughes and Gray, 2012a)

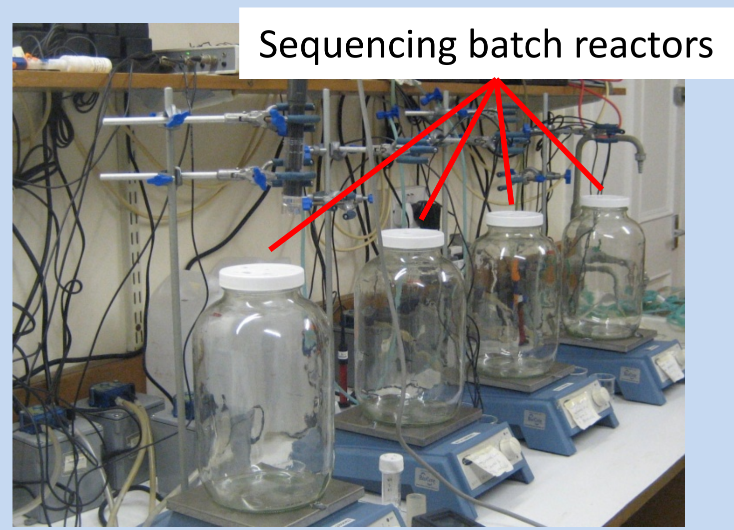
Acute toxicity?

- Evaluate effects of short-term exposure (3h) on microbial health
- Respiration inhibition tests

Acclimatization?

- Evaluate effects of long-term loading (26d)
- Multi-parameter assessments





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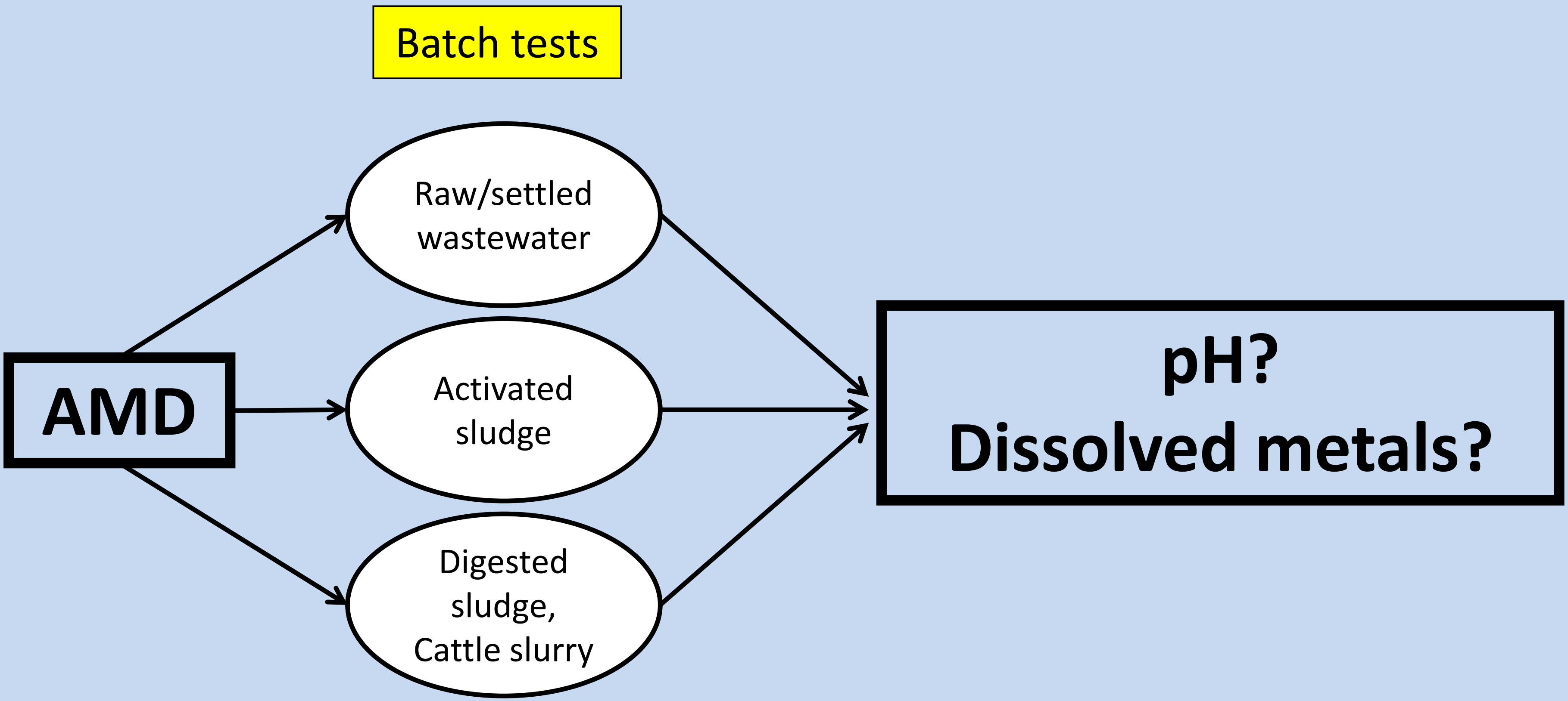
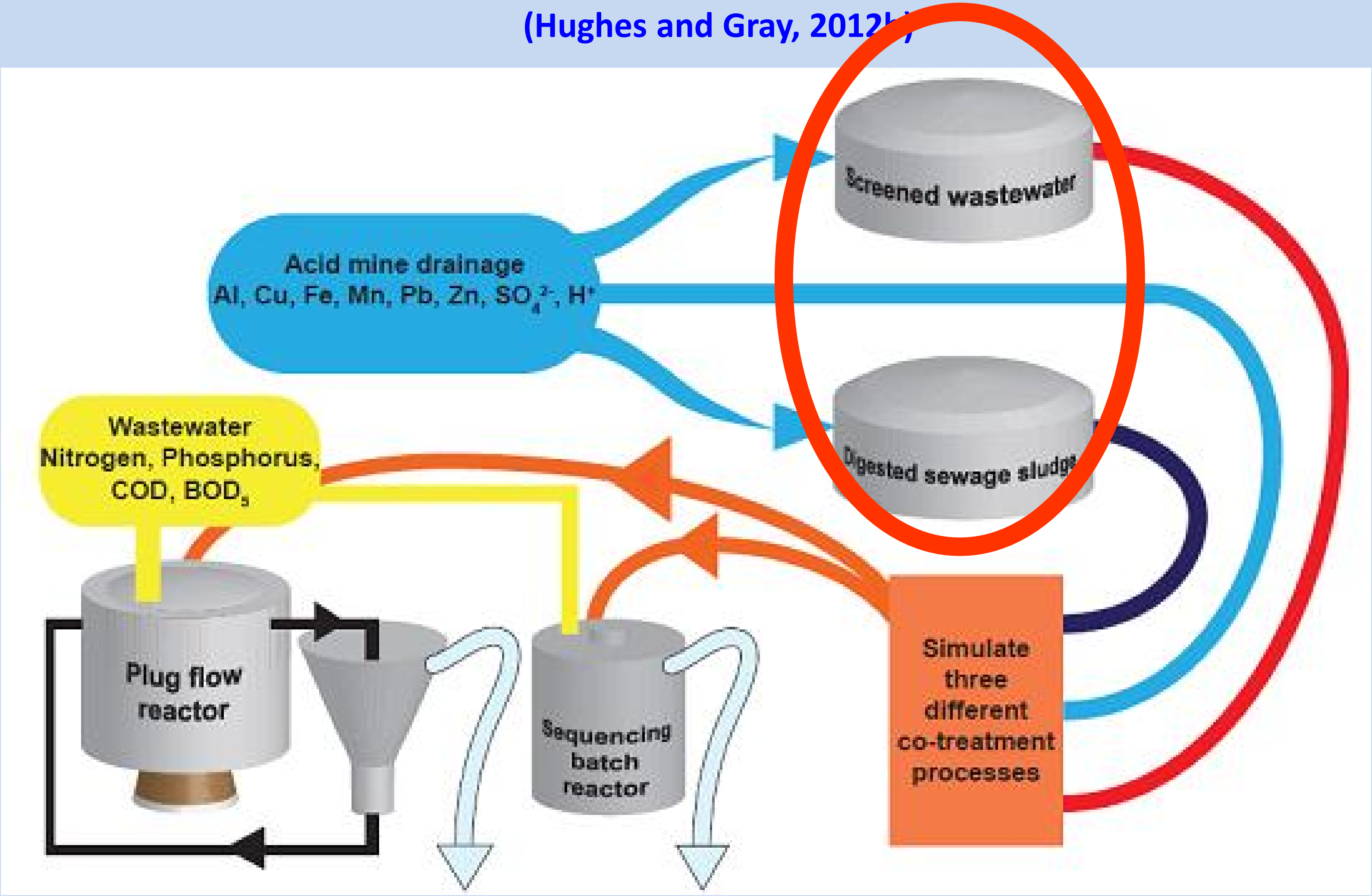
Metal removal and neutralization studies

(Hughes and Gray, 2013; Hughes, Gray, and Sánchez Guillamón, 2013)



Performance evaluation

(Hughes and Gray, 2012b)



Final effluent quality?

Performance evaluation: Simulating three processes

Dissolved metals, sulphate, and acidity concentrations in synthetic AMD

Parameter	Average concentration[a] (mg/L)		
	AMD: Process II	AMD: Process III	AMD: Process IV
Al	56	57	9.9
Cu	0.7	0.1	0.1
Fe	93	85	0.30
Mn	4.9	4.4	1.2
Pb	1	0.6	0.2
Zn	35	35	28
SO_4	210	170	36
pH	3.6	6.0	7.0
Alkalinity	0	7.2	27
Acidity	552.5	530.3	100.8
Net acidity	552.5	523.1	73.8

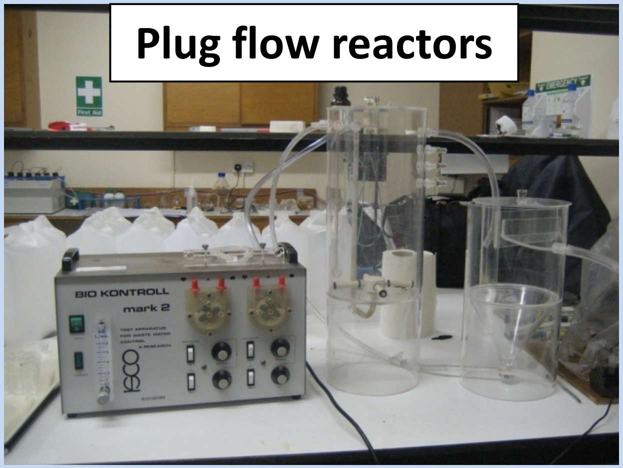
[a]: Arithmetic mean of n=3 measurements

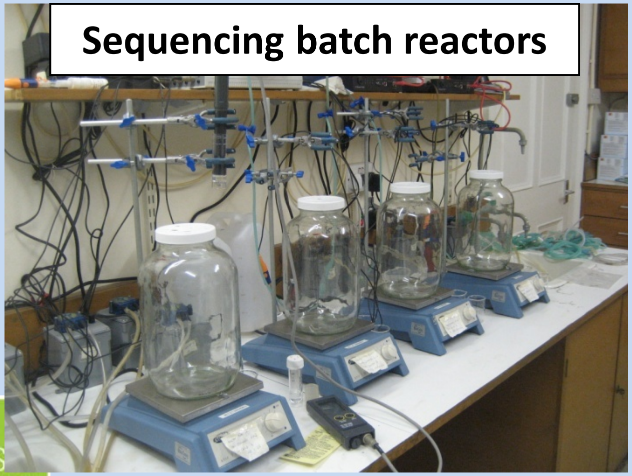
Process II: No pre-treatment

Process III: Mix with digested sludge

Process IV: Mix with MWW

Performance evaluation: AMD remediation





- Metal removals:
  - Al: 52-84%
  - Fe: 74-86%
  - Cu:47-61%
  - Pb: 100%
- Acidity:
  - Final effluents net-alkaline
  - Alkali supplement recommended
- **Process achieving best effluent quality: Pre-mixing with screened municipal wastewater (Process IV)**

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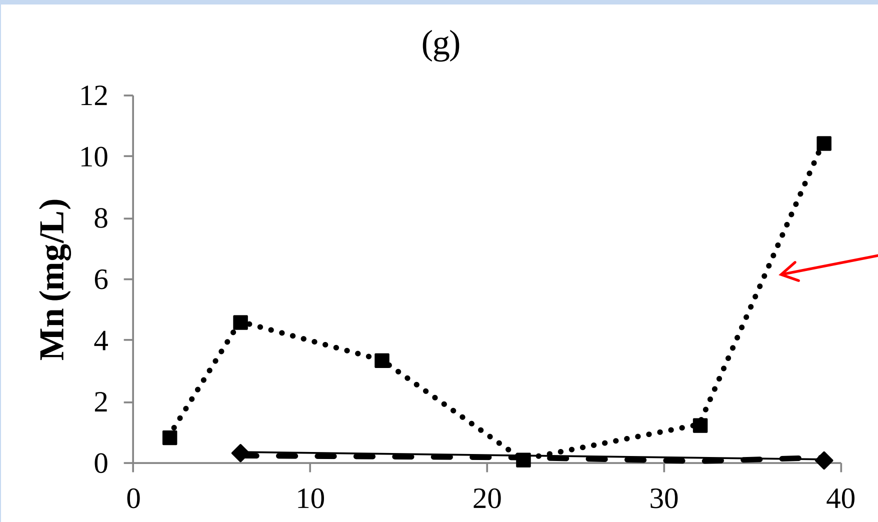
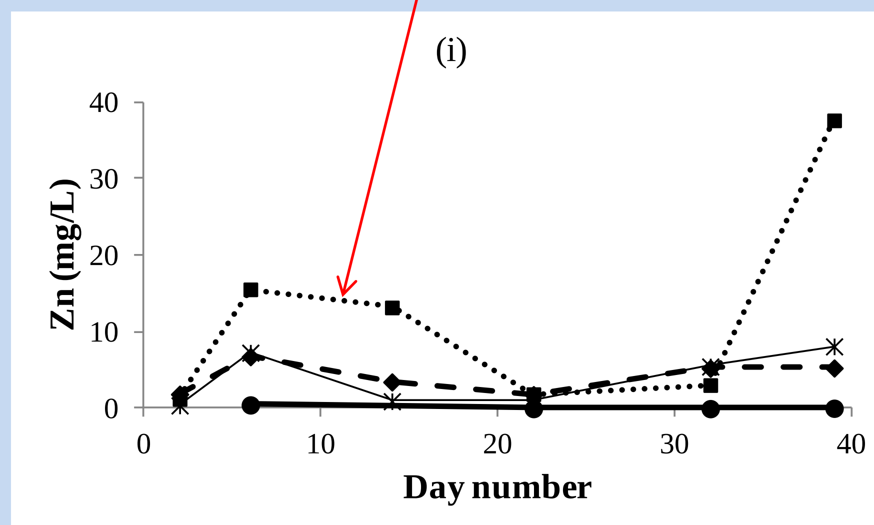
Performance evaluation: Metal removal



Process 2: No pre-treatment



- **Mn**
  - **Net-acidic AMD: <10%**
  - **Net-alkaline AMD: >90%**
- **Zn**
  - **Net-acidic AMD: <10%**
  - **Net-alkaline AMD: 58-90%**

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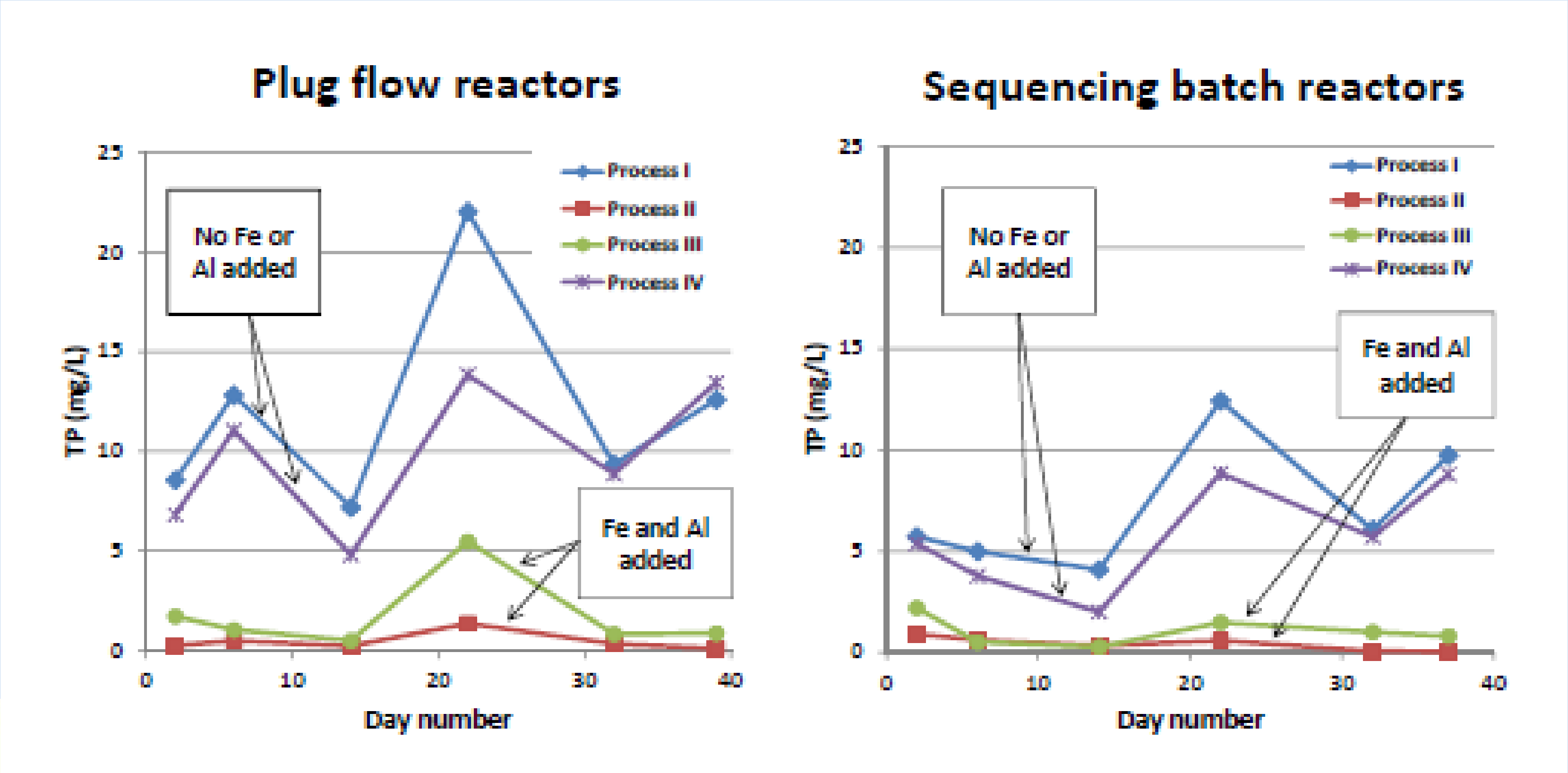
Performance evaluation: Wastewater treatment

- Organics? No significant decrease in removal efficiency
- Nutrients? Phosphorus removal significantly improved by Fe, Al



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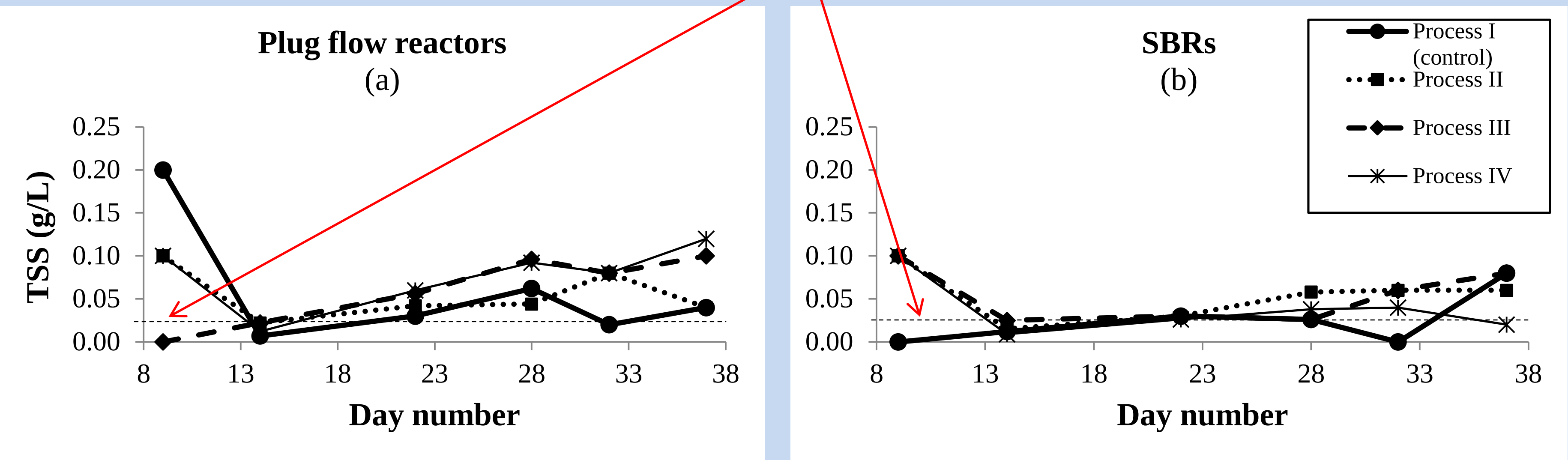
Performance evaluation: Sludge condition

Dashed line at 0.03 g L[-1] indicates the typical discharge limit for WWTPs



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Key questions revisited

- Impacts on wastewater treatment?
  - Metal removal, neutralization achieved without detrimental impacts on COD/TOC/BOD_5 removal
  - Total phosphorus removal significantly improved where AMD contained 30 mg L^{-1} Fe, 20 mg L^{-1} Al
- AMD remediation?
  - Metal removal: highest based on scenario of pre-mixing with MWW
  - Alkalinity key to metal removal

Concluding statement

Co-treating AMD with municipal wastewater using the activated sludge process is a feasible approach to AMD remediation which can achieve metal removal and neutralization without compromising wastewater treatment performance, provided that alkalinity is not a limiting factor. Process design must be selected according to AMD and empirically-determined removal efficiency using available materials.

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Future Work

- Sludge disposal?
- Metal recovery?
- Sludge reuse?

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Image credits

[A] http://www.waterworld.com/index/display/article-display/199084/articles/waterworld/environmental/the-composition-and-treatment-of-active-sludge.html

[B]http://water.me.vccs.edu/courses/ENV195Micro/ProtozoaID.htm

[C] http://smoige.com/discussion/219/the-activated-sludge-process-is-like-this.-first-.../p1

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