Biosolids and Crocodile Manure For Treating Acidic Metalliferous Mine Drainage

31st National Meeting of the American Society of Mining and Reclamation

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17/06/2014

The Problem

- Number of mine sites in Darwin area with legacy issues.
- Metal mines with acidic drainage.
- Not allowed to discharge in dry season
- Wet season are storms and flash floods

Typical Chemistry

Dissolved Metals	Al	As	Cd	Co	Cr	Cu	Fe	Pb	Mn	Ni	U	Zn	SO4	pH
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	pH Units
LOR	10	1	0.1	1	1	1	10	1	5	1	0.5	1	1	
ANZECC/ARMCANZ Guidelines[1]	55	24[2]	0.2	ID	1.0	1.4	ID	3.4	1900	11	ID	8.0	-	6-8
Mine water	950000	25	130	25000	1100	7900	1400000	29	260000	27000	1100	13000	35000	2.7

Possible Solution

- Had to consider climate, site available material and proximity:
  - Onsite dolomite, mountain of old waste tyres
  - Local farms (cow and crocodile)
  - Local sewage works with stockpiled biosolids (relatively new and 1-2 years old) as expensive to dispose in landfills
  - Local oyster farm with spent oyster shells
  - Green waste (mulch aged and fresh)

Historic Use

- Not new idea to use biosolids in US.
  - Studies have e.g. McCullough et al, 2008
  - Using sewage in acid pit lake and SRB column work (Eger et al, 2003)
  - Also taconite mine remediation in Minnesota mine reclamation (Eger et al 2013)
  - But new in Australia
- Water quality implications of using shredded tyres as an inert drainage layer in a wetland system (by Fannin et al, 2009).

Biosolids

- Biosolids
  - Non-industrial source
  - Chlorinated and non-chlorinated
  - Fresh and aged (1-2 years)
  - The older and more established stockpiles more likely to contain sulphate reducing bacteria
  - Both tested

The Study

- Examines use of biosolids and other organic/neutralising materials as providing organic matter/cellulose and SRBs
- First stage of tiered assessment:
  - **Proof of Principle testing – static test**
  - Bench scale testing: dynamic test
  - Pilot scale testing: dynamic test
- Leads to development of sizing and design criteria for full scale system

The Study

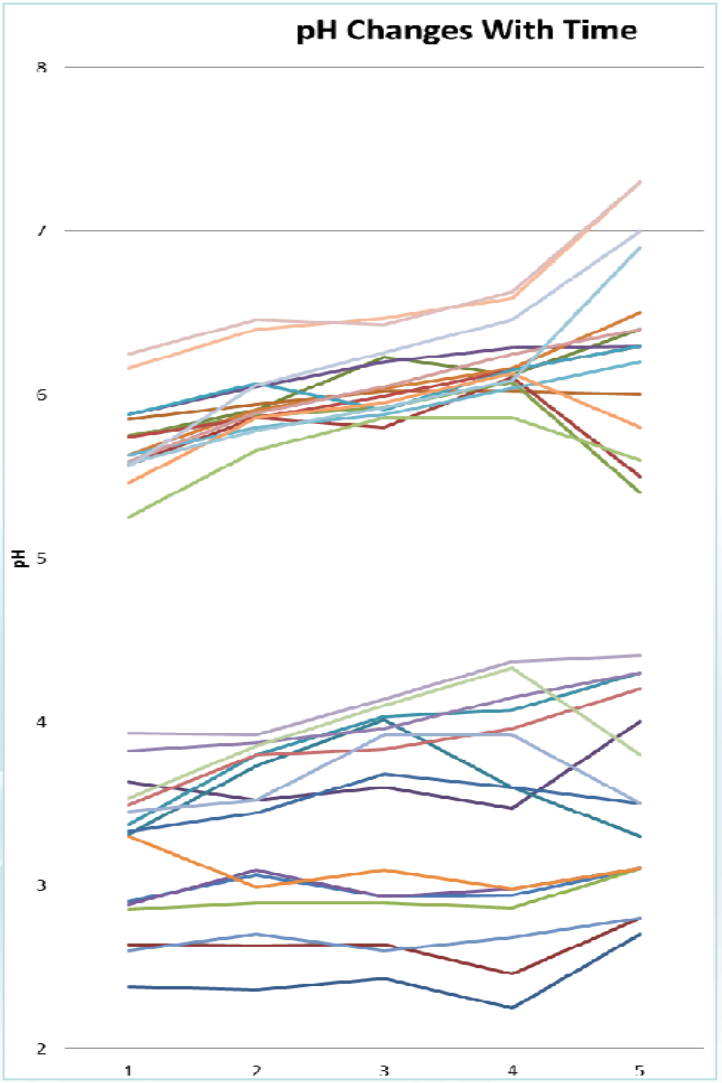
- Assessed biosolids (older, chlorinated and younger un-chlorinated) from sites in Darwin
- Manures from local farms, including crocodile
- Carbonate source – crushed oyster shells and local dolomite
- Mulch and shredded tyre from the site
- Vegetative organic carbon – mulch to sustain SRB
- Rubber tyres – suggested drainage layer

The Study

- Static proof of principle test
- Mixture of substrates with mine water in various proportions
- pH, conductivity and redox recorded weekly
- 30 samples (including duplicates, controls)

Results

- Most successful substrates, in terms of pH increasing from 2.5 – 7.1 included:
- Bio solids, chlorine dosed
  - older/lime present?
- Crocodile manure
  - diet relevant
- Waste oyster shells
  - calcium carbonate



Results

mg/l	Al	As	Cd	Co	Cr	Cu	Fe	Pb	Mn	Ni	U	Zn	SO4
Mine water	95	0.025	0.13	25	1.1	7.9	1400	0.029	260	27	1.1	13	35000

Substrate	Al	As	Cd	Co	Cr	Cu	Fe	Pb	Mn	Ni	U	Zn	SO4
Biosolid (Cl-dosed)	99.96	96.00	100.00	98.48	100.00	99.96	65.71	100.00	26.92	99.48	99.61	99.85	40.00
Oyster Shell	99.94	84.00	100.00	32.00	98.82	99.97	64.29	100.00	30.77	40.74	93.18	97.15	31.43
Shell,biosolid (Cl-dosed)	99.99	99.99	100.00	90.40	100.00	100.00	62.14	100.00	26.92	99.37	99.46	99.93	37.14
Biosolid(Cl),mulch	99.96	84.00	100.00	94.40	98.73	100.00	45.00	100.00	11.54	98.81	98.64	99.87	37.14
Mulch croc manure	100.00	99.99	100.00	98.76	100.00	100.00	99.74	100.00	82.69	98.37	99.38	99.96	51.43

Summary

- Croc manure, biosolid (Cl dosed) show potential.
- Up 100% reduction in metals (Al, Pb, Cu, Zn, As, Cd, Fe, U).
- Mn and Fe not removed fully in anaerobic systems.
- Oyster shell most effective alkalinity supplier.
- Sulfate reduced (40 - 50%) showing SRB?.
- Mulch potential cellulose source.
- Shredded tyre, inert.

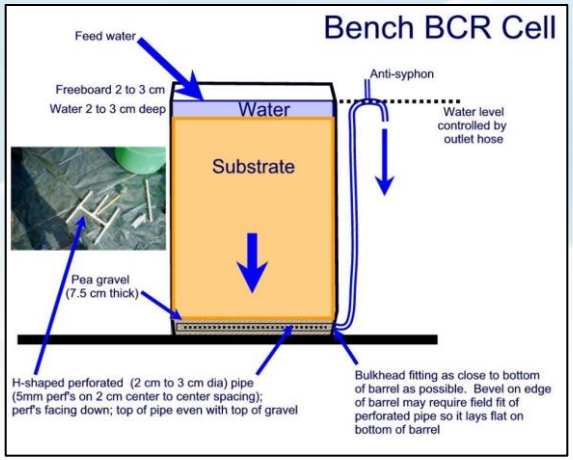
Oz and US Differences

- The Australia Department of Industry, Tourism and Resources (2007) drainage >800 mg/L $CaCO_3$ acidity and a loading of >150 kg $CaCO_3$/d not suitable.
- Developed by examining systems which failed and did not take into account area.
- In US, 3.5g acidity/m^2/d (Hedin, 1994) and rule of thumb (Wildeman, pers com.):
  - pH3 : 20 m^2/l/min
  - pH4 : 15 m^2/l/min

Ongoing Tiered Assessment

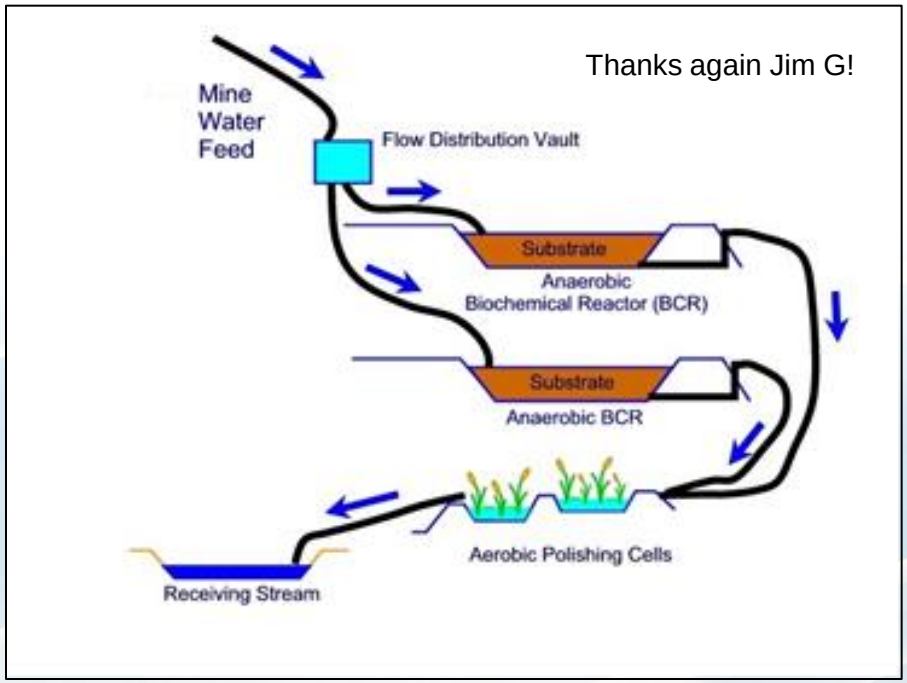
Bench Scale Testing

(thanks Jim Gusek)



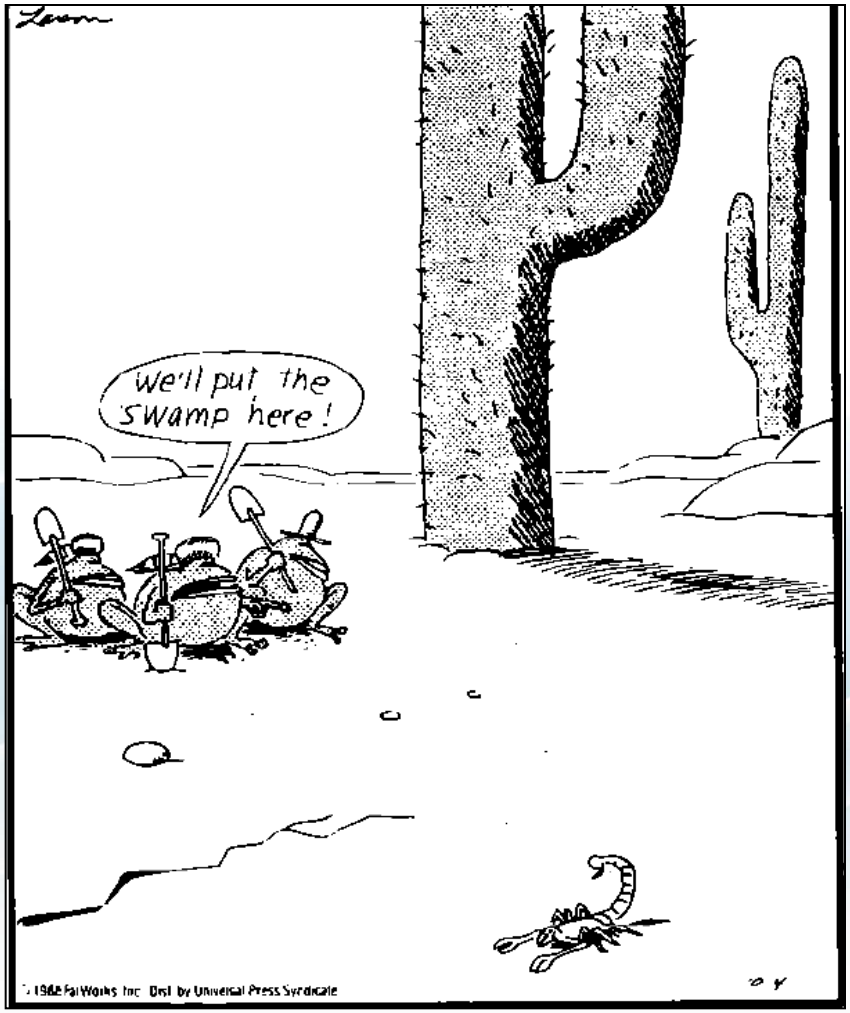
Pilot Scale Testing (Louisville, Kentucky)

Layout Options



- Flow control, balancing ponds etc. Flash floods in Darwin
- Usually two cells to cope with down time (maintenance)
- Aerobic polishing to remove Fe, Mn and BOD

Thank You



Larson's Frog Pioneers

- Still an innovative (pioneering) technology
- Systems can be built in nearly any climate – including NT!
- They can attract – roos and echidna!