Wealth from waste: a framework to evaluate the beneficial reuse of by-products as substrate in constructed wetlands

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Objective:

- Devise and assess an evaluation framework for industrial by-products with potential for productive use in engineered water treatment wetlands or similar deployments

Introduction

- Extensive land use change has substantially increased (diffuse) pollutant loads to many aquatic environments
- Conventional wastewater treatment systems frequently unsuitable due to on-going requirements for guaranteed power supply and skilled labour
- Wetlands and similar engineered structures for passive wastewater treatment widely recognised as a cost-effective means of attenuating diffuse water pollution
- Mining and industrial by-products may be suitable for productive use as substrate in water treatment wetlands or similar engineered structures for treatment of wastewater previously discarded or treated by less efficient or more costly means

Material Assessment Framework

BASIC REQUIREMENTS

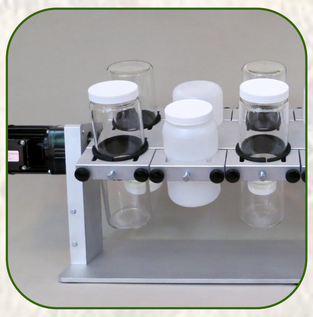
- MSDS – nominal chemical / physical properties, safe handling & use
- Material source & generation process
- Intended application(s)

REJECT
- Unsafe
- Not widely available

PRIMARY CHARACTERISATION

- Geochemistry
- Mineralogy (XRD)
- Radioactivity (U-Th series)
- P sorption capacity / retention index

REJECT
- Unsafe
- No P retention



SECONDARY CHARACTERISATION

- Identification of potential fit for purpose use
- Leach testing (e.g. modified TCLP)
- Ecotoxicity testing
- Microbiological testing *as required*

REJECT
- Unsafe
- No potential use ID'ed

TERTIARY CHARACTERISATION

- Longer-term laboratory and/or pilot-scale field trials to validate fit for purpose use
- Comprehensive assessment of material's projected life cycle

REJECT
- Poor performance

USE REGISTRATION/LICENSE

- Define conditions of use (limitations, reuse or disposal)
- Generate necessary supporting documentation for NRM agency/industry/domestic product use in intended locale

Example Material Assessment

Table 1: U-Th series radiochemistry, P sorption capacity, trace element geochemistry

	Absorbed dose rate, D (nGy/h)	Equivalent annual external dose (mSv)	Effective annual external dose (mSv)	P sorption capacity (mg/g)	Trace elements with concentration > relevant soil/sediment guidelines (mg/kg)
JX1	20	0.12	0.02	14.0	Ba(1138), Cr(1481), V(1925)
JX2	146	0.89	0.18	1.39	Ba(621), Se(5), V(96)
JX3	140	0.86	0.17	3.62	Ba(623), Se(6), V(96)
JX4	192	1.18	0.24	1.26	Ba(1110), Se(6), V(916)
JX5	20	0.12	0.02	9.93	Ba(1546), Cr(1774), Tl(4), V(3137)
JX6	39	0.24	0.05	3.20	As(244), Ba(453), Cr(1011), Cu(63), Pb(167), Sb(26), Se(3), Tl(6), V(1193), Zn(237)
JX7	110	0.68	0.14	2.44	As(25), Ba(416), Cr(366), Pb(150), Sb(10), Se(2), Tl(4), V(198)
JX8	26	0.16	0.03	21.1	As(173), Ba(287), Cr(840), Sb(25), V(1248)
JX9	186	1.14	0.23	16.1	As(314), Cr(174), Cu(68), Pb(192), Se(4), Tl(5), V(583)

Figure 1: Nutrient (N, P) attenuation in laboratory column trials

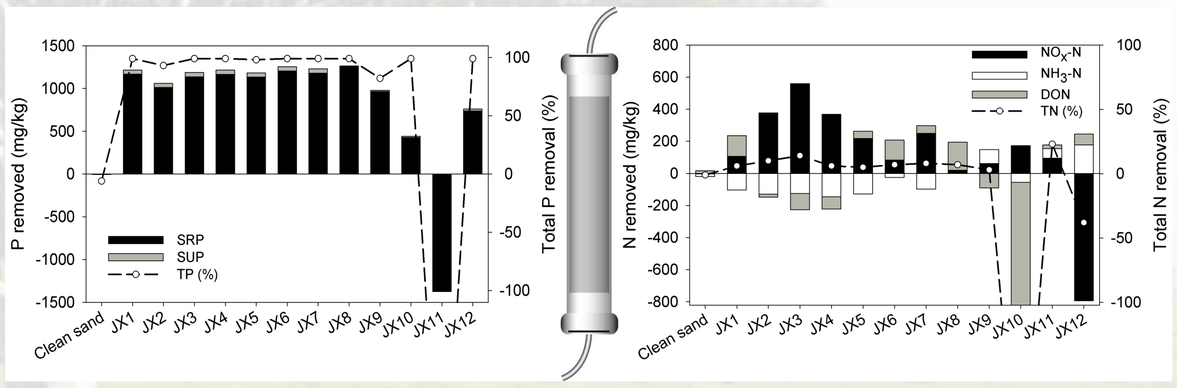
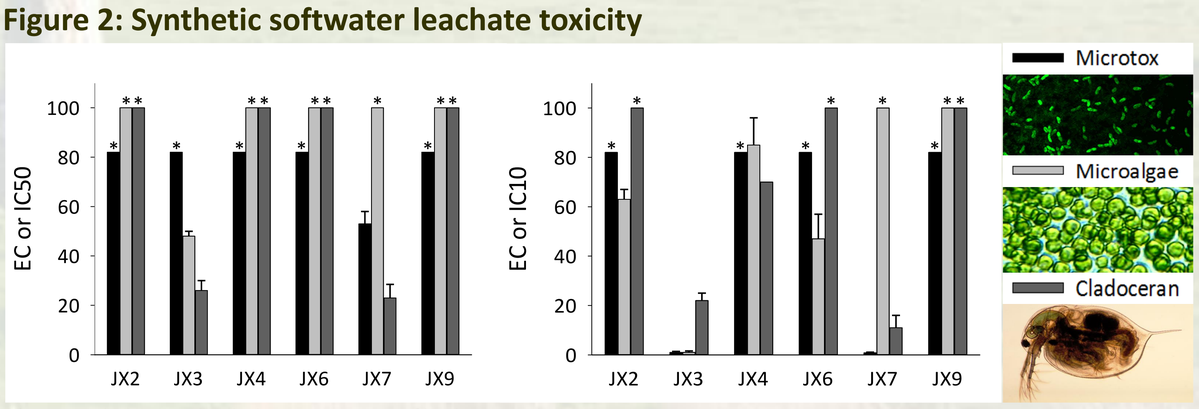
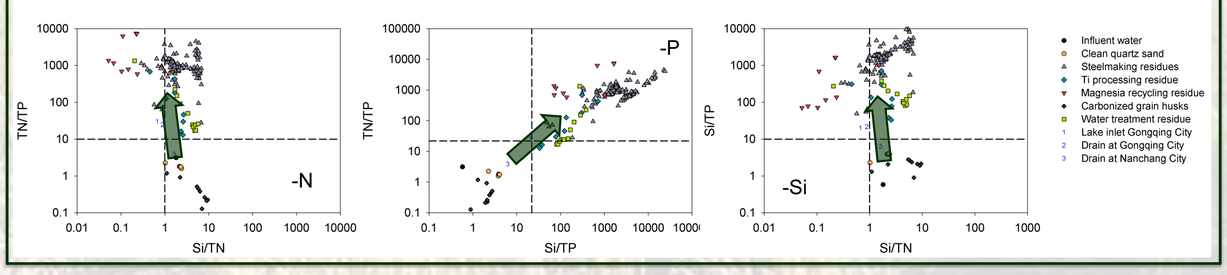


Figure 2: Synthetic softwater leachate toxicity



**toxicity value greater than highest concentration of leachate tested*

Figure 3: Potential N, P & Si limitation of column leachates



Example Assessment Summary

	Chemistry			Radioactivity mSv/y	Environmental Toxicity			Suitability for use in nutrient intervention schemes and recommendations
	pH	EC mS/cm	Potentially toxic elements		Algal growth	Cladoceran mobility	Microtox®	
JX1	12.4	8.08	Ba, Cr, V	0.12	ND	ND	ND	Dilution required to reduce leachate pH & EC; additional testing recommended prior to use
JX2	10.3	0.37	Ba, Se, V	0.89	L†	L†	L†	Dilution required to reduce leachate pH
JX3	11.6	2.38	Ba, Se, V	0.86	H	H	H	High toxicity of softwater leachates to algae, cladocera & marine bacteria
JX4	11.3	0.95	Ba, Se, V	1.18	L†	H	L†	High toxicity of softwater leachates to cladocera
JX5	12.4	9.40	Cr, Ba, Tl, V	0.12	ND	ND	ND	Dilution required to reduce leachate pH & EC; additional testing recommended prior to use
JX6	12.4	8.53	As, Ba, Cr, Cu, Pb, Sb, Se, Tl, V, Zn	0.24	L†	L†	L†	Dilution required to reduce leachate pH & EC
JX7	11.6	1.81	Ba, Cr, Pb, Sb, Se, Tl, V	0.68	L†	H	H	High toxicity of softwater leachates to cladocera & marine bacteria
JX8	12.5	10.47	As, Ba, Cr, Sb, V	0.16	ND	ND	ND	Dilution required to reduce leachate pH & EC; additional testing recommended prior to use
JX9	7.7	2.56	As, Co, Cr, Cu, Pb, Se, Tl, V	1.14	L	L	L	Outdoor use in nutrient intervention schemes (reduce mSv/y exposure)
JX10	9.4	98.97	Ba, Cl, Se, Zn	ND	ND	ND	ND	Release of substantial DON & increased total N in column effluents
JX11	7.7	3.04	Zn	ND	ND	ND	ND	Release of substantial PO_4-P & increased total P in column effluents
JX12	7.1	13.59	As, Ba, Co	ND	ND	ND	ND	Release of substantial NO_x-N & increased total N in column effluents