Alkaline residues and the environment:
A review of impacts, management practices and opportunities

Supplementary information

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Table 1. Major environmental accidents with alkaline residues since 2000.

Material	Date	Occurrence	Plant/Location	Volume (m^3)	Ref.
Fly ash	11 Oct 2000	Failure of the bottom of a coal slurry impoundment	Massey Energy / Martin County, Kentucky, USA	1 158 336	(McSpirit et al., 2005)
Fly ash	22 Dec 2008	Failure of a dredge cell containment wall	Tennessee Valley Authority Kingston Fossil Plant / Harriman, Tennessee, USA	4 100 000	(Bednar et al., 2013)
Red mud	4 Oct 2010	Failure of the north-western corner of the red mud depository Cell X	Ajkai Timfoldgyar Zrt / Ajka, Western Hungary	1 000 000	(Ádám et al., 2011)
Coal ash and untreated wastewater	2 Feb 2014	Collapse of stormwater drainpipes under a coal ash impoundment	Dan River, Eden, North Carolina, USA	39 t coal ash 122 745 m^3 wastewater	(Dennis Lemly, 2015)

Table 2. Summary of the use of alkaline residues for environmental applications.

Material	Environmental purpose	Development stage	Efficiency range Main results	Ref.
Bauxite residue (red mud)	Water treatment: removal of metals, nitrate, chlorophenols	Batch and column tests	20-100%	(Komnitsas et al., 2004),(Cengeloglu et al., 2006), (Nadaroglu et al., 2010), (Costa et al., 2010),(López et al., 1998), (Gupta and Sharma, 2002),(Gupta et al., 2004), (Clark et al., 2011), (Pulford et al., 2012)
	Immobilization of Cd, Zn and Pb in sewage sludge	Batch tests	82-100%	(Liang et al., 2012)
Steel slag	Water treatment: removal of metals, NH_4^+ and PO_4^{3-}	Batch tests	53–100%	(Oh et al., 2012),(Ahn et al., 2003),(Jha et al., 2004), (Luan et al., 2012),(Zhang et al., 2012)
	Acid mine drainage treatment	Full scale	Steel slag leach beds lost more than 75% of peak alkalinity production within 50 empty bed volumes	(Goetz and Riefler, 2014)
Blast furnace slag, coal fly ash, phosphorus slag, steel slag	Stabilization/solidification of hazardous and radioactive wastes	Lab and field tests	The leachability of contaminants is 100 × lower than from hardened cement stabilized wastes.	(Shi and Fernández-Jiménez, 2006)
Electric arc furnace (EAF) steel slag and iron melter slag	Removal of phosphorus from dairy effluent	Pilot tests	A resting period in EAF steel slag filters increased the P retention capacity by 49.5 and 42.4%	(Drizo et al., 2008)
Fly ash and steel slag	Amendments to multi-metal (Pb, Cd, Cu, and Zn) contaminated acidic soil	Pot experiments	84-96%	(Qiu et al., 2012)
Paper mill sludge Ground granulated blast furnace slag (GBFS) Ground converter steel slag, Green liquor dregs, Lime spoils	Forest soil amendments	Characterization and sequential extraction	The results for the use of GBFS with pulp and paper industry residues seem encouraging regarding the replacement of commercial fertilizers. The use of converter steel slag led to significant increases in the concentrations of Cr and V.	(Mäkelä et al., 2012)

Material	Environmental purpose	Development stage	Efficiency range Main results	Ref.
Green liquid dregs, fly ash, mesa lime, and argon oxygen decarburization (AOD) slag	Neutralization/prevention of acid rock drainage	Batch tests	Significant reduction of the concentrations of certain elements in the leachate and substantially increased the leachate pH.	(Alakangas et al., 2013)
Fly ash	Dry cover for mine tailings	Full scale	The dissolution of the fly ash layer resulted in a high pH (~ 12) in the tailings. This, together with the presence of organic matter, increased the weathering and mobilization of elements in the uppermost 47 cm of the tailings.	(Lu et al., 2014)
Fly ash	Brine remediation	Batch tests and modelling	Na^+ (15–29%), Mg^{2+} (53–87%), K^+ (70–88%), Ca^{2+} (40–73%), and SO_4^{2-} (12–36%).	(Grace et al., 2015)
Fly ash	Fixation reagent for low-activity radioactive waste	Batch test	14.2 - ~ 100%	(Lieberman et al., 2015)

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