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The Removal of Phosphate ions from aqueous solution by Fly ash, Slag, Ordinary Portland Cement and related blends

by

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SUMMARY

Phosphate ions have been removed from aqueous solution by fly ash (FA), slag, OPC and related cement blends. Characterisation of the adsorbents was done using XRD, XRF and laser Fraunhofer diffractometry. The rate and efficiency of phosphate removal was found to increase in the order: FA, slag, OPC, apparently mimicking the order of increasing percentage CaO in the adsorbents. Blending OPC with FA or slag evidently results in diminished phosphate removal efficiency.

Better removal was obtained with smaller particles, at higher solute concentration, acidic pH and higher temperature. The speed of mixing was not found to have a significant effect. A 400 mg/l PO_4^{3-}-P solution was fed at a steady velocity of 2.0 cm/min through a 2-cm fixed-bed column (at pH 9.0 and 25°C) to construct breakthrough curves. Adsorption capacity values of 32, 60, 75, 78 and 83 mg PO_4^{3-}-P/g adsorbent were obtained for FA, slag, OPC/FA, OPC/slag and OPC, respectively.

Adsorption is evidently the major phosphate removal mechanism, with a contribution from precipitation by calcium ions released into solution via dissolution and hydration. The Frumkin isotherm was found to be the appropriate equation for modelling the experimental adsorption data, and values have been

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obtained for the isotherm constants. A first order kinetic model was used to obtain values for overall sorption rate constants and intra-particle diffusion constants.

The use of a fixed bed consisting of a mixture of sand and OPC, OPC/slag or OPC/FA evidently offers a potential alternative to the established methods of large-scale phosphate removal using chemical and/or microbiological agents. An envisaged added value of this proposed method is that bed, after exhaustion with respect to phosphate removal, may be used for the production of masonry bricks. This will obviate the challenge of disposing of the spent bed.

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Die verwydering van fosfaatione uit waterige oplossing deur vlieg-as, slak, gewone Portland sement en verwante mengsels

deur

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LIST OF ABBREVIATIONS AND SYMBOLS

PO_4^{3-}-P	Phosphate phosphorus (i.e., the P in PO_4^{3-})
FDPA	Fraunhofer diffraction pattern analysis
XRF	X-ray fluorescence
XRD	X-ray diffraction
UV/VIS	Ultraviolet/visible
OPC	Ordinary Portland cement
FA	Fly ash
ACBFS	Air-cooled blast furnace slag
GGBFS	Ground granulated blast furnace slag
CAC	Commercial activated carbon
GAC	Granular activated carbon
ACC	Clothe activated carbon
PAC	Powder activated carbon
ACF	Fibre activated carbon
CEC	Cation exchange capacity
A	Al_2O_3
C	CaO
H	H_2O
CH	$Ca(OH)_2$
S	SiO_2

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$\underline{S}$	SO_3
C_2S	Dicalcium silicate
C_3S	Tricalcium silicate
C_3A	Tricalcium aluminate
C_4AF	Calcium aluminoferrite
$U(t)$	Fractional attainment of equilibrium
k'	First-order rate constant, per hour
D	Intra-particle diffusion constant, cm^2/s
α,β	Frumkin isotherm constants
h_Z	Height of the mass transfer zone, cm
h_T	Bed height, cm
t_E	Breakthrough time, min
X_0	Influent concentration, mg/l PO_4^{3-}-P
X	Effluent concentration, mg/l PO_4^{3-}-P
V_E	Effluent volume at breakthrough, cm^3
V_T	Effluent volume at bed exhaustion, cm^3
V_Z	V_T minus V_Z, cm^3
C_T	Specific dynamic adsorption capacity, mg/g