Removal and Recovery of Nutrients by Ion Exchange from Water and Wastewater

By

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CERTIFICATE

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that the thesis has been written by me and that any help that I have received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Signature of Candidate

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Monami Das Gupta
June 2011

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Nomenclature

BPR = biological phosphate removal

BV = bed volumes

Cl^- = chloride

CO_3^{2-} = carbonate

COD = chemical oxygen demand

CR = chemical reduction

Fe^{3+} = iron (III)

g/L = gram per litre

$H_2PO_4^-$ = dihydrogen phosphate ion

HAIX = hybrid anion exchanger

HCl = hydrochloric acid

HCO_3^- = bicarbonate

HFO = hydrated ferric oxide

HPO_4^{2-} = monohydrogen phosphate ion

hr = hours

LDHs = layered double hydroxides

MBR = membrane bioreactor

mg N/L = milligram nitrogen per litre

mg NO_3^- / L = mg nitrate per litre

mg P/L = milligram phosphorus per litre

mg PO_4^{3-} / g = mg phosphate per gram

mg/L = milligram per litre

min = minutes

mL/min = millilitre per minute

mM = milli Molar

N = nitrogen

NaCl = sodium chloride

NaOH = sodium hydroxide

Nitrate-N = N in the form of nitrate

Nitrite-N= N in the form of nitrite

nm = nanometre

NO_3^- = nitrate

oyster-zeolite = resin with crushed oyster shells

P = phosphorus

pH = measure of the acidity or basicity of an aqueous solution

ppm = parts per million

Purolite (A500PS) = used in the decolourisation of sugar syrups

Purolite (A520E) =Purolite (nitrate selective)

SO_4^{2-} = sulphate

Ti^{4+} = titanium (IV)

TiO_2 = titanium dioxide

U = uranium

U(IV) = uranium (IV)

UCT = University of Cape Town-type process

VFA = volatile fatty acids

zeolite = an aluminosilicate mineral

Zr^{4+} = zirconium (IV)

Abstract

In this study, a fixed bed ion exchange system for nutrient removal and recovery for water and waste water was developed and tested for nitrate and phosphate. A post-treatment consisting of a fixed bed bed ion-exchange system with a Purolite and an HFO column in series and individually was used to remove and recover nitrate and phosphate from synthetic water and wastewater. The efficiency of the ion exchange materials incorporated into the anthracite matrix at 1, 3, 5 and 10%, in their ability to remove and recover these nutrients was investigated. Another ion exchange material, HAIX, was also investigated for the removal and recovery of nitrate and phosphate. Also, the study considered regeneration and reuse of the ion exchange media in order to see how long the system can effectively remove and recover nitrate and phosphate before saturation. Purolite was found to exhibit a higher capacity for the removal of nitrate than for phosphate. HFO was found to exhibit a higher capacity for the removal of phosphate than for nitrate. Both these media were required in series to remove both nitrate and phosphate. Increase in dose of the two ion exchange materials incurred an increased in removal efficiency of nitrate and phosphate. However, the selectivity of Purolite for nitrate and HFO for phosphate decreased with increase percentage by mass of the ion exchanger in the anthracite matrix. Regeneration was undertaken using a distilled water wash as well as 3% NaCl wash. It was found that NaCl successfully regenerated the exhausted media for reuse. Distilled water wash was not a successful medium for regeneration. A column experiment was also conducted with MBR effluent to investigate the possibility of removing the nitrate and phosphate. Both N and P in the MBR effluent were found in different forms (as NH_4 – N, organic N, inorganic and organic phosphorus). Other competing anions like Cl^- and SO_4^{2-} were also present in the feed. Despite the different forms of N and P as well as competing anions, the Purolite and HFO in series system still had a removal efficiency of 87-100%. The column was able to remove almost 100% of nitrate and phosphate in the effluent. The Langmuir, Freundlich and Sips isotherm models were used to model the equilibrium isotherm of nitrate and phosphate removal by Purolite (A500PS), HAIX and HFO. The results show that the experimental data satisfactorily fitted to all three models. The kinetic data for the adsorption of both nitrate and phosphate were satisfactorily described by the Ho model. The fit for phosphate on HFO was less satisfactory than the other adsorbents.