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Application of Biochar Technologies to wastewater Treatment

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

In

Soil Science

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Kiran Hina
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This thesis is dedicated to my saviour and supervisor

Professor Michael James Hedley

Abstract

A review of wastewater treatment options and the properties of biochar (charcoal made from biomass with the intention of carbon sequestration in soil) indicated the potential application of biochar for removal of ammonium-N (NH_4^+-N) and various organic and inorganic pollutants from wastewaters. This thesis investigates (i) the capacity of alkaline activated and non-activated Pine and Eucalyptus biochars to retain N and P from wastewaters, and (ii) the potential use of these nutrient-rich materials as slow-release fertilisers in soil, thus assisting the recycling of nutrients from waste streams.

The retention of NH_4^+-N on different materials, pine bark, pine biochar (produced from wood chips at 550 °C) and zeolite was investigated. When shaken with a 39 mg NH_4^+-N L^{-1} influent solution, Zeolite proved to be the best sorbent of NH_4^+-N, followed by pine biochar and pine bark; 0.71> 0.38 > 0.27 mg NH_4^+-N g^{-1} sorbent, respectively. Ways of increasing the CEC (cation exchange capacity) and NH_4^+-N sorption capacity of biochar were investigated by (i) alkaline activation by tannery waste or (ii) physical activation using steam as pre and post treatment of biochars, respectively to increase their CEC. Washed alkaline activated biochars (Pine and Eucalyptus) showed a significant ($p < 0.05$) increase in the NH_4^+-N sorption capacity over corresponding non-activated biochars. Steam activation increased the internal surface area of biochars but did not prove increased retention of NH_4^+-N. The efficiency of NH_4^+-N removal from synthetic NH_4^+ solutions and urban and dairy wastewaters by alkaline activated and non-activated Pine and Eucalyptus biochars was evaluated and compared using batch and column studies under different flow rates and retention times. Greater NH_4^+-N sorption was observed in alkaline activated Pine biochar from both the synthetic solution and urban wastewater in column studies @ 2.40 mg N g^{-1} and 2.17 mg g^{-1} NH_4^+-N biochar, respectively. Inclusion of Okato tephra with alkaline activated pine biochar proved effective in removing both P and N from urban wastewater.

Finally, the activated pine biochar and tephra loaded with N and P from wastewater treatment were incorporated into two soils (Kiwitea and Manawatu) and the bioavailability of N and P was tested by growing ryegrass in an exhaustive Standford and Dement bioassay. The recovery of N and P was very low and this indicated that it was not economical to use biochar in wastewater treatment for subsequent use as a fertiliser.

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