Ecological Engineering 85 (2015) 193–200

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Use of amendments in a peat soil to reduce phosphorus losses from forestry operations

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ARTICLE INFO

Article history:
Received 19 March 2015
Received in revised form 6 October 2015
Accepted 7 October 2015
Available online 18 October 2015

Keywords:
Phosphorus
Forestry
Peat
Clearfelling
Harvesting
Buffer zones
Adsorption

ABSTRACT

Forestry harvesting on peats is known to result in significant losses of soil phosphorus (P) to adjacent waters, and the issue is becoming an increasingly serious concern as peatland forest stocks mature and reach harvestable age. One potential solution could be the use of low-cost P recovery techniques based on the chemical precipitation and/or adsorption of the dissolved fraction of soil P, which would otherwise be lost. Such recovery techniques have shown promise in similar applications on mineral soils. However, the interaction of peat with P adsorbing materials can significantly alter their adsorptive characteristics, and it is consequentially not known what materials might be suitable for this application. This study compared the performance of six potential soil amendments (aluminum water treatment residual (Al-WTR), crushed concrete, gypsum, magnesium hydroxide, magnesium oxide, and steel wool) in removing P from aqueous solution in the presence of a typical forest peat soil. Comparison of adsorption isotherms plotted from these batch adsorption studies showed that the observed P adsorption maxima of Al-WTR and steel wool were increased by the presence of peat, from 10.6 mg g^{-1} and 20.4 mg g^{-1}, to 11.8 mg g^{-1} and 52.5 mg g^{-1}, respectively. In contrast, the observed P adsorption maxima of crushed concrete, gypsum, and magnesium oxide were reduced in the presence of peat, by 44%, 87%, and 37%, respectively. The maximum P adsorption achieved by magnesium hydroxide was increased from 29.8 mg g^{-1} to 59 mg g^{-1} at an amendment to peat–solid ratio of 1:4, but decreased from 73.9 mg g^{-1} to 23.6 mg g^{-1} at an amendment to peat–solid ratio of 1:10. It was concluded that Al-WTR, in particular, shows considerable promise for use as a soil amendment for P immobilization in a peat environment.

1. Introduction

Ireland's forestry stock of 731,000 ha covers about 10.5% of the country, of which 44% is planted on peats (National Forest Inventory, 2012). Peats, especially ombrotrophic upland blanket peats, are generally lacking in minerals like aluminum (Al) and iron (Fe), and consequently have extremely low soil phosphorus (P) sorption capacities (Renou et al., 2000). As a result, any P released by the forestry operations, such as clearfelling and afforestation, is liable to leach unimpeded into adjacent receiving waters, even with the application of current best management practices targeted at preventing such pollution (Finnegan et al., 2014).

Nutrient enrichment, or eutrophication, of inland waters is recognized as Ireland's most serious environmental pollution problem (Department of the Environment, 2002). As P has been identified as the primary nutrient limiting eutrophication in freshwaters (Carpenter et al., 1998; Boesch et al., 2001), preventing its migration from soil to aquatic environments is paramount. The oligotrophic nature of Ireland's upland catchments, and the unique flora and fauna present in these waters, make them particularly sensitive to eutrophication (Mainstone and Parr, 2002; Hutton et al., 2008). These forested peat catchments are headwaters for many of Ireland's river systems, a great number of which contain important salmonid populations (Giller and O'Halloran, 2004), as well as other species protected under European Union (EU) legislation (O'Driscoll et al., 2012; Reid et al., 2013). Consequentially, pollution from diffuse, low concentration sources of P, such as forestry, is capable of causing considerable environmental damage to an area much larger than that which is forested.

The sustained release of P following forestry harvesting has been highlighted as an issue of particular concern, as much of Ireland's current peatland forestry stock was planted between the 1950s and the 1990s (Renou and Farrell, 2005) and has now reached, or is reaching, harvestable age (Rodgers et al., 2010). Clearfelling is the harvesting technique most prevalent in Ireland, and accounted for

Abbreviation: Al-WTR, aluminum water treatment residual.

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http://dx.doi.org/10.1016/j.ecoleng.2015.10.016
0925-8574/

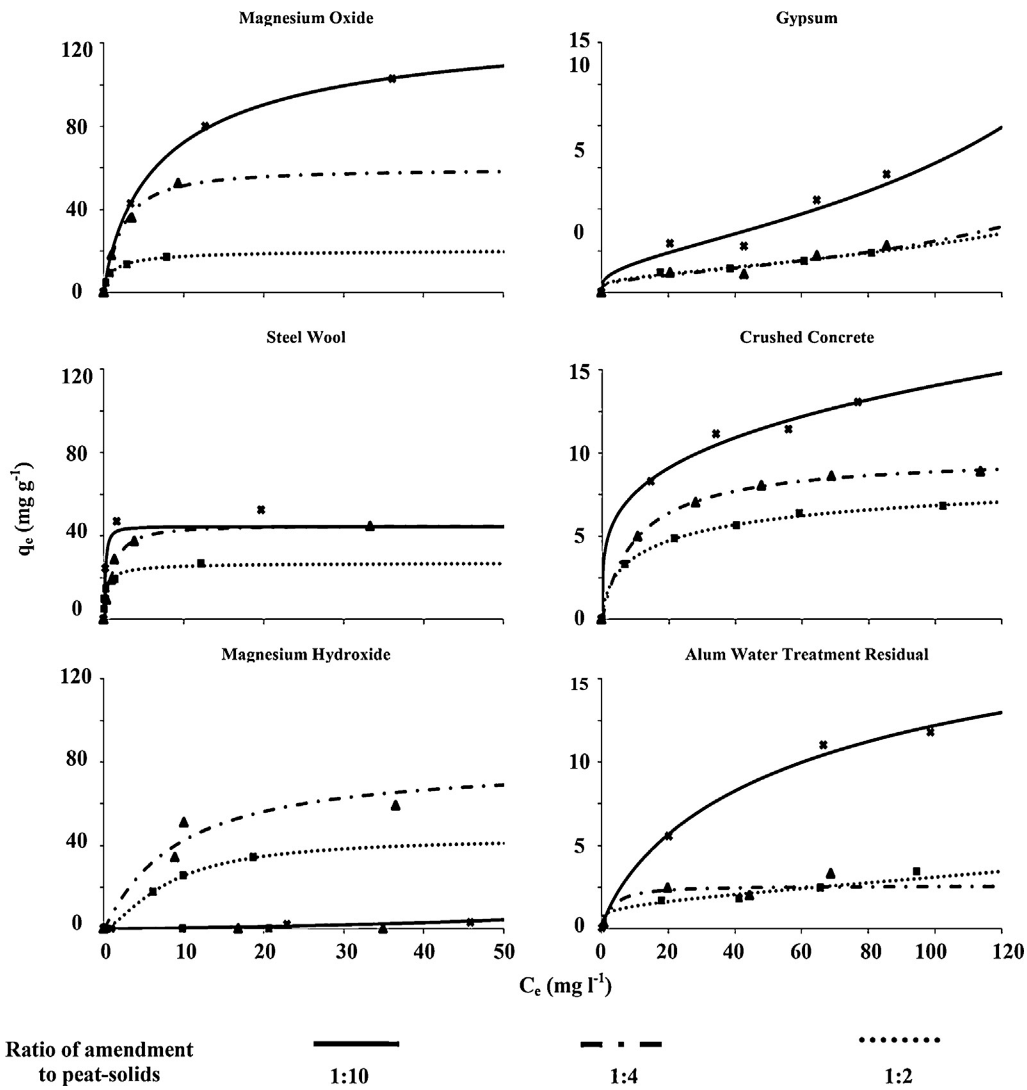

Fig. 1. Best fit Koble–Corrigan adsorption isotherm models derived using non-linear regression methods for (a) magnesium oxide, (b) gypsum, (c) steel wool, (d) crushed concrete, (e) magnesium hydroxide, and (f) Al-WTR, at amendment to peat–solid ratios of 1:10, 1:4, and 1:2.

76.6% of timber felled between 2006 and 2012 (National Forest Inventory, 2012). Clearfelling involves the removal from site of the commercially viable portions of the forestry crop (i.e. tree trunks), leaving large amounts of P to remain onsite, present both in the soil and in the non-commercial logging residues, or 'brash'. This brash accounts for a considerable percentage of the above ground nutrients contained in a typical coniferous tree (Moffat et al., 2006), and it has been shown to release these nutrients for many years following its deposition (Titus and Malcolm, 1999; Hyvönen et al., 2000). To compound the issue, the use of brash mats to form temporary driving surfaces for heavy felling machinery is an essential management practice, as it prevents serious damage to the underlying soil (Moffat et al., 2006). Clearfelling completely disrupts natural P cycling in a forest ecosystem, with the deposition of brash mats resulting in increased P availability, while the concurrent removal of trees from site results in decreased P uptake and sequestration – a situation which greatly increases the threat of P leaching to aquatic ecosystems (Schaller et al., 2015).

While rates of afforestation on blanket peats have been in decline in recent years (National Forest Inventory, 2012), the harvesting of presently established forest is inevitable, as are the resulting water quality issues, if effective pollution mitigation measures are not implemented. Current best management practices advocate the use of riparian buffer strips between forestry and adjacent aquatic zones (Forest Service, 2000). Previous research has found the use of suitably large riparian buffer zones on peat soils to be largely successful in protecting surface waters from influxes of suspended sediments and associated particulate nutrients (Nieminen et al., 2005). However, with peat's low P adsorption capacity, the performance of these buffer zones in satisfactorily mitigating the flow of dissolved P off site varies greatly. Moreover, it has been found that these buffer zones' effect can be anywhere from positive, with total retention of released P (Vaananen et al., 2008), to negative, compounding the issue with additional P release (Vasander et al., 2003; Liljaniemi et al., 2003).

There has been increasing interest in the use of soil amendments to control P losses from diffuse sources, such as land spreading of manure from dairy cattle (Brennan et al., 2011a,b) and pigs (O'Flynn et al., 2012), land spreading of dairy waste water from washing of milking parlors (Serrenho et al., 2012), and construction of wetlands on sites previously used for agriculture (Ann et al., 1999). The use of chemical amendments has shown much promise in these instances, though there has been little to no investigation into the practice's potential in abating the loss of P from peatland forestry.