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Laboratory study of a denitrification system using a permeable reactive barrier

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Introduction Point-source nitrate (NO_3) contamination of shallow groundwater can result in NO_3 plumes of high concentration. Pressure to clean these waters under the EU Water Framework Directive (WFD) has seen the need for *in situ* remediation technologies. One such technology is a Permeable Reactive Barrier (PRB). A PRB comprises a layer of carbon (C)-rich material positioned perpendicular to the direction of flow of contaminated groundwater. In this study, the objective was to build laboratory-scale PRBs to determine the best reactive media to be used in a field-scale study to treat NO_3-rich water. This paper presents the finding from two reactive media – (1) lodgepole pine woodchips and (2) cardboard – that have been loaded with NO_3-amended water for a period of greater than 130 days. Future work will test new materials and will address the production of greenhouse gas (GHG).

Materials and methods 100mm-diameter x 1m-deep acrylic columns were constructed in a temperature-controlled room operated at a temperature of 10°C. Each column comprised a 1.5cm-deep 'water tank' (built using a fine metal mesh) at the base to allow uniform distribution of influent water into the column. 0.8m-deep reactive media rested on top of the metal mesh. The columns were sealed at the top with rubber stoppers. Influent water was applied at the base of each column using a peristaltic pump (operated continuously) and the water exited the column via a 1cm-diameter tube positioned just above the reactive media surface. This mode of operation was in accordance with existing work in this area (Hunter & Shaner 2009; Moon *et al.* 2008; Rocca *et al.* 2007; Saliling *et al.* 2007; Volokita *et al.* 1996)and prevented the occurrence of preferential flow pathways that may occur if the system was loaded from the surface. Rubber septum stoppers were positioned at 20 cm-intervals along the side of the columns to enable water samples to be collected (Figure 1).

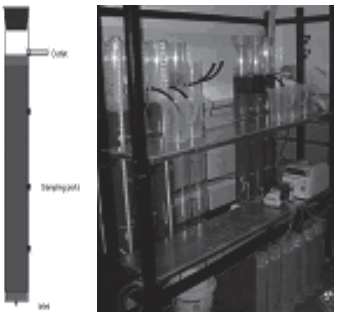

Figure 1 Columns set-up

Two reactive media were used in this study: lodgepole pine woodchips (LPW) (~14-20 mm in size) and cardboard (CB) (cut in squares of ~25mm). Both sets of columns were constructed in triplicate (n=3). The LPW were placed in the columns in alternating 30mm-deep layers with soil from the proposed study site. The average initial porosity was ~33%. The CB columns were constructed in a similar manner to LPW columns. Here, the average initial porosity was ~41%. All 6 columns were covered with black plastic. Prior to operation, all columns were loaded with tap water, loaded at a rate of 19-22.5 mm d^{-1} (to establish background C and nutrient release), after which they were seeded with ~1L of bulk fluid containing heterotrophic bacteria from a wastewater treatment plant and loaded with NO_3-N solution at a concentration of 20 mg/L. Almost daily water samples exiting the columns were analysed for: pH, chemical oxygen demand (COD), ammonium (NH_4-N), NO_3-N, nitrite (NO_2-N) and ortho-phosphorus (PO_4-P).

Results The results are presented in Table 1. The LPW and CB columns have been working for more than 150 and 130 days, respectively, and continue to produce effluent NO_3-N concentrations below 0.0076mg/L. Student t tests were utilized in the data analysis, and a P-value greater than 0.05 was obtained, indicating no statistical difference between the columns (LPW and CB). This represents a removal of almost 100%. Effluent COD from both sets of columns continues to remain high (>572 mg/L), indicating an abundant C source in the media. Effluent NH_4-N from both columns is high (>3.85mg/L), indicating N release from the media.

Table 1 Average results from the Lodgepole pine woodchips (LPW) and Cardboard (CB) columns.

	pH outlet	COD	NH_4-N		PO_4-P		NO_3-N inlet		NO_3-N outlet	
		mg/L	mg/L	stdev	mg/L	stdev	mg/L	stdev	mg/L	stdev
LPW	7.37	572	4.8	2.2	0.20	0.17	21.35	0.93	0.008	0.015
CB	7.16	911	3.9	2.5	0.10	0.16			0.005	0.013

Conclusions The results from this study indicate that lodgepole pine and cardboard are good media for use in PRBs. Both media have produced effluent NO_3-N concentrations below 0.0076mg/L. This represents a removal of almost 100%. Effluent pH, COD and PO_4-P concentrations have continued to remain stable.

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