Phosphorus and pathogen removal from wastewater, storm water and groundwater using permeable reactive materials

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Introduction

Eutrophication of aquatic ecosystems as a consequence of excessive loading of phosphorus and other nutrients is a common local and watershed-scale problem. Phosphorus is typically present at concentrations between 0.005 and 0.05 mg/L in ground water and surface water. Elevated concentrations of phosphorus significantly above background levels can be generated through activities and facilities associated with agriculture, waste management and urbanization. To minimize impacts on groundwater and aquatic systems, phosphorus removal from groundwater, domestic wastewater and storm water can form part of nutrient management programs.

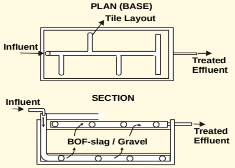
Permeable reactive mixtures containing Basic Oxygen Furnace (BOF) slag can remove phosphorus from water to very low concentrations. BOF slag is a non-metallic waste byproduct of steel production and is a poorly sorted mixture of material ranging in grain size from silt to fine gravel. Generated at several steel plants across North America, BOF slag contains significant concentrations of iron and calcium oxyhydroxides (Proctor et al., 2000). In contact with water, BOF slag promotes high pH (~10 to 12) conditions. BOF slag in permeable mixtures can be used to remove phosphorus and pathogens from groundwater in permeable reactive barriers (PRBs), and in chambers or large basins for treatment of storm water and effluent from domestic and communal wastewater systems.

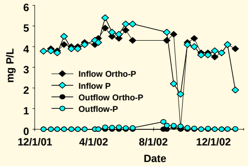
Testing and Applications

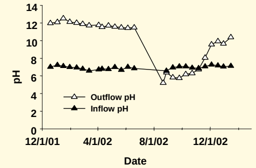
Continuous testing to assess the long-term performance of phosphorous removal systems has been carried out for more than 10 years, Baker et al. (1998) initiated testing with laboratory columns containing BOF oxide and slag mixtures. Column influent concentrations of 3 mg/L PO_4-P were lowered to less than 0.05 mg/L for more than 10 years of continuous operation. Phosphorus removal was through adsorption and precipitation of a Ca-PO_4 solid. Baker et al. (1997) evaluated BOF slag in a PRB to treat phosphorus in groundwater emanating from a septic system. Excellent removal was observed. Phosphorus also was removed from a stream of effluent from a municipal wastewater treatment plant using BOF oxide. More recently, BOF slag in chambers has been used to treat septic-system effluent at a lakeside home near North Bay, communal wastewater effluent in Cape Cod, Massachusetts, and storm water associated with a new development north of Toronto, Ontario.

Cape Cod Demonstration

A concrete tank containing BOF slag was installed at the Massachusetts Alternative Septic System Test Center in October 2001. Aerobically treated communal wastewater with low biological oxygen demand (BOD) was introduced to the chamber over a period of two years. Flow of water is upward through the BOF slag mixture. Removal of total phosphorus and ortho-phosphate P to concentrations of approximately 0.05 mg/L or less was routinely achieved.

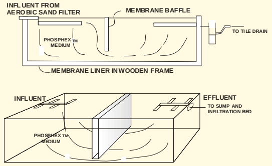


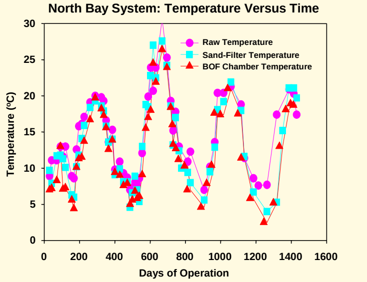


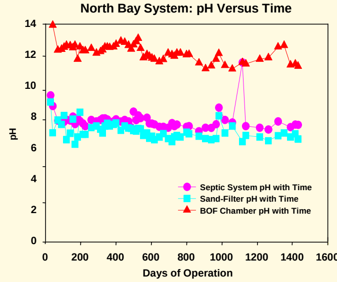


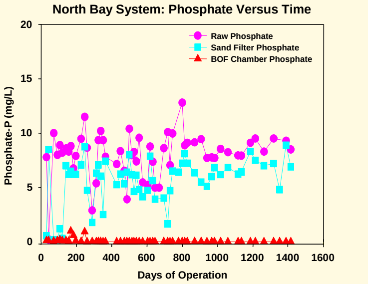
North Bay Demonstration

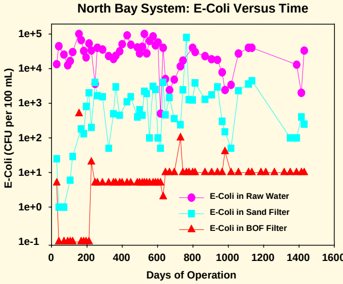
A project was implemented and administered by the provincial and municipal governments to remove phosphorus from septic system effluent. Since 1999, septic effluent from a single-family residence near North Bay, Ontario, has been treated in an aerobic sand filter, followed by a BOF slag chamber (Smyth et al., 2002). Phosphorus concentrations of approximately 5 mg/L PO_4-P in the septic system effluent were lowered to less than 0.02 mg/L PO_4-P in discharge from the BOF slag treatment chamber. The chamber also effectively removed E-coli from the wastewater. Neutralization of the pH occurred in groundwater adjacent to the subsurface discharge gallery. No maintenance of the influent and effluent lines of the BOF chamber was required for the first four years of operation. The lines were flushed hydraulically once to remove accumulated sludge.











Summary

Reduction of phosphorus concentrations in water entering aquatic ecosystems is a key component of many nutrient management programs. BOF slag can be applied in passive permeable reaction systems to intercept and remove phosphorus to very low levels prior to discharge to aquatic ecosystems. The approach is low cost, and makes beneficial use of waste materials from the steel industry.

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