Use of Steel Slag to Remove Soluble Phosphorus from Closed Marine Systems

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The accumulation of soluble phosphorus is a major problem in closed marine systems as it favors excessive algae growth, requiring constant efforts to maintain water quality. In recent studies, steel slag produced in electric arc furnaces (EAFs) retained more than 6 g P/kg slag in bench scale tests with freshwater (Lospied et al, 2003). It also efficiently removed phosphorus from the effluent of a freshwater fish farm (Boumecied et al, 2003). Our goal was to determine whether EAF slag could also be used to remove soluble phosphorus from a large marine aquarium. The study was conducted in a 3,000 m³ marine system at the Montreal Biodome. The system is home to about 100 seabirds, 600 fishes and 2,000 invertebrates from the Gulf of St. Lawrence. It contained 20 mg P/L of orthophosphate (60 kg P) at the end of 2003.

A 10 m³ pilot unit was built using 2.5 cm thick polypropylene (2 m x 3 m x 1.2 m high) and PVC piping 10 cm ø. It was then filled with 9,500 kg of EAF slag gravel 2-5 mm in size. The steel slag contained 34% FeO, 32% CaO and 19% SiO_2 (Lospied et al, 2003). Water was gravity fed into the unit and flowed through it in upflow mode at rates up to 20 L/min. Two runs were conducted 5 months apart using the same slag batch. The slag was dried between the runs. Run 1 lasted 93 days and the flow rate varied between 3 and 9 L/min. Run 2 lasted 60 days and the flow rate was constant at 5 L/min.

During Run 1, the pilot unit removed 7 kg P (0.75 g P/kg slag). Maximum daily removal was 165 g P/d at a flow rate of 9 L/min (Day 37). Slag cementation and channelling were observed 30 days after startup, but they did not get worse nor cause operating problems. Both pH and alkalinity increased in the effluent. During Run 2, the pilot unit removed 2.3 kg P (0.24 g P/kg slag). Maximum daily removal was 82 g P/d (Day 1). Little adsorption was observed after 60 days. Again, both pH and alkalinity increased in the effluent. Total adsorption was much lower than expected from the bench scale tests with freshwater. It was probably limited by the short hydraulic retention time (8.3 hrs at 4 L/min) and the formation of a bacterial biofilm. Operation of the pilot unit had no adverse effect on fishes and invertebrates.

The use of steel slag offers a promising solution to safely reduce soluble phosphorus in closed marine systems. Its efficiency is limited by the formation of a bacterial biofilm but this can be overcome by drying the slag at regular intervals. More runs are needed to assess the full potential of steel slag in marine systems. Given a net annual input of 4 kg P (Trépanier et al, 2002), complete removal of soluble phosphorus from the system would require at least two years and four slag batches with the pilot scale unit. A larger unit would speed up the process and help maintain the pH and alkalinity of the system.

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References

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