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Decreasing phosphorus discharge in fish farm ponds by treating the sludge generated with sludge drying beds

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ABSTRACT

Two sets of experiments were carried out to assess the net advantage of treating the sludge generated during fish production with sludge drying beds (SDBs). The first experiment consisted of monitoring the concentration of o-PO_4-P and total phosphorus (TP) at the effluent of four 1 m^2 SDB. The SDBs were set up in a fish farm facility and were fed with fresh settled sludge every week (two of them were operated at 32 kg DM/m^2.year and two of them were operated at 18 kg DM/m^2.year). The second experiment consisted of monitoring under lab conditions the long term aerobic and anaerobic leaching of o-PO_4-P of fish farm sludge. Phosphorus leaching from SDBs was that of 3 μg o-PO_4-P released/g TP and 5 μg TP released/g TP, regardless of sludge loading. Phosphorus leaching rates under lab conditions was that of 280 μg o-PO_4-P/g TP and 520 μg o-PO_4-P/g TP under aerobic and anaerobic conditions, respectively. Furthermore, SDBs leached phosphorus to a greater extent during high raining episodes (up to 4 mg o-PO_4-P/m^2 d and 7.3 mg TP/m^2 d). However, the implementation of a slag filter treating the SDB effluent could reduce the phosphorus leached by the SDB, thus evidencing its potential utilization to reduce leaching variability of SDBs. The main conclusion of the present work is that of the use of a SDB may reduce the phosphorus discharged by a trout production pond (either in terms of soluble or particulate phosphorus) by 36%. More precisely, sludge treatment with a SDB will save about 0.52 kg of P/ton of fish produced and between 0.215 and 0.402 g of o-PO_4-P/ton of fish produced.

1. Introduction

Aquaculture effluents are recognized to be a source of organic pollution for the receiving watershed (Gowen et al., 1990). Phosphorus (P) is a limiting nutrient in most freshwater environments and is responsible for accelerating eutrophication (Smith et al., 1999). Solids produced in trout facilities (uneaten food and feces mainly) contain up to the 90% of the total phosphorus load (Cripps, 1994; Cripps and Bergheim, 2000). Moreover, the phosphorus fraction contained in uneaten food and feces is susceptible to be solubilized after entering the system (Garcia-Ruiz and Hall, 1996; Stewart et al., 2006). Consequently, many authors have proposed not only to rapidly remove solids produced during fish production to minimize phosphorus discharge (Cripps and Bergheim, 2000) but also to enhance the solids settleability to avoid leaching and particle disaggregation (Brinker et al., 2005). Many technologies have been developed to remove solids produced during fish farming such as microscreens, filter beds, Cornell-type circular tanks and settling tanks (Cripps and Bergheim, 2000). Such systems, however, are rarely used in small production facilities as they are relatively expensive and labor intensive. Accordingly, in small fish production facilities solids trapping systems coupled to sludge drying beds could be a suitable strategy to properly manage sludge generated during fish production (Lefrançois et al., 2010). Sludge drying beds (SDBs) is a low cost technology that has been used over the past 20 years to treat thickened sludge (1–7% solids) produced in the clarifier underflow at wastewater treatment plants (Liénard et al., 1990; Uggetti et al., 2010). SDBs have also been described to be a suitable technology to treat fish farm wastes (Summerfelt et al., 1999). However, to the knowledge of the authors, there is little information available on to what extent the application of this technology may contribute to reduce phosphorus discharge from fish farms facilities. Moreover, the application of slag filters has been described to be a suitable technique to treat a wide range of phosphorus-rich waters (Chazarenc et al., 2007; Johansson, 1999), also being suitable for treating the supernatant water of fish farm concentrated sludge (Drizo et al., 2006). However, there is scarce information on the application of slag filters to further treat the leachate of SDBs devoted to fish farm sludge disposal (Comeau et al., 2006). The main objective of the present work was, on one hand, to assess the efficiency of sludge drying beds on phosphorus removal and, on the other hand, assess the long-term phosphorus release capacity of fish farm sludge by means of lab experiments. Confronting the phosphorus

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Table 1
Grain size of filter media and height of each media layer from top (smaller sand) to bottom (bigger gravel).

	Grain size (mm)	Layer height (cm)
Silica sand	0.6	2
Silica sand	1–2	6
Silica sand	2–3	12
River gravel	4–8	9
River gravel	10	6
River gravel	19–32	5
Total filter height		40

leaching of fish farm sludge under lab conditions with the phosphorus leaching of sludge deposited on SDBs will give insight of the net advantage of sludge extraction and disposal on SDBs for minimizing phosphorus discharge in fish farm facilities. The potential application of slag filters downstream of a SDB to improve phosphorus removal is also discussed.

2. Material and methods

2.1. Sludge drying beds

For the purposes of this study 4 sludge drying beds (SDBs) were set up in a fish farm facility devoted to rainbow trout production (*Oncorhynchus mykiss*). The fish farm (intensive pond-based fish farm) is situated at Sainte-Marguerite-de-Lingwick, Quebec (Canada) and the efficiency of the SDB on phosphorus removal (on mass balance basis) was monitored from late May to September 2009. Each SDB consisted of a reservoir of 1 m^3 filled with different types of river gravel (bottom layer of 20 cm) and sand (top layer of 20 cm) (Table 1). Each SDB had a surface of 1 m^2 and was planted one year before the experiments (in spring 2008) with *Typha latifolia* obtained from surrounding wet areas at an initial density of 8 plants per SDB. Two of the SDBs were operated at a loading of ca. 18 kg DM/m^2.year and two of them at ca. 32 kg DM/m^2.year. SDBs were fed once a week with fish farm sludge from a concrete pond within the fish farm facility. Fish farm sludge was collected by means of a settler placed just below the surface floating aerator (0.5 HP, 500 gpm, 3450 rpm) of a concrete pond following the recommendations of Lefrançois et al. (2010). Technical details of the sludge collecting device are out of the scope of the present paper and can be found in Marcotte (2008). Sludge accumulated within the settler was weekly pumped (around 200 L of sludge per week) to an intermediate reservoir (1 m^3) from which the sludge was manually collected (after a settling period of 24 h) to feed the SDBs once a week. Before feeding the systems, the leachate from the former feeding episode was completely removed from the SDB and its total volume measured. Physical and chemical variables measured on both feeding sludge and SDB leachate (namely total phosphorus, soluble phosphorus, ammonia, nitrates, total COD and soluble COD) were conducted once a week, for thirteen weeks, according to APHA (2001). Fig. 1 summarizes the experimental set up. Because sludge loading was different for each experimental line the leachate volume collected each week was also different. Therefore, in order to compare treatment efficiencies between SDBs operated at different sludge loading its effluent concentration was calculated on a mass balance basis according to:

$$EC = \frac{C_l \cdot \frac{L}{t}}{S}$$

where,

EC	is effluent concentration, in mg/m^{-2} .d
C_l	is the SDB effluent concentration, in mg.L^{-1}
L	is the leachate volume collected each sampling day, in L
t	is the time between the sampling event and the former feeding episode, in days
S	is the surface area of each wetland, in m^2.

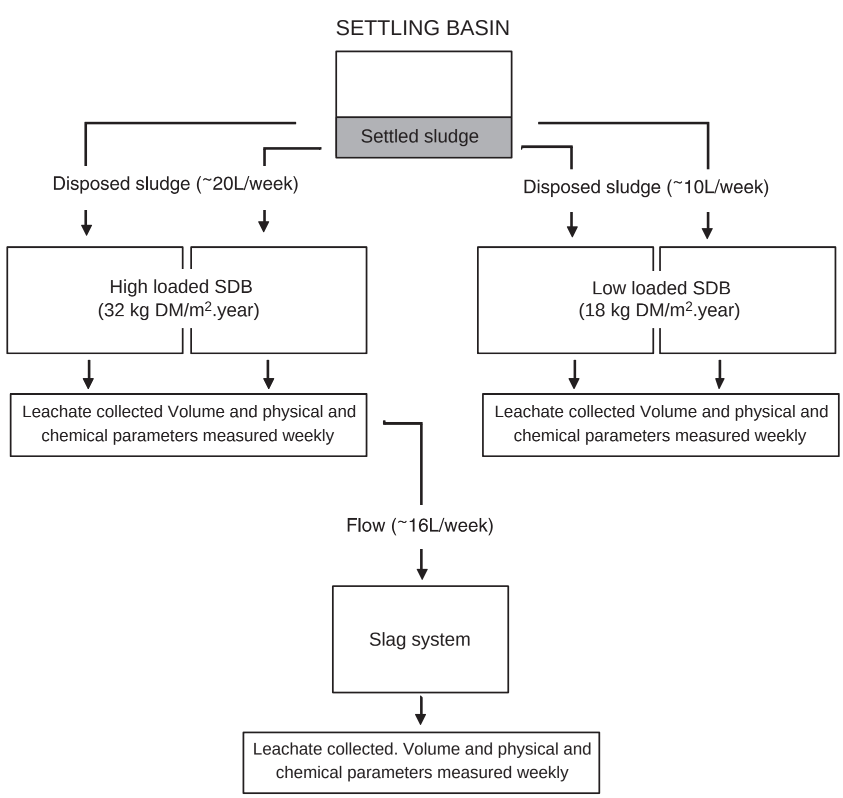

Fig. 1. Outline of the experimental set up.