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Biological nutrient removal by a sequencing batch reactor (SBR) using an internal organic carbon source in digested piggery wastewater

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Abstract

Experiments in a lab-scale SBR were conducted to demonstrate the feasibility of using an internal carbon source (non-digested pig manure) for biological nitrogen and phosphorus removal in digested piggery wastewater. The internal C-source used for denitrification had similar effects to acetate. 99.8% of nitrogen and 97.8% of phosphate were removed in the SBR, from an initial content in the feed of 900 mg/l ammonia and 90 mg/l phosphate.

Keywords: Piggery wastewater treatment; Internal carbon source; Sequencing batch reactor; Nutrient removal; Nitrification; Denitrification; Biological phosphorus removal

1. Introduction

Biological denitrification is a reliable method for nitrogen removal from wastewater (Abufayed and Schroeder, 1986). Heterotrophic bacteria use the available carbon source. Since nitrified liquor is usually deficient in organic carbon and the low carbon source level limits the biological denitrification process, sufficient organic carbon sources must be provided for proper denitrification. In addition, for proper biological phosphorus removal, an easily biodegradable carbon source is needed at the P release stage. Effluents from pig manure anaerobic digesters still contain a large amount of COD and a large nutrient load (ammonia and phosphate). Though a small fraction of the COD consists of volatile fatty acids and could be used for denitrification, easily biodegradable COD is clearly needed, given the amounts of nitrogen and phosphorus. Synthetic chemicals, such as methanol or acetic acid, are expensive, but are quite effective. However, the use of non-digested pig manure as a source of easily biodegradable carbon is an alternative and cheaper method. The use of wastewater as an electron donor for denitrification in sequencing batch reactors (SBRs) was suggested by Pallis and Irvine (1985) and implemented for piggery wastewaters by Bortone et al. (1992). This approach has aroused greater interest recently, especially the use of domestic wastewater with the organic fraction of municipal solid waste (OFMSW) as carbon source. For instance, Beccari et al. (1998) studied the potential of readily biodegradable COD obtained from acidogenic fermentation of the OFMSW as electron donor for denitrification. Experiments at an SBR pilot plant used domestic wastewater from the wastewater treatment plant at Fusina (Venice). The results showed a remarkable improvement both in denitrification rate and in flexibility of the response to influent load peaks. The main advantage of this approach is economic, as no expensive external carbon source is required. Other studies have followed this idea of using residual effluents as substitutes for chemical carbonaceous sources (e.g. Monteith et al., 1980; Skrinde and Bhagat, 1982; Bernet et al., 1996; Lee et al., 1997; Ra et al., 2000; Graja and Wilderer, 2001; Cervantes et al., 2001).

This study aimed to establish an approach to removing nutrients from digested pig manure in an SBR with internal easily degradable organic matter and to explore the feasibility of this more cost-efficient removal

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system. SBRs provide a simple and even economical way of treating piggery wastewaters. SBR systems offer substantial benefits over alternative conventional flow systems, because of their flexibility and capacity to meet various treatment objectives (Norcross, 1992; Ketchum, 1997).

In the experiments, non-digested pig manure was added at the beginning of the denitrification stage, together with acetic acid in different ratios. Reactor performance was then studied under three operating conditions (P1, P2 and P3), with different proportions of external (acetic acid) and internal (volatile fatty acids of pig manure) carbon.

The appropriate C/N ratios were established with care, so as to achieve complete denitrification without any carbon source excess. Thus, both waste of time and oxygen consumption were avoided.

Table 1
Characterisation of the digested and non-digested piggery wastewater supernatant after centrifugation

Parameters	Digested piggery wastewater	Non-digested piggery wastewater	No. of analyses
pH	8.42	8.45	–
TS (g/l)	11.21	13.42	5
VS (g/l)	5.35	6.23	5
TSS (g/l)	2.58	3.10	5
VSS (g/l)	1.96	2.2	5
VFA (mg/l)	1050	5275	3
BOD_5 (mg/l)	1730	3250	4
COD (mg/l)	3085	7450	8
$Alkal_{7.74}$ (mg/l)	1183	1450	5
$Alkal_{3.53}$ (mg/l)	5226	6530	5
Total N (mg/l)	1650	785	8
NH_4^+-N (mg/l)	1600	720	6
NO_3^--N (mg/l)	0	0	6
NO_2^--N (mg/l)	0	0	6
PO_4^{3-}-P (mg/l)	147	120	6

2. Methods

2.1. Substrate and readily biodegradable C-source

Raw and digested pig manure was obtained from a piggery at Caldes de Montbui, 30 km from Barcelona. The latter had been treated in an industrial anaerobic digester on the farm. The effluent from the digester was centrifuged (Beckman model J2-21) at 4000 rpm for 15 min at 5 °C, to remove most of the suspended solids. The supernatant was used as substrate for the experiments. The non-digested pig manure was used after centrifugation as an easily biodegradable carbon source.

Before being fed into the reactor, the supernatant was diluted with tap water to the desired concentration (see Fig. 1 for feed preparation). Table 1 shows the characteristics of the supernatant and of the non-digested pig manure.

2.2. Experimental device

The SBR, a cylindrical tank with a volume of 3 l, was made of Pyrex glass and fitted with mixing and air sparging systems (Fig. 2). It was complemented by two peristaltic pumps (Cole Parmer Instruments, Model number 7553-85, Chicago), one for feeding, the other for drawing off effluent and excess sludge. The SBR operation cycles were controlled by programmable timers.

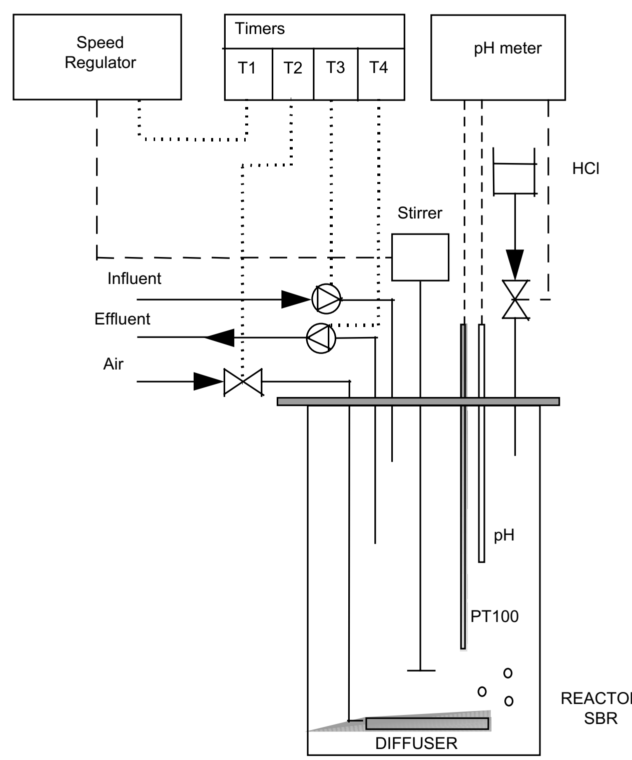

Fig. 2. Diagram of the SBR.

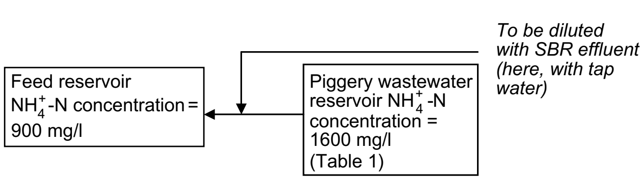

Fig. 1. Feed preparation: after feed is prepared, it is introduced in the reactor. As there are 2 l remaining from the previous cycle, the initial concentration of NH_4^+-N is 300 mg/l.

A data acquisition system (model CRISON pHrocon 18, Barcelona) was used for the continuous recording of the mixed liquor temperature and of pH. Optimum pH was set at 8.1. Higher pH was corrected by mechanical addition of hydrochloric acid HCl (0.5 N).