Available online at www.sciencedirect.com

ScienceDirect

Bioresource Technology 98 (2007) 1573–1578

BIORESOURCE TECHNOLOGY

Removal and recovery of phosphorous from swine wastewater by demonstration crystallization reactor and struvite accumulation device

Kazuyoshi Suzuki *, Yasuo Tanaka, Kazutaka Kuroda, Dai Hanajima, Yasuyuki Fukumoto, Tomoko Yasuda, Miyoko Waki

Pollution Control Research Team, National Institute of Livestock and Grassland Science (NILGS), 2 Ikenodai, Tsukuba, Ibaraki 305-0901, Japan

Received 23 February 2006; received in revised form 6 June 2006; accepted 12 June 2006
Available online 21 August 2006

Abstract

A demonstration crystallization reactor and struvite accumulation device for the removal and recovery of phosphorous was constructed and their performance was evaluated using actual swine wastewater for 3.5 years. The wastewater pH was increased by aeration, and the concentrations of total P and soluble PO_4–P were reduced by a struvite crystallization reaction induced under a high pH condition. A 30% $MgCl_2$ addition was effective in enhancing the struvite crystallization reaction. The concentrations of suspended solids, total Zn and total Cu, were also decreased by the settling function of the reactor. On removing the efficiencies of these components, no noticeable seasonal fluctuation in performance was observed during the 3.5-year operation. In terms of maximum yield, 171 g struvite was obtained from 1 m^3 swine wastewater by the demonstration accumulation device for struvite recovery. The recovered struvite needed only air-drying before use since it was approximately 95% pure even without washing.

Keywords: Swine wastewater; Struvite; Suspended solids; Cu; Zn

1. Introduction

Swine wastewater contains phosphorous in high concentrations. Japanese law requires reducing phosphorous concentration to the legal limit before it can be discharged into public waters (Haga, 1998). Yet, all the phosphate rock Japan needs must currently be imported from abroad, since it lacks subterranean phosphorous resources. There is a need to develop and establish the technologies for phosphorous recovery from swine wastewater given its especially high potential for phosphorous recovery in Japan (Suzuki et al., in press).

In addition to PO_4 and NH_4, swine wastewater contains high concentrations of Mg. Once the pH of swine wastewater rises to 8–9, PO_4, Mg and NH_4 become crystallized, forming struvite (MAP: magnesium ammonium phosphate) (Borgerding, 1972; Suzuki et al., 2001a; Nelson et al., 2003). These properties of swine wastewater lead to problems of scale accumulating in wastewater treatment plants where crystallization reactions occur under natural conditions. That scale building up in pipes and pumps sometimes causes serious problems at such plants (Borgerding, 1972; Booram et al., 1975). However, such properties can also provide the technology for phosphorous removal and recovery when they are made to occur under controlled conditions (Wrigley et al., 1992; Maekawa et al., 1995; Suzuki et al., 2001a,b). In addition, struvite can be used as a valuable slow-release fertilizer (de-Bashan and Bashan, 2004).

Several reactors for removing and recovering phosphorous from swine wastewater have been designed (Bowers and Westerman, 2005a,b; Laridi et al., 2005), one of which has a dual function i.e., crystallization through aeration, and separation of formed struvite by settling (Suzuki et al., 2002). The pH of wastewater increases with aeration

---

* Corresponding author. Tel.: +81 29 838 8677; fax: +81 29 838 8606.
E-mail address: szkazu@affrc.go.jp (K. Suzuki).

0960-8524/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2006.06.008

because of CO_2 stripping (Waki et al., 1987; Battistoni et al., 1997). For the recovery of struvite, an experimental struvite-recovery device was designed, and its performance has been evaluated (Suzuki et al., 2005). The removal and recovery of phosphorous with this reactor should be conducted during the very first stage of wastewater treatment so as to reduce the concentration of phosphorous, thereby minimizing the risk of damage from scaling (Suzuki et al., 2002; Tanaka and Suzuki, 2004; Suzuki et al., in press).

In this paper, we report the results of 3.5-years of operation using a demonstration crystallization reactor for phosphorous removal and recovery and a demonstration accumulation device for struvite recovery.

2. Methods

2.1. Swine wastewater

Screened (1.5 mm mesh) swine wastewater from a piggery at the Tsukuba campus of the National Institute of Livestock and Grassland Science (NILGS, Tsukuba City, Japan) was used for all experiments.

2.2. Demonstration crystallization reactor for removing phosphorous

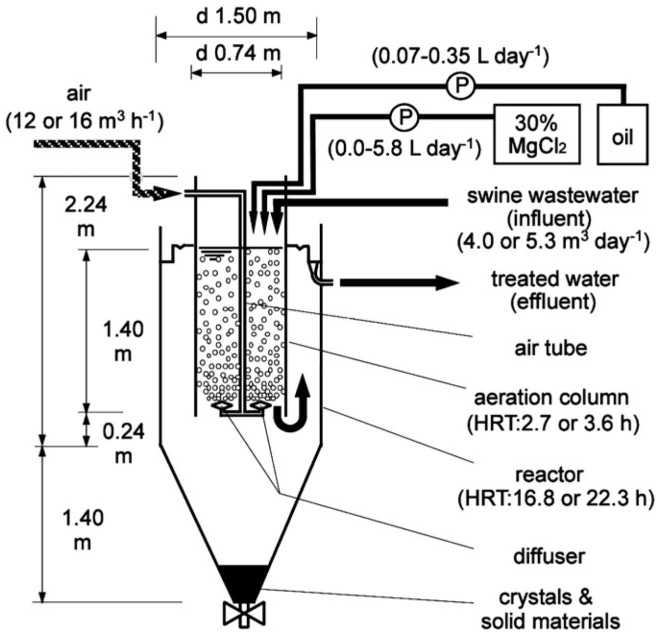

Fig. 1. Layout of demonstration crystallization reactor.

Demonstration crystallization reactor was used for removing and recovering phosphorous with the dual function of crystallization by aeration and settling (Suzuki et al., 2005). The swine wastewater was fed to the aeration column of the reactor and aerated continuously. A solution of 30% $MgCl_2$ (bittern) was dropped (0.0, 2.0, 3.1, 4.1 and 5.8 L day^{-1}) into the aeration column, with oil also added (0.07–0.35 L day^{-1}) to decrease foam formation (Fig. 1). The operational conditions of the reactor during its 3.5 years of operation are shown in Table 1. When the supply rate of swine wastewater to the reactor was 4.0 (5.3) m^3 day^{-1}, the HRT in the aeration column (0.60 m^3) and the total reactor (3.72 m^3) was 3.6 (2.7) and 22.3 (16.8) hours, respectively. The crystals formed in the aeration column settled with other suspended solids. Settled sludge was automatically removed from the bottom of the reactor four or eight times a day. Influents (swine wastewater) and effluents (treated water) were collected periodically, and the concentrations of soluble forms of PO_4–P, NH_4–N, Mg, Ca, Cu and Zn were measured. The concentrations in the samples of suspended solid, total P, total Mg, total Ca, total Cu, total Zn, BOD, alkalinity and pH were also measured.

2.3. Demonstration accumulation device for struvite recovery

Based on information from previous studies (Suzuki et al., 2005), a demonstration accumulation device for struvite recovery was designed. It was constructed with three layers of stainless steel wire (1.5 mm in diameter) mesh (1 cm^2 each) columns (0.2, 0.4 and 0.6 m in diameter, 0.8 m high) as accumulation faces, and an angle for fixing wire mesh columns and lifting the device. Total area of the accumulation faces was 3.0 m^2. At the struvite recovery experiment, the demonstration accumulation device was submerged in the aeration column of the demonstration

Table 1
Operational conditions of demonstration crystallization reactor

Term	Period	Wastewater supply rate (m^3 day^{-1})	Aeration rate (m^3 h^{-1})	30% $MgCl_2$ supply rate (l day^{-1})
A	02 04.2002–27.06.2002	4.0	12	0.0
B	27.06.2002–20.02.2003	4.0	16	0.0
C	20.02.2003–14.03.2003	4.0	16	4.1
D	14.03.2003–17.04.2003	4.0	16	5.8
E	17.04.2003–02.09.2003	4.0	16	2.0
F	02.09.2003–11.03.2004	4.0	16	3.1
G	11.03.2004–14.07.2004	4.0	16	4.1
H	14.07.2004–28.03.2005	5.3	16	4.1
I	28.03.2005–23.05.2005	5.3	0	0.0
J	23.05.2005–19.10.2005	5.3	16	4.1