Available online at www.sciencedirect.com
ScienceDirect
Bioresource Technology 99 (2008) 7750–7757
BIORESOURCE TECHNOLOGY

Three-step biological process for the treatment of the liquid fraction of cattle manure

E. Marañón [a,*], L. Castrillón [a], L. García [a], I. Vázquez [b], Y. Fernández-Nava [a]

[a] Department of Chemical and Environmental Engineering, Higher Polytechnic School of Engineering, University of Oviedo. 33203 Gijón, Asturias, Spain
[b] Sustainable Environmental Research Centre, School of Applied Sciences, University of Glamorgan, CF37 1DL Pontypridd, South Wales, United Kingdom

Received 19 April 2007; received in revised form 21 January 2008; accepted 27 January 2008
Available online 3 April 2008

Abstract

The liquid fraction of cattle manure was subjected to a biological treatment combining anoxic–anaerobic and oxic processes in order to stabilize the organic matter and reduce nitrogen and phosphorus so as to avoid problems of pollution when applying it to the land. The anoxic process was carried out at 30 °C in a CSTR reactor, the anaerobic process in a UASB reactor at 37 °C and the oxic treatment in another CSTR at 20 °C. The following results were obtained when working under optimum conditions (removal efficiencies in brackets): COD was reduced from 42 to 3.8 g/L (>90%); total solids from 41 to 14 (67%); total volatile solids from 22 to 7.0 (68%); total Kjeldahl nitrogen from 2.2 to 0.1 g/L (95%); $NH_4^- - N$ from 1.10 to 0.02 g/L (98%) and Total-Phosphorus from 0.696 to 0.058 g/L (92%). Nitrates, undetected in the liquid fraction of cattle manure, were present in the final effluent as a result of nitrification. To reduce the amount of nitrates, different recirculation rates were tested. The minimum nitrate concentration achieved was 127 mg/L using a recirculation ratio of 4.

Keywords: Cattle manure; Anaerobic treatment; Nitrification; Denitrification

1. Introduction

Livestock production systems have had an ever-increasing impact on the environment in recent years. In areas of highly intensive dairy cattle production, the amounts of nitrogen, phosphorus, organic matter and other minerals in cattle manure may far exceed the amounts of these substances than can be taken up by crops. Accumulation of minerals and organic compounds can take place due to this imbalance and contamination of surface and ground waters may subsequently occur as a result of leaching and runoff.

In Asturias, a region in Northern Spain with a bovine population of around 310,000 LU that produces meat and milk, the industrialization of cattle farming had led to surplus manure that cannot be used as fertilizer in certain areas with insufficient farming surface. Furthermore, the highest concentration of dairy farms (cows are usually kept in stables) is found in the areas near the coast, where the removal of cattle manure by means of its use as a fertilizer may lead to environmental problems.

Following Directive 91/676/CEE, concerning the protection of waters against pollution caused by nitrates from agricultural sources, the maximum value of nitrogen that can be applied to the land when using manure as fertilizer is 170 kg N/ha.year in zones where drinkable water may be affected or there are problems of eutrophication.

Besides the problem of water pollution, the air also becomes polluted by odours, ammonia, methane and nitrous oxide due to gas emissions from stables, stored manure and from the application of manure onto cropland. An analysis of ammonium emissions in Spain shows that the agricultural sector was the major contributor to these emissions during 2002, representing 91.2% of total ammonium emissions. Filipy et al. (2006) identified volatile

* Corresponding author. Tel.: +34 985182027; fax: +34 975182337.
E-mail address: emara@uniovi.es (E. Marañón).

0960-8524/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2008.01.065

organic compounds (VOCs) on a dairy farm that contribute to odour and air quality problems. These authors measured emission rates of ethanol, dimethyl sulphide, acetone, 2-butanone, methyl isobutyl ketone, 2-methyl-3-pentanone and dimethyl disulfide in different places of the farm.

A possible solution to this problem is the treatment of cattle manure to remove or reduce biodegradable organic matter, ammonia and other components that it may contain. A commom pretreatment is to apply a solid–liquid mechanical separation (Moller et al., 2002) to obtain two fractions that are then treated separately. Zhang et al. (2006) analysed the removal of odour from swine manure after treatment in batch aeration reactors. Amon et al. (2006) found that untreated slurry emitted 226.8 g NH_3/m^3 and 92.4 kg CO_2 eq/m^3 from storage and field application (ammonia emissions mainly from field application) and that anaerobic digestion was a very effective way to reduce GHG emissions (37.9 kg CO_2 eq/m^3). Harikishan and Sung (2003) investigated the applicability of the TPAD (temperature-phased anaerobic digestion) process to the stabilization of dairy cattle manure, achieving overall TS reductions of 37–42% and VS reductions of 36–41% for an HRT of 14 days. Marañón et al. (2001) and Castrillón et al. (2002) studied the anaerobic treatment of the liquid fraction of cattle manure in UASB-type reactors at different HRT, under both mesophilic and thermophilic conditions. Removal efficiency of organic matter (COD) oscillated between values of 36.2% and 75.5% for HRT of 5.3 and 22.5 days, respectively, at mesophilic temperature. There were no significant differences in the COD removal and biogas production obtained at both temperature ranges. Obaja et al. (2003) evaluated the possibilities of using an SBR to treat anaerobically digested piggery wastewater containing 1500 mg/L of ammonium and 144 mg/L of phosphate, obtaining removal efficiencies of 99.7% and 97.3% for nitrogen and phosphate, respectively. Martínez Almela and Barrera (2005) applied this technology to reduce the content of ammonia in pig slurry after solid–liquid separation, achieving nitrification efficiencies in the range of 97–99%.

To date, the main experiments to be found in the literature for the removal of nitrogen from cattle manure have been carried out at relatively low concentrations of $NH_4^+ - N$. For example, Qureshi et al. (2007) studied the nitrification of dairy manure diluted approximately 10 times with tap water, using a batch reactor (SBR) at pilot scale.

As regards phosphorus, Hodgkinson et al. (2002) recommend that liquid farm manures should not be applied to recently drained clay soils in order to avoid direct contamination and phosphorus enrichment of drainage water. The most common processes for the removal of phosphorus are biological by means of a combination of anaerobic–oxic reactors and precipitation of the orthophosphate employing inorganic salts (Al, Fe) (Morse et al., 1998).

The aim of the present research work was to study the removal of organic matter, nitrogen and phosphorus from the liquid fraction of cattle manure using a three-step biological treatment that combines anoxic–anaerobic–oxic processes. A continuous operation was planned in order to obtain steady-state operation data.

2. Methods

2.1. Equipment employed

The laboratory plant employed (Fig. 1) consists of:

- A denitrification reactor made of PVC with a capacity of 9.3 L. The reactor is equipped with a mechanical stirrer and an electrical resistance to maintain the temperature at 30 °C. In order to maintain anoxic conditions in the reactor, its length is much greater than its diameter (0.53 m high and 0.15 diameter).
- A UASB reactor made of transparent PVC with two cylindrical sections; the lower one being jacketed and separated from the upper one by a deflecting ring to facilitate phase separation. The upper body has a larger diameter and contains the gas collector, as well as two outlets for the effluent and recirculation. The lower body is equipped with two side-outlets situated at different heights for sample taking. The volume of the reactor up to the triphasic separator was 9 L and the operating temperature was 37 °C. A settler (approximately 5 L in

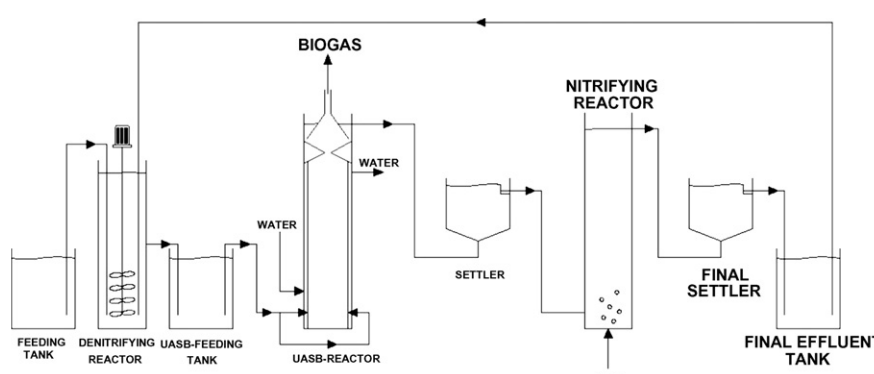

Fig. 1. Experimental equipment employed.