Waste Management 46 (2015) 577–587

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

# Complete nitrification–denitrification of swine manure in a full-scale, non-conventional composting system

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ARTICLE INFO

*Article history:*
Received 23 January 2015
Revised 19 July 2015
Accepted 20 July 2015
Available online 3 September 2015

*Keywords:*
Compost
Denitrification
Nitrogen
Nitrates
Ammonia emissions
Manure
Livestock

ABSTRACT

A full-scale composting plant (track type, aerated by screws), treating liquid swine manure (94.8% on mass basis) with straw (<0.8%) and sawdust (4.4%), was monitored. The main objectives were testing the performance of the process and assessing its environmental sustainability. Particular attention was dedicated to verify the possibility that this process could determine significant mass reduction, along with Nitrogen reduction, mainly by denitrification. Emissions were evaluated by measuring $NH_3$, $N_2O$ and $CH_4$ (by static chamber), $H_2S$ and odor emissions (by dynamic olfactometry). Quality and quantity of inputs and outputs and process parameters (redox, oxygen, and temperature) were monitored. The process produced a mature, highly humified (Humification Index = 0.27), solid product with 92.8% mass reduction (mainly evaporation), and nitrogen reduction (85.8% referred to input TN). The process was revealed to be environmentally sustainable: emissions of odors and $H_2S$ resulted negligible; emissions of N–$N_2O$ represented 0.18% of TN input, while emissions of N–$NH_3$ represented 0.87% of input TN. Microbiological analyses determined the presence of $10^7$ CFU/g of bacteria related to N cycle and real time PCR demonstrated the presence in the final product of $4.77 \cdot 10^7$ couples of genes of Bacterial amoA/gTS and $2.46 \cdot 10^7$ couples NosZ/gTS, indicating nitrification and complete denitrification. These results exhibit that nitrification and complete denitrification can efficiently occur in a composting process effectively transforming $N_2O$ into $N_2$ as consequence of the optimized alternation of aerated and anoxic phases in the feedstock.



## 1. Introduction

Swine livestock farming has been recently facing critical challenges related to the management of manure (Szanto et al., 2007). Swine manure represents a valid source of nutrients for croplands, but scale economics determined an increase in size of farms resulting in high concentrations of animals in small areas (Inbeah, 1998) causing environmental concerns related to gaseous emissions and impact of nutrients on surface waters (eutrophication) and in water tables (Nitrates pollution).

Composting is widely implemented worldwide for the treatment of agricultural by-products and of various organic wastes, including manures of different origin. The advantages of the process are represented, in general, by the production of a final product characterized by relevant quality in terms of agricultural utilization as amendment (Chiumenti et al., 2005; Szanto et al., 2007).

The biology of composting has been studied for years, nonetheless, a deeper knowledge of the biological activity related to the Nitrogen (N) cycle, and to the gaseous emissions of nitrogen compounds is required. Furthermore, appropriate Nitrogen load is a key factor in terms of environmental sustainability and of compliance with the Nitrates Directive (91/676/EEC) for the agricultural utilization of animal manure; in addition, $N_2O$ and $NH_3$ represent the main concern in terms of gaseous emissions of Nitrogen from composting, along with other gasses such as $CH_4$ (Sun et al., 2014; Wang et al., 2014a,b).

In general, in intensive farms, manure is collected in liquid form as a consequence of the use of slatted floor in animal housings. This determines advantages in terms of automation considering that manual operations related to the use of litter are avoided and that the dislocation of manure from housings to the storage is performed by pumps or gravity. High water content, however, represents a difficulty in case of traditional composting normally operated on solid feedstocks, such as litter or solids from liquid solid separation (Inbeah, 1998).

It is possible, however, to treat liquid swine manure in a composting system if mixed with absorbing feedstocks. The possibility of treating liquid manure in combination with absorbing feedstocks, such as straw or sawdust, was experienced mainly at small

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http://dx.doi.org/10.1016/j.wasman.2015.07.035
0956-053X/

scale. Eiland et al. performed tests of composting liquid pig manure and straw of Miscanthus, whereas USDA researchers on liquid pig manure and woodchips (Cook and Bolster, 2015; Eiland et al., 2001).

Tests were performed also in greater scale in composting tracks (15.2 m long, 2.2 m wide and 1.6 m deep and 30.3 m long, 3.64 m wide and 1.82 deep) by filling the tracks with straw and spreading swine manure with a inclined belt turning equipment (Park et al., 2006; Thompson et al., 2004). The aim of these researches was to evaluate the potential of composting in terms of reduction of greenhouse gasses emissions (nitrous oxide and methane), in comparison to traditional management of swine manure (long storage in tank prior to spreading on cropland).

The present research was focused on the study of a patented system, the CLF Modil, a peculiar composting process that consists on the treatment of liquid inputs, such as liquid manure or digestate from biogas plants, on a bed of absorbing dry material (straw, wood chips, sawdust, corn stalks, etc.), with the production of a final product in solid phase. The research was focused on verifying the performance of the system and on assessing its environmental sustainability. The hypothesis was that the process was capable of achieving significant mass and N reductions. It appeared necessary to verify if this supposed N reduction was related to $N_2O$ or $NH_3$ emissions, and to understand if these type of plants needed to be confined and equipped with air treatment (scrubber and/or biofilter). Preliminary tests confirmed significant mass and N reduction, with low emissions of both gasses, indicating the necessity to achieve a deeper understanding of the transformations of nitrogen achieved in the process, and to verify whether denitrification or anammox could be the explanation of this result.

Four plants of this type, treating swine manure and digestate, were monitored but the present article reports the results obtained by the monitoring of one of these plants in relation to a single cycle.

## 2. Materials and methods

The tests were performed in a swine reproduction farm with 1,000 sows (open cycle with piglets sold at 25–30 kg), located in Bosco Chiesanuova (VR), Lessinia – Italy, at 1200 m of elevation. Manure produced by the animals is collected in a uncovered, reinforced concrete storage tank. The treatment system is used to process, in two or three cycles per year, the entire production of swine liquid manure from the farm, corresponding to a total of aproximately 8000 $m^3$/year.

The process occurs in an horizontal reactor, represented by a track 77 m long, 10 m wide, and 1.3 m deep (Fig. 1). The absorbing feedstock can be represented, in general, by straw, wood chips, sawdust, corn stalks, etc.

The concrete walls of the track have the function of supporting and guiding a bridge, which spreads the liquid input over the absorbing bed and performs mechanical turning and aeration of the feedstock (Figs. 1 and 2). The turning of the material is performed by 5 screws mounted on a mobile apparatus installed on

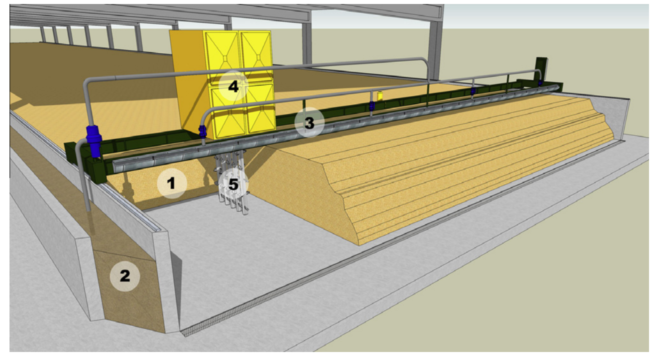


**Fig. 2.** Schematic of the system: 1. the reactor; 2. the channel for the liquid input; 3. the bridge for spreading turning/aeration operations; 4. the turning mobile unit (5) and the turning/aeration screws.

the bridge itself. The screws, which are lowered at the beginning of the turning phase and raised at the end, operate also as aeration equipment by forcing air inside the feedstock by means of a compressor with a capacity of 200 $Nm^3/h$. For each operation (spreading and turning), the bridge moves in two directions lengthwise at a speed of approximately 5.4 m/min. The translation of the screws is operated at 0.35 m/min.

The plant was monitored on weekly basis for the entire period of several complete cycles. For each monitored cycle, quantity and quality of all inputs and outputs, process parameters, and gaseous emissions were monitored. Only one cycle is reported in this paper.

Mass of input absorbing materials at the beginning of the cycle, additions, and mass of output product at the end of the cycle were determined by a truck scale installed in the farm, 8 m long with a capacity of 40 t (Model EV2002, Bilanciai, Italy). The load of input swine manure was monitored by an electromagnetic flow-meter (Model Promag 10W1H by Endress-Hauser, Switzerland).

Input and output products were subject to the determination of Total Solids (TS), Volatile Solids (VS), pH, $NH_4^+$, Total Kjeldhal Nitrogen (TKN), nitrites ($NO_2^-$), nitrates ($NO_3^-$), while the final product was subject to the determination of the Humification Index (HI) (APHA, AWWA, WPCF Standard methods, 1992). Sampling locations were middle and 1/3 of length at each front, in the middle of the feedstock. The Humification Index, determined by the Sequi method, was adopted as stability index for compost (de Nobili and Petrussi, 1988; Sequi et al., 1986). This parameter is calculated as ratio between non humified fraction (NH) and the humified fraction, represented by Humic Acids (HA) and Fulvic Acids (FA) (Chiumenti et al., 2005; de Nobili and Petrussi, 1988; Sequi et al., 1986), as reported in the following formula:

$$HI = NH/(HA + FA)$$

HA and FA are determined by chemical extraction with alkaline sodium pyrophosphate and adsorption on polyvinylpyrrolidone columns (de Nobili and Petrussi, 1988).

**Fig. 1.** Panoramic and detailed views of the treatment plant (photo: A. Chiumenti).