Pig slurry treatment strategies - dealing with nitrogen management

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Abstract

Nitrogen commonly is the main limiting factor to consider when managing livestock waste. In those situations where its correct reuse as crop nutrient can not be fulfilled, complementary treatment strategies should be implemented. This paper presents two full-scale experiences located in Catalonia (NE Spain) based on different treatment strategies, biological removal and thermal concentration respectively. Both approaches have been successful in a context of nitrogen surplus, showing that different technological solutions are feasible depending on the specific situation.

Keywords: Livestock waste, ammonium, nitrification-denitrification, thermal concentration.

Background and objectives

Livestock waste handling based on its reuse as fertilizer is, in principle, the most adequate option. Nevertheless, high animal densities may result in larger manure stocks than crop needs. Although several criteria could be considered as limiting in this scenario, nitrogen plays the central role (Burton and Turner, 2003). Potential environmental problems caused by N surplus makes necessary to consider complementary strategies to a nearby land spreading.

In terms of N management, common pig slurry treatment processes may be grouped in two main categories: biological and physicochemical (Table 1). The former implies ammonium removal via its conversion to N_2, which is then transferred to the atmosphere. The typical example is the combined process of nitrification-denitrification (NDN). More sustainable new developments within this category include the partial nitrification coupled with the incipient process of anaerobic ammonium oxidation, which could become a viable option in the near future. The latter physicochemical methods comprise processes such as water evaporation (thermal concentration, TC) or ammonia stripping-absorption, which allows concentrating N-compounds for an easier handling and transport. The election of a particular strategy basically depends on the treatment cost although environmental, scale or social considerations may also influence on the final decision. A recovery to recycle approach may initially seem more adequate but its cost can exceed that of a biological treatment, becoming the last a more interesting option. Slurry preliminary treatments such as solid-liquid separation and/or anaerobic digestion (AD) may improve the subsequent processing in relation to N. Prices of energy coming from biogas generated through anaerobic digestion can favour a given strategy. Anaerobic digestion also favours the quality of the recovered products. More details on treatment strategies can be found in Campos *et al.* (2004).

The aim of this work is to characterize two successful full-scale facilities for pig slurry processing located within N surplus areas in Catalonia (NE Spain), a region with a large swine production. These plants are based on NDN and AD-TC respectively.

Table 1. Main pig slurry treatment processes related to N management.

Group	Target	Process
Biological	N transferring to the atmosphere as N_2	- NDN
Physicochemical	N separation in a concentrated stream	- Solid-liquid separation - Stripping-absorption - Struvite precipitation - Thermal concentration

Materials and methods

Description of facilities

SAT La Caseta d'en Grau, Calldetenes (Osona) - 15,000 tonnes per year. This farm-scale treatment plant allows processing the slurry generated in a sow-herd farm (Gurri, 2004). When housing pits lockgates are opened, slurry flows to an outdoors reception tank. Slurry is separated in a solid (SFPS) and a liquid fraction (LFPS) by means of a screw press. The solid fraction is managed by an external authorised agency and the liquid fraction is treated through NDN. Biological treatment is carried out in two separated tanks, in a configuration of pre-denitrification. Hence, a recirculation flow connecting aerobic (nitrification) and anoxic (denitrification) reactors is fundamental to ensure a properly process performance. The aerated effluent is stored in a final pond and used for watering adjacent crops. Although it would be possible to decant the biological sludge it is not usually practiced. Data here regarded correspond to a weekly sampling programme followed during July 2004.

Tracjusa, Juneda (Les Garrigues) - 110,000 tonnes per year. These are two large-scale treatment plants which allow processing the slurry surplus generated in approx. 100 farms. Slurry is pumped from the storage tanks to anaerobic digesters where biodegradable organic substrates are converted to biogas. Thereafter, the digested slurry is separated in two fractions by means of decanter centrifuges. The LFPS is acidified to avoid ammonia volatilization and then concentrated through a low temperature vacuum evaporation process. The vapours formed in the evaporator are conducted to a surface condenser and used in the cooling system of a combined heat and power (CHP) plant, using as energetic input a mix of recovered biogas and natural gas. The remaining concentrated material is joined with the SFPS decanter stream and dried by an enclosed steam system, using thermal energy supplied by the CHP plant. Data here considered correspond to a sampling programme followed during 2004-2005.

Analytical methods

Total solids (TS), chemical oxygen demand (COD), Kjeldahl-N (TKN), ammonium (NH_4), nitrite and nitrate (NO_X=NO_2+NO_3) were determined according to APHA *et al.* (1995).

Results and Discussion

SAT La Caseta d'en Grau. Nitrogen loading rate (NLR) of the biological unit is one of the most important parameters related to the process performance. According to the nominal volume (410 m^3), the inflow rate (35 m^3 d^{-1}) and the LFPS composition (22.2 ±4.7 kg TS m^{-3}, 2.9 ±0.5 kg TKN m^{-3}, COD/TKN = 7.7 ±1.5), the hydraulic residence time (HRT) of the NDN system was of about 12 days (final pond not included) and the NLR of 0.25 kg TKN m^{-3} d^{-1}. Investment is correlated with NLR since smaller reactor sizes will be needed when adopting higher loads. Treatment plant was operated by the own farmer. Evaluated data shown that 60% of the N initially present in the slurry was susceptible of being removed by NDN (Figure 1). Operational costs (Table 2) are mainly attributable to the electric energy consumption linked to oxygen requirements during nitrification (4.57 kg O_2 kg^{-1} NH_4-N stoichiometrically). No external organic carbon sources were needed for a proper denitrification.

Tracjusa. Anaerobic digestion is operated under mesophilic conditions (35°C) with an HRT of 20 days (volume of 6.000 m^3) and results in an organic reduction of about 55-60% on COD basis. The degradation of proteins increases the NH_4-N/TKN on the digested slurry. Thermal processes (evaporation and drying) are conducted on enclosed vacuum systems at low temperature (85-95°C) to ensure non atmospheric emissions of ammonia or volatile organic compounds (VOCs). A previous acidification step (pH<5.5) using sulfuric acid as reagent allows minimization of ammonia volatilization. Anaerobic digestion prior to evaporation has several advantages: 1) provides part of the energetic input required (14-18 m^3 biogas per tonne of slurry), and 2) removes VOCs, and consequently, it allows obtaining evaporation condensates almost free of organic matter (Palatsi *et al.*, 2005). In agreement with the evaluated data, 94% of the N initially present in the slurry is recovered in the palletized dried product (N/P/K ~ 7.5/3.5/5.0 % w/w) being partially recovered using condensates scrubbing techniques (Figure 1). Operational costs are mainly attributable to maintenance and natural gas requirement, the later with a significantly fluctuant price over time (Table 2).

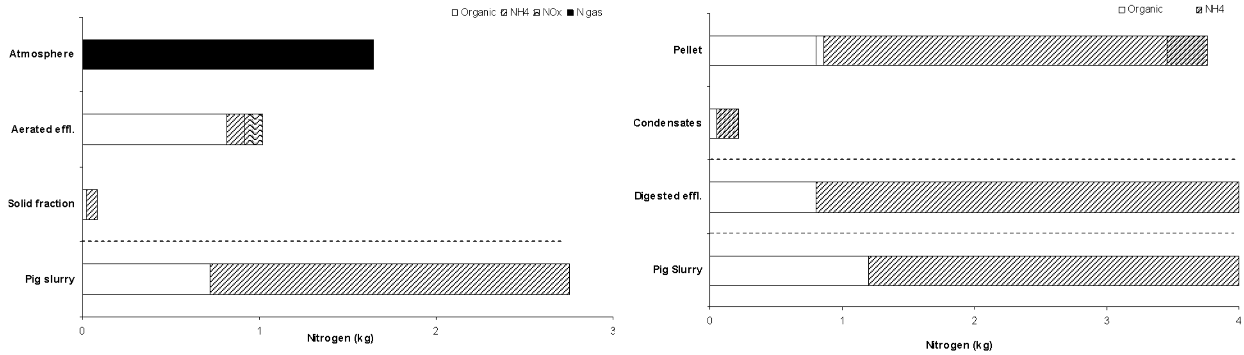

Figure 1. N balance per tonne of slurry processed. *Left:* Caseta d'en Grau. *Right:* Tracjusa.

Table 2. Costs comparative estimation between both characterized facilities.

Issue	Caseta d'en Grau	Tracjusa
Technical data		
Treatment capacity (tonnes year^{-1})	15,000	110,000
Investment (€)	300,000	19,000,000
Energy consumption (MWh year^{-1})	225 (electric grid)	350,000 (natural gas)
Electric energy production (MWh year^{-1})	0	124,000
Costs (€ tonne^{-1})	*3.5*	*103.0-119.0*
Energy cost	1.5	64.0-80.0
Other operational cost	0.7	27.5
Investment repayment (15 years, non financed)	1.3	11.5
Incomes (€ tonne^{-1})	*0.0*	*85.5-119.5*
Electric energy sale (government grant included)	0.0	84.0-118.0
Fertilizing valuable products sale	0.0	1.5

Conclusions

Two successful full-scale pig slurry treatment facilities, based on NDN and AD-TC respectively, have been described corroborating that different technological approaches are feasible in a context of N surplus. These experiences are also representative of different treatment scale levels, individual or collective, to deal with slurry processing.

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