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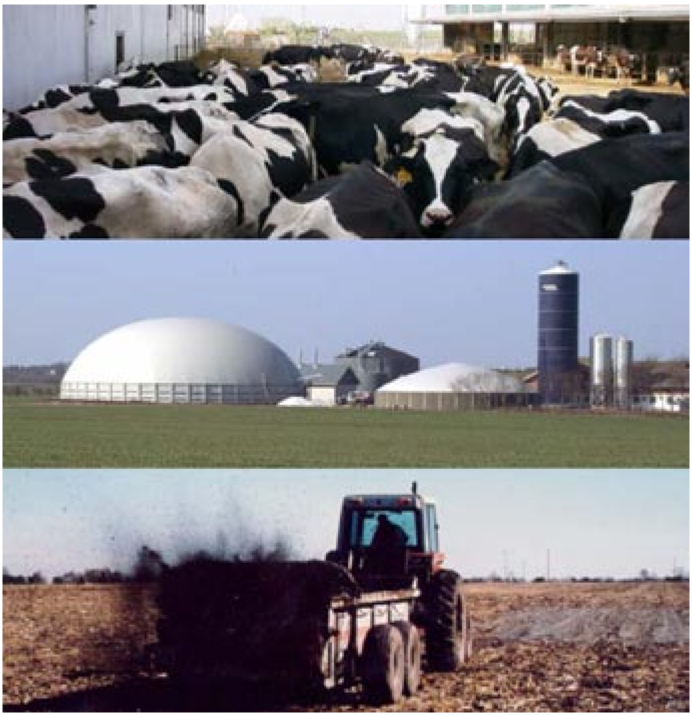
12th Ramiran International conference

Technology for Recycling of Manure and Organic Residues in a Whole-Farm Perspective. Vol. II



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Technology for Recycling of Manure and Organic Residues in a Whole-Farm Perspective. Vol. II

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The Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture (RAMIRAN) is part of ESCORENA - the European System of Cooperative Research Networks in Agriculture. ESCORENA was established by the FAO Regional Office for Europe (REU) in 1974. It is a form of voluntary research cooperation among interested national institutions involved in research in food or agriculture in European countries. Over the years, ESCORENA has expanded its field of activities to include topics and themes of interest to other countries, particularly those from the Near East and Mediterranean area.

The objectives of ESCORENA are to:

- Promote the voluntary exchange of information and experimental data on selected topics.
- Support joint applied research on selected subjects of common interest according to an accepted methodology and an agreed division of tasks and timetable.
- Facilitate voluntary exchange of experts, germplasm and technologies.
- Establish close links between European researchers and institutions working on the same subject to stimulate interaction.
- Accelerate the transfer of European technology advances to, and in cooperation with, developing countries.

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Much of the detailed work of the network is undertaken by the Working Groups. There are currently 7 Working Groups within RAMIRAN including 2 new groups that were established at the last Workshop in Gargnano.

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Cattle slurry digestion does not improve the long term nitrogen use efficiency of farms

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Introduction

Anaerobic digestion of slurry increases the amount of directly available nitrogen (Nm), be it at the expense of the amount of organic nitrogen (Norg). When proper attention is given to the timing and method of applications, digested slurries may thus show a higher nitrogen (N) fertilizer replacement value (NFRV) in the first growing season after their application. However, such an increase of the short term NFRV may carry a price in terms of residual N effects, as less Norg is applied to the soil. The N use efficiency (NUE) of a farm is not just determined by the long term NFRV of the slurry, but also by the N fluxes crossing the farm boundaries. These fluxes may change when a farmer decides to promote the digestion process by either importing substrates or by using a fraction of his crops as a substrate ('co-digestion'). The aim of the present work was to compare the long-term NFRV of digested and untreated cattle slurry and explore the consequences of co-digestion for the NUE.

Methods

We determined dry matter (DM) and N yields of cut pure grass stands from a continuous (2002-2005) replicated field trial on a sandy soil to which either 300 kg total N ha^{-1} yr^{-1} of undigested (Nm/Norg = 1.0) or digested (Nm/Norg = 1.4) cattle slurry had been applied via sod injections (at the start of the growing season, after the first cut and after the second cut) during 1, 2, 3 or 4 years. These yields were compared with yields of controls without N and yields of treatments with mineral fertilizer N. Differences in phosphate and potassium supply between treatments were fully compensated with mineral fertilizers. The relative NFRV of both slurries was calculated as the ratio of the apparent N recoveries (N yield increase, kg per kg total N applied) or N efficiencies (DM yield increase, kg per kg total N applied) of slurry and mineral fertilizer N (Schröder, 2005). Subsequently, N fluxes were quantified for an imaginary 11,000 liter ha^{-1} yr^{-1} dairy farm with and without the use of additional substrate (with a N content arbitrarily set at 50 kg N ha^{-1}), of which 50% was home-produced at the expense of available forage and the other 50% imported, using a N flux model (Schröder et al., 2003). NUE was calculated as the ratio of N exported in milk and meat and N imported as feed, fertilizer and substrate.

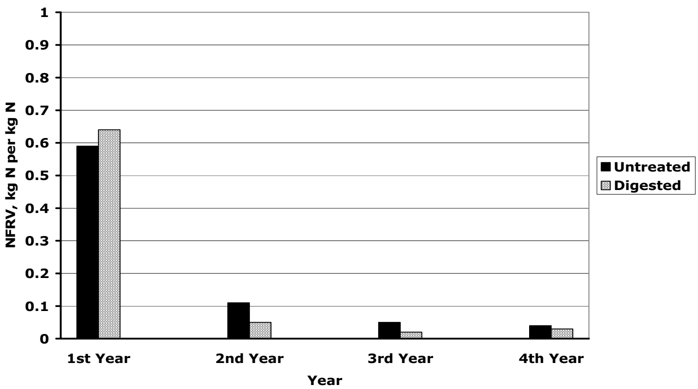

Figure 1. Nitrogen fertilizer replacement value (NFRV, kg N per kg N applied, based on both N recoveries and N efficiencies) of cattle slurry in 1^{st} season after application and in subsequent years, as affected by anaerobic digestion (results shown for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} year, are the averaged results from the 2002-2005, 2003-2005, 2004-2005 and 2005 seasons, respectively).

Results

In the first season after application, the relative NFRV of digested slurry exceeded the NFRV of undigested slurry by 5%. However, this initial advantage was completely offset when the residual N effects were taken into account, yielding similar long term NFRV's for both types of slurries (Figure 1). The analysis of separate cuts (data not shown) did not reveal a better synchrony between N release and crop N demand due to digestion. The scenario study on the impact of co-digestion on whole farm NUE's showed that the imports of N via additional feeds and substrates (Figure 2), affected the NUE adversely, as the negative effect of imports on NUE is, according to our experiments, not compensated for by an improved NFRV. Consequently, co-digestion reduced the NUE from an initial 36% to approximately 32% in the present example.

Implications

The long term NFRV of digested cattle slurry is not any better than that of untreated slurry, as positive effects in the first season are nullified by negative effects in later seasons. Accordingly, digestion will generally not improve the NUE. Whenever feeds and/or substrates, imported for the sake of co-digestion, contain N as they usually will, digestion may even reduce the NUE at the farm level. Only if an alternative destination of these substrates elsewhere would lead to a considerable loss of the associated N ('potential wastes' in Figure 2), NUE of the society as a whole could yet benefit from co-digestion.

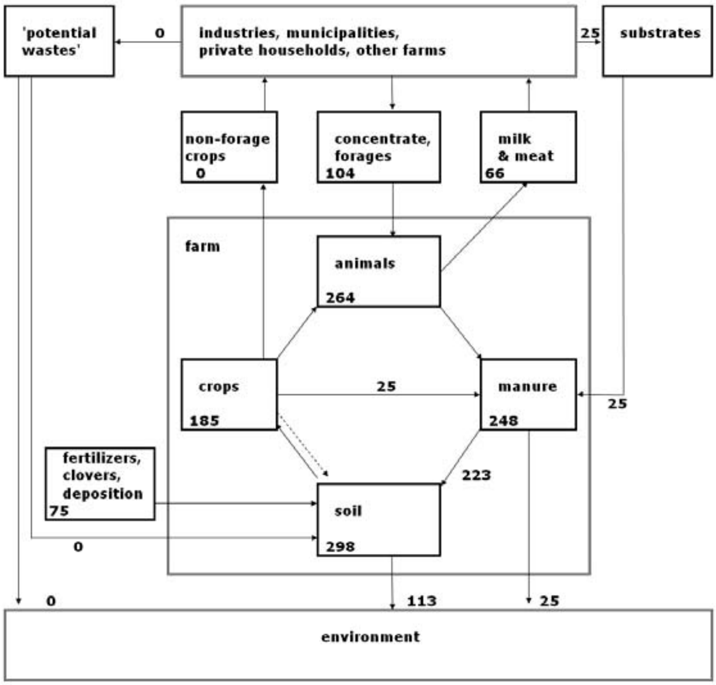

Figure 2. Diagram of an imaginary dairy farm (see text for specifications) showing the N fluxes involved when using home-produced and imported substrates for co-digestion (internal N conversion efficiencies after Schröder et al. (2003) and the present field experiment).

References

Schröder, J.J., Aarts, H.F.M., Ten Berge, H.F.M., Van Keulen, H. and Neeteson, J.J., 2003. An evaluation of whole-farm nitrogen balances and related indices for efficient nitrogen use. European Journal of Agronomy 20 (1-2), 33-44.

Schröder, J.J., 2005. Manure as a suitable component of precise nitrogen nutrition. Proceedings 574, International Fertiliser Society, 32 pp.

Overview of evaluations of alternative swine manure management systems in North Carolina, USA

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In the last ten years, there have been three significant funding efforts in North Carolina to evaluate and demonstrate alternative manure management technologies with a total of about thirty projects. The most recent effort was through an agreement in 2000 between the NC Attorney General's Office and Smithfield Foods, Inc. (SF) ($15 M) and also with Premium Standard Farms (PSF) ($2.3 M) to identify "Environmentally Superior Technologies" (EST) that are economically feasible. The funding supported construction, operation and evaluation of the technologies.

Dr. Mike Williams of the Animal and Poultry Waste Management Center (APWMC) at NC State University was named as the designee in the agreement that would be responsible for making determinations of ESTs. He selected an advisory panel of 23 people from diverse backgrounds, including academic research scientists, engineers, public health and public law experts, economists, government, agribusiness people, farm owners or contract growers, the companies (SF and PSF), and representatives from environmental advocacy groups to advise him during the process. Proposals were solicited nationwide, and from about 100 proposals received, 18 were selected and 15 were completed. A 15-step systematic process was required to complete the projects. An engineering consulting firm was selected to assist with construction oversight and permitting procedures. Legal agreements were made with the technology provider and the farm owners to cover liability and disposition of the technology system at the end of the evaluation period. A principal evaluator of the manure treatment system effectiveness was selected for each project and they developed monitoring proposals. One team was selected from each of two competitive processes: one for evaluating odor, ammonia emissions and pathogen reductions, and one for conducting a comprehensive economic analysis for all the treatment systems.

The criteria for determination of EST were written in the agreement. Some criteria required further development by the designee with assistance from the advisory panel because the criteria had terminology such as “substantially eliminate” which was taken from a state statute. To be determined an EST, the technology first had to meet the technical environmental standards, and then had to meet the economic criteria. The technical environmental criteria were basically to “substantially eliminate” waste discharge to surface waters and groundwater, nutrient and heavy metal contamination of soil and groundwater, ammonia emissions, odor at the property boundary, and release of disease-transmitting vectors and airborne pathogens. A sub-committee of the Advisory Panel recommended quantitative measures for the criteria which the Designee used as guidelines in his determinations of ESTs. The economic analysis included predicted annualized (10 years) costs and returns and predicted impact of the additional costs on the competitiveness of the swine industry in North Carolina.

Projects included technologies such as solids/liquid separation, aerobic treatment, nitrification/denitrification, phosphorus precipitation, anaerobic digestion ponds with permeable cover or impermeable cover with biogas collection, and combustion or composting of solids. The only technology system for treating the liquid manure that was determined to meet the environmental requirements was the SuperSoil project. It included solids/liquid separation, nitrification/denitrification and phosphorus precipitation. Performance included 98 % removal of suspended solids, 99 % ammonia removal, 95 % phosphorus removal, 1.4 to 4.4 Log10 reductions in various pathogens or pathogen indicators, and an odor intensity of 2.1 (maximum scale of 8) at 200 m from the source. However, the annualized (10 year) cost calculated to retrofit this system to an existing farm with an anaerobic lagoon and spray field was 352 euro per 500 kg steady-state live weight (SSLW) (1 AU) per year (using 1.25 US$ per euro conversion rate), and was determined not to meet the economic criteria. For comparison, the cost of constructing a lagoon and spray field system in 2004 was 76 euro per AU per year. The solids from the SuperSoil project were composted in a covered facility with costs calculated to be an additional 73 euro per AU. This composting system and three other solids management systems were determined to meet the environmental criteria. The other solids treatment systems and their annual costs in euro per AU were: gasification (67), centralized fluidized bed combustion facility (225), and a high solids anaerobic digester (329).

The final report (phase 3) of the designee was released in March 2006 and can be found at http://www.cals.ncsu.edu/waste_mgt/. A summary from that report is that 5 technologies were identified that meet environmental standards established by the state of North Carolina (and quantified through this process), economic feasibility has been defined, the process for development and verification of EST has been documented, additional technologies have been verified that with modification may be capable of meeting EST standards, and the process for implementation of EST has been proposed. The economic feasibility definition selected by the designee was that implementation of new technologies could result in up to a 12 % reduction in pig production for a particular type of farm (i.e. sow, nursery, finish, etc.) based on extensive economic modeling of impacts of increased costs. This translated into about 78 euro per AU. The implementation recommendations included: (1) continue, as expeditiously as possible, current efforts by targeted technology suppliers and researchers to improve their treatment processes to reduce costs of their respective treatment systems, (2) establish a framework or process by which additional technologies may be determined viable Environmentally Superior Technologies, and (3) identify potential institutional incentives, public policies, and markets related to the sale of byproducts (with priority on energy production) that will reward farmers for utilizing technologies identified by this process that are shown to yield environmental benefits over the current lagoon spray field system. The favored method of achieving net cost reductions and even positive revenue flows from alternative technologies is to install targeted technologies on a sufficient number of farms to facilitate engineering improvements, value-added product market development, and other cost reduction methods.

The EST determination process has developed a large amount of information on manure management treatment effectiveness of various technologies to manage nutrients, and reduce odor, pathogens and ammonia emissions, and their costs. It also resulted in development of an extensive model for predicting the effect of added costs on the competitiveness of the swine industry in North Carolina. The overall project has also shown that a diverse group of representatives from industry, government, University, environmental groups, and farmers can benefit from working together for solutions for better manure management and reduction of environmental impacts.

Managing dirty water to reduce slurry volumes on UK dairy farms

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Introduction

The well-managed application of animal manures to land is key to improving soil fertility and avoiding pollution of air and water environments. Adequate storage for liquid slurry is essential if nitrate leaching following autumn applications is to be avoided, and crop uptake maximised in spring. On average, storage capacity on cattle farms in England is sufficient for 2.5 months (Scott *et al*., 2002) and a considerable financial investment is required if the recommended 4 months storage period recommended in the UK Codes of Good Agricultural Practice (MAFF 1998) are to be achieved, and to meet the closed periods for spreading slurry on farms on sandy and shallow soils in designated Nitrate Vulnerable Zones (NVZs). A recent survey of manure management practices in England, Scotland and Wales identified simple ways in which the amounts of slurry generated, stored and spread to land on dairy farms could be reduced, thus aiding compliance with good practice and regulations for winter storage and application timing, whilst reducing the pollution risk and storage and spreading costs.

Methodology

Slurry was characterised and information on slurry storage and spreading practices was collected on 31 commercial dairy farms in England, Scotland and Wales. A water audit was carried out on each farm in which the amount of water used in the parlour was measured and water from other sources (e.g. yard and roof run-off, rainfall capture in the store) was assessed.

Results

Of the farms managing manure as slurry (30 farms; 97% of the total), slurry was partially de-watered with variable proportions of 'dirty water' collected and stored separately on 15 (50%) farms, the rest used a system of 'total containment' in which both slurry and dirty water were stored together. Excreta accounted for 71% of slurry on farms managing dirty water separately and 61% on farms with total containment (Figure 1).

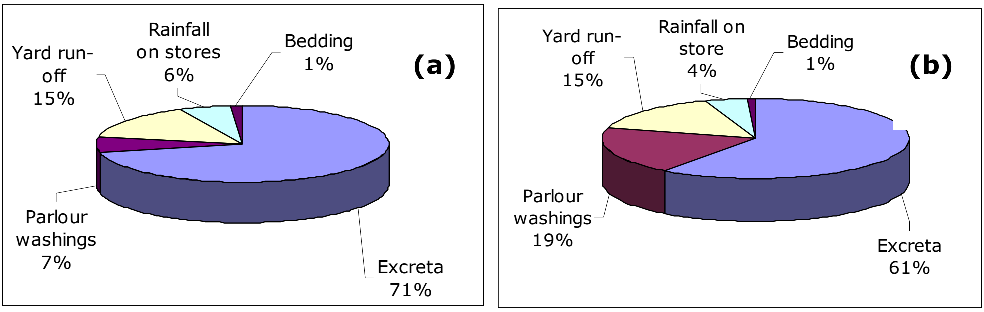

Figure 1. Characterisation of slurry on farms managing dirty water separately (a) and farms with total containment for slurry and dirty water (b).

On average, over the housing period each cow generated 13.6 m^3 slurry (range, 4.6 - 22.4 m^3) and 6.2 m^3 dirty water (range, 2.0 – 17.4 m^3) on farms with a separate dirty water store and 19.7 m^3 slurry (range, 12.5 – 31.0 m^3) on farms with total containment, representing a 31% reduction in the amount of slurry requiring storage and spreading for farms collecting dirty water separately.

Parlour washings, run-off from roofs and yards and rain water falling directly on the store accounted for 32%, 50% and 18%, respectively, of total water addition to slurry on farms with a separate dirty water store and 56%, 34% and 10%, respectively, on farms with total containment. Further examination showed that, where high-volume hoses were used to wash the milking parlour, the average hose flow rate was 97 litres/minute (range, 51 – 188 l/min) and the hose was used, on average, for 37 minutes daily so that the average daily water use was 28 litres/cow (range, 17 – 40 litres/cow). A 50% reduction in the amount of water from this source would result, on average, in an 8% reduction in the amount of slurry collected annually on farms with separate dirty water handling facilities and 15% reduction for those with total containment, with associated average annual cost savings (storage and spreading) of €1400 and €2491, respectively.

On average, 9.6 m^3 of storage space was provided for each cow (range, 2.5 – 28.9 m^3) being sufficient for 3.2 months or 80% (range, 18 – 237%) of the recommended storage period of 4 months. Only 31% of farms satisfied this requirement.

Practical implications

Improved water management and de-watering were identified as the first considerations in reducing slurry volumes and associated costs. Restricted water use, separation of 'clean' and 'dirty' water, and de-watering of slurry, particularly on farms collecting slurry and water together in one store, would go some way towards meeting the required storage capacity to comply with good practice guidelines and legislation for NVZs and optimise slurry application timing in spring. In addition, savings in water costs and in costs associated with storing and spreading slurry could be realised. Further substantial reductions in the amount of water collected in slurry stores could be made by the improved maintenance of roof gutters and down-pipes and the segregation of 'clean' and 'dirty' water run-off from yards (i.e. water running from yards soiled by cattle and from unused yard areas, respectively). Reducing the amount of slurry collected was considered to be the first consideration in the provision of adequate storage capacity for slurry and a cost-effective way to comply with good practice guidelines, and to aid the provision of slurry storage capacity where herd intensification was being considered. Reducing the flow rate or daily use of hoses in the milking parlour was seen as a simple remedial action incurring no cost.

References

Scott, P., Crabb, J., Smith, K.A. (2002). Report on the 2001 Farm Practices Survey (England)

MAFF 1998. The Water Code. Code of Good Agricultural Practice for the Protection of Water. (PB0585). Defra Publications. The Stationary Office.

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Funding of this work by the Milk Development Council (Great Britain) is gratefully acknowledged.

Treatment of sewage sludge with zeolite alone or in combination with lime on selected parasitological and bacteriological parameters

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Intensification of agriculture, concentration of people in towns and cities, and growing awareness of increasing environmental pollution has resulted in the necessity to treat animal and human wastes in waste water treatment plants. However, the products of such treatment depend very much on the treated materials, system of treatment and its efficiency, and the way of recycling the products. Animal and human wastes may be a source of spreading of diseases if they are infected with causative organisms which survive the treatment (Dubinský et al., 2000, Novák, 1996, Venglovsky, et al., 2006).

The hygienic risk arising from the presence of parasites and bacterial pathogens in pig slurry and sewage sludge, and in the products of biological aerobic, mesophilic waste water treatment plants treating pig slurry and municipal sludges, depends on the health status of the respective human or animal populations, and on the disposal or use of the products of treatment (Juriš et al., 1992, Venglovsky et al., 2005).

The aim of the study was to investigate the parasitological and bacteriological risk arising from sewage sludge and products of aerobic treatment of pig slurry and municipal sewage with regard to the recipient of the effluent and application of pre-treated sludges with or without additional treatment with quick lime and zeolite.

Materials and methods

In the first stage of the experiment, samples for chemical and bacteriological examination were taken from two waste-water treatment plants (WWTP-1, treating pig slurry and WWTP-2, treating municipal waste water) during one year at monthly intervals (Table 1). Parasite eggs and oocysts were determined in individual stages of the treatment (influent, effluent, solid fraction) during this period.

In the second stage the treated and dewatered sludge from WWTP-2 was collected, and its stabilisation was examined under laboratory conditions after adding quick lime, powdered zeolite and zeolite with lime (3% by weight each) during 42 days of storage. Commercially available lime (CaO, Carmeuse, Slovakia) and Slovak powdered zeolite (main fraction 0.125-0.250 mm, 42 - 56 % clinoptilolite) was used in the study. Chemical examination included determination of pH, dry matter, total, ammoniacal and nitrate nitrogen and total phosphorus.

Parasitological examinations of solid samples were carried out by the method of Kazacos (1983). The helminth eggs from liquid samples (influent and effluent) were isolated by a sedimentation-floatation method of Cherepanov (1982) modified by Romanenko (1968). Bacteriological examination consisted of determination of plate counts of mesophilic, coliform and faecal coliform bacteria (STN 83 0531-4 and STN-ISO 9308-2) on solid cultivation media (Endo agar, Imuna, Slovakia) and faecal streptococci in the municipal sludges (STN-EN ISO 7899-2) on Slanetz-Bartley agar (Biomark, India).

Results and discussion

Results of chemical examinations were reported by Venglovský *et al*. (2005). No helminth eggs were found in effluents from both plants. The solids from WWTP-1 contained eggs of *Ascaris suum* (12-35 eggs.100g^{-1}), *Oesophagostomum* spp. (2-6 eggs.100 g^{-1}), *Trichuris* spp. (1-2 eggs.100g^{-1}) and *Eimeria* spp. (2-12 oocysts.100g^{-1}). *Ascaris* spp. and *Trichuris* spp. eggs were found in 2 out of 40 samples of sludge from WWTP-2.

Mean efficiency of removal of selected groups of bacteria (mesophilic, coliform, faecal coliform) ranged between 86.5 % (coliforms) and 95.7 % (mesophiles) in WWTP-1 and between 79.8 % (faecal coliforms) and 97.9 % (mesophiles) in WWTP-2. In the majority of cases the bacterial plate counts decreased by 2 orders except for faecal coliforms in WWTP-2 (faecal coliforms decreased by 1 order).

The pH of municipal sludge treated with lime and lime and zeolite increased to 11.8 - 11.9 for up to about 12 days. During this period, no

coliform or faecal coliform bacteria were detected in sludge amended with lime or with lime and zeolite, and faecal streptococci were lower by two orders in the presence of lime and zeolite up to day 27 of storage.
No viable helminth eggs were recovered from samples after 42-day storage. The high pH in the sludge amended with lime and lime and zeolite was probably one of the principal factors that affected survival of bacteria and viability of helminth eggs (Allievi et al., 1994).

Table 1. Parasitological examination of samples from WWTP-1

	Influent (eggs.1000 ml^{-1})	Effluent (eggs.1000 ml^{-1})	Solid fraction (eggs.100g^{-1})
A. suum	28 - 29	0	12 - 35
Oesophagostom spp.	5 - 19	0	2 - 6
Trichuris spp.	1 - 3	0	1 - 2
Hymenolepis spp.	0 - 5	0	0
Isospora spp.	0 – 9*	0*	0*
Eimeria spp.	6 – 34*	0*	2 – 12*

*- oocysts

References

Allievi, L., Colombi, A., Calcaterra, E. And Ferrari, A,. 1994. Inactivation of fecal bacteria in sewage sludge by alkaline treatment. Biores. Technol. 49: 25 – 30.

Dubinský, P., Juriš, P. and Moncol, D. J., 2000. Environmental protection against the spread of pathogenic agents of diseases through the wastes of animal production in the Slovak Republic. Harlequin, Ltd. Košice: 7 – 23.

Juriš, P., Plachý, P., Tóth, F. and Venglovsky, J., 1992. Effect of biofermentation on Ascaris suum eggs. Helminthologia 29: 155 – 159.

Venglovsky, J., Sasáková, N., Vargová, M., Pačajová, Z., Plachá, I., Petrovský, M. and Harichová, D., 2005. Evolution of temperature and chemical parameters during composting of the pig slurry solid fraction amended with natural zeolite. Biores. Technol, 96: 181 – 189.

Venglovsky, J., Martinez, J. and Placha, I., 2006. Hygienic and ecological risks connected with utilization of animal manures and biosolids in agriculture.102: 197 – 203.

Salmonella reduction in manure by the addition of urea and ammonia

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Background

Cow manure may contain substantial amounts of pathogenic microorganisms such as *Salmonella*, *Campylobacter*, enterohaemorragic *E. coli* (EHEC), parasites and viruses (Pell, 1997). Insufficiently disinfected manure has been shown to be a significant factor for the occurrence of pathogens in animal herds (Veling *et al.*, 2002). Transmission of disease from manure to man has been verified, for example the outbreak of EHEC in Sweden during the summer of 2005. Microorganisms may survive for extended periods of time in soil and water (Nicholson *et al.*, 2005), and treatment of the manure before application to land has been suggested to decrease the risk of disease transmission since .

In this project the potential for pathogen disinfection with urea or ammonia was evaluated. *Salmonella*, enterococci and a bacteriophage were added to liquid cow manure (TS 12 %) in numbers between 10^6 and 10^8 colony- or plaque forming units (CFU/PFU) per gram manure. After the organisms had adapted to the material overnight, 2 % urea or 0.5 % ammonia was added to the material. There was also a control treatment with no addition of ammonia or urea. The incubations were carried out in triplicate at 4 and 14 °C.

Results

Salmonella were severely affected by the ammonia treatment and could not be detected after 2 days at 14 °C and 6 days at 4 °C after the addition of ammonia (~pH 9.7). Urea treatment (~pH 9.2) also gave a significant die-off of Salmonella at 14 °C, as well as 4 °C. The time for 1 log reduction (90 %), i.e. decimal reduction, was reduced between 76 % and 97 % compared to the controls (Table 1). Enterococci was not affected in the same way as Salmonella even if the die-off was significantly quicker in ammonia and urea treated manure than in the control. However, in the latter case only at 14 °C (Table 1). The phages were not affected at all by ammonia treatment, but the reduction was significantly quicker at 14 than at 4 °C.

Table 1. The time (days) for one log reduction (90 %), i.e. decimal reduction, for Salmonella, enterococci and bacteriophages in nitrogen treated cow manure at 4 and 14 °C.

Treatment	Temperature [°C]	Organism and time for decimal reduction[a] (days)		
		Salmonella	Enterococci	Bakteriophages[b]
Urea 2 %	14	2.0	15	24
Urea 2 %	4	4.8	43	31
Ammonia 0.5 %	14	0.4	6.2	28
Ammonia 0.5 %	4	1.1	9.1	37
Control	14	8.3	26	25
Control	4	34	30	39

[a] Time for one log, 90 %, reduction.
[b] *Salmonella Typhimurium* phage 28B (Lilleengen, 1948).

Another *Salmonella* experiment was carried out, where an outbreak situation at a farm was simulated. Ammonia or urea was added to liquid manure in jars that were kept over the weekend; an unamended control was also included. During the following week, 1 % manure contaminated with salmonella (10^7 CFU/g) was added on top of the nine manure treatments (experiment carried out in triplicate). This should simulate what would happen at a farm, if disinfection was performed during the time of an asymptomatic outbreak. Contaminated manure was added during five consecutive days without any incorporation into the disinfected manure. After the following weekend, the contents of the jars were mixed and the material sampled. The *Salmonella* densities were 1 000 times lower in the ammonia treated, and 100 times lower in the urea treated, manure than in the control. After another two days, the *Salmonella* level was below the detection limit in the ammonia treated manure. After four days this was also the case in the urea treatment, while it was still possible to detect *Salmonella* in the control after 35 days, when the experiment was ended.

Significance

Ammonia, added as a water-soluble or in the form of urea, proved to effectively disinfect *Salmonella* in cow manure (liquid manure with a dry substance, DS, content of 12 %). If a five-log reduction (99,999 %) is desired, less than a week treatment with 0.5 % ammonia is needed, also taking into account the uncertainty of the regression analyses (upper 95%). Treatment with urea for 15 days at 14 °C, or for 33 days at 4 °C will also lead to the same hygiene effect. This time can be shortened by raising the pH (and thereby the concentration of free ammonia) in the material by the addition of a stronger base such as lime, ashes, sodium- or potassium hydroxide. The time for a five-log reduction without additives (upper 95%) was 66 days at 14 °C and 606 days at 4 °C. Thus, storage of manure should include at least one summer during Swedish conditions.

Recontamination of hygienised organic material has caused problems during transports (Vinneras *et al.*, 2004). However, the long-term effect of ammonia in covered compartments would lead to further treatment during transports in tanks. Further, disinfection of manure is a safety barrier in case of an asymptomatic outbreak at a farm. Ruminants are an important reservoir for EHEC, and healthy animals may shed a lot of bacteria of clinical importance for humans. If disinfection is routinely performed before the manure is spread, disease transmission to humans and other animals will probably decrease.

The use of enterococci as an indicator of *Salmonella* occurrence after ammonia treatment would lead to an overestimation of the risk due to their tolerance and different behaviour in the material. We suggest that other indicators, for example *E. coli* or faecal coliforms, are used as indicators of *Salmonella* occurrence in ammonia treated manure. For viral die-off, further studies are warranted looking at the reduction with different ammonia concentrations and at the effect on viruses that carry their genome in different shapes, e.g. single- or double stranded DNA/RNA, to be able to draw any conclusion on how effective ammonia treatment may be for different types of viruses.

References

Lilleengen, K. 1948. Typing of Salmonella typhimurium by means of bacteriophage. PhD Thesis in The bacteriological hygenical department of the royal veterinary college, Royal Veterinary College. Stockholm.

Nicholson, F.A., S.J. Groves & B.J. Chambers (2005). Pathogen survival during livestock manure storage and following land application. Biores Technol 96:135-43.

Pell, A.N. (1997). Manure and Microbes: Public and Animal Health Problem? J Dairy Sci 80:2673-81.

Veling, J., H. Wilpshaar, K. Frankena, C. Bartels & H.W. Barkema (2002). Risk factors for clinical Salmonella enterica subsp. Enterica serovar Typhimurium infection on Dutch dairy farms. Prev Vet Med 54:157-68.

Vinnerås, B., Berggren, I., Albihn, A., Bagge, E. & Sahlström, L. 2004. Removal of Salmonella contamination before using plant nutrients from household waste and wastewater in agriculture. Proceedings from 2nd IWA Leading-Edge Conference on Sustainability in Water Limited Environments, 8 - 10 November, Sydney.

Effect of integrated forage rotation and manure management systems on soil carbon storage

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The sequestration of carbon (C) in agricultural soils is one suitable activity for alleviating the rise of anthropogenic carbon dioxide (CO_2) in the atmosphere (Lal, 2004). However, there is lack of information on quantification and accounting of soil C storage associated with agricultural activities (Freibauer et al., 2004). The objectives of this study were to determine: (i) the effect of application of different types of manure to forage rotations on soil C content; (ii) whether integrated forage rotation and manure management systems can be regarded as a C sink in comparison with no-till permanent meadow.

A poliennial field experiment was established in 1993 at the Istituto Sperimentale per le Colture Foraggere, located in Lodi, Northern Italy (Lat. 45°19' N, Long. 9°28' E, 80 m a.s.l.). The soil of the site is classified as a coarse-loamy, mixed, mesic, Typic Haplustalf. The experiment compares: a 1-year rotation (R1: Italian ryegrass, *Lolium multiflorum* Lam.+ silage maize, *Zea Mays* L.,); a 6-year rotation (R6: 3 years of Italian ryegrass+ silage maize followed by three years of alfalfa, *Medicago sativa* L.). Each rotation has received two types of manure: 1) farmyard manure (FYM) or 2) semi-liquid manure (SLM) (without straw). The amounts applied matched the criterion of returning to each unit soil area the manure produced by the number of adult dairy cows sustained (in terms of net energy) by the forage produced in each rotation (respectively 6 adult cows ha^{-1} for R1 and 4 adult cows ha^{-1} for R6). Consequently, 66 t ha^{-1} of FYM and 100 m^3 ha^{-1} of SLM were applied annually to R1; 44 t ha^{-1} of FYM and 66 m^3 ha^{-1} of SLM were applied annually to R6. Moreover, each manure treatment was applied in combination with two annual rates of industrial N supply: N0 (i.e. 0 kg N ha^{-1} for all crops) and N1 (i.e. 75 kg N ha^{-1} for Italian ryegrass; 150 kg N ha^{-1} for maize; 0 kg N ha^{-1} for alfalfa). The experimental design was a strip-strip-split–plot, with three replications. The size of an elementary plot was 13*7=91 m^2.

In the same year, 1993, a permanent meadow was established on a contiguous field. Initially, a pure tall fescue (*Festuca arundinacea* Schreb.) was sowed, but then the crop gradually evolved into a stable association with ladino white clover (*Trifolium repens* L.), an invasive forage plant in this environment. The meadow has received no fertilization, albeit the presence of white clover ensured an N input to the system via N2-fixation. Soil cores were sampled in September 2003 for the layers 0.-0.2 m and 0.2-0.4 m. Walkley & Black organic C and Kjeldahl total N were measured according to Page et al. (1982).

For the rotation R1, the application of FYM combined with N1 resulted in the highest soil C storage, 82.8 t C ha^{-1}, with an increment of +50% over SLM, either combined with N0 or N1. This treatment also resulted in +20.2 t C ha^{-1} compared to the permanent meadow. For the rotation R6, the application of FYM in combination with N0 increased C storage by +24% compared to SLM with N0, and by +21% compared to SLM with N1. The rate of FYM applied to R6 did not increase C storage compared to the permanent meadow. The comparison between FYM and SLM provide evidence that the increase in soil C storage can be attributed to the straw added to manure.

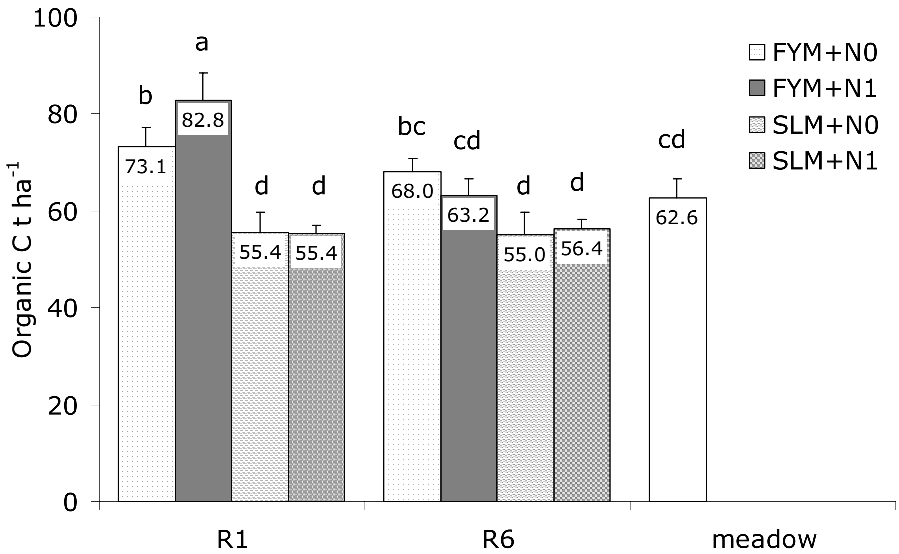

Figure 1. Carbon storage in the top soil profile 0.-0.4 m. Means sharing common letters are not significantly different at p<0.05. REGWQ multiple range test. Mean values are shown within the columns. Bars indicate +1 SD. FYM=farmyard manure; SLN=semi-liquid manure.

Assuming that about 8 kg of straw cow^{-1} day^{-1} are used for producing farmyard manure, the 6 cows sustained by rotation R1 requires an overall amount of 6 cows*8 kg*365 days=17520 kg of straw year^{-1}. About 3 ha of wheat are necessary for producing annually this quantity of straw. Assuming 85 % dry matter in straw, and 44 % of C, then 17520*0.85*0.44=6552 kg C in straw had to be produced elsewhere in order to achieve the observed C storage after 10 years in the forage rotations with FYM. Therefore, from the standpoint of C balance, the benefit of FYM in increasing soil C storage appears to be somewhat illusory, because it occurs at the expense of C removed elsewhere. On the other hand, Yamulki (2006) reported that the addition of straw to manure reduced substantially the emissions of the greenhouse gases nitrous oxide and methane from stored farmyard manure. In addition, there are numerous ancillary benefits associated with an increase of soil organic C (Lal, 2004). In particular, the above mentioned gain in C sink of 20.2 t C ha^{-1} for the treatment R1-FYM-N1 compared to meadow, was accompanied by an accumulation of about 1600 kg N ha^{-1} in soil organic matter. In fact, a C to N ratio of 8.9 (R^2= 0.76, n=6) and 8.1 (R^2= 0.84, n=6) were calculated, respectively, for the treatments R1-FYM-N1 and meadow. Thus, 82800/8.9=9300 kg N ha^{-1} for the treatment R1-FYM-N1 and 62600/8.1=7730 kg N ha^{-1} for meadow, so 9300-7730=1570 kg N ha^{-1}. This is a long term soil fertility capital that is important to consider anyway.

We conclude that: i) FYM application resulted in most cases in a higher C storage than both SLM and meadow; ii) the advantage of FYM application apparently overcame any negative effect of conventional tillage (plowing) on soil C storage. Nevertheless, we argue that the benefit of FYM in terms of C sink is questionable if the boundaries of the system are set wide enough to include the area required to produce the cereal straw that will be added to excreta in litter-based housing systems.

References

Freibauer, A., Rounsevell, M.D.A., Smith, P., Verhagen, J., 2004. Carbon sequestration in the agricultural soils of Europe. Geoderma, 122:1-23.

Lal, R., 2004. Soil carbon sequestration to mitigate climate change. Geoderma, 123:1-22.

Page, A.L., Miller, R.H., Keeney, D.R. (eds.) 1982. Methods of soil analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Yamulki, S., 2006. Effect of straw addition on nitrous oxide and methan emissions from stored farmyard manures. Agric. Ecosys. Environ.,112:140-145.

Manure organic carbon inputs and soil quality

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Introduction

The depletion of soil organic matter (SOM) reserves through oxidation following the cultivation of tillage land has led to concerns that SOM levels may be reaching critically low levels in some soils in the UK, and that arable crop production may not be sustainable in the long-term. Farm manure applications in the UK recycle *c*. 5 million tonnes of organic carbon (OC) each year and provide a valuable means of replenishing SOM, which could confer benefits to soil quality and fertility. However, in the medium-term following application, many of the claimed benefits from organic manure additions across a range of soil types are largely based on anecdotal evidence. The aims of this study were to determine relationships between OC inputs and soil OC status, and to evaluate the effects of OC additions on selected soil physical, chemical and biological properties.

Methods

The study was undertaken at four experimental sites, on contrasting soil types, with a history of repeated farm manure additions (Table 1).

Table 1. Experimental sites

Site	Topsoil (% clay)	Manure type	No. annual additions	OC loading (t/ha)
1. Gleadthorpe	6	Broiler litter	9	0-65
2. Harper Adams	12	Cattle FYM & slurry	7	11-25
3. Bridgets	23	Cattle FYM & slurry	7	11-25
4. Terrington	28	Pig FYM & slurry	7	5-14

Manures were applied at a target rate of *c*. 250 kg/ha total N at all sites, except Gleadthorpe, where 6 rates of broiler litter (0-25 t/ha) were compared. Supplementary inorganic fertiliser N was applied to all treatments at 'optimum' economic rates calculated from MANNER model predictions of manure crop N availability (Chambers *et al.,* 1999), with the un-manured control receiving the full recommended rate of inorganic N. Combinable crops were grown at each site over the study period.

Manure total N and OC loadings were measured each year, and the effects of these OC additions on key indicators of topsoil physical, chemical and biological quality were measured in spring 2001.

Results
Over all the study sites, there was a positive relationship between manure OC inputs and changes in total soil OC and 'light' fraction OC (Fig. 1). Total soil OC increased by an average of 2.5% relative to the control for every 10 t/ha manure OC applied, with the measured soil OC increases equivalent to *c*. 23% of the OC applied over the 7-9 year period. However, the 'light' fraction OC was a more sensitive indicator of changes in SOM status and increased by 15% for every 10 t/ha manure OC applied.

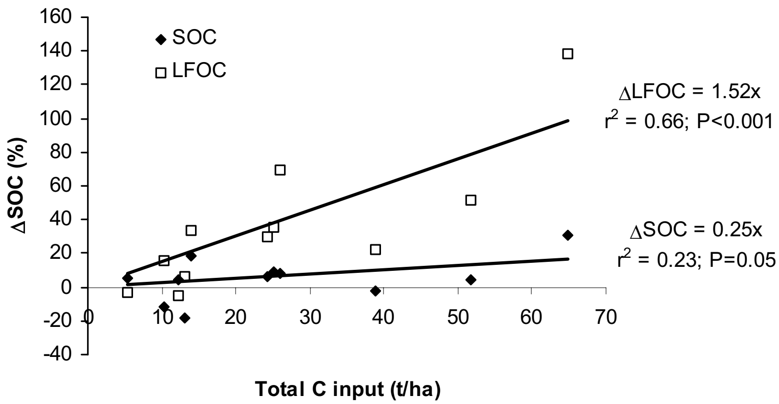

Fig.1 Change in topsoil total organic carbon (SOC) and light fraction organic carbon (LFOC) with total carbon inputs. Results are expressed as a difference from the control at each site.

Increases in soil OC were associated with increased topsoil porosity, decreased bulk density and increased plant available water capacity (AWC). The 10% increase in plant AWC (at 40 t/ha OC input) measured across the sites (Fig. 2) was estimated to increase the yield of unirrigated potatoes by *c*. 1.25 t/ha (worth *c*. £100/ha).

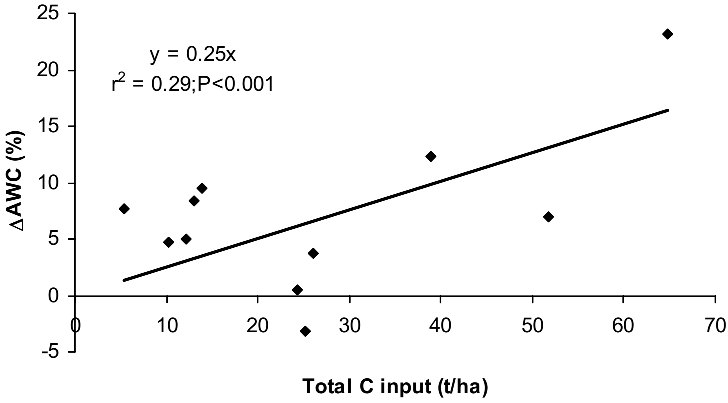

Fig. 2 Change in topsoil available water capacity (AWC) with total carbon inputs. Results expressed as a percentage difference from the control at each site.

The OC inputs also increased the size (P<0.01) of the soil microbial community (biomass C increased by 10% for every 10 t/ha OC input) and it's activity (respiration rate increased by 17% for every 10 t/ha OC input). Similarly, manure N inputs increased (P<0.001) soil microbial biomass N (by 15% for every t N/ha applied) and the potentially mineralisable N capacity (by 14% for every t N/ha applied) of the topsoil, which has implications for long-term effects on nitrate leaching losses.

Conclusions

Repeated and relatively large OC inputs were needed to produce measurable changes in soil properties, particularly physical properties. However, the OC inputs changed a large number of soil properties, which in combination produced measurable improvements in soil quality and fertility. However, the soil quality benefits of OC inputs need to be balanced with any potential environmental impacts and sustainable crop production aims.

References

Chambers, B.J., Lord, E.I., Nicholson, F.A. & Smith, K.A. 1999. Predicting nitrogen availability and losses following application of manures to arable land: MANNER. Soil Use and Management ***15****, 137-143.*

Recycling organic wastes from food production: the GRUB'S UP perspective

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Introduction

The fruit and vegetable industries in Europe generate about 30 million tonnes of waste a year. At present the most common practice is to landfill those wastes or to use them without (or with very scarce) treatment as animal feed and fertiliser. The objective of the GRUB'S UP Coordination Action is to encourage the exploitation of food processing by-products whose value is currently lost. The project aims to increase the utilisation and sustainable management of organic matter from food production and processing, by coordinating research into processes and technologies for recycling these wastes and encouraging the development of these processes within the industry.

The objectives

- To co-ordinate current research into the processing of fruit and vegetable wastes to generate high value-added products, and to identify centres of excellence in this research.
- To document the state of the art of research into these processes.
- To identify the needs of the fruit and vegetable industry that could be addressed by these technologies and processes.
- To assess the environmental and food quality, safety and economic impacts of a group of new processes for upgrading food waste.
- To analyse the market for and consumer/retailer opinion of the novel processes and their products.
- To produce a guide to new processes for upgrading wastes from vegetable and fruit processing.
- To develop the basis for a self-funding network of researchers, end-users and stakeholders with respect to the processes and approaches for recycling and upgrading food waste.

Working structure

The project brings together 6 research institutes and 2 universities, 9 industries from the food sector and 4 other specialists (including consumer associations and consultants). The project is managed by a coordinator, a network committee, consisting of a representative of each partner, and a Steering Committee, comprising the leader of each work package. The work is structured in 6 work packages: 1. Management; 2. Mapping current research; 3. Co-ordination of activities; 4. Cost/benefit analysis; 5. State of the market and industry; and 6. Technology transfer. Four expert groups were organised in order to study in depth the suitable technologies for obtaining quality products from fruit and vegetable wastes: i) Polyphenols, ii) Organic growth media and fertilisers, iii) Polysaccharides and polysaccharides degradation products, and iv) Colorants, odours and flavours. The 8 technologies selected (Table 1) met the following criteria:

- An emerging consumer demand, with favourable trends in legislation.
- Raw materials must be easily-available.
- One process must be from each of the sectors: Fruits and vegetables, olives and wine.
- Health promoting benefits, and environmental advantages.
- Information on the technology and the technology itself must be available.
- High quality product.
- Technology suitable for cost benefit analysis.

Co-composting of olive mill solid waste

Olive husk ("alperujo") is the main waste generated in the olive mills using the two-phase centrifugation technology. Olive leaves are a commonly used bulking agent for olive mill solid waste (OMSW) composting (10-20 % w:w), since they are generated in the mill after the separation from the olives. As N is required to adjust the initial C/N ratio for composting, urea is used at the rate 1-0.4 % of the initial mixture. Table 2 shows the general characteristics of the OMSW compost. The absence of undesirable compounds in the compost is due to the 66 - 90 % degradation of phenols during the process, giving a concentration in mature compost of 0.06 – 4.1 g/kg. Fats are also degraded (70 - 96 % reduction), the concentration in the mature compost can be 0.31 - 10.2 g/kg. Very low or non-detectable concentrations of heavy metals (Cd, Ni, Pb, Cr) have been reported in the composts. The compost produced can substitute for up to 50 % of the peat used in the substrate formulation for soil-less culture, the electrical conductivity being the limitation.

For the cost/benefit analysis a comparison has been made between the short-listed technology and existing technologies. Where an existing technology is unavailable for comparison, a basic process has been designed for a specific production volume including all financial impacts to give a total cost. This is broken down into an investment cost and production cost. The analysis includes an indication of the payback period. The environmental and risk assessment try to identify the microbial risks and food quality and safety impacts associated with the short-listed processes. Common indicators include raw material use, energy use, waste, emissions generated, improvement in food flavour and nutritive value and nitrogen efficiency in high value composts.

Updated information of the project and partners can be found at: www.grubs-up.org.

Table 1. Description of the different technologies selected.

	Technology description
Polyphenols	Supercritical extraction with CO_2 for polar polyphenols from olives
	Grape seed enzymatic release having a low content of monomeric polyphenols.
Organic growth media and fertilisers	Co-composting of olive waste with another material to produce good quality growing media.
	Composting of grape pomace, cuttings or stalks to produce a fertilisers for use by wine producers on their own land.
Polysaccharides	Microbial production of xylitol.
	Recovery of antioxidants fibres from fruits
Colorants, odours and flavours.	Natural anthocyanin-betalain mixtures for food colouring.
	Carotenolipoproteins – byproducts obtained in the seabuckthorn fruit juice production line.

Table 2. General characteristics, stability and humification parameters of the compost from olive mill solid waste.

OM (%)	84-95[a]; 45-64[b]	Water soluble-C (g/kg)	26.4-35.0
Total-N (%)	1.4-2.3[c]	Water soluble-C/org-N	1.01-1.54
Total-P (%)	0.10-0.33	CEC (cmol/kg)	77.2-110
K (%)	2.2-3.7	CEC/TOC (me/g C)	1.45-2.01
C/N	20-30	Germination index (%)	>80
Extractable-C (%)	7.8-13.6	HAC/FAC	1.95-3.05
Humic acid-C (%)	5.3-9.0	Humification index (%)	11.6-18.3
Fulvic acid-C (%)	2.15-4.62	Percentage humic acids (%)	66-75
		Humification ratio (%)	16.7-27.7

[a]Stone included; [b]Stone removed; [c]N-source. CEC: Cation exchange capacity.

Quantifying heavy metal inputs to agricultural soils in England and Wales

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Introduction

The soil is a long-term sink for the group of potentially toxic elements often referred to as heavy metals. Whilst these elements display a range of properties in soils, leaching losses and plant uptake are usually relatively small compared to the total quantities entering the soil from different diffuse and agricultural sources. As a consequence, they slowly accumulate in the soil profile over long periods of time, which can have long-term implications for the quality of agricultural soils. Therefore, reducing heavy metal inputs to soils is a strategic aim of developing soil protection policies in the UK and EU (Defra, 2004; EC, 2002). However, information on the significance and extent of soil contamination with heavy metals from different sources is required so that appropriate actions can be effectively targeted to reduce inputs to soil.

Methodology

This paper presents a quantitative inventory of heavy metal inputs (Zn, Cu, Ni, Pb, Cd, Cr, As and Hg) to agricultural soils in England and Wales in 2004. The major sources accounted for included atmospheric deposition, sewage sludge, livestock manures and footbaths, inorganic fertilisers and lime, agrochemicals, industrial 'wastes' and green waste composts, canal/river dredgings, metal corrosion, lead shot and irrigation water.

Results

For Zn and Cu, approximately 30% of the total annual inputs to agricultural land were from livestock manures. Around 90% of total Pb inputs were accounted for by lead shot, whilst dredgings were an important source of Ni, Cr and As (22-27% of total inputs). For Cd, 56% of inputs were from atmospheric deposition and 23% from inorganic fertilisers (mainly phosphate fertilisers) and lime. Over 85% of Hg inputs were from atmospheric deposition (Table 1).

Table 1. Annual heavy metal inputs (t) to agricultural land in England and Wales for the year 2004.

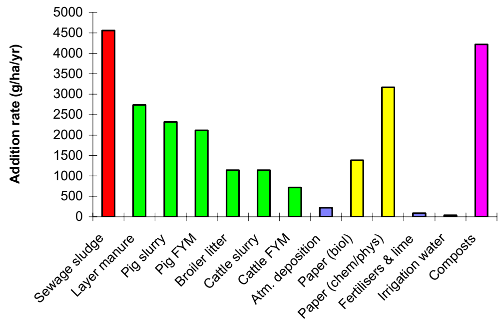
Source	Zn	Cu	Ni	Pb	Cd	Cr	As	Hg
Atmospheric deposition	2485	638	180	611	22	84	35	11
Livestock manures	1666	541	47	44	4	32	15	<1
Sewage sludge	394	271	28	106	2	78	3	1
Industrial 'wastes'	65	25	4	7	1	6	nd	<1
Inorganic fertilisers	199	67	30	13	9	94	6	<1
-Phosphate fertilisers	*152*	*22*	*15*	*2.4*	*7.1*	*74*	*5.1*	*<0.1*
Agrochemicals	22	5	0	0	0	0	0	0
Irrigation water	5	2	0	0	0	0	0	nd
Composts	52	13	5	28	<1	6	nd	<1
Corrosion	59	-	-	-	-	-	-	-
Dredgings	615	86	77	152	2	83	22	<1
Lead shot	-	-	-	18000	-	-	-	-
Footbaths	381	0	-	-	-	-	-	-
Total	5944	1648	371	18960	39	383	80	13

nd = no data

Atmospheric deposition was an important source of many heavy metals to agricultural land in terms of total quantities on a national scale. However, addition rates at the field level were low compared with those associated with sewage sludge, compost and livestock manures. Excluding dredgings and lead shot, the highest addition rates of most metals were from sewage sludge and compost (applied at 250 kg total N/ha/yr). However, the land area receiving these materials annually was relatively small (<1% of UK agricultural land receives sewage sludge). Zinc and Cu addition rates from pig and poultry manures applied at an equivalent N rate (250 kg total N/ha/yr) were *c*. 45% of sewage sludge addition rates for these metals (Figure 1a and 1b). Metal addition rates from cattle manures were generally low in comparison with sewage sludge and pig or poultry manures.

Estimates were made of the time required to raise topsoil concentrations from background values to the maximum permissible advisory limits for heavy metals where sewage sludge is applied to agricultural land, accounting for losses via leaching and crop offtake. For example, soil Zn would be raised to the limit value (200 mg Zn/kg dry soil) after approximately 87 years of sewage sludge additions compared with 94 years for composts, and 149-177 years for pig slurry or laying hen manure applied annually at rates of 250 kg/ha total N. Annual applications of paper sludge would also raise soils to the Zn limit value after 128-313 years.

a) Zinc



b) Copper

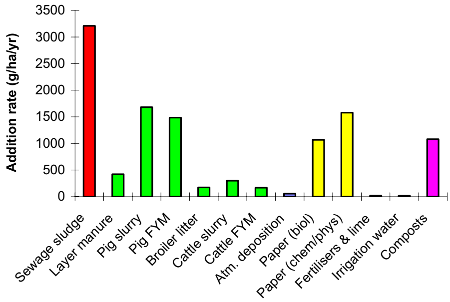


Figure 1. Zinc and copper addition rates to agricultural soils in England and Wales for 2004 (g/ha/yr).

Conclusion

The inventory of heavy metal inputs to agricultural land has shown that agricultural soils are at risk from heavy metal accumulation through the application of organic manures, in particular pig and poultry manures, sewage sludge, composts and paper sludge. Hence it may be appropriate to consider the introduction of maximum permissible soil metal concentrations to protect agricultural land from long-term heavy metal accumulation for all organic manures (similar to the controls currently in place for sewage sludge applications), unless strategies can be found to further reduce their metal content (e.g. by reducing the trace element supplementation of livestock feeds).

References

Defra (2004a). The First Soil Action Plan for England : 2004-2006. Defra publication PB 9441.

EC (2002). Towards a Thematic Strategy for Soil Protection, Brussels 16.4.2002 COM (2002) 179 Final.

Consumer attitudes and potential markets for composted food wastes in south west England

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UK markets for composted green wastes are well established, and various reports have examined the suitability of these materials as a peat substitute in growing media, as mulch, for turf production and many other uses. However, if national targets for diversion of biodegradable municipal waste from landfill are to be met, then it is essential that food wastes be diverted, and one possible outlet for this material is as a compost feedstock (The Composting Association, 2005). Since there has been very little exploration of markets for composts containing a food waste component, a review was undertaken in south west England to examine attitudes towards composted food wastes and to identify possible markets for such substrates.

A questionnaire-based approach was adopted, with 500 individual enterprises identified and contacted from the following sectors: agriculture and field horticulture; local authority (parks and gardens); mushroom farms; amenity horticulture (including landscape industries, nurseries and retail outlets); golf courses; mineral extraction and aggregates.
All questionnaires contained these three questions:

1. Did you know that food wastes could be recycled into composts?
2. Would you consider using (or selling) such composts?
3. If not, why not?

To determine whether particular markets could be more appropriate for composted food wastes than others, sector-specific queries were made to identify patterns of compost use, quantities of any composts currently used, and their cost (if any) to each enterprise within that sector. The questionnaire was accompanied by a colour information sheet, which explained the in-vessel composting process that such wastes are required to undergo in order to comply with the Animal By-Products Regulations. An overall response rate of 33% was achieved.

Attitudes towards composted food wastes

Awareness of composting as a disposal route for food wastes exceeded 80% in all sectors (data not shown), and although not so high, the response in favour of composted food wastes was still extremely encouraging (Figure 1).

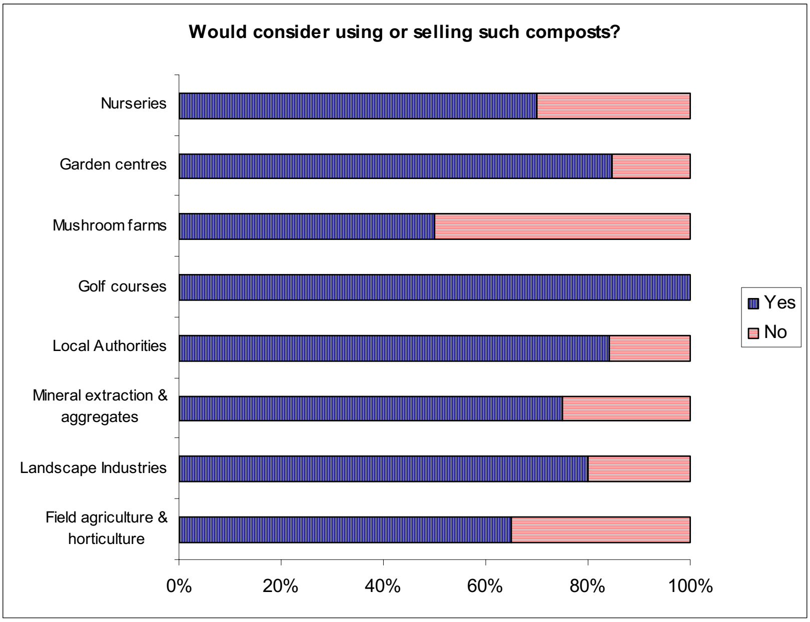

Figure 1. Attitudes towards composted food wastes among different user groups.

Reasons given for not wishing to use composted food wastes were split rather evenly among those who had no use for such composts (or in some cases, for any composts – such as agricultural enterprises generating their own animal manures) and those who were worried about safety, cost and lack of information about composted food wastes. Concerns about their nutrient status, consistency, contamination (pathogens and heavy metals), attractiveness to vermin and implications for waste management licensing were also raised. Previous research by the authors has not only demonstrated that heavy metals and pathogens pose no threat, but that composted food wastes may offer nutrient advantages over composted green wastes. Further work is necessary to examine the consistency of composted food wastes from batch to batch, and if composted properly, they are no more or less attractive to vermin than other composted materials.

In the UK, disposal of composted food wastes to land falls within the control of both the animal by-products regulations and waste management licensing legislation. They may also be controlled by legislation governing Nitrate Vulnerable Zones (NVZs). If spread as a waste material, then composted food wastes (as with other composts and vegetable residues) would require a Waste Management License Exemption, available from the Environment Agency. To comply with Animal By-Products legislation, records must be kept of the type of material received, when received and to which parcel of land such composts are applied, together with the first date on which grazing animals were admitted to those parcels of land (or the date when any forage crop was harvested from those parcels). Those holdings within NVZs and those accepting sewage sludge or other biowastes for land spreading should already have appropriate bookkeeping procedures in place, and the use of composted food wastes would represent a minimal additional burden.

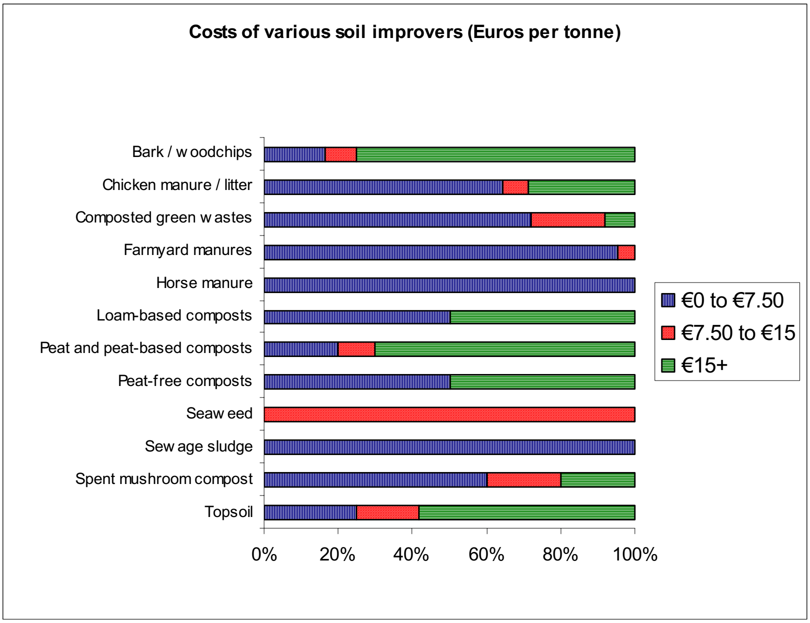

Figure 2. Prices paid for various soil improvers (by percentage of respondents).

Markets for composted food wastes

The costs of various soil improvers are presented in Figure 2. This demonstrates that enterprises are paying most (€15+) for peat (and peat-based composts), topsoil and bark. In contrast, little (€0 to €7.50) is generally paid for animal manures, sewage sludges or composted green wastes.

Although there is a possibility that over-sized screenings removed during production of composts could be transformed into a woodchip product, the most obvious high-value market is in compost use for manufactured topsoils – further work would be necessary to determine the size of any potential market in manufactured topsoil in south west England. In addition, although these new composts can be shown to be 'safe', they will be difficult to promote until individual case studies are available, demonstrating their successful use in a range of markets. Indeed, given the relatively low volume of such composts (when compared with composted green wastes) it may not be appropriate to develop separate markets for composted food wastes. Instead, they may come to be viewed as one more component in peat-free or peat-reduced media.

Reference

The Composting Association, 2005. The State of Composting in the UK 2003/2004. The Composting Association, Wellingborough.

Whole-farm nitrogen balances on Basque Country dairy farms

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Background and objectives

The whole-farm balance can be considered a useful and reliable indicator for assessing the efficiency and potential environmental impacts of nutrient use (Schröder et al., 2003). The aim of this study was to calculate whole-farm nutrient balances for estimating the potential environmental pressure of sixteen dairy farms in the Basque Country by nutrients.

Material and methods

Sixteen dairy farms were chosen by local advisors, representing the type of farms that will remain in farming in the future. Annual nitrogen inputs and outputs were reported for all farms in 2004. Required inputs for the balance were purchased concentrates and forages, fertilisers, purchased animals, legume fixation and deposition. Required outputs were sold products (milk and meat) and exported manure. A summary of the characteristics of the farms are shown in Table 1. The survey included 8 farms growing maize and 8 farms with grassland and no maize.

Table 1. Characteristics for all the farms, for farms that grew maize, and for farms that grew no maize (standard deviations in brackets).

Parameters	Mean (SD)		
	(n=16)	Maize (n=8)	No maize (n=8)
Agriculture area (ha)	60 (31)	74 (28)	47 (29)
Grassland (ha)	51 (22)	55 (17)	46 (27)
Maize (ha)	7 (10)	15 (9)	0 (0)
Number of cows	98 (43)	129 (35)	67 (23)
Milk production (L cow^{-1} yr^{-1})	9060 (1203)	9872 (767)	8249 (1004)
Livestock Unit per Agriculture area (LU ha^{-1})	2.7 (1.13)	2.7 (0.9)	2.7 (1.4)
Concentrate (kg cow^{-1} yr^{-1})	4042 (1242)	4443 (789)	3641 (1521)

Results and conclusions

The results in Table 2 show that the whole-farm N balance for all the farms (n=16) was highly determined by the use of concentrates and forages, which represented 80 % of total N input, followed by mineral fertilisation. A multiple regression analysis showed a positive correlation between whole-farm N surplus and concentrates inputs (R^2 = 0.82, $P < 0.0001$). The average annual N surplus of the dairy farms studied was 252 kg N ha^{-1} yr^{-1}, which exceeded the soil N surplus reference level estimated for The Basque Country (110 kg N ha^{-1} in the North and 70 kg N ha^{-1} in the South) to ensure concentrations of nitrate in groundwater and surface waters below 50 mg L^{-1} (del Hierro *et al*., 2005).

The N efficiency (percentage of N in inputs recovered in outputs) was 28 %. This means that 28 % of the N coming onto the farm could be accounted for in milk, meat, crops or exported manure. This imbalance between the nutrient inputs and the nutrient outputs is either lost to the environment directly or added to nutrient reserves in the soil, increasing the risk for future environmental losses.

Table 2. Components of the N balance (kg N ha^{-1} yr^{-1}) for all the farms (n=16), for farms that grew maize (n=8) and for farms that grew no maize (standard deviations in brackets).

Parameters	Mean (SD)		
	(n=16)	Maize (n=8)	No maize (n=8)
Concentrates	210 (105)	225 (94)	195 (1)
Forages	70 (64)	76 (72)	64 (58)
Animals	3 (6)	6 (7)	0 (1)
Fertilisers	28 (38)	41 (49)	15 (18)
Fixation	19 (5)	17 (4)	21 (4)
Deposition	20 (3)	21 (3)	20 (3)
N INPUTS	351 (220)	386 (228)	316 (85)
Milk	86 (39)	89 (31)	83 (47)
Meat	7 (6)	8 (6)	6 (7)
Manure	6 (12)	4 (11)	8 (14)
N OUTPUTS	99 (57)	101 (48)	97 (67)
N SURPLUS	252 (116)	284 (127)	219 (102)
N EFFICIENCY	28 (5)	27 (5)	29 (5)

In this study, farms with maize had a significantly larger herd size and higher milk production per cow (intensive dairy farms). The average herd size for farms that grew crops was nearly 2-fold higher than for farms that grew no crops (129 and 67 dairy cows, respectively), while the average milk production per cow was 9872 and 8249 L cow^{-1} yr^{-1}, respectively.

The N surplus per area for farms that grew crops and those that did not was 284 and 219 kg N ha^{-1} yr^{-1}, and the N efficiency was 27 and 29 %, respectively. But there were no significant differences between the two groups. The multiple regression analysis of whole-farms showed a positive correlation between whole-farm N surplus and concentrates inputs (farms with maize $R^2 = 0.91$, $P < 0.0001$; farms without maize $R^2 = 0.84$, $P < 0.0001$).

The whole-farm N balance was significantly higher on farms that grew maize (19270 kg N per farm) than on farms that grew no maize (8106 kg N per farm). When the data were corrected for number of dairy cows per farm, the N Surplus was slightly higher for farms that grew maize, but the difference was not significant (147 and 121 kg N cow^{-1} yr^{-1}, respectively).

In conclusion, the most responsible factor for the N surplus in Basque Country dairy farms is the utilization of high quantities of purchased concentrates (4000 kg cow^{-1} yr^{-1}). On contrary of expected, the farms with maize did not show a decrease in N surplus. The maize yield was not enough to reduce the need for purchase of external concentrates because the increase in the milk production per cow and year is based on the gradual increase in the supply of concentrates.

Acknowledgements

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References

Schröder, J.J., Aarts, H.F.M., ten Berge, H.F.M., van Keulen, H., Neeteson, J.J., 2003. An evaluation of whole-farm nitrogen balances and related indices for efficient nitrogen use. European Journal of Agronomy 20, 33–44.

Del Hierro, O., Artetxe A. and Pinto, M. 2005. Use of agricultural nitrogen balances to asses N pressure on ground and surface water for municipalities in The Basque Country. 14th N Workshop. Maastricht. The Netherlands.

Effect of sexual neutralization on fattening Piemontese male calves' nitrogen excretion

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A trial was carried on to verify the effect of the sexual neutralization and age of castration on the estimated nitrogen excretion in intact, pre- and post-pubertal castrated males. In fact, sexual neutralisation affects efficiency in producing lean carcasses, such as nitrogen retention, average daily weight gain, feed conversion rate, body conformation, and growth or proportion of dissected carcass tissues (Parrassin et al., 1999; Knight et al., 2000).

24 double-muscled Piemontese calves were divided in 3 groups: early castrated (EC - 5th mth of age), late castrated (LC - 12th mth of age) and intact males (IM - control group). The animals were reared under the same environmental condition from the same age (about 5th mth) until the proper market fattening degree and then slaughtered (about 18th mth of age). During the trial the animals were fed at the same energy and protein level with hay and concentrate, according to live weights monthly recorded. During the trial, feed intake and live weights were recorded shortly before each castration and before slaughtering. At slaughter and during dissection carcass and total meat, fat and bones weights were also recorded. Empty body weight (EBW), body crude protein (BCP) and daily nitrogen excretion (N-Ex) were calculated: the first on the basis of the empirical expression proposed by NRC (1996); the second using EBW fraction weight and N content of different parts (INRAN, 2000); the last according to the final report of the European Commission Directorate General XI (ERM/AB-DLO, 1999) relative to the assessment of N content in animal manure and N excretion. Data were analyzed by GLM ANOVA (SPSS, 1999) procedure.

The evolution of live weight and the average daily feed intake (both as hay and concentrate) are shown in Table 1. Differences were found in 12th mth live weight, higher in LC than EC ($P<0.05$), and in final live weight, higher in IM than EC and LC ($P<0.01$). Slaughtering, EBW, BCP and N-Ex data are showed in Table 2. The IM showed heavier carcass than EC and LC ($P<0.01$). Carcass components weight showed higher total meat in IM than EC and LC (P<0.01) and higher total fat in EC and LC than IM (P<0.01).

Table 1. Live weight and feed intake in early castrated (EC), late castrated (LC) and intact (IM) Piemontese males cattle (mean ± standard deviation)

	EC	LC	IM
5^{th} mth l.w. (kg)	163.75±23.46	167.25±16.21	156.13±18.54
12^{th} mth l.w. (kg)	379.00±19.80^{b}	416.75±25.14^{a}	405.63±35.65^{ab}
18^{th} mth l.w. (kg)	526.75±34.44^{B}	539.00±35.15^{B}	589.25±41.58^{A}
5-12^{th} mth conc. intake (kg/d)	4.23±0.94	4.43±1.04	4.32±1.02
5-12^{th} mth hay intake (kg/d)	1.83±0.04	1.83±0.04	1.83±0.04
12-18^{th} mth conc. intake (kg/d)	6.45±0.85	6.72±0.77	6.82±0.85
12-18^{th} mth hay intake (kg/d)	1.86±0.01	1.86±0.01	1.86±0.01
5-18^{th} mth conc. intake (kg/d)	5.27±1.43	5.50±1.48	5.49±1.58
5-18^{th} mth hay intake (kg/d)	1.84±0.03	1.84±0.03	1.84±0.03

A, B: P<0.01; a, b: P<0.05

Table 2. Slaughtering data, EBW, BCP and N-Ex in early castrated (EC), late castrated (LC) and intact males (IM) Piemontese males cattle (mean ± standard deviation)

	EC	LC	IM
carcass (kg)	356.50±30.34^{B}	356.63±19.80^{B}	397.75±31.18^{A}
blood (kg)	13.14±0.86^{Bb}	13.45±0.88^{ABb}	14.70±1.04^{Aa}
head (kg)	20.99±1.25^{Bb}	22.90±1.68^{Ba}	25.38±1.39^{Aa}
skanks (kg)	9.74±0.88	9.91±0.82	9.91±0.84
hide (kg)	27.03±6.86^{B}	32.28±3.17^{AB}	37.03±3.87^{A}
empty rumen (kg)	10.68±2.47	10.98±1.39	9.63±1.11
empty stomachs+guts (kg)	15.76±2.09	16.33±1.75	15.20±1.68
offal (kg)	15.45±0.68	15.55±1.31	15.63±1.06
total meat (kg)	291.45±28.84^{B}	290.75±16.40^{B}	333.93±26.64^{A}
total fat (kg)	16.69±4.26^{A}	16.29±2.56^{A}	10.65±1.72^{B}
total bones (kg)	48.36±4.59	49.58±5.79	53.17±5.14
EBW_{5} (kg)	145.90±20.90	149.02±14.44	139.11±16.51
EBW_{12} (kg)	337.69±17.64^{b}	371.32±22.40^{a}	361.41±31.76^{ab}
EBW_{18} (kg)	469.33±30.67^{Bb}	480.25±31.3^{ABb}	525.02±37.05^{Aa}
BCP (kg)	95.14±8.40^{Bb}	98.10±5.23^{ABb}	108.19±7.22^{Aa}
BCP/EBW_{18} (%)	19.46±1.88^{b}	20.00±1.35^{ab}	22.06±1.69^{a}
N-Ex $_{5\text{-}12}$ (g/d)	122.14±5.17	119.89±4.71	117.76±5.45
N-Ex $_{12\text{-}18}$ (g/d)	114.06±8.03^{B}	127.78±7.79^{A}	112.12±5.76^{B}
N-Ex $_{5\text{-}18}$ (g/d)	118.54±5.95^{ab}	123.40±4.95^{a}	115.25±4.69^{b}

A, B: P<0.01; a, b: P<0.05

EBW was higher in LC than EC at 12th mth of age ($P<0.05$) and in IM than EC ($P<0.01$) and LC ($P<0.05$) at 18th mth of age. Obviously IM showed also higher BCP than EC ($P<0.01$) and LC ($P<0.05$), but the ratio BCP/EBW was higher only in IM than EC ($P<0.05$). Estimated N daily gain was higher in LC and IM than EC ($P<0.05$) in the first rearing period (5-12th mth) and in IM than EC and LC ($P<0.01$) in the second ones (12-18th mth). So also the total N daily gain was higher in IM than EC and LC ($P<0.01$). For N-Ex LC showed higher value than EC and IM ($P<0.01$) in the second rearing period and higher value than IM ($P<0.05$) in the total period. These findings suggest that calves castration reduces the N use efficiency, perhaps also due to an increased endogenous proteinase activity on myofibrillar protein turnover (Morgan et al, 1993), especially if it is accompanied by increased stress and discomfort as the late castration. So Piemontese steers required more attention in the N, protein and energy supplies than bulls, and perhaps it could be possible to reduce protein and increase energy supply, particularly immediately after the castration, to improve total N use efficiency.

The accuracy in prediction of protein retention is fundamental to N-Ex reduction. In particular, it is well known that optimisation of ruminal fermentation and high quality sources of abomasal amino acids could significantly improve the N balance and the protein accretion. In despite of this, Piemontese breed frugality suggests also difference in the N use efficiency, but this aspect needs deeper studies.

References

ERM/AB-DLO. 1999. Establishment of criteria for the assessment of the nitrogen content of animal manures. European Commission, final report.

INRAN, 2000. http://www.inran.it/Documentazione/documentazione.htm.

Knight, T.W., Cosgrove, G.P., Death, A.F., Anderson, C.B., 2000. Effect of age of pre- and post-pubertal castration of bulls on growth rate and carcass quality. New Zeal. J. Agr. Res., 43, 585-588.

Morgan, J.B., Wheeler, T.L., Koohmaraie, M., Crouse, J.D., Savell, J.W., 1993. Effect of castration on myofibrillar protein turnover, endogenous proteinase activities, and muscle growth in bovine skeletal muscle. J. Anim. Sci., 71, 408-414.

NRC - National Research Council, 1996. Nutrient requirements of beef cattle. National Academy Press, Washington, DC.

Parrassin, P.R., Thenard, V., Dumont, R., Grosse, M., Trommenschlger, J.M., Roux, M., 1999. Effet d'une castration tardive sur la production de boeufs Holstein et Montbéliards. INRA Prod. Anim., 12, 207-216.

SPSS, 1999. SPSS Base 9.0 Manuale dell'utente. SPSS Inc. Chicago, IL, USA.

Explaining the diversity of environmental performances according to a typology of farming practices combinations: the case of the dairy cattle breeding in Réunion Island

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A farm-gate budget is the most integrative measure of environmental pressure and seems most suitable as environmental performance indicator (Oenema *et al.*, 2003). The farm-gate budget can also be used to identify farming practices which are not environmentally sustainable (Goodlass *et al.*, 2003). Taking the case of the Réunion Tropical Island, and focusing on the nitrogen (N) element, this paper applies the nutrient budget method to answer the question "Are some dairy farming models in the island more environmentally friendly than others?"

After an exceptional development period, the dairy sector (23,850,000 liters, 4,290 cows, 135 farmers) in Réunion Island (21°06'S, 55°32'E, 2700 km², 774,000 inhabitants) has to integrate environmental questions in the developmental orientation of the whole production chain, at the farm level in particular. However, development of grasslands is really limited by relief and dynamics of urbanization. In the majority of cases, the total utilised agricultural area (UAA) per dairy farm available to produce forage and spread manure is limited, with high stocking densities (often > 3 LU ha^{-1}). Therefore the farming models are generally based on high levels of inputs. Hence, it is important, to analyse the environmental impacts of the dairy farming practices in Réunion.

The sampling of the enquired farms was based on a technical-economical typology. 35 dairy farms were selected to represent all the farm types (assuming that the management style-diversity was covered). Semi-structured questionnaires were administered to the 35 farmers. They were questioned about their management practices which correspond to technical operations that generate biomass flows. As discussed by

Hedlund *et al.* (2003), these interviews with local farmers were the basis for quantifying the biomass flows on a yearly basis.

In the present study, the chosen method of nutrient budgeting was the "farm gate balance" (Simon *et al.*, 2000). Total "N in" was the sum of N inputs in purchased biomass: concentrates, forages (including straw for mulching), animals, mineral fertilisers and manure. Total "N out" was the total amount of N in exported biomass: milk, animals and manure. The whole farm N surplus was calculated as (total N input – total N output)/ UAA. The farm N use efficiency was defined as N output/ N input. N contents of the different types of biomass were derived from data of previous works conducted in Réunion.

A principal components analysis was carried out on data from the 35 farms characterised by their practices. The two first axes (data not shown) could be interpreted as axes of "land desintensification". i) The first axis characterised the "feed autonomy" of the farms. Feed autonomy can be defined as low use of concentrate and no import of forages by valorisation of on-farm produced forage. ii) The second axis expressed the "fertiliser autonomy" of the farms. Fertiliser autonomy is low use of mineral fertiliser per unit of UAA, significant on-farm recycling of manure. We propose a farm classification of 5 types. Type 1 and 2 cluster farms that have land intensive and technically intense practices. Farms of type 4 and 5 have land extensive practices. Type 3 is intermediate to 1-2 and 4-5 types.

Concentrates and mineral fertilisers are the main sources of N input (average values for all farm types: 51 and 41% of the N imports, respectively), similar to regions with intensive dairy farming systems (Hedlund *et al.*, 2003). The average N surplus per hectare UAA among Réunion's dairy farms is higher than that found in the intensive milk production in other regions of the European Union (Kelm and Taube, 2003), like Flanders (Nevens *et al.*, 2006). But this significant potential environmental impact has to be contextualised by considering the low density of dairy farms in Réunion (1% of the total area of the island). Moreover, Réunion farms have a better N efficiency (see Table 1) than Western European farms.

Table 1. Means of farms' characteristics per type (2004).

	Type 1	Type 2	Type 3	Type 4	Type 5	Average	Flanders[1] (2001)
UAA (ha)	15.7 +/- 11.1	8.2 +/- 0.7	17.3 +/- 11.1	23.1 +/- 25.9	30.3 +/- 25.7	18 +/- 14.5	32.5
Stocking density (LU ha^{-1})	5.3 +/- 11.1	5.1 +/- 0.7	4.0 +/- 11.1	2.7 +/- 25.9	3.0 +/- 25.7	4.2 +/- 2.1	3.0
N surplus (kg N ha^{-1} yr^{-1})	660 +/- 225	505 +/- 290	480 +/- 255	365 +/- 170	220 +/- 135	490 +/- 260	240
N Efficiency	0.27 +/- 0.13	0.31 +/- 0.13	0.21 +/- 0.18	0.21 +/- 0.20	0.36 +/- 0.16	0.25 +/- 0.16	0.22
Milk productivity (kg cow^{-1} yr^{-1})	6720 +/- 1355	6310 +/- 1155	5650 +/- 1180	5690 +/- 1255	5995 +/- 950	6020 +/- 1230	5830

[1] (Nevens *et al.*, 2006)

Extensive practices (types 4 and 5) appear to further lower N surplus. But N importation (intensification) is necessary to have higher milk productivity (types 1 and 2). Farms of types 1 and 2 compensate those N imports by exporting solid manure so they have a higher N efficiency.

From an economical point of view, if subsidies are linked to milk production, farmers will still have to aim at a high level of milk production. Therefore, considering only land limitation the intensive models (with high milk productivity) would really be defensible. Whereas if subsidies become decoupled or in the case of pluriactivity development (type 4), the extensive model could be retained, also for land limited systems.

Combining the typology of practices with environmental performances of the farm types revealed "environmentally positive practices", like export of manure. Knowing the importance of sugar cane crop (59% of the total UAA of the island vs. 5% for dairy farming), there is a high potential capacity of the sugar cane sector for accepting organic fertilisers from the dairy sector.

The current study was a first attempt to identify "environmentally positive practices" among dairy farms of Réunion. A whole farm model is being developed to simulate the influence of management practices on the N cycle in the dairy production system and the resulting sustainability of this system.

References

Goodlass, G., Halberg N., Verschuur G., 2003. Input output accounting systems in the European community—an appraisal of their usefulness in raising awareness of environmental problems. European Journal of Agronomy 20: 17–24.

Hedlund, A., Witter, E., Bui Xuan An, 2003. Assessment of N, P and K management by nutrient balances and flows on peri-urban smallholder farms in southern Vietnam. European Journal of Agronomy 20: 71–87.

Kelm, M., Taube, F., 2003. Characterisation of dairy farming systems in the European Union and nutrient cycles. In: Bos, J., Pfimlin, A., Aarts, F., Vertès, F., (Eds.), Nutrient Managment on Fram Scale, Workshop Proceedings, Quimper, France, pp. 17-33.

Oenema, O., Kros, H., De Vries, W., 2003. Approaches and uncertainties in nutrient budgets: implications for nutrient management and environmental policies. European Journal of Agronomy 20: 3–16.

Nevens, F., Verbruggen, I., Reheul, D., Hofman, G., 2006. Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: evolution and future goals. Agricultural Systems 88: 142-155.

Simon, J.C., Grignani, C., Jacquet, A., Le Corre, L., Pagès, J., 2000. Typologie des bilans d'azote de divers types d'exploitation agricole: recherche d'indicateurs de fonctionnement. Agronomie 20: 175-195.

Dietary and faecal phosphorus levels in commercial dairy farms of the Basque Country

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In the European Union (EU), phosphorus (P) losses from dairy manure to the environment are becoming a more severe pollution problem. Recent research indicates that dietary P management could be a key strategy for reducing P accumulation on dairy farms (Cerosalleti et al., 2004). Strategies for decreasing P concentrations in animal diets fall under two main categories: (i) reducing P overfeeding, which is still a common practice (often called safety margin), and (ii) increasing the bioavailability of feed P to improve P utilization efficiency by the animals (Maguire et al, 2005).

A survey was conducted on 64 Basque commercial dairy farms between July 2003 and April 2004 to assess average dietary, faecal and slurry P levels. Farmers were interviewed face-to-face to collect data on herd size (ranged from 19 to 300 Holstein lactating cows), production level (ranged from 5541 to 12166 kg/cow/year), formulated ration and feeding systems classified as Total Mixed Rations (TMR) and grass silage based non-TMR. In total 240 diet ingredients , faecal samples (representing at least 10% of the cows of each farm), and slurry samples (three to five subsamples combined into a composite sample) were analysed for total P (UV spectrophotometry, VARIAN CARY 100). The Cornell Net Carbohydrate and Protein System 5.0 (CNCPS 5.0) model was used to estimate the daily faecal excretion (kg/d) and the daily required P (g DM/day). Milk P content (g P/day) was estimated using INRA´s reference value for P content in milk (2.17 kg P_2O_5/1000l).

Dietary P mean value for lactating cows was 3.97 g DM/kg DM and ranged from 2.8 to 5.4 g DM/kg DM. 66.6% of the ingested P came from concentrates. On average, P was fed 38.4% above the CNCPS 5.0 model P requirement for the mean milk yield (29.7 kg/d per cow), and all farms showed P overfeeding (ranged from 16% to 56%). Higher dietary P concentrations were not associated with higher milk yields ($P > 0.05$, $r = 0.2$) (Fig. 1). Thus, the highest milk yield (39.9 kg/d per cow) was achieved with 3.86 g P/kg DM. Mean P utilization efficiency was 31.9% and positively correlated with milk yield ($P < 0.05$, $r = 0.48$) (Fig.2).

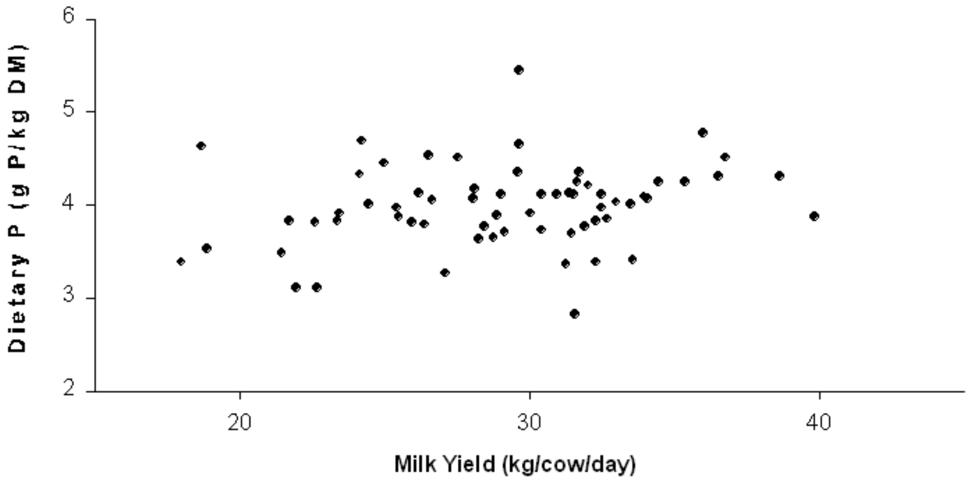

Figure 1. Dietary P (g P/kg DM) and Milk Yield (kg/cow/day).

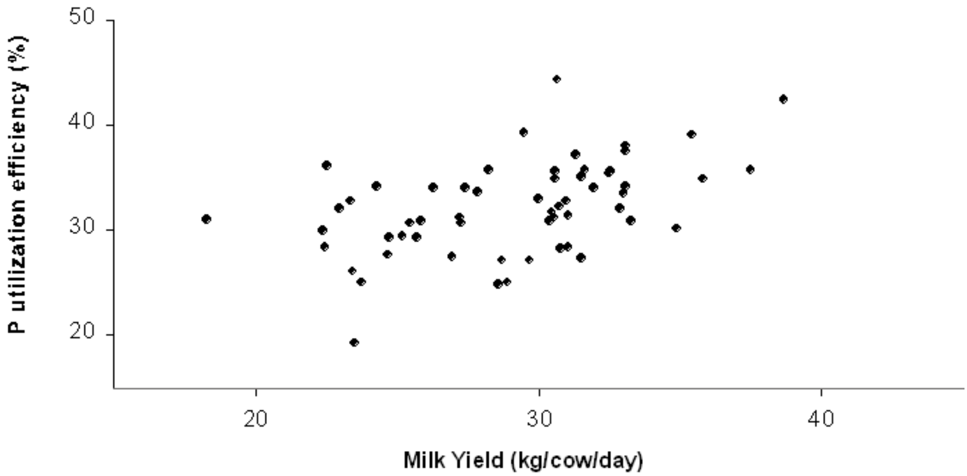

Figure 2. P Utilization Efficiency (%) and Milk Yield (kg/cow/day).

Ingested P concentration showed a weak positive correlation with faecal P concentration despite the farm variability ($p<0.05$, $r = 0.29$) (Fig.3). Faecal mean P concentration was 8.2 g/kg DM and ranged from 5.9 to 10.7 g/kg DM. Estimated daily faecal P excretion (g DM/d) per ingested P (g DM/d) was higher for grass silage based non-TMR than for TMR (p <

0.01), probably due to the lower apparent total digestible nutrient (TDN) shown by non-TMR feeding system ($p<0.01$).

Total P concentrations in faeces and slurry showed a positive correlation ($p<0.05$, $r = 0.44$), and P concentration was higher in faeces (0.82% DM) than in slurry (0.78% DM), mainly due to the dilution effect caused by the urine and farm cleaning water collected in the farm pit.

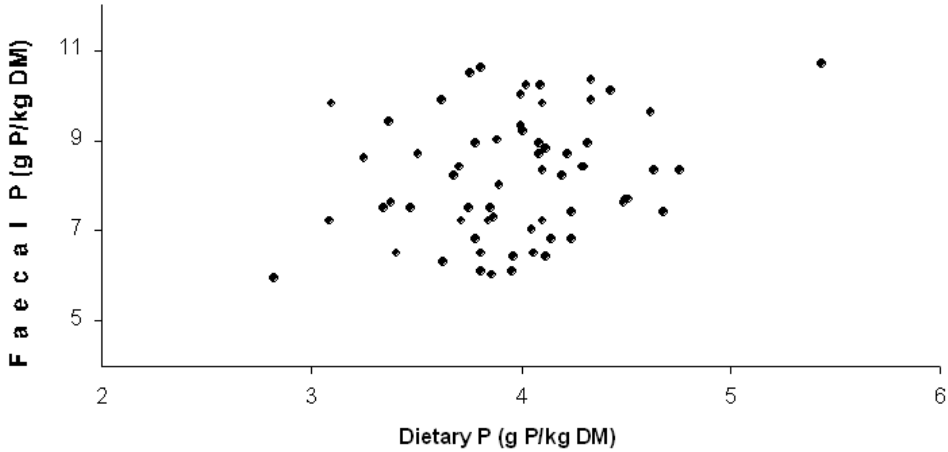

Figure 3. Dietary P (g P/kg DM) and Faecal P (g P/kg DM).

Data from Basque commercial dairy farms support that P over-feeding is a common practice among farmers which does not improve mean herd milk yield and might lead to higher P excretion. Adjusting the P intake and ration digestibility could increase milk yield while also reducing P excretion.

References

Cerosaletti, P.E., Fox, D.G. and Chase, L.E. 2004. Phosphorus Reduction Through Precision Feeding of Dairy Cattle. J. Dairy Sci. 87:2314-2323.

Maguire, R.O., Dou, Z., Sims, J.T., Brake, J. and Joern, B.C. 2005. Dietary Strategies for Reduced Phosphorus Excretion and Improved Water Qulity. J. Environ. Qual. 34:2093-2103.

Assessment of the balance between livestock effluent production and nutrient demand by crops in a small agricultural area of The Reunion Island

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Introduction

Recycling livestock effluents has interest as a way to improve the sustainability of livestock farms as far as it is based on agronomical reasoning. In the Reunion Island, these effluents represent the main source of organic matter, the recycling of which without risking water and soil pollution is a true challenge for the island's agriculture. In the Southern part of the island (e.g., in 'Petit Tampon' and 'Grand Tampon') significant and diversified livestock farming (pigs, poultry, dairy, suckling and fattening cattle) is found together with diversified cropping systems (sugar cane, fruit crops, market gardens, and grasslands). The current farming practices exhibit management drawbacks: on the one hand effluent recycling on crops is badly developed, generating pollution risks, whereas on the other hand the requirements of crops for organic fertilisers remain unsatisfied. Until now no agronomic diagnosis had been carried out in this area at the regional scale in order to assess the harmony between crop requirements and the effluent supply from the livestock farms. This baseline study bridges this gap, which is essential to allow us to consider possible transfers of organic matter between farms. The aim of this paper is to present the method which we implemented to achieve this diagnosis.

Material and methods

Usually, the balance between supply and demand is simply given by the difference between the amount of nitrogen in the livestock effluents produced and the crops requirements for nitrogen (Figure 1). The originality of our approach lies in the method used for calculating the nutrient requirements by the crops. This approach is based on the reasoned fertilization principle using the nitrogen efficiency equation (Muller et al., 2001) in a tropical area with a strong altitudinal gradient. Calculation at the plot scale is based on the effective supply of endogenous nitrogen by the soil and the nitrogen efficiency ratios of fertilizer applications (apparent fertilizer use ratio and equivalent fertilizer ratio) experimentally measured. The plot data (crops, expected yield, nitrogen supply from soils, nitrogen efficiency ratios) were stored in a database allowing us to calculate the crop requirements at the plot scale. This calculation was carried out according to allocation rules of effluents to crops, the relative part of mineral fertilizers in the total nitrogen fertilization, and the type of spreading regulations holding in France. This last option coupled with a GIS allowed us to define the net spreading area of a plot and thus to adjust the crop requirements as well as possible.

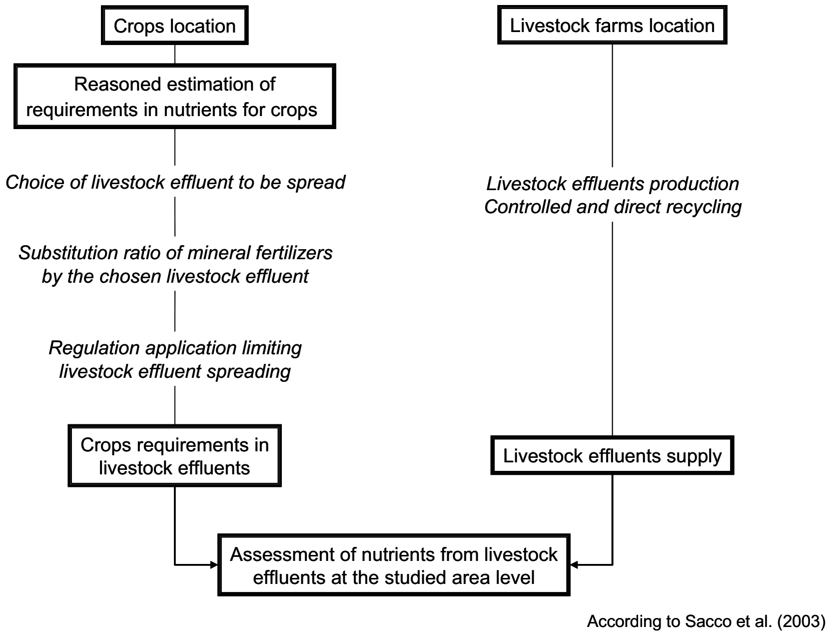

Figure 1. Method for the assessment of the balance between livestock effluents production and nutrient demand by crops.

Results

According to the inventory of nutrients stemming from livestock production (57 500 kg of nitrogen), the determination of crop requirements and the cartography of the spreading areas of the agricultural land, it appeared that the Petit Tampon and Grand Tampon area could recycle all nitrogen from the solid manure. With regard to liquid manure, the results lead us to establish two diagnoses according to the spreading regulations that should apply to the livestock farms: If it was assumed that the livestock farms comply with the French 'Réglement Sanitaire Départemental' (i.e., general constraints on spreading), then surpluses were found. If it was assumed that all the livestock farms comply with the French ‘Installations Classées pour la Protection de l’Environnement’ regulation, then by substitution of 66% of mineral fertilizer needs with organic fertilizers it would be possible to recycle all nitrogen produced in the area (Figure 2). In addition to this diagnosis, this work enabled us to devise, with Microsoft Access, a calculation tool of the crops requirement using a generic form of request. This tool was built to be used by agricultural advisers.

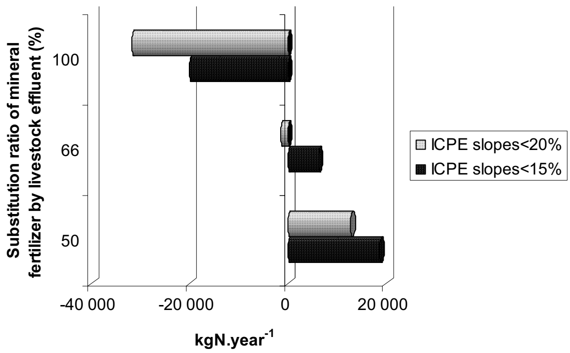

Figure 2. Livestock effluent mass balances (kg of nitrogen per year) for the studied area of ‘Petit Tampon’ and ‘Grand Tampon’ according to the French ‘Installations Classées pour la Protection de l’Environnement - ICPE’ regulation. The levels of substituting mineral fertilizers were evaluated, i.e. 50, 66 and 100%.

Prospects

This global diagnosis will be completed by diagnoses to be made within individual farms in order to determine possible difficulties of effluent management at the farm scale. These farm diagnoses should also enable us to use flow simulation models in order to design more efficient effluent management strategies in association with the agricultural stakeholders of the area.

References

Sacco, D., Bassanino M. and Grignani C., 2003. Developping a regional agronomic information system for estimating nutrient balances at a larger scale. Europ. J. Agronomy 20: 199-210.

Muller J.C., Decroux J. et Schvartz C., 2001. Guide de la fertilisation. Fascicule 1: Sols et agriculture. Cycles biogéochimiques. Comifer 93 p.

Environmental risk assessment of manure management

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This paper analyses the environmental problems generated by intensive stock-breeding of animals, and it introduces a methodology for appraising the environmental compatibility of the manure management practices used by these facilities. The aim of the work was to define an environmental risk assessment related to the agronomic use of manure, and to apply it to an area with a high intensity of tillage and characterized by a large concentration of farms with cattle and piggery breeding.

The methodology was based on an assessment model constructed in the form of a ranking system (*Magette, 2002*). The model itself constitutes a system that codifies information relative to the management and use of organic manures into risk classes. Table 1 reports the factors and classes used in the application. Each class has a value related to the increasing risk of the factor. According to the approach of *Hughes et al. (2005)*, the values increase exponentially. It should be emphasised that the ranges used for each factor have to be defined according to the dataset of the area under evaluation.

In order to obtain an index of the environmental risk of the area, a weight was assigned to each factor, and a sum of the risk scores (where risk score = weight x value) for each factor and each field was calculated. The dataset used for the assessment was obtained by collating different sources of information. Manure Management Plans were available for all the livestock farms in the test area, therefore the quantities of planned nutrient inputs at the field level were used as one source of input. Spatial information, such as the proximity of farms to rivers or to urban areas, the topology of fields and topographic data of the area (urban area, streets, water table height, etc.), were other sources of data and were managed using GIS.

The database and the GIS were then linked together, and a number of risk factors were calculated on a field-by-field basis, such as the loading of nitrogen, the manure distribution schedule, the distance of fields from water, the clay content of the soil etc.

Table 1. Risk factors, weights and classes used for the application of the risk assessment methodology.

Risk factor	unit	weight	risk class I value=1	II value=2	III value=4	IV value=8
Nitrogen load from manure	$kg.ha^{-1}$	1	0-110	110-280	280-430	>430
Phosphorus load from manure	$kg.ha^{-1}$	1	0-70	70-200	200-310	>310
Nitrogen load from mineral fertilisers	$kg.ha^{-1}$	1	0-20	20-70	70-140	>140
Nitrogen uptake from crops	$kg.ha^{-1}$	1	>630	470-630	320-470	0-320
Phosphorus uptake from crops	$kg.ha^{-1}$	1	>100	80-100	60-80	0-60
Manure spreading period	(*)	0.6	0-0.6	0.6-1.6	1.6-2.4	2.4-4
Soil clay content	%	0.2	>36	30-36	21-30	0-21
Liquid manure to total manure ratio	%	0.3	0-20	20-50	50-70	70-100
Soil texture (run off)		0.5	sandy	sandy-loam	loam	clay
Soil texture (leaching)		0.9	clay	loam	sandy-loam	sandy
Soil covering	(**)	0.8	0-1,5	1,5-2,6	2,6-3,5	3,5-6,8
Annual rainfall	mm	0.5	<600	600-900	900-1200	>1200
Distance from surface water	m	0.8	>1300	600-300	300-600	<300
Watertable depth	m	0.2		2-5	0-2	
Distance from urban center	m	0.2	>1000	600-1000	300-600	<300

(*) spreading period was evaluated as follows: 1 – springtime; 2 –September and October; 4 other periods.

(**) soil covering was evaluated as follows: 1 – permanent; 2 – double crop; 4 - single crop; 8 – no coverage.

The risk factors were weighted and combined as reported in Table 2 to obtain a set of risk indexes for different types of environmental hazards (e.g. risk related to fertilizers, to run off, to infiltration, to odours).

The results of the application of the proposed methodology to the study area highlight the different classifications according to the indexes. In fact, 50% of the area could be classified at high risk of pollution due to the use of fertilizers, but just 8% of the total area was considered hazardous for the infiltration of nutrients (Figure 1). The connection to the GIS made it possible to identify spatially the location of the zones at different risks. The appraisal made it possible to define an index of the risk of environmental pollution for every portion of the area examined, and to characterize the zones in which the management of the manure from animal breeding results in critical values of risk.

Table 2. Factors utilised to calculate risk indexes

Risk factor	**risk**			
	fertilizers	**run off**	**infiltration**	**odours**
Nitrogen load from manure	X			
Phosphorus load from manure	X			
Nitrogen load from mineral fertilisers	X			
Nitrogen uptake from crops	X			
Phosphorus uptake from crops	X			
Manure spreading period	X			X
Soil clay content	X			
Liquid manure to total manure ratio	X			
Soil texture (run off)		X		
Soil texture (leaching)			X	
Soil covering		X		
Annual rainfall		X		
Distance from surface water		X		
Watertable depth			X	
Distance from urban center				X

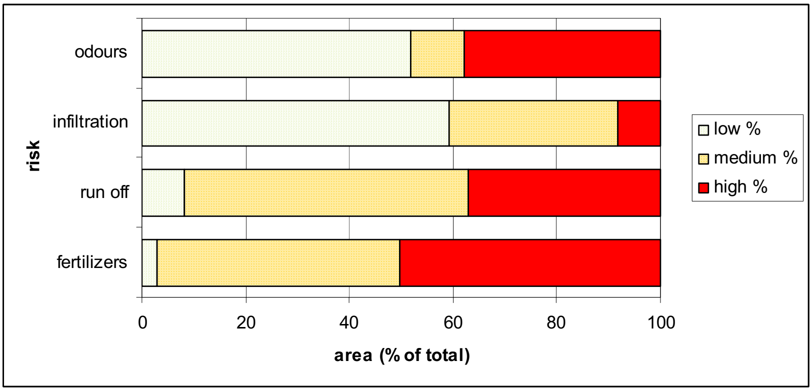

Figure 1 – Area classified according to the risk indexes obtained

References

Hughes, K. J., W. L. Magette, and I. Kurz. 2005. Identifying critical source areas for phosphorus loss in Ireland using field and catchment scale ranking schemes. J. Hydrology 304:430-445.

Magette W.L., (2002), Identifying Diffuse Pollution Sources Using Multicriteria Analysis, 2002 ASAE Annual International Meeting/CIGR XVth World Congress, Chicago, USA, July 28-July 31, 2002.

Effect of ration on faecal nutrient output from sheep and dairy cows

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Rations fed to ruminants vary in both chemical composition and digestibility. As a consequence, both faecal output and faecal chemical composition vary considerably. When apparent digestibility is measured, nutrients in cell content like protein, fat, starch and sugar are generally highly digestible, whereas NDF (neutral detergent fibre) has lower and more variable digestibility. Neutral detergent solubles (NDS), calculated as (organic matter – NDF), is a measure of cell content nutrients. Apparent digestibility is calculated as the feed-faeces difference, and as faeces also contains non-fibre substances of endogenous origin, apparent digestibility of cell content nutrients is lower than their true digestibility, where true digestibility is defined as the digestibility of the nutrients originating from the feed.

In the present paper, individual animal data from several Danish digestibility experiments with dairy cows and sheep have been evaluated with respect to chemical composition of rations and faeces, and the effect of ration chemical composition on faecal nutrient output has been determined.

The composition of feed ration and faeces for dairy cows and sheep is shown in Table 1. For cows fed highly variable rations ad libitum, average concentrations (% of dry matter (DM)) in faeces compared to feed generally increased for nitrogen (3.03 vs. 2.69 %), crude fat (4.87 vs. 3.64 %), crude ash (12.3 vs. 7.72 %) and NDF (44.8 vs. 33.4 %), and decreased for NDS (42.7 vs. 58.8 %). For sheep, fed highly variable rations restricted at maintenance level, average nutrient concentrations in faeces compared to feed generally decreased for nitrogen (0.94 vs. 2.44 %), crude ash (5.39 vs. 8.00 %), NDS (41.2 vs. 45.2 %) and increased for NDF (53.3 vs. 46.6 %).

Prediction of digestibility of different fractions of the feed cell content based on chemical feed analysis is well known. The basis is the so-called Lucas formula (Van Soest, 1994). The principle behind the Lucas formula is that a nutrient, independent of the feed, has a constant true digestibility, and that the faecal endogenous loss of the respective nutrient is a constant proportion of the feed dry matter intake. This assumption is not always correct for all individual feedstuffs. However, the principle enables us to make more general tools for prediction of digestibility and faecal output of specific nutrients. When the principle was applied to the cow data set and corrected for random effects of experiments, true digestibilities of 0.962, 0.767 and 1.11 and endogenous losses (g/kg feed DM) of 8.3, 6.6 and 203 were estimated for nitrogen, crude fat and NDS, respectively, as shown in Table 2. The table shows similar prediction equations published earlier on sheep digestibility data from experiments where sheep were fed at maintenance level.

Table 1. Feed and faecal composition in dairy cows fed ad libitum and sheep fed restricted at maintenance (% in DM)

		Feed ration			Faeces		
	N	Ave.	Min.	Max.	Ave.	Min.	Max.
Dairy cows							
Nitrogen	375	2.69	1.27	4.86	3.03	1.69	4.53
Crude fat	292	3.64	0.71	9.90	4.87	1.72	14.0
NDS	378	58.9	26.7	74.1	42.7	26.7	64.1
NDF	378	33.4	16.6	66.6	44.8	21.8	63.3
Ash	378	7.72	3.81	14.71	12.3	6.35	37.6
Sheep							
Nitrogen	5474	2.44	0.34	5.90	0.94	0.10	3.31
NDS	2479	45.2	14.1	79.2	41.2	15.1	71.2
NDF	2479	46.6	16.5	81.5	53.3	24.1	81.8
Ash	5638	8.00	2.47	21.7	5.39	0.27	26.1

When faecal output was directly estimated instead of digestibilities in dairy cows, the following prediction equations for output of nitrogen, fat and NDS were found:

Faecal nitrogen (g/day) = 0.0529(nitrogen intake, g/day) + 0.00792(DM intake, g/day) (N = 375; root MSE 23 g/day)

Faecal crude fat (g/day) = 0.226(crude fat intake, g/day) + 0.00686(DM intake, g/day) (N = 292; root MSE 53 g/day)

Faecal NDS (g/day) = -0.0749(NDS intake, g/day) + 0.176(DM intake, g/day) (N = 378; root MSE 366 g/day).

Table 2. Estimates of true digestibility and endogenous loss using the Lucas principle in dairy cows (production level) and sheep (maintenance level).

	N	True digestibility	Endogenous loss (g/kg feed DM)
Dairy cows			
Nitrogen	375	0.962	8.3
Crude fat	292	0.767	6.6
NDS	378	1.11	203
Sheep			
Nitrogen[1]	5501	0.936	5.4
Crude fat[2]	441	0.96	10
NDS[3]	2337	1.013	90.2

[1]Weisbjerg et al. (2002); [2]Weisbjerg et al. (1991); [3]Weisbjerg et al. (2004)

A considerable difference was observed between dairy cows and sheep in the ratio between nutrient concentration in feed and in faeces (Table 1). Ash and nitrogen concentration in faeces compared to feed was higher for cows, and lower for sheep. The reason for the difference for ash is not fully known, but part of the explanation could be that dairy cows in most cases were supplemented with minerals whereas the sheep were unsupplemented. For nitrogen the difference was also remarkable. The Lucas estimations (Table 2) show that the difference is not due to a lower true digestibility of nitrogen in cows, but due to a higher loss of endogenous nitrogen. The reason is probably a more extensive hind gut fermentation in cows compared to sheep, and thereby a higher loss of microbial protein with the faeces.

The composition of faeces will affect both the nitrogen fertiliser value and the biogas production potential of the manure. Nutrient detergent solubles which are easily metabolised impair the N fertilizer effect as soil microbial growth immobilizes the nitrogen for immediate use by the plants. Contrary, easily metabolised nutrients improve the biogas production potential of the manure. Ability to predict faeces and thereby manure composition is essential for prediction of both fertilizer value and biogas potential of manure.

In conclusion, the Lucas principle allows for prediction of faecal losses of cell content nutrients based on the nutrient content in the feed ration. However, prediction equations deviate considerably between dairy cows fed ad libitum and sheep fed restricted at maintenance level.

References

Van Soest P.J., 1994. Nutritional Ecology of the Ruminant. 2. ed. Cornell University Press, Ithaca. 476 pp.

Weisbjerg M.R., Hvelplund T., Frandsen J., Højland Frederiksen J. and Aaes O., 1991. Estimering af råfedts fordøjelighed hos drøvtyggere baseret på fodermidlernes indhold af råfedt. 804. Medd., Statens Husdyrbrugsforsøg. 6 pp.

Weisbjerg M.R., Hvelplund T. and Søegaard K., 2002. Prediction of true digestibility and faecal endogenous losses in sheep of protein and total cell content from the proportion of the nutrient in feed dry matter. Proceedings, TSAP Conferences Series 29:143-151.

Weisbjerg M.R., Hvelplund T. and Søegaard K., 2004. Prediction of digestibility of Neutral Detergent Solubles using the Lucas principle. J. Anim. Feed Sci., 13, suppl. 1:239-242.

Comparison of models used for the calculation of national ammonia emission inventories from agriculture in Europe

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Introduction
The Gothenburg Protocol of the UN Convention on Long-range Transboundary Air Pollution requires the reporting of national annual emissions of ammonia (NH_3). Accurate inventories of agricultural NH_3 emissions are required since they commonly account for more than 80% of the total emissions. To allow a co-ordinated implementation of the Protocol, different national inventories should be comparable.

A core group of emission inventory experts has therefore inaugurated the EAGER network (European Agricultural Gaseous Emissions Inventory Researchers Network), with the aims of achieving a detailed overview of the present best available inventory techniques, compiling and harmonizing the available knowledge on emission factors (EF) and initiating a new generation of emission inventories that satisfies protocol requirements. As a first step in summarizing the available knowledge, the objective of the work reported here was to determine the degree to which results obtained with different NH_3 emission models currently used for inventory calculations agree, and to evaluate any larger disagreements.

Methods
The models used for the comparisons have been used in the framework of the national NH_3 emission inventory calculations and manure policy

analyses in different countries of Europe (Table 1). The models all use a mass-conservation N-flow approach starting with a specific amount of nitrogen (N) excreted by a defined livestock category, and simulating the total ammoniacal nitrogen (TAN) flow over the different stages of emissions (grazing, housing, manure storage and application). Ammonia emissions are generally calculated with EF, where the EF is the percentage of the respective TAN pool emitted. Emissions were compared for a dairy cattle and a pig scenario, with different levels of model standardizations. At a first level of comparison, the congruency of the underlying N flow was tested. For this purpose, the national specific N excretions rates, TAN contents and EFs were replaced by a set of standardised values (FF scenario). At a second level of comparison, only the N excretion and TAN contents were standardised, whereas the national EFs were used for the calculations (FN scenario). Finally, emissions were also calculated using the national N excretion rates, TAN contents and EFs (NN scenario).

Table 1. Models used in the comparison.

Model	Country	Objectives of the model	Reference
DYNAMO	Switzerland	Estimation of the magnitude of NH_3 losses at the farm and national level	Reidy and Menzi, 2006
DanAm	Denmark	Estimation of the magnitude of NH_3 losses at the national level	Hutchings et al. 2001[1)]
GAS-EM	Germany	Estimation of NH_3 and other N losses at the national and district levels	Dämmgen et al. 2002[2)]
NARSES	United Kingdom	Estimation of the magnitude, spatial distribution and time course of agricultural NH_3 emissions at the national level	Webb and Misselbrook 2004
MAM	Netherlands	Manure policy analyses and estimation of NH_3 emissions at the farm and national level	Groenwold et al. 2002
FARMMIN	Netherlands	Ex-ante evaluation of the effect of management on profitability and nutrient losses	van Evert et al. 2003

1) An updated model fully based on the N-flow was used in this study.
2) An updated model fully was used in this study.

Results and Discussion

Running the models with the defined livestock and manure management parameters and the standardised N excretion and EF (scenario FF) resulted in very similar estimates of the NH_3 emission for the respective emission stages as well as total emissions. This indicates that the underlying N flows of the different models are highly comparable. The small differences observed could largely be explained with slight modifications of the N flow, either related to an altered partitioning of the N deposited during grazing and housing or to the extent that other N transformations are taken into account (e.g. mineralization or denitrification processes) in the different models.

Differences between the models were more pronounced when the emissions were calculated with national emission factors and/or national N excretion rates (FN and NN scenario). The variation in the calculated emissions was primarily the result of distinct national emission factors and N excretion rates. Both parameters reflect the specific livestock and manure management systems of the different countries and can be explained by:

- Differences in N excretion that result from differences in feeding practice (e.g. the protein concentration in the diet) or from different production intensities (e.g. milk yield per cow, growth rate per pig).
- Variations in the types of animal housing, storage and technology used for field applications.
- Variations in animal management (e.g. duration of the grazing period)
- Climatic factors

The variations in the calculated emissions of the FN and NN scenarios are therefore real.

Conclusions

The models compared were generally well congruent, and observed differences in the results obtained could mostly be explained by existing differences in natural conditions and farm management in the countries from which the models originate. For this reason emission inventories are most appropriately constructed at a scale that reflects the heterogeneity in agriculture and climate. The congruency exercise has also led to a greater harmonization of the structure and function of the models tested, because the scientific debate necessary to understand the variation in results from the different models generated awareness and consensus concerning the importance of some processes (e.g. mineralization).

References

Dämmgen, U., Lüttich, M., Döhler, H., Eurich-Menden, B. and Osterburg B., 2002. GAS-EM – a procedure to calculate gaseous emissions from agriculture. Landbauforschung Völkenrode 52:19-42.

Hutchings, N. J., Sommer, S.G., Andersen J.M. and Asman W.A.H., 2001. A detailed ammonia emission inventory for Denmark. Atmospheric Environment 35:1959-1968.

Luesink, H.H., Daatselaar, C.H.G., Doornewaard, G.J. and Prins H. 2004. Sociaal-economische effecten en nationaal mestoverschot bij varianten van gebruiksnormen. LEI, Den Haag, Rapport 3.04.08

Reidy B. and Menzi H., 2006. DYNAMO: An ammonia emission calculation model and its application for the Swiss ammonia emission inventory. Proceedings of the Workshop on Agricultural Air Quality: State of the Science. June 5-8, Bolger Center, Potomac, MD, USA.

Van Evert, F., van der Meer, H., Berge, H., Rutgers, B., Schut T. and Ketelaars J., 2003. FARMMIN: Modeling crop-livestock nutrient flows. Agronomy Abstracts 2003, ASA/CSSA/SSSA, Madison, WI.

Webb, J., and Misselbrook T.H., 2004. A mass-flow model of ammonia emissions from UK livestock production. Atmospheric environment 38, 2163-2176.

Historical development of livestock and manure management in Switzerland

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Introduction

The importance of reliable and robust information about livestock and manure management in projects looking at environmental impacts of agriculture is increasingly recognised. For a better understanding of the relevance of emissions, their impacts and potential mitigation options not only the current management should be known, but information with respect to the historical development of emissions should also be available. In the framework of projects regarding ammonia emissions from agricultural sources, we therefore aim at compiling historical information about livestock and manure management practices in Switzerland over the last approximately 150 years, to be able to estimate historical emissions of ammonia and greenhouse gases.

Material and methods

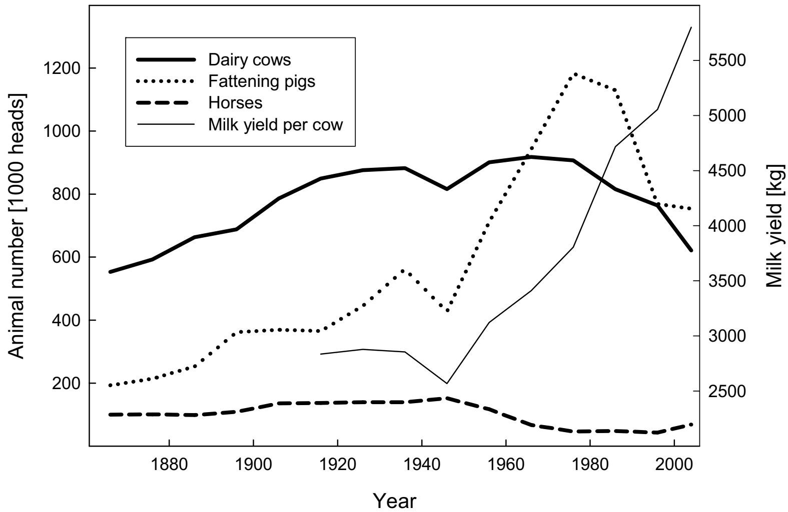
A multitude of historical sources was consulted, especially publications for farmers about good management practice (e.g. Wirzklander). Also an extensive review of agricultural production systems (e.g. Brugger 1978 and 1985) and official statistical data have been consulted. They were mined for a broad range of relevant information about livestock and manure management, such as livestock numbers, livestock weight and production parameters, typical rations, grazing, housing types and manure management systems and mineral fertilizer use. Livestock and manure management data were compiled for six distinct periods: 1866-1900, 1900-1920, 1920-1940, 1940-1966, 1966-1978, 1978-1990. Results are expected in the course of the summer 2006.

Preliminary results

The first preliminary results show the following general aspects:

- With respect to the most important animal categories, the livestock numbers for dairy cows and fattening pigs almost steadily increased until the seventies of the last century (Figure 1), with the exception of a slight reduction during the Second World War. Between 1900 and the maximum around 1980 the increase was approximately 32% for dairy cows and 227% for fattening pigs. Compared to the dairy cow herd, the development pattern for fattening pigs was much more pronounced from the end of the Second World War until 1980: +177% and +11% for fattening pigs and dairy cows respectively. Since the historical maximum of livestock numbers in the seventies, numbers for both animal categories have been decreasing. A different pattern could be observed for horses. From 1866 until the Second World War the number of horses increased steadily. Thereafter horse numbers declined drastically, primarily because of the rapid and widespread introduction of tractors and power engines during the second half of the last century. Since 1990 the number is increasing again.

Figure 1. Development of dairy cow and fattening pig numbers from 1866 to 2004 in Switzerland. Average milk yield per dairy cow is shown for the period of 1916 to 2004.



- The biggest change in production systems could be observed between 1950 and 1980, with a rapid increase in the overall agricultural production intensity. Within this period, for example, the average milk yield per dairy cow almost doubled, from 3000 to 6000 kg per animal. The intensification had strong effects on animal performance, feed rations, mineral fertilizer use and the appreciation of the nutrient value of manure. This can be best illustrated by the dramatic increase in the use of mineral nitrogen, phosphorus and potassium fertilizers, which increased by 711%, 79% and 244% between 1950 and 1980.

Conclusions

Although much more information than expected is available about good farming practices, even for the second half of the 19th century, the biggest challenge of the project will be to differentiate between good farming practices as described in historical technical documents and the prevalent farming in practice.

Even though the project was initiated in the framework of ammonia emission inventory work, the potential use of the information goes far beyond. It will help to create a better understanding of the evolution of current farming and manure management systems, and to assess the development of gaseous emissions, as well as other negative environmental aspects of intensive agricultural systems.

With respect to the development of agricultural ammonia emissions it can be expected that, taking into account the considerable changes in livestock and farm management, the project will suggest a more pronounced increase in the emissions between 1950 and 1990 than previously estimated by Menzi et al. (1997) and Stadelmann et al. (1998).

References

Brugger, H., 1978. Die Schweizerische Landwirtschaft 1850-1914. Huber, Frauenfeld, Switzerland. 242 pp.

Brugger, H., 1985. Die Schweizerische Landwirtschaft 1914-1980. Huber, Frauenfeld, Switzerland. 320 pp.

Menzi, H., Frick R. and Kaufmann R., 1997. Ammoniakemissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials (Ammoniaemissions in Switzerland: Present situation and assessment of the abatement potential). Schriftenreihe der Forschungsanstalt für Agrarökologie und Landbau (FAL), Nr. 26. Zürich-Reckenholz, Switzerland. 107 pp.

Stadelmann, F.X., Achermann, B., Lehmann, H.J., Menzi, H., Pfefferli, S., Sieber U. and Zimmermann A., 1998. Ammonia emissions in Switzerland: Present situation, development, technical and economic assessment of abatement measures, recommendations. Institut für Umweltschutz und Landwirtschaft Liebefeld (IUL) und Forschungsanstalt für Agrarwirtschaft und Landtechnik (FAT), 56 pp.

Wirzkalender. Volumes 1895-1988. Wirz's Schreib-Kalender für Schweizerische Landwirte. Druck und Verlag von Emil Wirz, vorm. J.J. Christen, Aarau, Switzerland.

The composition of faeces and urine from slaughter pigs and gestating sows is determined by diet composition

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Introduction

Pig diets vary in chemical composition, especially with respect to protein and carbohydrates. Varying feed composition influences the pattern and extent of digestive and fermentative processes, as well as the site of absorption (i.e. small intestine or caecum colon), and thereby also the volume and composition of faeces and urine (Fernández, 1997). It has been shown that when fibre in the diet increases, more nutrients are transferred to the caecum colon (Just et al, 1983). In addition, increased amounts of nutrients, mainly carbohydrates, are excreted with the faeces (Just et al. 1983).

The type of carbohydrate in the diet changes the pattern of excretion of nitrogenous compounds. Substitution of maize starch with raw potato starch in pig diets induces an increased microbial activity in the hind gut and decreased nitrogen excretion in the urine in otherwise identical diets (Mason et al., 1976).
We have studied systematically the effect of diets varying in protein concentration/quality and in carbohydrate composition on the amount, volume and composition of faeces and urine from pigs.

Material and methods

Experimental diets: Eight different diets for growing pigs and four diets for dry sows were formulated according to Danish nutritional recommendations. Growing pigs' diets were optimised at 2 levels of protein. In addition, diets for growing pigs and for sows contained high and low fermentable fibre, each at 2 levels (pigs 2 x 2 x 2, sows 2 x 2 design, respectively), as shown in Table 1. Animals: Female growing pigs (5 groups of 8 each) placed in individual metabolic cages for 12 days with free access to drinking water were fed the experimental diets. After an adaptation period of 5 days, quantitative collection of faeces and urine was performed daily for seven days. Bladder catheters were used to ensure complete and separate collection of faeces and urine. In addition, diets similar to nos. 2, 4, 6 and 8 (Table 1) were assayed with adult sows.

Results

Although main effects were significant in many cases (Table 2), there were also a few cases of 2- and 3-way interactions. Thus, water intake (l/kg feed dry matter intake) was not influenced by dietary protein level or fibre type. However, increased fibre level reduced water intake, but only in the diet with low fermentable fibre and high protein level, and in the diet with high fermentable fibre and normal protein level. Pigs fed high fermentable fibre

Table 1. Composition of experimental diets

	Fibre type and level		
Diet no.	Low fermentable	High fermentable	Protein
1	Normal	-	High
2	Normal	-	Normal
3	High	-	High
4	High	-	Normal
5	-	Normal	High
6	-	Normal	Normal
7	-	High	High
8	-	High	Normal

High protein = All essential amino acids supplied by natural protein sources
Normal protein = Reduced protein level fortified with industrial amino acids (LYS, MET, THR).

voided substantially less faeces, but more urine. Regardless of fibre type, faecal volume increased with increasing dietary fibre. Similar results were found for sows. The amount of urine voided decreased with increased fibre level. High fermentable fibre increased the urine volume, but only in diets with normal protein level. Urinary N was not influenced by diet composition. Diets with high fermentable fibre resulted in significantly higher ash, protein and fat, and consequently also in higher dry and organic matter of faeces in relation to diets with low fermentable diets. Opposite, diets with high fibre levels produced faeces with lower content of ash, protein, fat and carbohydrates. Faecal protein content was increased by high fermentable fibre regardless of fibre level, but was decreased by increased level of low fermentable fibre. Increased dietary protein level increased faecal protein, the difference being significant only in the case of low fermentable fibre.

Table 2. Water intake and voided faeces and urine (per kg DM ingested) and the composition of faeces (g/kg) from growing pigs and sows fed different diets.

	Fibre type (FT)		Fibre level (FL)		Protein level (PL)		Significance		
	Low	High	Norm	High	Norm	High	FTxFL	FTxPL	FLxPL
				Growing Pigs					
Water, l	5.6	6.2	6.3	5.4*	6.0	5.8	NS	*	NS
Faeces, g	871	641*	590	922*	782	728	NS	NS	NS
Urine, l	2.6	3.5*	3.6	2.5*	3.1	3.0	NS	*	NS
Urinary N, g/l	5.2	4.9	4.3	5.8	4.3	5.8	NS	NS	NS
Faecal DM	268	297*	308	258*	275	291	NS	NS	NS
Faecal ash	34	46*	45	35*	38	42*	NS	*	NS
Faecal protein	53	68*	66	56*	56	66*	*	*	NS
Faecal fat	23	33*	33	23*	27	29*	NS	NS	NS
Faecal CHO	159	150	165	144*	154	154	NS	NS	NS
				Adult sows					
Water, l	6.4	5.9	6.5	5.8	6.2		NS		
Faeces, g	874	462*	497	838*	667		*		
Urine, l	3.6	3.2	3.7	3.1	3.4		*		
Urinary N, g/l	8.1	7.9	8.4	7.6	8.0		NS		
Faecal DM	276	355*	348	284*	315		*		
Faecal ash	39	75*	60	53*	57		*		
Faecal protein	37	66*	55	49*	52		*		
Faecal fat	21	44*	36	28	32		NS		
Faecal CHO	179	170	196	153*	175		NS		

Fibre type: low or high fermentability; Fibre level: normal or increased with fibre rich feedstuffs; Protein level: Normal, achieved by addition of industrial amino acids; high level, without industrial AA.
*Denote significance ($p<0.05$) within FT, FL or PL and their interactions
DM: Dry matter; CHO= DM-ash-protein-fat

References

Fernández, J. A. 1997. Aflejring og indhold af N, P og K hos slagtesvin. In: Normtal for husdyrgødning. Eds. Poulsen & V.F. Kristensen. Beretning nr. 736. Danmarks JordbrugsForskning, pp. 102-122.

Just, A., Fernández, J.A. and Jørgensen, H. 1983. The net en ergy value of diets for growth in pigs in relation to the fermentative processes in the digestive tract and the site of absorption of nutrients. Livest. Prod. Sci., 10: 171-186.

Mason, V.C., Just, A. and Bech-Andersen, S. 1976. Bacterial activity in the hind gut of pigs. 2. Its influence on the apparent digestibility of nitrogen and amino acids. Z. Tierphysiol. Tierernähr. Futtermittelkd., 36: 310-324.

Transport of estrogenic hormones and faecal bacteria through structured soils amended with manure from a weaner producing farm

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Introduction

While the contamination risk posed by leaching of nutrients applied in manure is a well recognised problem, the contamination risk from concomitantly applied antibiotics, steroid hormones and microbial pathogens has received much less attention. Among the steroid hormones, especially the estrogens including 17β-estradiol (E2) and its degradation product estrone (E1), are of major environmental concern due to their strong potential for causing endocrine disruption. The lowest observable effect levels (LOEL) of E1 and E2 are as low as 3.3 and 4.0 ng/L, respectively (Andersen 2004), although a 17β-estradiol concentration as low as 1.0 ng/L has also been found to cause feminisation of male fish (Purdam et al 1994). Concern has also been raised about microbial pollution of groundwater. A potential contamination pathways may be the leaching of enteric pathogens entering agricultural soils via manure spreading. In contrast to sewage sludge there are no limits to the pathogen content of manure.

The present study examined the transport of estrogens and the pathogenic indicators *Escherichia coli* (*E. coli*) and coliforms in general under field conditions to determine the risk that these contaminants might leach into the aquatic environment through structured soils.

Material and methods

The leaching risks were evaluated under field conditions at two tile drained loamy field sites at Silstrup and Estrup, Denmark. The two sites were cultivated as similar conventional fields within the local areas regarding crop rotation, fertilization and soil tillage. At the Estrup site 53.0 tons/ha (3.15% dry matter) of pig slurry was injected to a depth of approximately 8-10 cm on 18th April 2005 and, within a few hours, ploughed to approximately 20 cm depth. The Silstrup site was amended with slurry twice. Firstly, 30.2 tons/ha (8.3% dry matter) was injected to a depth of 8 cm on the 23rd April. Secondly, on the 29th August 15.8 t/ha (2.9% dry matter) was trail hose applied and immediately ploughed. The amounts of E1, E2, *E.coli* and coliforms in the slurry are given in Table 1.

Table 1. Measured concentrations of E1, E2, *E.coli* and coliforms in the applied slurry derived from a weaner producing farm.

	Application date	E2 (µg/kg DM)	E1 (µg/kg DM)	*E.coli* (CFU/100 ml)	Coliforms (CFU/100ml)
Estrup	18.04.2005	n.d.	866	7×10^6	4.7×10^6
Silstrup	23.04.2005	392	643	1×10^6	8.5×10^5
	29.08.2005	1068	n.d.	n.a.	n.a.

n.d.: not detected with a level of detection of 2.5 µg/kg dry matter;
n.a.: not analysed

Concentrations of E1, E2, *E.coli* and coliforms were determined on drainage water samples collected during "typical storm flow events" which would occur at the two fields during a 12 months period following the slurry application. The events was sampled flow-proportionally for approximately 1 day, and a weighted average concentration for each event was obtained by analysing a pooled water sample taken throughout the storm flow event. Prior to the manure application, "background" samples of the drainage water was collected and analysed. None of the contaminants were detected in these samples.

Results

At both sites steroid hormones, applied to the soil via manure injection, leached in concentrations considerably exceeding the LOEL. At Silstrup maximum concentrations of 68.0 ng/l E1 and 1.8 ng/L E2 were detected in the tile drains as long as three months after the application. A similar tendency was observed at Estrup, where a maximum concentration of 11 ng/L E1 was found in the tile drains three months after application.

Coliforms were seen in the drainage water from both fields, in numbers reaching 6700 CFU/100 ml, for up to seven and twelve months after application at Silstrup and Estrup, respectively. *E. coli*, which is regarded as a better indicator of faecal pollution, was not found in the Silstrup fields, whereas at Estrup *E. coli* was present in all samples between 50 to 211 days following the slurry application.

Conclusion

This study suggests that on well-structured soils with spreading of manure according to recommended practices, injection or trail hose application followed by ploughing poses a potential contamination risk to the aquatic environment with both steroid estrogens and *E.coli.* Measured amounts of leached estrogens and bacteria exceeded the LOEL and the European Union threshold for drinking water, respectively.

References

Andersen, H. R. (2004): Forurening af vandmiljøet med steoride østrogener (in Danish) phD afhandling, afdeling for Analytisk kemi, Danmarks Farmaceutiske Universitet

Purdum, C.E.: Hardiman, P. A; Bye, V.J.; Eno, N. C.; Tyler, C. R. and Sumpter, J. P. (1994) : Estrogenic effect of effluents from sewage treatment works, Chemistry Ecology, 8, 275 – 285.

Use of different manures and organic wastes in the suppression of the cereal cyst nematode *Heterodera avenae* by biofumigation

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The cereal cyst nematode *Heterodera avenae* Wollenweber 1924 (NEMATODA: HETERODERIDAE) is widespread in most cereal-growing regions of the world, including the uplands of the Castilian plateau (Central Spain). It can reduce yields of winter wheat and barley as much as 50% in infested soils, with the additional difficulty of a restricted use of pesticides in these – due to economic, ecological, or social factors - low-input agricultural systems. The use of passive solar heating in a moist soil mulched with a plastic sheeting, has been proved as an effective method for the control of pathogens in agricultural areas with hot weather periods, in greenhouses or in soil containers, and with a parallel increase in the health, growth, yield, and quality of crops (Stapleton, 2000). Improving the efficacy of the process is possible by combining solarization with a low dose of pesticide treatment or with the simultaneous addition of residual organic matter: crop residues, animal manure, agroindustrial byproducts, compost or green manure (Gamliel et al. 2000).

More commonly used in horticultural crops, their practice could be introduced into other extensive crops such as cereals, potatoes or sugar beet, if it was properly managed. In some instances, wetting the soil with the simultaneous incorporation of raw materials and, thereafter, passing a roller could create a soil crust that is enough to maintain the soil under anaerobic conditions and to retain temporally the gases produced during the organic matter decomposition. The aim of this work was to test the ability of different animal manures and agroindustrial byproducts to suppress the pathogenic nematode *H. avenae* in an infested soil using these previous experiences.

Material and methods

The biofumigation experiments have been carried out in the laboratory using a *Xerochrept* calcareous clay loam soil affected by *H. avenae*. The main soil properties were: pH 8.51, organic matter content 3.43%, total N

2.4‰ and total P 0.489‰. The biofumigation experience was conducted by incubating, in sealed zip plastic bags, mixtures of 500 g soil, previously saturated with water, and 0, 5, 10 and 20 g of the different organic amendments over a period of thirty days at 30 ºC in a randomised block design with four replicates. The organic residues added were: crop residues of strawberry plants (S), sewage sludge compost (SS), compost of urban solid wastes (US), dehydrated pig slurry (P), spent mushroom compost of *Pleurotus* spp. (PM), sheep manure (SM), poultry litter (CH), and mixtures of sewage sludge compost and lime (SS+C), in which 0.2, 0.4 and 0.6 g of lime were added to 5, 10 and 20 g of sewage sludge, respectively, as the necessary amount to reach a pH of 12 in the final mixture. All of the treatments were done in quadruplicate.

The populations of *H. avenae* in each plastic bag were estimated in the mixtures with (Pf) and without incubation (Pi). Cysts were extracted from 100 g of soil using a flotation technique (Fenwick 1940), thereafter crushed in a homogeniser (Eijkelkamp, Netherlands) and the eggs counted. The final result was expressed as No. eggs 100 g^{-1} of dry soil.

Results and Discussion

All the treatments significantly reduced the pathogen population as compared with the control with a range between 20 and 85% of the initial populations. The most efficient treatment was the mixture of sewage sludge compost and lime at all doses (SC), and the dehydrated pig slurry (P) at the highest dose (Figure 1). For the rest of the organic residues, the response was closely related to their N content; the lowest efficacy was obtained with the residue of strawberry crops that presented also the lowest amount of N content and the highest rate C/N, the compost of urban refuse (US) and the spent mushroom compost (SM). Similar, high responses were obtained with N-rich residues, such as sewage sludge compost and animal manures generated in pig, sheep or poultry production. This positive effect was magnified by the addition of lime, which could increase the volatilization of ammonia after the mineralization of organic residues.

The response to the increasing doses of the residue added to soil and the positive effect of lime addition indicates that the most important factor affecting nematode viability could be the liberation of ammonia during decomposition or basification of the added residual organic matter.

Table 1. Summary statistics for a two-way ANOVA in which organic residue and dose were considered as independent factors.

Source	Sum of Squares	df	Mean Square	F	Signif.
Corrected Model	44137.325	23	1919.014	293.789	0.000
Intercept	278475.322	1	278475.322	42632.837	0.000
RESIDUE	41757.717	7	5965.388	913.264	0.000
DOSE	819.162	2	409.581	62.704	0.000
RESIDUE*DOSE	1617.633	14	115.545	17.689	0.000
Error	470.300	72	6.532		
Total	323896.000	96			
Corrected Total	44607.625	95			

Model: Intercept+RES+DOSE+RES * DOSE+E; R Squared = 0.989 (Adjusted R Squared = 0.986)

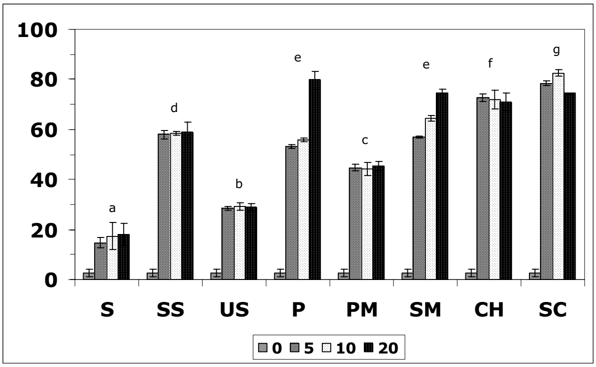

Figure 1. Percentage of reduction of the population of *H. avenae* after biofumigation with different organic amendments. For abbreviations see the text.

Only with dehydrated pig slurry (P), sheep manure (SM) and the mixtures of sewage sludge and lime (SC) was it possible to detect significant differences with the dose of added residue. The absence of a proportional response could suggest that in most of the cases the lowest dose was enough to obtain an important suppression of the pathogen *H. avenae* in this infested soil.

Conclusions

- The use of organic residues with high contents of N could be applied to biofumigation processes with a positive reduction of soil-borne pathogens.
- The anaerobic organic matter degradation involves the generation of biocidal compounds that could exert a biofumigant effect. Among them, the volatile ammonia could be the main biocide agent.

- Future research of the group is directed to determine the changes in soil microbial properties and the evolution of soil solution composition during and after the biofumigation process in terms of suppressive and soil fertility properties.

Acknowledgments

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References

Fenwick, DW. 1940. Methods for the recovery and counting of cysts of Heterodera schachtii from soil. Journal of Helminthology 18:155-172.

Gamliel, A., Austerweil, M. and Kritzman, G., 2000. Non-chemical approach to soilborne pest management – organic amendments. Crop Protection 19: 847-853.

Stapleton, J.J., 2000. Soil solarization in various agricultural productions systems. Crop Protection 19: 837-841.

Survival of *Ascaris suum* eggs and *Eimeria* oocysts during composting

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Composting is considered a suitable method for recycling of organic wastes compatible with the environment. The currently used approach in Slovakia is the stratification of the composting material in piles or troughs.

Biotika a. s. Slovenská Ľupča (Slovak Republic) worldwide ranks among the most important manufacturers of Penicillin V, Penicillin G, veterinary antibiotics and feed additives for breeding farm animals. Large amounts of various wastes are produced during the biotechnological production. This waste has a negative influence on the surrounding environment. The most serious problem is the liquidation of biomass. Utilisation and disposal of wastes has been the subject of many investigations, which have described contamination of the environment with emissions, toxicity of treated wastes to plants, but also potential survival and spreading of pathogenic agents (Bernal et al., 1993; Ayuso et al., 1996; Juriš et al., 2000; Papajová et al., 2002 and others).

The aim of this study was to monitor the effect of aerobic composting of organic wastes on the survival of non-embryonated *Ascaris suum* eggs and coccidia of the species *Eimeria acervulina, E. tenella* and *E. maxima* under operating conditions in the composting factory Kompostáreň, a. s. Biotika in Čebovce (Slovak Republic).

The composting process proceeded at a 28-day retention time and in the thermophilic temperature range (from 49 to 64°C). A by-product from Penicillin production (mycelium), straw and sawdust were composted in the composting trough, which was periodically dug up (shovelled). The following changes in physical and chemical properties of the stored wastes were monitored: pH, dry matter (DM), inorganic (IM) and organic (OM) matter, ammonium ions (NH_4^+), total nitrogen (N_t), total phosphorus (P_t) and C:N ratio. The methods used corresponded to the STN 465 735. The C content was calculated according to the content of OM by the method of Navarro et al. (1993), and the C:N ratio was calculated.

We used the ”artificial contamination of trough” with non-embryonated *A. suum* eggs and *Eimeria* oocysts approach to make sure that there was a sufficient number of positive samples in our observations. Eggs and oocysts were inoculated into polyurethane carriers, prepared according to Plachý and Juriš (1995), at a dose of 1000 eggs and 1000 oocysts per carrier. The carriers were placed to perforated PET bottles (50 ml) and introduced into a composting trough. After exposure in the trough, samples for parasitological and physical and chemical examination were collected after 0, 24, 48, 72, 96, 168, 198 and 672 hours of aerobic composting. Three samples were taken and analysed at the given sampling intervals. The controls with eggs and oocysts were incubated in distilled water. Significance of differences between experimental and control groups were determined using Dunnet’s multiple comparison test at the levels of significance 0.05; 0.01; and 0.001 (Statistica 6.0). The physical and chemical properties of the organic material, as well as the number of devitalised non-embryonated *A. suum* eggs and *Eimeria* oocysts, were expressed as the mean values±standard deviation ($\bar{x}$ ±SD). The physical and chemical properties of the composting material are given in Tables 1a and 1b.

Table 1a. Physical and chemical properties of the organic material during aerobic stabilisation.

Exposure (hours)	pH	DM %	IM % DM	OM % DM
0	6.68±0.03	34.91±0.65	3.35±0.54	96.65±0.54
24	8.84±0.01	40.08±0.14	5.89±0.11	94.11±0.11
48	8.83±0.01	39.42±3.62	3.68±0.13	96.32±0.13
72	8.85±0.02	48.66±0.63	5.91±0.15	94.09±0.15
96	8.66±0.01	41.41±0.38	5.24±0.60	94.76±0.60
168	8.95±0.01	46.51±0.14	4.70±0.30	95.30±0.30
192	9.02±0.02	46.98±0.14	6.07±0.03	93.93±0.03
672	7.69±0.06	61.53±1.33	6.60±0.50	93.40±0.50

Table 1b. Physical and chemical properties of the organic material during aerobic stabilisation.

Exposure (hours)	NH_4^+ mg.kg^{-1} DM	N_t mg.kg^{-1} DM	P_t mg.kg^{-1} DM	C:N
0	1053.23±2.80	50234.20±1120.56	3587.05±3.58	10.02:1
24	1052.50±1.62	43754.39±2801.40	3974.10±5.47	11.23:1
48	1228.84±24.16	51862.66±596.04	3165.17±13.30	9.70:1
72	772.89±5.60	46329.76±333.50	2664.82±14.89	10.53:1
96	1043.49±20.20	43025.60±840.42	2821.88±25.44	11.50:1
168	782.52±15.43	47160.55±894.07	3517.74±199.1	10.47:1
192	726.99±1.62	34439.17±3430.29	3730.80±160.54	14.20:1
672	471.77±28.43	24314.38±1599.76	2552.80±155.40	19.97:1

A. suum eggs are amongst the helminth eggs most resistant to environmental factors (Roepstorf and Murrell, 1997 and others). This is the reason why they were chosen as the model. Coccidia of the species *Eimeria acervulina, E. tenella* and *E. maxima* were chosen for the comparison because coccidia oocysts can also survive for a long time in the environment. *A. suum* eggs were totally devitalised as early as between 24 and 48 hours, and *Eimeria* oocysts after 24 hours of composting (Table 2) due to the high temperature and changes in physical and chemical properties of the composting materials during the composting process.

Table 2. Damage of *A. suum* eggs and *Eimeria* oocysts during aerobic composting.

Exposure (hours)	Damaged ($\bar{x}$ %±SD)	
	A. suum eggs	*Eimeria* oocysts
0 (control)	16.02±2.61	9.11±0.75
24	98.74±1.18*	100*
48	100*	100*
72	100*	100*
96	100*	100*
168	100*	100*
192	100*	100*
672	100*	100*

*Significance at the level P<0.001

We can conclude that from a parasitological point of view thermophilic aerobic composting had a lethal effect on the viability of helminth eggs and coccidia oocysts. This way of treatment is thus not associated with a risk of dissemination, survival and potential spread of developmental stages of endoparasites to the environment via composted organic wastes. Output from the aerobic composting is a universal organic fertiliser Veget with certificates for sale in Slovakia and the Czech Republic issued by UKSUP.

The authors are thankful for the co-operation with the composting factory Kompostáreň, a. s. Biotika in Čebovce. This study was supported by the project VEGA No. 2/4178/26 and project VEGA No. 1/0562/03.

References

Ayuso, M, Pascual, J. A., Garcia, C. and Hernandez, T., 1996. Evaluation of urban wastes for agricultural use. Soil Sci. Plant Nutr. 42: 105–111.

Bernal, M. P., Lopez-Real, J. M. and Scott, K. M., 1993. Application of natural zeolites for the reduction of ammonia emissions during the composting of organic wastes in a laboratory composting simulator. Biores. Tech. 43: 35-39.

Juriš, P., Rataj, D., Ondrašovič, M., Sokol, J. and Novák, P., 2000. Sanitary and ecological requirements on recycling of organic wastes in agriculture. Vyd. Michala Vaška, Prešov: 1-178 (in Slovak).

Navarro, A. F., Cegarra, J., Roig, A. and Garcia, D., 1993. Relationships between organic matter and carbon contents of organic wastes. Biores. Tech. 44: 203-207.

Papajová, I., Juriš, P., Lauková, A., Rataj, D., Vasilková, Z. and Ilavská, I., 2002. Transport of Ascaris suum eggs, bacteria and chemical pollutants from livestock slurry through the soil horizon. Helminthologia 39: 77-85.

Plachý, P. and Juriš, P., 1995. Use of polyurethane carrier for assessing the survival of helminth eggs in liquid biological sludges. Vet. Med. 40: 323-326.

STATISTICA 6.0, StatSoft Inc., USA.

STN 465 735: Industrial composts, 1991.

Phosphorus in pig faeces and urine can be manipulated by dietary means

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The physiological phosphorus (P) requirement of pigs must be covered by their feed intake. For many years, mineral feed phosphates have been added to pig diets as the P content in feedstuffs was not sufficiently available to fulfil their requirement. In addition, knowledge about pigs' P requirement has been poor and, therefore, it has for many years been common practice to include quite a lot of feed phosphates in pig feeds for safety. This has resulted in a low utilisation of P and large excretions of P. In areas with intensive pig production this has given rise to large accumulations of P in arable soils (Poulsen *et al*., 1999). However, there are several ways to improve P utilisation in pigs.

Up to 80% of P is present as phytate that is difficult to digest for pigs. This is the main reason why feed phosphate supplementations are needed. Phytate can, however, be hydrolysed by the enzyme phytase rendering P available for absorption (Johansen & Poulsen, 2003). Phytase is an endogenously occurring enzyme in plant seeds, but phytase is also available as a commercial feed additive (microbial phytase). Both plant and microbial phytase increases phytate degradation, thus improving P utilisation and limiting the excretion of undigested P in manure.

In experiment 1, three diets differing in P content (excessive, sufficient or deficient) were used. The basal diet included 50% barley, 20% wheat, 24% soybean meal and 6% fat, molasses, amino acids, vitamins and minerals (no P) and was not heat-treated. The P deficient diet was not supplemented with feed phosphates, whereas the two other diets were supplemented (Table 1). Microbial phytase was not added, but the plant phytase activity was analysed to 547 FTU/kg DM. The diets were fed to female pigs for 12 days, 5 days for adaptation and 7 days for separate collection of faeces and urine. Eighteen pigs (6 litters of 3 litter-mates) were allocated to the diets resulting in 6 pigs per diet. The pigs were housed in stainless steel cages, and urine was collected by insertion of catheters into the urinary bladder. The amount of faeces and urine was recorded, and samples of feed, faeces and urine were analysed for P content. The P digestibility and P balance were calculated (Table 1).

Table 1. Dietary phosphorus (P) content, P intake, retention and excretions in experiment 1.

	Excessive	Sufficient	Deficient
Diet P, g/kg DM	7.9	5.9	4.4
Phytate P, g/kg DM	3.6	3.6	3.5
Feed phosphate, g P/kg DM	3.5	1.5	0
P intake, g/day	13.6	10.2	7.6
P digested, g/day	7.9	5.1	3.1
P digestibility, %	58	50	41
P retention, g/day	4.8	4.6	3.1
P excretion, g/day: by faeces	5.7	5.1	4.4
by urine	3.1	0.5	0.03

The results showed that the P digestibility of the P deficient diet without feed phosphate was only 41%, whereas the P digestibility increased when feed phosphate was added. The low P digestibility in the P deficient diet was due to the fact that 80% of the plant P content was phytate bound. Furthermore, P retention was very low in the P deficient diet, whereas the retention was the same in the other diets. This means that an excessive P intake did not result in greater P retention compared with sufficient P. In contrast, the excessive P intake resulted in greater excretions of P. Feeding the P deficient diet resulted in no P in the urine, whereas 100% was excreted via faeces. Pigs fed P above their requirement (excessive P) excrete large amounts of P via urine. In this experiment, 35% was eliminated via urine, but the amount depends on P content in the diet and thus P intake. In general, faeces are the main route for P excretion (undigested P), whereas urinary P excretion reflects the amount of P that is absorbed, but not retained. In former days, growing pigs were fed diets comparable to the "Excessive P" diet, and it is obvious that the P content in manure at that time was high (in both the urinary and faecal fractions).

Experiment 2 was carried out to study the effect of microbial phytase on P digestibility and overall P balance. The experimental conditions were the same as in the former experiment. However, the basal diet included 25% barley, 47% wheat, 18% soybean meal, 9% rapeseed meal and 1% amino acids, vitamins and minerals (no P). The diet was heat-treated

(90^0 C). The basal diet was divided into three parts, and microbial phytase was added (Table 2). The P balance and digestibility is shown in Table 2.

Table 2. Dietary phosphorus (P) content, P intake, retention and excretions in experiment 2.

Treatment	1	2	3
Microbial phytase[1)], FTU/kg	0	375	750
Diet P, g/kg DM	4.9	4.8	4.8
Phytate P, g/kg	3.4	3.3	3.4
Phytase activity, FTU/kg	207	609	980
P intake, g/day	7.7	7.8	7.8
P digested, g/day	3.3	4.2	4.6
P digestibility, %	43	54	60
P retention, g/day	3.3	3.8	3.9
P excretion, g/day: by faeces	4.4	3.6	3.2
by urine	0.05	0.4	0.7

1) The supplemented microbial phytase was prepared from *Peniophora lycii*

The P digestibility increased from 43 to 60% when microbial phytase was added to the basal diet. This resulted in an increased P retention, although the retention did not reach the amount that was seen in the first experiment. Further, the excretion of P was reduced by 11-13% after phytase addition. Interestingly, the P excretion shifted from mainly via faeces (99%) without microbial phytase to 79% via faeces and 21% via urine when microbial phytase was added. These findings might be important when studying e.g. different separation techniques used for manure processing.

In conclusion, P excretion is to a large extent affected by dietary conditions. Replacing feed phosphates by microbial phytases improves P utilisation and reduces P in pig manure. Hereby the P load on arable soils is lowered. Further, the eliminating pathways for P are also affected. This might be important when different separation techniques are embedded.

References

Johansen, K. & Poulsen, H.D., 2003. Substitution of inorganic phosphorus in pig diets by microbial phytase supplementation - a review. Pig News and Information 24 (3), 77N-82N.

Poulsen, H.D., Jongbloed, A.W., Latimier, P. and Fernández, J.A. (1999). Phosphorus consumption, utilisation and losses in pig production in France, The Netherlands and Denmark. Livestock Production Science 58, 251-259.

Quantification of nitrogen and phosphorus in manure in the Danish normative system

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Denmark has a long tradition for calculating standards for manure composition and content of nitrogen (N), phosphorus (P) and potassium (K). Twenty years ago, the first standards were very rough estimates, as the basis for the calculations was mainly theoretical. Since then, the standards have been revised several times, and the complexity and dynamics of the system have increased over the years (Poulsen & Kristensen, 1998; Poulsen *et al.*, 2001). The standard values (*ex storage*) are used for fertilizer planning and control by Danish farmers and authorities. In addition, the standards (*ex storage*) have recently been used to define the Danish Livestock Unit (LU) and for other purposes.

The system is based on calculations of input and output, and the procedure is divided into three steps. First, we calculate the standards *ex animal* (excretion), and after that we take into consideration what happens in the stable (e.g. emissions and addition of bedding materials in the different housing systems) and calculate standards *ex housing*. Finally, we incorporate emissions etc. during storage and obtain standards *ex storage*. In principle, the system can be used for all nutrients. Currently the Danish system includes, in addition to N, P and K, manure volumes and dry matter contents. The flow dynamics are shown in Figure 1. The system calculates standards for each relevant species of livestock, and we have included cattle, pigs, poultry, furred animals, horses, sheep and goats. Each species is further subdivided into subcategories and weight classes, age classes etc. relevant for Danish livestock production. Depending on species and category, standard values are calculated per produced animal or per animal per year.

Ex animal. Calculations of standard values are performed as a simple difference between input and output. Input is founded on recordings and calculations of feed intake for the different categories combined with statistics on nutrient concentrations in the diets. Thereafter, the nutrient

Nutrient flow

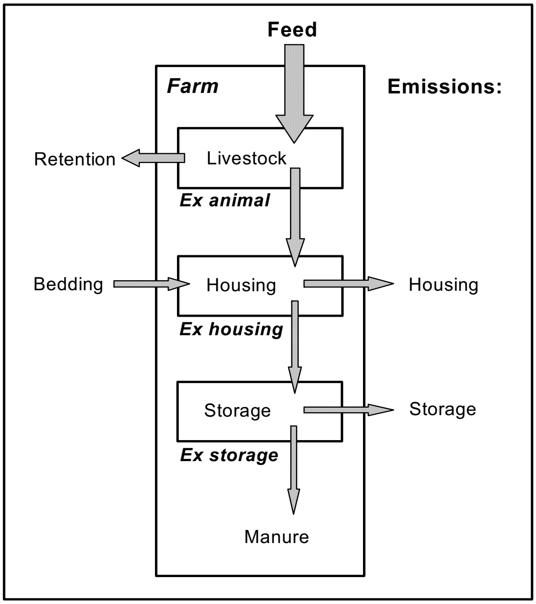

Figure 1. The flow dynamics of the Danish normative system that quantifies nutrient content in livestock manure ex *animal*, *ex housing* and *ex storage*.

retention in the animal products is calculated based on standard values obtained from published literature and then subtracted. The separated excretion of nutrients into faecal and urinary fractions is also calculated using digestibility coefficients of the different nutrients.

Ex housing. Based on *ex animal* standards we then calculate the content of nutrients in manure leaving the stable for storage or to be spread directly on agricultural soil. First, we include for each species (and subclass) the different housing systems relevant for Danish agriculture. Thereafter, default values for N loss due to emissions are included for each housing system mainly based on results from experimental studies. So far, the emissions are calculated based on total N, but the principle will soon be based on TAN (total ammonia nitrogen). Hereafter, the contributions of nutrients from bedding materials are added, and the soaking of urine into the bedding materials and faeces is calculated in order to establish values for *(i)* slurry (faeces and urine together) and separately for *(ii)* faeces (manure or deep litter) and *(iii)* urine (liquid manure). For each housing system the manure type (the three mentioned types above) is defined and standards *ex housing* are calculated.

Ex storage. Based on the *ex housing* standards, the final step takes into consideration what happens while the different manures (from different livestock species and categories and species specific manure types) are stored. First, the losses of N (due to emissions of ammonia and denitrification) and dry matter are subtracted. Furthermore, redistributed nutrients, dry matter and liquid due to leakage of juice from faeces etc. are included in the model.

The obtained standards are default values that are used by most farmers, but the Danish normative system also includes possibilities for correction of the standards if the farmers can document that their own farms' values on e.g. dietary N or P content deviate form the default values. In such cases the farmer can use defined equations and calculate farm-specific corrected values for nutrient content in the manure on the specific farm. Therefore, the Danish system is very dynamic, detailed and specific and reflects the current Danish livestock production. The standard values are updated annually (www.manure.dk) and are to a large extent based on data from Danish livestock production (official statistics on performance, feed intake, housing of animals etc.).

Acknowledgements
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References

Poulsen, H.D. and Kristensen, V.F. 1998. Standard values for farm manure. A revaluation of the Danish Standard Values concerning the Nitrogen, Phosphorus and Potassium content of manure. DIAS report no. 7, 160 pp.

Poulsen, H.D., Børsting, C.F., Rom, H.B. and Sommer, S.G. 2001. Kvælstof, fosfor og kalium i husdyrgødning – normtal 2000. DJF rapport nr. 36 (Husdyrbrug), 152 pp.

www.manure.dk *(annually updated standard values on N, P and K in manure from different livestock species and categories).*

(The paper P-126 is to be found on p. 329)

Biogas production and process kinetics in serial coupled anaerobic digesters

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Introduction

Much of the organic material in manure is slowly degradable, and by conventional digestion only 60% of the organic matter is converted to gas. However, alternative digester configurations might enhance degradation and optimize the methane (CH_4) yield.

Thermophilic post digestion performed in CSTRs treating effluent from a main CSTR has to be considered when evaluating and comparing different reactor configurations for improving the CH_4 yield from anaerobic digestion (Fig. 1).

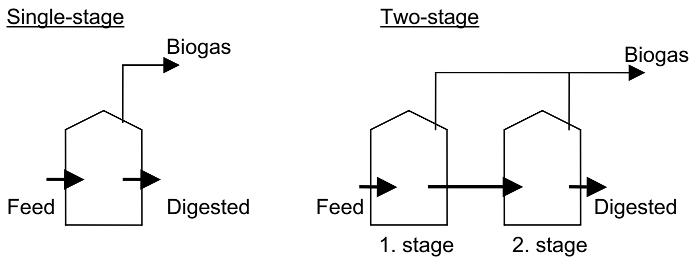

Figure 1. Two reactor configurations: single-stage and two-stage. The first reactor of a two-stage configuration is called the main reactor.

The age profile of slurry in the CSTR of the second step of a two-stage configuration is very different from the age-profile of the slurry in a single-stage CSTR (Table 1). One of the advantages from the two-stage configuration compared to the single-stage CSTR comes from an older age profile in the digested sludge (Angelidaki et al., 2005) leading to a lower residual CH_4 potential in the effluent from the second step of a two-stage

<u>Abbreviations:</u> t = number of slurry shifts; CSTR = continuously stirred tank reactor; V_{CSTR1} = volume of first CSTR in a two-stage configuration; V_{CSTR2} = volume of second CTSR in a two-stage configuration; VSS = Volume of slurry shift.

configuration than in the effluent from a single CSTR operated at the same overall hydraulic retention time (HRT).

Table 1. Age profiles of digested slurry from two common reactor configurations.

Reactor configuration	Percentage slurry aged t slurry shifts in different reactors
Single-stage CSTR	$100 \cdot \frac{VSS}{V_{CSTR1}} \cdot (\frac{(V_{CSTR1} - VSS)}{V_{CSTR1}})^{t}$
Two-stage CSTR	$100 \cdot \frac{1}{V_{CSTR2}} \sum_{x=0}^{t-1} (\frac{V_{CSTR1} - VSS}{V_{CSTR1}})^{t-(x+1)} (\frac{V_{CSTR2} - VSS}{V_{CSTR2}})^{x}, t \geq 1$

Furthermore, dividing the process into two steps may allow for optimization of each step individually with respect to optimal growth conditions for the bacteria involved in the anaerobic digestion.

The objective of this study was (part 1) to investigate CH_4 yield from anaerobic digesters operated at thermophilic conditions, but at varying sludge age-profiles, and (part 2) to compare the CH_4 yield from coupled digesters to the CH_4 yield from a single CSTR operated at the same total HRT. Results were analysed (part 3) in a Java implementation of the ADM1 model adjusted to simulate the serial coupling of reactors.

Methods

Part 1: Two CSTRs, R2 and R3, were coupled in a two-stage configuration and analysed for biogas production, CH_4/CO_2 distribution in the biogas, VFAs, VS, TAN and pH. Parameters were measured at regular intervals, and the reactors were operated at 51±1C. The HRT of the coupled reactors were 14/10 days (Table 2).

Table 2. Reactor settings.

Configuration	V_{CSTR1}/V_{CSTR2}	VSS	HRT
R2→R3 (Part 1)	≈170/≈120	≈4.0 kg 3 times d^{-1}	14/10
R2→R3 (Part 2)	≈160/≈80	≈4.5 kg 4 times d^{-1}	10/5
R4 (Part 2)	≈150	≈5.0 kg 2 times d^{-1}	15/0

Part 2: The CH_4 yield from the coupled digesters was compared to the CH_4 yield from a reference reactor operated at same temperature and same overall HRT.

Part 3: A model, based on the ADM1 model, is developed to study the two-stage configuration and the kinetics of the bacterial processes.

Discussion and results

Preliminary data from part 1 of the study suggest (Fig. 2) that 19±3% of the CH_4 yield is produced in the second stage.

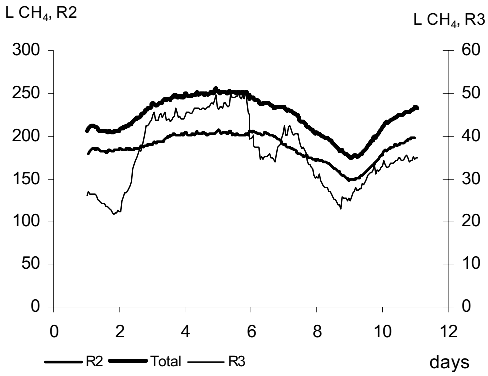

Figure 2. 24-h running mean of daily CH_4 yield. The effluent from R2 is digested in R3.

Data also show that the CH_4 production in second stage resembles the CH_4 production in the main reactor. The close resemblance might suggest that a substantial part of the residual CH_4 potential in the effluent from the main reactor is digested immediately after entering the second reactor. This might lead to the conclusion that a single-stage CSTR operated with a 14 days HRT may not be the optimal configuration, since only 81±3% of the CH_4 yield was from the main digester.

References

I. Angelidaki, K. Boe and L. Ellegaard (2005) Effect of operating conditions and reactor configuration on efficiency of full-scale biogas plants. Water Science & Technology Vol 52:189–194.

D.J. Batstone, J. Keller, R.I. Angelidaki, S.V. Kalyuzhnyi, Pavlostathis, S.G., A. Rozzi, W.T.M. Sanders, H. Siegrist and V.A. Vavilin (2002) 'Anaerobic Digestion Model No.1. Scientific and Technical Report No.13'. IWA Publishing, London, UK.

Biogas Forum Austria: network for research, extension service, and commercial farms

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Introduction

In Austria, a new law on green electricity production was issued on 1 January 2003. It forms the legal frame for a forward-looking biogas production from agrarian biomass. In Austria, a dynamic development in the area of agricultural biogas production can be observed. Electricity production from biogas increased from 20 GWh in 2002 to 102 GWh in 2004. Performance in Austria increased from 12 (year 2003) to 81 MW installed electric power capacity (year 2005), the positive trend still continuing. However, biogas potentials are still highly under-utilised. If biogas was produced from a variety of energy crops and crop residues grown in sustainable crop rotations in the whole of Europe, 96 % of the EU-25 road traffic energy demand could be covered by biogas (Amon et al. 2006).

Agricultural biogas plants must fulfil technological, as well as security standards. The building of biogas plants must be cost-efficient, and an economic operation must be possible. Operators of existing or future biogas plants, planners, and authorities need clear, transparent, and binding quality standards for the whole biogas process starting from the production of energy crops, and ending at the stage of biogas utilisation.

Biogas Forum Austria

Mode of Work

The "Biogas Forum Austria" is a centre of economic, technological, and research excellence with the aim to optimise biogas production from agrarian biomass. It comprises horizontal and vertical co-operation between partners from research, extension service, authorities, planners, biogas plant operators, and companies that work in the field of biogas production. The "Biogas Forum Austria" communicates with other national and international networks. The consortium consists of representatives from all fields of the biogas production chain. These propose future research programs, and assist in the preparation of manuals and guidelines. The consortium members profit from the rapid transfer of new research and development results.

In the brains trust, a trans- and interdisciplinary team of researchers works together. They work out research proposals, and manage research activities. Manuals, guidelines, certificates, and inspection reports are worked out in collaboration with the other members of the "Biogas Forum Austria". The brains trust advices and evaluates the work of the "Biogas Forum Austria" in the fields of advice, planning, and certification. It considers the whole chain of biogas production from energy crops, and agrarian raw materials.

Aims

The "Biogas Forum Austria" aims at improving biogas production from energy crops and animal manures through optimising the whole process from energy crop production to biogas utilisation. This ambitious aim can only be achieved through interdisciplinary collaboration. The "Biogas Forum Austria" focuses on the following: building of biogas plants with optimum technology and safety standards, development of a quality assurance system for the whole biogas process chain, reduction of investment risks for biogas plant operators, reduction of planning risk for authorities and biogas plant operators, stimulating system-oriented research, rapid dissemination of information and know-how, improving competitive ability of biogas production.

Through the work of "Biogas Forum Austria" the following is achieved: rapid dissemination of new know-how, critical mass in R & D, collaboration with international networks, know-how pool for the whole biogas process chain, improved lobbying, intensification of research and development activities, rapid market introduction of new technologies.

Current focus of work

Currently, the "Biogas Forum Austria" works in a number of fields. I) Biomass production and raw materials: quality requirements for energy crops and other raw materials, optimisation of the methane hectare yield of sustainable crop rotations through variety selection, crop management and harvesting time, recommendations on optimum variety and cultivation of energy crops, harvesting technologies adapted to the special needs of biogas production, benchmarks on methane yield from various raw materials, sustainable production of energy crops. II) Biomass processing and optimum biomass quality: conservation, chopping, additives, pre-treatment. III) Biogas plants, technology and fermentation: adaptation of biogas technology to the special requirements of energy crops, optimisation of the conditions during anaerobic digestion, benchmarks on the nutrient requirement of micro-organisms in the digester, technical analysis and optimisation of biogas plants, data on management, work requirement and economic efficiency. IV) Biogas utilisation: requirements on biogas quality for different options of utilisation, technical and economic benchmarks for biogas purification systems. V) Fertilisation: recommendations on the fertilisation with digestates from anaerobic digestion of energy crops and animal manures, technologies for an environmentally friendly fertiliser application, development of sustainable fertilisation systems.

Conclusions and outlook

The "Biogas Forum Austria" currently works with bilateral or multilateral collaborations between the various partners from research, extension service, authorities, planners, biogas plant operators, and companies that work in the field of biogas production. A multitude of research topics has already been and are currently handled. The rapid dissemination of the results is a core element of the "Biogas Forum Austria". For a further improvement of the Forum's efficiency, the collaboration will receive a more formalised framework. A registered association was founded in June 2006. Internal rules of procedure will be worked out and partners will have the possibility to become official members of the "Biogas Forum Austria".

Acknowledgments

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References

Amon T., Amon B., Kryvoruchko V., Machmüller , A., Hopfner-Sixt K., Bodiroza V., Hrbek R., Friedel J., Pötsch E., Helmut Wagentristl H., Schreiner M., Zollitsch W., 2006. Methane production through anaerobic digestion of various energy crops grown in sustainable crop rotations, Bioresource Technology. In press.

Monitoring of energy crop digestion in Austria

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Introduction

EU policy has improved the legal framework conditions for energy production from renewable sources. This has lead to an increased use of energy crops for biogas production. Anaerobic digestion of energy crops requires that biogas technology be adapted to the new substrates, but currently reliable data on key figures and benchmarks for biogas production from energy crops are unavailable. A detailed monitoring, especially of recently built biogas plants, could provide valuable information on the technology, economic efficiency and ecology of anaerobic digestion of energy crops. Information on the state of the art and future needs should be gathered. It is crucial to develop quality assurance and quality control measures that ensure a safe and efficient biogas production from energy crops.

Approach

An intensive monitoring was carried out on 55 Austrian biogas plants that went into operation between 1999 and 2005. The monitoring covered data on technology, management, nutrient and energy flow, and economics. From these data, a clear picture on the current state of the art and of the performance of biogas plants could be drawn, and possibilities for the optimisation of biogas production could be derived. In addition to the area-wide monitoring, a detailed monitoring was carried out on two biogas plants for eight months.

Results

Technical benchmarks

About 10 % of the new biogas plants only digested energy crops. About 65 % digested energy crops and animal manures, with 61 % of these being fed with pig slurry and 39 % with cattle slurry. About 25 % of the monitored biogas plants co-digested animal manures and organic wastes. Most biogas plants digested two to five different substrates. About 13 % even digested six or seven different substrates. The Green Electricity Act

2002 encourages the digestion of energy crops and/or animal manures, because when organic wastes from food industries are co-digested, the guaranteed price for the produced electricity is 25 % lower.

The digestion of energy crops and the increase in the capacity of biogas plants require the application of technologies that can feed solid substrates directly into the digester. With animal manures and other liquid substrates, a preparation pit had been used from which the viscous substrates were pumped into the digester. This technology has disadvantages for the digestion of energy crops. Thus, a range of technologies for feeding solid substrates directly into the digester was installed on the new biogas plants. Earlier, mainly dropping shafts, flushing systems, and systems with feed screws were used. These methods did, however, not offer the possibility of continuous feeding and of weighing the amount of input. Thus, nowadays the main approach is to use adapted feed mixers and adapted push-off trailers on weighing cells. These systems ensure a constant and exact supply of organic matter, which is the basis for a stable digestion process and a good biogas quality.

The mixer is an essential part of an agricultural biogas plants. The recent changes in substrate composition has strongly influenced the mixing technologies. Earlier, rapid velocity submersible-motor propeller mixers were most commonly applied. The monitoring of the new biogas plants revealed a strong trend towards low velocity mixers, which keep energy consumption at a low level and can be operated continuously. More than 54 % of the new biogas plants operated with slowly moving paddle mixers. About 9 % of all mixers were slowly moving long-shaft mixers, and only 7 % were rapid velocity submersible-motor propeller mixer. On more than 50 % of the new biogas plants only one mixer was installed. However, the tendency goes towards digesters with two or three mixers.

Process benchmarks

In horizontal digesters, the hydraulic retention time of the first process step ranged from 24 to 62 days. In vertical digesters, the hydraulic retention time was between 23 and 113 days. In the second process step, the range of the hydraulic retention time was between 20 and 187 days.

In horizontal digesters, the average volume load amounted to approximately 4.4 kg VS per day and m³. In the vertical digester, in the first process step, the average volume load was approximately 3.3 kg VS per day and m³. In the second process step, the volume load amounted to on the average 3.5 kg VS per day and m³.

The monitoring showed that co-fermentation of energy crops and manure produces a stable digestion process and high methane production rate. Biogas plants that jointly digest energy crops and manure showed the highest methane production rate, on the average 0.36 m³ CH_4/kg VS. In plants which only utilised energy crops the specific methane yield on the average amounted to 0.33 m³ CH_4/kg VS. Biogas plants which utilised energy crops and manure, as well as organic waste, generated an average specific methane yield of 0.33 m³ CH_4/kg VS.

Conclusions

The increased use of energy crops induced adaptations in digester, feeding, and mixer technologies, as well as in the process control. An optimisation of the efficiency along the whole process chain from the substrate input over technology, process control, digestate utilisation up to energy conversion is necessary to realize the very promising potentials of biogas technology, and to establish viable biogas plants. Currently only 3 – 5 % of the available organic substrates are used for biogas production in Austria. For a better exploitation of the available potentials, it is important that the legal framework conditions given under the Green Electricity Act 2002 are further guaranteed. Guidelines must be provided on the optimum feeding of digesters and on the optimum use of organic wastes. The detailed monitoring produced, for the first time, reliable data on technology and management of recently built biogas plants that digest energy crops.

Acknowledgments

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European Biogas Initiative to improve the yield of agricultural biogas plants (EU-Agro-Biogas)

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Introduction

Today, there is a large range of different systems for agricultural biogas production depending on the local, regional or national political and social circumstances, as well as on the available substrates. In order to provide a better knowledge and understanding and – where appropriate – a Europe-wide harmonisation, the EU-AGRO-BIOGAS STREP project was developed. On the 11th RAMIRAN conference in Murcia/Spain, the core team of the EU-AGRO-BIOGAS project agreed to set up and hand in the proposal. In the meantime, the project has been positively evaluated, contract negotiations have been finalised and the project will start in autumn 2006.

The EU-AGRO-BIOGAS STREP wants to (i) develop and demonstrate a standard methodology to assess the methane yield of a range of energy crops and other organic substrates; (ii) develop and demonstrate an automatic monitoring, management and early-warning system for agricultural biogas plants; and (iii) optimise and demonstrate innovative approaches to improve biogas yield and energy output. The EU-AGRO-BIOGAS project focuses on the improvement of the entire biogas production and conversion process, thus, increasing the degree of efficiency in the digester and conversion technologies, as well as improving the competitiveness of such plants. A weak-point analysis will generate information about the main critical factors. An efficient technology transfer and demonstration activities on full scale commercial agricultural biogas plants are key elements of the research programme.

The EU-AGRO-BIOGAS project will focus on the agricultural sector and the following several waste / substrate streams: energy crops, animal manures, agricultural cropping residues, residues from plant production, harvesting and silage, agricultural wastes (e.g. decomposed seeds, sugar beet waste, molasses, distillers wash, organic waste).

It is the aim of the consortium to analyse and identify the most important influencing factors which are responsible for the currently sub-optimal performance of agricultural biogas plants. The innovative approaches of this project will be tested and demonstrated on pilot plant level and up-scaled to the commercial plant level. The consortium already defined 16 medium to large scale agricultural biogas plants in different regions of Europe which will be used as demonstration sites for the activities during the work plan of the project.

Consortium

The consortium for the EU-AGRO-BIOGAS project combines different expertises and competences in the field of agricultural biogas plants from different European regions which reflect know-how out of the whole life-cycle or chain of biogas production and utilisation.

Table 1. Partners of the EU-AGRO-BIOGAS project

Country	Participant name	Short name
Austria	Universität für Bodenkultur, Department of Sustainable Agricultural Systems	BOKU coordinator
Austria	RTD Services	RTDS
Austria	GE Jenbacher	GEJ
Austria	Thoeni Industriebetriebe GmbH	Thöni
Czech Republic	Research Institute of Agricultural Engineering	VUZT
Denmark	Danish Institute of Agricultural Sciences	DIAS
Germany	Institute of Agricultural Engineering	ATB
Germany	Federal Agricultural Research Center	FAL
Germany	Kuratorium für Technik und Bauwesen in der Landwirtschaft	KTBL
Germany	Vogelsang GmbH	Vogelsang
Italy	Universitá degli Studi di Torino	UNIT
Poland	EC Baltic Renewable Energy Centre	EC Brec
The Netherlands	Agrotechnology & Food Innovations	A & F
UK	Institute of Grassland & Environmental Research	IGER

The consortium includes two universities and eight applied research institutions with the necessary partnerships to the operators of agricultural biogas plants, two industrial and one SME partner (Table 1). The applied research institutions are essential for the success of the project because they will be responsible for the optimisation and implementation of new technologies and systems to improve the biogas production yield. Due to the close partnerships with the operators of the agricultural biogas plants in the region, on-site development and demonstration activities have been secured. The consortium will get access to the commercial agricultural biogas plants for demonstration purposes.

Main objectives and work plan

The main objectives of the EU-AGRO-BIOGAS project are:

(i) To optimise the planning and operating process of agricultural biogas plants through the development of a European online substrate atlas-database and a standardised methane energy valuation model with the aim to reduce investment costs.

(ii) To optimise biogas production through demonstration of an innovative feeding technology for agricultural biogas plants.

(iii) To monitor, identify and benchmark the main influencing factors during the technological process in agricultural biogas plants based on already available and newly monitored data.

(iv) To test, implement and demonstrate a newly developed monitoring, management and early-warning system for agricultural biogas plants and new and innovative technological solutions under full-scale operating conditions in agricultural biogas plants: to improve the degree of efficiency in the digester, to increase the biogas yield, to optimise and guarantee quality and safety of the digestate.

(v) To improve, optimise and demonstrate several selected conversion technologies which will lead to an improvement of the degree of efficiency.

(vi) To reduce the investment and operational costs of medium and large agricultural biogas plants.

(vii) To disseminate the results and provide inputs for the future development of energy policy and legislation.

Acknowledgments

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Process performance of biogas plants integrating pre-separation of manure

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Introduction

In terms of yield per volume the biogas production from liquid manure (slurry) is low, often causing a poor economical performance for plants treating manure as the only substrate. Pre-treatment of liquid manure by separation for producing a concentrated solid fraction increases significantly the biogas potential per waste volume (Møller et al. 2006). However there is no experience with the process performance of plants substituting liquid manure with varying amounts of concentrated manure solids.

In the present study, different concepts integrating solid-liquid pre- and post separation were studied. In lab scale CSTR digesters liquid manure was substituted with varying amounts of the solid fraction from manure separation, starting with 20% substitution and ending with 60%. By increasing the substitution, the organic loading and the NH_3 level will increase considerably. The process stability was evaluated by monitoring the VFA and NH_4-N levels at regular intervals.

Results and discussion

In a pilot digester (120 liter), liquid pig manure (4-6.6% DM) was gradually substituted with pig manure solids (21-25% DM) produced with a slurry separator using flocculants (Møller et al. 2003). A reference digester received only liquid pig manure. For 190 days, 20% of the slurry in the "solids digester" was substituted with manure solids. The solid fraction was then increased to 33-40% and finally for 100 days the substitution was 60%. The average retention time was 15 days, and the temperature was varied between 48 and 52^{o}C except for a few fall-out's of the thermostatic control.

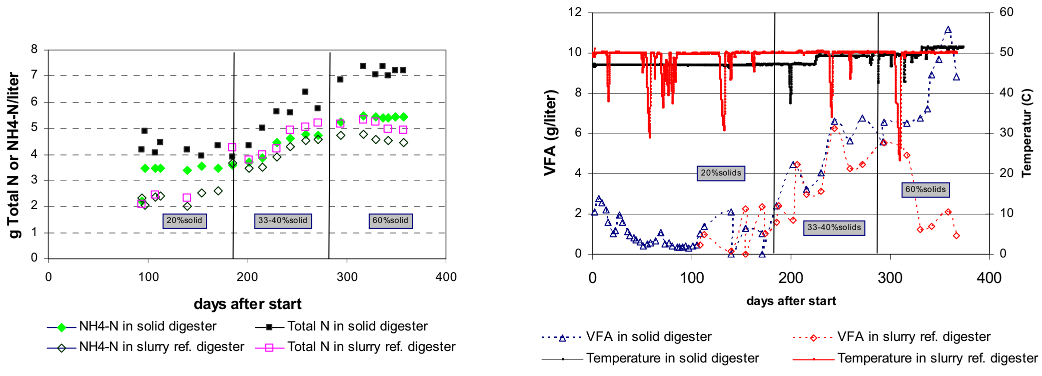

Figure 1. Total N and NH_4-N (left), and VFA and temperature (right) in a solids-amended digester and a reference digester with liquid pig manure only.

Process balance

The NH_4-N content and the amount of volatile fatty acids (VFA) were monitored. It was expected that the NH_4-N content would increase during substitution of liquid manure with increasing amounts of manure solids, since the total N content of the solids was 7.9 g/l against only 3.9-4.2 g/l in the liquid manure. In Fig. 1 it can be seen that the NH_4-N content increased in both the solids digester and the reference digester; this was a consequence of increasing total N in the liquid manure.

Up to 40% solids substitution, the NH_4 concentration was below 4 g N/l, while the content stabilized around 5.4 g NH_4-N/l at 60% substitution. This NH_4-N level might cause serious inhibition of methanogenesis (Hansen et al. 1998), however, it was possible to maintain a high and stable gas production. The VFA content increased gradually with increasing NH_4-N content.

With 20% substitution, the VFA content was low and at the same level as in the reference digester. When the substitution was 30-40%, the VFA content in both solids and reference digester increased, but only minor differences between the two digesters was observed. By transition to high substitution (60%), the VFA content increased further, but the level was quite stable around 6500 mg/l as long as the temperature was kept at 50°C. By increasing the temperature to 52°C, the level increased significantly to 11.000 mg/l, but without significantly affecting the gas yield. After a period with microbial adaption to the higher temperature, the VFA content was below 9.000 mg/l. In the same period the VFA level declined in the reference digester, maybe because the NH_4-N was also slightly reduced in this period.

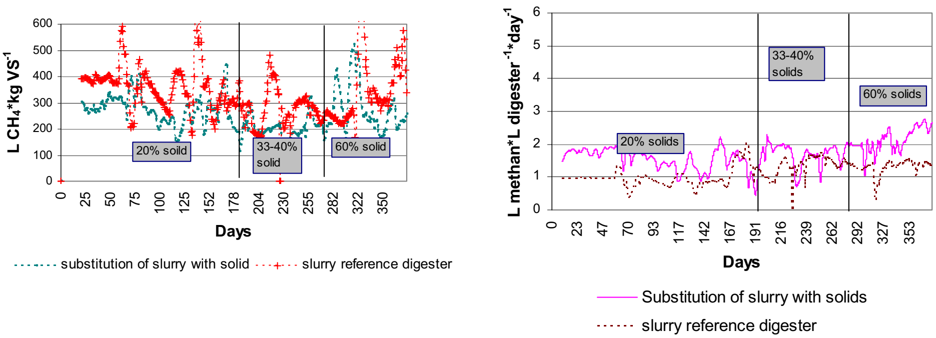

Figure 2. Methane yields relative to volatile solids (left) and digester volume (right) in a digester with partial substitution of liquid manure with manure solids and in a reference digester.

Methane yield

The yield of methane relative to VS was in general higher in the reference digester, which was expected since the concentration of the most degradable components are lower in manure solids than in the un-separated liquid manure (Møller et al, 2006). However, the yield in the solids digester was in all periods acceptable at >200 l CH_4/kg VS. In Figure 3 high fluctuations in methane yield relative to VS was observed, especially in the reference digester. This might be explained by the fact that the biomass loaded varied in DM content, because the mixing of the pre-tank had been insufficient, while a steady VS load was assumed in the calculations.

The methane yield in terms of digester volume was significantly higher in the solids digester, and in the period with 60% substitution the yield was more than 100% higher in the solids digester compared to the reference digester.

Conclusion

A high ratio of solids increased the NH_4 level to more than 5 g/l, which is beyond the normal inhibitory level, and gave rise to VFA levels higher than is normally associated with a stable process. However, substitution of slurry with up to 60% solid manure resulted in a high and stable gas production at 50°C. Substitution of 20-60% of the slurry with manure solids can thus improve the overall performance of a biogas plant

References

Hansen KH, Angelidaki I, Ahring BK 1998. Anaerobic digestion of swine manure: Inhibition by ammonia. Wat Res 32:5-12

Møller H.B. 2003. Energy and nutrient recovery of manure. Ph. D thesis. BioCentrum. Danish Technical University.

Møller H. B., Jesper Dahl Hansen, Claus Aage Grøn Sørensen 2006. Nutrient Recovery by Solid–Liquid Separation and Methane Productivity of Solids. Submitted to Transactions of the ASAE.

Impact of peat and polystyrene ball covers on the ammonia emissions from the storage and spreading of pig slurry: a farm-scale study

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Intoduction

Slurry pit covers is one of the current techniques used to reduce NH_3 emissions. Moreover, recent research has shown that the reduction of NH_3 emission could also be sustained when considering the whole process (i.e. storage plus land application) (Portejoie et al, 2003). Based on this research, the efficiency of a floating peat cover and polystyrene (∅:20cm) balls for a slurry store was evaluated (i) in a farm and (ii) after experimental spreading. The impact of the two covers on the emission of greenhouse gases (CH_4, CO_2 and N_2O) during the storage was also determined.

Materiel and methods

Experiments were carried out at a farrowing-fattening farm (200 sows) equipped with two below-ground rectangular concrete stores. One store was covered with peat or polystyrene balls, and the second one was left uncovered as the control. Farm measurements were carried out for 7-10 weeks in summer for the peat cover, and during winter for the polystyrene balls cover. Gaseous emissions (NH_3, N_2O, CH_4, CO_2) from the store were measured using a dynamic chamber (0.12 m²). Ammonia volatilisation from the field following slurry application was measured for three days using the wind tunnel method (Lockyer, 1984). Slurry from the covered and uncovered stores were sampled after stirring and they were manually applied at a dosage of 60 $m^3.ha^{-1}$ using a splash-plate spreading technique.

Results

The results of emission factors (Table 2) show for a peat cover a reduction of about 25% of ammonia emissions during the storage period compared to the uncovered control, but an increase of 30% of CH_4 and CO_2 emissions. However, some results (not shown) suggest a higher volatilization of NH_3 or less CH_4/CO_2 when the peat cover was wet or dry, respectively. Analysis of such variability revealed no significant difference (Student's Test, 0.05) between the uncovered and the peat covered storages. For the spreading step (Table 3) a reduction of 8% of NH_3 emissions was measured. This low reduction of NH_3 emissions and the related technical problems (e.g. cover application, peat filtration before injection spreading) suggest that the use of a natural peat cover is unsatisfactory.

Table 1. Slurry characteristics.

	Peat cover experiment			Polystyrene ball experiment		
		After storage for 40 days			After storage for 70 days	
	Raw slurry	Uncovered slurry	Covered slurry	Raw slurry	Uncovered slurry	Covered slurry
TAN (g N/kg)	2.3	2.7	2.3	3.3	3.2	2.9
TKN (g N/kg)	3.8	4.2	3.3	4.9	4.8	4.3
COD (gO_2/kg)	58	68	38	61	40	39
DM (%)	5.3	4.9	3.8	6.6	4.5	4.7
OM (%)	3.8	3.5	2.5	4.0	3.2	3.2

TAN: total ammoniacal nitrogen; TKN: total Kjeldahl nitrogen; COD: chemical oxygen demand; DM: dry matter; OM: organic material.

Table 2. Farm measurement of gaseous emissions (Mean values, ND: no detection.

	Peat cover experiment		Polystyrene ball experiment	
	Uncovered slurry	Covered slurry	Uncovered slurry	Covered slurry
NH_3 (gN/m² and day)	4.1	3.1	3.3	0.5
N_2O (gN/m^3 and day)	ND	ND	ND	ND
CH_4 (gN/m^3 and day)	56.9	75.8	66.6	69.4
CO_2 (gN/m^3 and day)	44.5	58.5	34.6	36.2

The results for the polystyrene balls cover indicated a reduction of NH_3 emissions up to 80% during the storage. No significant difference (Student's Test, 0.05) was observed for the greenhouse gases (N_2O, CH_4, CO_2) and the subsequent volatilization of NH_3 during the spreading experiment.

Table 3: Ammonia emission following surface-application of slurry (given as the % of applied TAN).

	Peat cover experiment		Polystyrene ball experiment	
Test	Uncovered slurry	Covered slurry	Uncovered slurry	Covered slurry
1	47.6	33.6	40.0	37.5
2	27.6	24.5	34.3	28.0
3	30.7	39.6	14.2	19.7
Mean value	35.3	32.6	29.5	28.4

Conclusion

This farm-scale study evaluated two types of store cover to reduce the emissions of NH_3 and their impact and the greenhouse gases (N_2O, CH_4, CO_2) during pig slurry storage. No significant reduction was achieved with the peat cover, and its use can not be recommended based on these results. However, using a cover made from a raft of polystyrene balls reduced emissions of ammonia by up to 80%. Furthermore, there was no significant increase of NH_3 after the spreading the slurry stored in this way.

References

Lockyer D.R., 1984. A system for the measurement in the field of losses of ammonia through volatilisation. Journal of the Science of Food and Agriculture 35, 837-848.

Portejoie S., Martinez, J., Guiziou F., Coste C.M., 2003. Effect of covering pig slurry stores on the ammonia emission processes. Bioresource Technology 87(3), 199-207.

Ammonia emission from the management of solid fraction derived from the mechanical separation of slurry

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Abstract
Emissions of ammonia (NH_3) were measured both from the spreading and the storage of the solid fraction derived from mechanical separation of slurry by means of three Open Large Dynamic Chambers (OLDC) and three wind tunnels. Up to 30% and 42% of the total nitrogen spread with pig and cattle slurry solid fractions was lost as NH_3 respectively. Emission of NH_3 from the heaps were very similar whether they were measured by the OLDC technique or by wind tunnels and ranged from 134 to 143 g NH_3/m^3 of solid fraction at the end of the entire period of trial (12 days). These latter values corresponded to 3.5% and 3.7% of the total nitrogen content of the heaps.

Introduction
Mechanical separation of liquid manure is a reliable method to concentrate nutrients in the solid fraction. Moreover, the liquid fraction, characterized by a low Total Solids (TS) content, can be conveniently land applied by fertirrigation. Currently, few data concerning the potential air pollution related to the agronomic use of such fractions are available. To partially cover this gap of knowledge, NH_3 emissions from the storage and spreading of the solid fraction were measured.

Materials and methods
Trials were performed at two experimental sites: Grugliasco, Torino (Site 1) and Racconigi, Cuneo (Site 2). <u>At site 1</u>, emissions of NH_3 were measured from spreading and storage of the solid fraction by means of three OLDC (Balsari et al., 2004). The air velocity within the chambers was set at ~1 m/s. Emissions from the land spread solid fraction (derived from cattle and pig slurries, spread at a rate of 70 kg N/ha) were measured under two temperature conditions, 26-27°C (trial 1) and 13-18°C (trial 2), on a sandy soil (pH 8.2). Emissions were measured continuously for six days. NH_3 losses from the heaps of solid fraction of pig slurry were measured under summer conditions (~25°C) for a period of 12 days. Once the heaps were established, no fresh product was added

during the following days of trial. All trials were performed in three replicates. At the second site, emissions of NH_3 from a heap of solid fraction (pig slurry, static conditions) were measured by three wind tunnels (Schmidt et al., 2002). The trial was performed only in summer (~25°C), in three replicates and lasted twelve days with daily sampling of NH_3 losses. The air velocity within the tunnels was set to ~1 m/s.

Results

The main chemical characteristics of the solid fractions used for the trials are shown in Table 1.

Ammonia emissions during storage of the solid fraction. The environmental conditions of the trials are shown in Table 2. Emissions from the two heaps (site 1 and site 2) were very close whether they were measured by the OLDC or by wind tunnels. At Site 1, at the end of the 12 day trial, the emission of NH_3 from the storage of pig slurry solid fraction was close to 135 g NH_3/m^3 byproduct. At site 2, emissions of NH_3 from the heap with solid fraction reached 144 g NH_3/m^3 after 12 days of trial.

Table 1. Chemical characteristics of the solid fractions used for the trials.

	Storage		Spreading (pig)		Spreading (cattle)	
	Site 1	Site 2	Trial 1	Trial 2	Trial 1	Trial 2
TS (%)	30.8	29.4	23.2	28.9	22.8	20.9
TKN (%)	0.76	0.77	0.72	0.68	0.51	0.47
$N\text{-}NH_4$ (%)	0.17	0.16	0.33	0.25	0.18	0.14
pH	8.05	8.4	8.4	8.2	8.7	8.2

Table 2. Main environmental conditions at site 1 and 2.

	Site 1	Site 2
Environmental temp. (°C)	24.4 (17.2-32.4)	24.6 (20.2-30.5)
Relative humidity (%)	65 (47.5-88.2)	58 (37.0-77.5)
Heaps inner temp. (°C)	46 (31.0 – 50.0)	53 (33.0-67.0)
Heaps surface temp. (°C)	35 (29.0 – 38.0)	41 (33.0-58.0)

Ammonia emission from the spreading of solid fractions. The environmental temperatures of the trials are shown in Table 3. In trial 1, up to 30% and 42% of the total nitrogen spread with pig and cattle slurry solid fractions respectively was lost as NH_3 during the six days of trial. Up to 25% and 38% of the nitrogen spread was lost as NH_3 from pig and cattle solid fraction in trial 2.

Table 3. Environmental temperatures of the field spreading trials.

Product	**pig slurry**	**cattle slurry**
Trial 1 (°C)	27.3 (17.8-35.6)	26.1 (15.2- not available)
Trial 2 (°C)	13.1 (9.1-22.1)	18.1 (8.8-21.1)

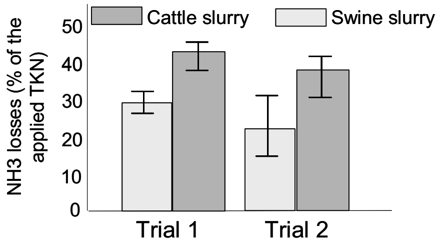

Fig. 1. Ammonia losses (% of the total Kjeldahl nitrogen (TKN) spread).

Conclusions

Ammonia emissions from heaps of solid fraction derived from the separation of pig slurry ranged during summer conditions from 3.5% (Site 1) to 3.7% (Site 2) of the heap TKN content. It must be pointed out that trials were performed without daily addition of fresh material to the heaps. As elsewhere pointed out (Balsari, 2004 – unpublished data), emissions of NH_3 measured from "dynamic" FYM heaps are higher than those measured from static heaps. The nitrogen lost as NH_3 after land spreading of the solid fraction was shown to be related to environmental temperature and to the type of slurry. Higher emissions were measured in warmer weather. Cattle slurry solid fraction emitted a higher amount of NH_3 than pig slurry did. Further trials will be performed to compare from an environmental point of view the traditional management of pig and cattle slurries (no separation) with the management system that includes mechanical separation.

References

Balsari, P., Gioelli, F., Airoldi, G., 2004. Open Large Dynamic Chamber for the measurement of ammonia emission from land applied FYM. Proceedings of the International Conference "Greenhouse gas emissions from agriculture-Mitigation Options and Strategies" – Leipzig, Germany (241-242)

Schmidt, D.R., Bicudo, J. R., 2002. Using a wind tunnel to determine odor and gas fluxes from manure surfaces. Paper No. 024083 presented at XXXII ASAE-CIGR Meeeting, Chicago, USA.

Optimising degradation of PAHs in soils using different composting approaches

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Introduction and aim of study

The aim of this study was to investigate and optimise the usage of manure to bio-remediate hydrocarbon contaminated soil. A small scale composting experiment was carried out and the effect of different types of manure on the degradation of hydrocarbons in oil-contaminated soil were analysed.

Persistent organic chemicals and in particular poly-aromatic hydrocarbons (PAHs) are of environmental concern, especially when remediating polluted soils e.g. oil spills. Bioremediation by biodegradation has been shown to be most effective at degrading PAHs. Composting is a bioremediation method whereby PAHs are mineralised by micro-organisms and not just immobilised. Although immobilisation might reduce the overall risk of dispersing PAHs, it leaves the long-term fate of PAH contaminants uncertain.

To achieve good PAH mineralisation rates by micro-organisms, composting conditions such as pH, temperature and especially the nutrient content and availability of the substrate must be optimal. Manure is readily available and rich in nutrients as well as micro-organisms. In this study different aerobic thermophilic composting processes were investigated by adding different manure types to optimise PAH degradation.

Methods

To investigate the decay process, small-scale compost vessels were filled with a mixture of contaminated soil, sawdust, and a manure type as shown in Table 1.

To imitate the natural composting process and to estimate the optimum conditions for PAH degradation the temperature profile was simulated to reflect that naturally occurring during composting. The temperature was gradually increased from room temperature (19°C) to 25°C (day 4), 35°C (day 11), 50°C (day 18), 65°C (day 25), and decreased again to 35°C (day 32). To maintain aerobic conditions, air at the desired temperature was blown through the bottom of each vessel. The air was pre-humidified to prevent the compost-mixture drying out.

Table 1. Description of the different treatments used in the PAH bioremediation trial.

Treatment	Description
A	Horse manure mixed with contaminated soil and sawdust
B	Cattle manure mixed with contaminated soil and sawdust
C	Chicken manure mixed with contaminated soil and sawdust
D	Control treatment: Contaminated soil mixed with sawdust

The composting process was characterised using a range of chemical, physical and microbiological methods (e.g. pH, redox-potential, electrical conductivity, and CO_2 and NH_3 emissions). The impact of time and treatment on microbial community structure was also examined using PLFA (phospholipid fatty acid) analysis. PAH degradation rates were determined using GC-MS (gas chromatography-mass spectrometry). To assess the metabolic decomposition rate and any loss of PAHs through volatilisation, gaseous emissions from the headspace of the composting vessels were analysed using GC-MS.

Results and Discussion

The results showed significant differences in compost quality, PAH degradation and microbial community development between the various treatments and with the duration of composting. Those differences and their significance were confirmed statistically by principal component analysis (PCA). Extractable PAH concentrations decreased for all of the four treatments. In agreement with previous studies (Antizar-Ladislao *et al.* 2005), our results showed that greatest PAH degradation rates generally occurred when the temperature was *ca*. 35°C (both at the start and end of the composting process). Overall, there was a 50% decrease for single PAHs at each of these start and end stages.

The microbial community structure, as observed by PLFA analysis, showed the largest changes from day 4 to 18 for the horse manure treatment (A), from day 11 to 25 for the cattle manure treatment (B), and from day 4 to

11 for the chicken manure treatment (C). The control treatment (D) showed no significant changes over the whole process.

The volatilisation rates of PAHs were highest with the chicken manure treatment, whereas the treatments with cattle and horse manure showed very similar volatilisation rates with only minor differences to those observed in the control treatment. In this study, the volatilisation of naphthalene relative to its abundance in the contaminated soil was generally higher than for the heavier PAH compounds across all the treatments. This was in agreement with other studies, where it was found that volatilisation was likely to be important for naphthalene but not for higher ringed compounds (Park *et al.* 1990; Wild *et al.* 1990).

Conclusions

By excluding the influence of climatic factors and conducting the experiments under controlled monitoring conditions this study has revealed the fate of the PAHs during the co-composting of animal wastes and contaminated soil. It has also demonstrated the importance of microbial community structure on the mineralisation of PAHs. Overall, PAH concentrations were decreased by up to 50% within all composting treatments compared to a decrease of around 20% within the control treatment. Initial results, with reductions of up to 65% for naphthalene, indicate that the chicken manure was the most successful amendment. Principal component analysis revealed interdependencies of the microbial communities and the effects of physical and chemical conditions on PAH degradation. In conclusion, manure is effective for the bio-remediation of hydrocarbon contaminated soil by co-composting.

References

Antizar-Ladislao, B., Lopez-Real, J., and Beck, A.J. (2005) Laboratory studies of the remediation of polycyclic aromatic hydrocarbon contaminated soil by in-vessel composting. Waste Management 25: 281-289.

Park, K.S., Sims, R.C., Dupont, R.R., Doucette, W.J., and Matthews, J.E. (1990) Fate of PAH compounds in two soil types. Influence of volatilization, abiotic loss and biological activity. Environmental Toxicology and Chemistry 9: 187-195.

Wild, S.R., Waterhouse, K.S., McGrath, S.P., and Jones, K.C. (1990) Organic contaminants in an agricultural soil with a known history of sewage sludge amendments: polynuclear aromatic hydrocarbons. Environmental Science and Technology 24: 1706-1711.

Proportions and characteristics of particle size fractions in two different cattle slurries

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Background and aim of the research

Slurry contains different particle sizes, which enter the soil at different times and rates after slurry application due to the natural filtration induced by the soil (Bol et al., 2004), i.e. coarser particles may remain in the upper soil layers with higher biological activity, and finer particles can percolate to deeper soil layers with lower biological activity. Consequently, the particle size composition of slurry may affect its soil degradation rate. This has particular relevance with respect of the current trend by farmers towards slurry separation. Slurry separation is mainly performed using a screw-press, which leads to a nutrient-rich solid fraction with particle size > 2000-5000μm and a liquid fraction with particle size < 2000-5000μm depending on the separation efficiency. This technology improves slurry management in terms of nutrients utilisation, reducing costs related with slurry storage, and using the liquid fraction for fertigation.

In the present study, a particle size fractionation of two different cattle slurries was developed, and the relative contribution of each isolated fraction was determined. Each fraction was characterized in terms of its lignin, total C and N content.

Methods

Two types of cattle slurry were used, a maize silage-derived C_4 slurry and a ryegrass silage-derived C_3 slurry. The slurry was successively passed through 5 sieves in order to obtain 6 fractions: > 2000μm, 2000-425μm, 425-250μm, 250-150μm, 150-45μm and <45μm. The protocol used was: 500 ml of slurry was put into a 2 mm sieve placed in a basin. In order to facilitate the fractionation, two litres of water were added. The sieve, partially immersed, was shaken horizontally to allow the separation of the smallest particles. The solution was then removed to another basin and another 2 litres of water were added to the sieve. This operation was performed three times in total. The solution obtained, 6 litres of water + slurry particles (<2000μm) was then successively passed through the

425μm, 250μm, 150μm and 45μm sieves. Each solid fraction was then carefully removed from the respective sieve and conserved in a fresh state at <4º C. Total C and N contents, lignin and moisture content of each slurry fractions were determined.

Results and discussion

For both slurries, more than 50% (dry weight basis) of slurry was made up of particles <45μm fraction, with the >2000μm and 2000-425μm fractions together representing, by weight, about 30% of the total (Table 1). The C_4 slurry had relatively more of the <45μm and less of the >2000μm size fraction compared to the C_3 slurry.

Table 1. Relative weight of each fraction obtained in C_3 and C_4 slurry ($g.g^{-1}$ - dry weight basis), N=5.

Fraction	C_3 slurry	C_4 slurry
> 2000μm	0.158 ± 0.022^a	0.115 ± 0.007^b
2000-425μm	0.239 ± 0.049^a	0.277 ± 0.023^a
425-250μm	0.038 ± 0.01^a	0.021 ± 0.007^b
250-150μm	0.020 ± 0.009^a	0.013 ± 0.09^a
150-45μm	0.041 ± 0.007^a	0.025 ± 0.005^b
< 45μm	0.503 ± 0.042^a	0.548 ± 0.033^a

Means with unequal superscripts within fraction are significantly different at P<0.05

The total carbon content varied between 32 and 47 % in all fractions of C_3 and C_4 slurry (Table 2). The majority (ca. 90%) of all C was found in the three >250μm fractions, with the 425-250μm fraction containing more than 40% of total C in both slurries. The N content varied more widely than C content with values between 0.8 % and 4.2% in all C_3 and C_4 slurry fractions. The distribution of total N between the particle size fractions followed the same order in C_3 and C_4 slurry with about 80% of total N present in the <45μm size fraction. The value of the C:N ratio was positively correlated with the particle size (R^2 = 0.876 for C3 slurry and R^2 = 0.880 for C4 slurry) and values varied in the range [8.1 – 36.1] for the C3 slurry and [8.9 – 54.3] for the C4 slurry. Lignin content in both slurry types was significantly higher in the fractions <2000μm than in the whole slurry or in the fraction >2000μm.

It can be concluded that a slurry separation leading to two size fractions (>45μm and <45μm) is a good tool for slurry management at farm scale, because it results in very distinct fractions in terms of N and C content.

However, in practical terms a separation at 150μm would be more feasible and, in view of the N mineralisation data, as efficient.

Table 2. Total C and N, C:N ratio, lignin and moisture content of the C_3 and C_4 slurry fractions used. N=4.

Fraction	Parameters	C_3 slurry	C_4 slurry
Whole slurry	C (%)	38.1 ± 0.1	43.1 ± 0.5
	N (%)	2.5 ± 0.1	2.3 ± 0.1
	C/N	15.1 ± 0.6	18.9 ± 0.2
	Lignin (%)	10.6 ± 0.3	12.2 ± 0.5
	Moisture content	86.1 ± 1.1	85.1 ± 0.7
> 2000μm	C (%)	43.3 ± 0.4	43.6 ± 1.1
	N (%)	1.2 ± 0.1	0.8 ± 0.1
	C/N	36.1 ± 1.9	54.3 ± 2.2
	Lignin (%)	11.3	13.2 ± 1.2
	Moisture content	73.5 ± 1.0	60.2 ± 2.1
2000-425μm	C (%)	37.3 ± 2.7	46.6 ± 0.3
	N (%)	1.1 ± 0.1	1.1 ± 0.1
	C/N	34.5 ± 1.6	42.4 ± 0.9
	Lignin (%)	18.4 ± 1.1	18.1 ± 0.3
	Moisture content	69.5 ± 0.9	76.0 ± 0.4
425-250μm	C (%)	39.7 ± 1.0	44.4 ± 0.3
	N (%)	1.5 ± 0.1	1.3 ± 0.1
	C/N	26.7 ± 1.0	33.1 ± 1.2
	Lignin (%)	17.6 ± 0.5	19.0 ± 0.4
	Moisture content	61.4 ± 1.2	63.5 ± 1.4
250-150μm	C (%)	36.3 ± 1.2	41.6 ± 1.0
	N (%)	1.6 ± 0.1	1.61 ± 0.1
	C/N	22.3 ± 0.5	26.0 ± 1.2
	Lignin (%)	16.3	
	Moisture content	63.1 ± 2.3	61.5 ± 3.5
150-45μm	C (%)	35.6 ± 0.8	40.5 ± 0.6
	N (%)	1.9 ± 0.1	1.8 ± 0.1
	C/N	18.6 ± 0.1	22.2 ± 0.5
	Lignin (%)	18.2 ± 1.1	16.9 ± 1.3
	Moisture content	64.9 ± 1.1	63.6 ± 0.9
< 45μm	C (%)	32.3 ± 0.5	37.4 ± 0.7
	N (%)	4.0 ± 0.1	4.2 ± 0.1
	C/N	8.1 ± 0.3	8.9 ± 0.1
	Moisture content	95.8 ± 0.4	96.6 ± 0.2

References

Bol, R, Moering, J., Preedy, N. And Glaser, B. (2004) Short-term sequestration of slurry-derived carbon into particle size fractions of a temperate grassland soil. Isotopes in Environmental and Health Studies, 40, 81-87.

Assessment of the potential N mineralization of six particle size fractions of two different cattle slurries

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Background and aim of the research

The C:N ratio is generally used to predict N mineralization rates of cattle slurry (Chadwick et al., 2000). However, it may be possible to predict overall N mineralization rates of slurry considering the proportion and C:N ratio of the different particle sizes, assuming that the substrate quality in organic materials, such as cattle slurries, is related to particle size. Indeed, large particles are dominated by relatively intact plant material, whereas smaller particle sizes consist of partially digested plant and microbially processed material. This information has particular relevance as currently an increasing number of farmers invest in slurry separation. Mechanical slurry separation using a screw press leads to a nutrient-rich solid fraction with particle size >2000-5000 μm and a liquid fraction with particle size <2000-5000μm depending on the separation efficiency. In the present work, six particle size fractions of two different cattle slurries were isolated, and the N mineralization potential of each fraction was determined in order to establish the relationship between the particle size and the N mineralization rate.

Methods

The six particle size fractions (>2000μm, 2000–425μm, 425-250μm, 250-150μm, 150-45μm, <45μm) were obtained by wet sieving two dairy slurries from cows fed either predominantly grass silage (C_3) or maize silage (C_4). Proportions and characteristics of each fraction are described in Fangueiro et al. (2006). An anaerobic incubation method (Lober and Reeder, 1993) was used to assess the potential N mineralization of the fresh slurry fractions. An amount of a specific slurry fraction corresponding to 0.02 g of N was added to 10 g of field moist soil in a 60 ml syringe, and the amount of water was corrected to a total volume of 25 ml. Ten replicates of each slurry fraction and non-separated whole slurry were prepared to allow one half to be incubated for 7 days at 40º C, whilst the other half was extracted immediately after the injection of 25 ml of 2

M KCl into each syringe to give a 1:5 soil/slurry: 1 M KCl extraction ratio. After shaking for 1 h, the suspensions were filtered and the filtrates analysed for NH_4^+. Soil only treatments acted as controls. The same extraction method was used after the 7 days incubation period. Potential mineralization was calculated as the difference between post- and pre-incubation NH_4^+-N concentrations.

Results and discussion

Potential mineralisation in the C_4 and C_3 whole slurry treatments were 17 and 7 % of the N applied, respectively (Figure 1). These values are lower than those reported by Kyvsgaard et al. (2000) and Castellanos & Pratt (1991), with values ranging from 18 to 21 %, probably due to a lower N content of the slurry used in the present study.

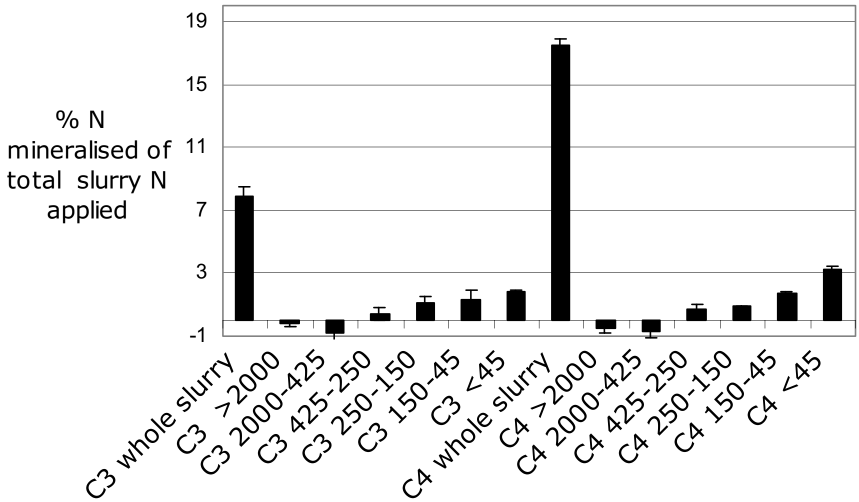

Figure 1: Potential N mineralization from different size slurry fractions

Nitrogen mineralization occurred for both slurries in the 425-250μm, 250-150μm, 150-45μm and <45μm, whereas there was evidence of N immobilization in the >2000μm and 2000-425μm slurry fraction treatments. The greatest values of % N mineralised for the separated fractions were from the 150-45μm and <45μm fractions, but these values were still consistently lower than values obtained with the non-separated whole slurry. It is important to note that higher values of % N mineralised were obtained from the C_4 slurry fractions than from the C_3 slurry even though the C:N ratios of the different fractions were always higher in the C_4 slurry than in the C_3 slurry.

There was a significant relationship between the C:N ratio of the 2000-425µm, 425-250µm, 250-150µm, 150-45µm fractions and the corresponding particle size (R^2= 0.9952 for C_4 and R^2= 0.9979 for C_3). Furthermore, there was a good correlation between the % of N mineralized and the C:N ratio of these fractions (Figure 2). Therefore, slurry particle size may be a useful parameter to help predict N mineralization rates from slurry.

It is known that plant decomposition is affected by the lignin content (Kyvsgaard et al.; 2000) but there was no relationship between the lignin content of slurry fractions and the % N mineralized in the present study. However, our results showed that greater N mineralization occurred when the lignin:N ratio was low.

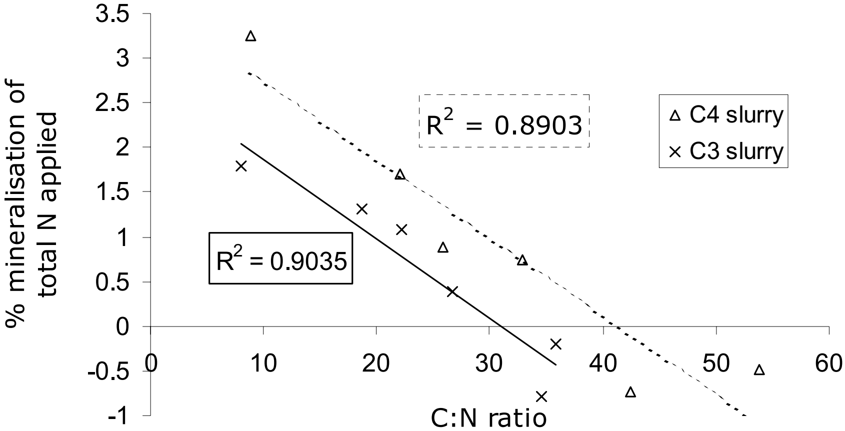

Figure 2: Relationship between the C:N ratio and the potential N mineralization.

In conclusion, potential N mineralization observed in the separated fractions was higher in slurry fractions containing small particles (<150µm), but always lower than in the whole slurry, probably due to the value of the C:N ratio of these fractions. Therefore, at farm scale, a slurry separation at 150µm should be enough to obtained distinct fractions of slurry in terms of N mineralisation.

References

Castellanos, J. & Pratt, P. (1981) Mineralization of manure nitrogen–correlation with laboratory indexes. Soil Science Society of America Journal, 45, 354–357.

Chadwick, D. R., John, F., Pain, B. F., Chambers, B., Williams, J. (2000). Plant uptake of nitrogen from the organic nitrogen fraction of animal manures: a laboratory experiment. Journal of Agricultural Science, 134, 159-168.

Fangueiro, D, Bol, R., Chadwick, D. (2006), Proportions and characteristics of particle size fractions in two different cattle slurries. Ram36, 12th RAMIRAN International Conference, Aarhus, Denmark.

Kyvsgaard, P., Sorensen, P., Moller, E. and Magid, J. (2000) Nitrogen mineralization from sheep faeces can be predicted from the apparent digestibility of the feed. Nutrient cycling in Agroecosystems, 57, 207-214.

Lober, R.W. & Reeder, J.D. (1993). Modified waterlogged incubation method for assessing nitrogen mineralization in soils and soil aggregates. Soil Science Society of America Journal, 57, 400-403.

Characterization of pig slurries and treatment efficiencies in Central Spain

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Differences in climatic conditions, land availability for manure disposal, pig farm concentrations and other variables make pig slurry management to be very different from one region to the other. Pig farms in the Castilla-León region (central north-west part of Spain) are characterized by their low-to-medium size, high water use, low level of manure treatment, and high land availability for disposal. Pig slurry characteristics and the efficiency of different treatments are still subject to study, and almost no data are available about the microbial and basic physico-chemical variables of these wastes.

Materials and methods

About ten pig farms and slurry treatment plants were occasionally sampled during 2005 in this region. Raw swine slurry pits, pre-treatments using fine screens (0.5 mm pore diameter) or centrifuge, and full activated sludge treatment plants were microbiologically and physico-chemically characterized in their efficiencies. Three types of surplus sludge (ready for use as fertilizer), dried using either a rotatory drying trommel at 200ºC, a fluidized bed furnace at 95ºC, or conventional composting, were also compared with regard to faecal bacteria counts. All systems were expected to be functioning under routine optimum conditions.

Chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total suspended solids (SS), total coliforms (TC), *E. coli* (EC), faecal streptococci (FC) and *Clostridium perfringens* (CP) were analysed following standard methods. Sludge was oven-dried at 105ºC to constant weight. Helminth eggs were also quantified in raw slurry using World Health Organisation standard protocols.

Results

Raw slurry characteristics are presented in Table 1, together with data on the efficiency of three treatment options. Pre-treatment using fine screens or centrifuge were effective for most groups of bacteria except for FS and CP. Resuspension and desorption of these bacteria from the solid phase could be the reason for the observed increase after treatment. Full scale activated-sludge plants showed high efficiencies for all groups (higher than 2 log units) with the exception of CP.

Table 1. Physico-chemical and microbiological characteristics of raw pig manure and their treatment efficiency (in % or log of bacteria removed). n= number of systems studied.

	Raw slurry				Efficiencies		
	Mean (n=8)	Max.	Min.	S.D.	Fine-screens (n=2)	Centri-fuge (n=1)	Activated Sludge (n=3)
TSS (g/l)	40	87	14	24	20 – 53 %		95%
COD (g/l)	56	89	32	19	23 – 36%		90%
TKN (g/l)	6	11	1	21	8 – 10%		95%
Log CF (ufc/100ml)	12.705	13.602	6.602	13.150	0.6 – 0.9	8.22	2.55
Log EC (ufc/100ml)	11.230	12.000	7.079	11.551	0.2 – 0.8	6.63	3.48
Log FS (ufc/100ml)	9.249	9.890	6.782	9.486	-0.4 – 0.8	2.36	2.67
Log CP (ufc/100ml)	3.446	4.243	1.544	3.776	-0.8 – 0.02	-0.41	0.76
Helminths (egs/l)	575	2600	0	951			

Analyses of dried sludge showed high densities of bacteria, even after theoretically extreme temperatures (e.g. trommel), with similar values for both furnace-dried and composted sludge (Table 2).

Although bacterial densities were lower after the trommel drying procedure than after fluidized bed furnaces or composting, it was evident that thermal treatment using high temperature did not produce sterile fertilizer materials.

Table 2. Microbiological characteristics of dried sludge from swine manure treatment plants after different drying procedures. Data in log cfu/g DW.

	Trommel (200ºC)	Composting	Fluidized-bed furnace
FC	3.568	5.108	5.270
EC	1.836	3.108	1.820
FS	1.681	6.848	-
CP	2.836	4.284	4.121

Acknowledgements

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Determination of the organic matter biodegradability using physico-chemical and biological fractionation

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Human activities produce increasing amounts of wastes which have to be treated before reuse or disposal in order to avoid harmful effects on the environment. The properties of the wastes, particularly the biodegradable fraction, determine its fate: disposal, reuse or treatment (aerobic or anaerobic). Moreover, the evaluation of the biodegradability is a useful tool for a better understanding of the processes involved in organic matter (OM) biodegradation. During OM biodegradation, only the biodegradable fraction undergoes transformations, while the inert fraction is stable. Biodegradable OM can be split into a rapidly (S_S) and a slowly degradable fraction (X_S) considering physical and biological parameters. The evaluation of the biodegradability is usually performed with physico-chemical methods (soluble/particulate, for example) or biological ones (respirometry, biogas production, ultimate BOD etc.).

The aim of this work was to compare and evaluate different procedures used to determine the biodegradability of organic wastes. For this purpose, an organic product was characterized using different methodologies.

The organic product was composed of a mixture of wastewater treatment sludge and pine barks intended to be treated by composting. The biodegradability of this mixture was characterized using solid respirometry (Trémier et al. 2005). A sample of the mixture was extracted using two successive aqueous solid-liquid extractions followed by physical separations (sieving and centrifugation). The final supernatant of these extraction/separation was considered as the water-soluble fraction. Characterisation of this water-soluble fraction biodegradability was performed using liquid respirometry (Boursier et al., 2005), ultimate BOD

(Roeleveld and van Loosdrecht, 2002) and 45 days batch experiments (Servais et al., 1995)

The OM characteristics of the water-soluble fraction, determined using the different methodologies, are presented in Figure 1. The total COD of the water-soluble fraction was estimated to 3733 mg O_2/l. The estimations of the S_S fractions were quite similar whatever the methodology used and comprised between 1170 and 1440 mg O_2/l, representing 31-39% of the total soluble COD. In contrast, the estimated X_S fraction varied from 525 to 1500 mg O_2/l depending of the methodology used. As a consequence, the inert fraction, calculated as the difference between total COD and S_S+X_S, comprised between 1340 and 2030 mg O_2/l. According to these results, the quantification of the S_S fraction seems to be independent of the methodology used for the determination, while the quantification of the X_S and inert fractions are highly dependent on it. The biomass quantity and the duration of the tests are probably the main factors influencing the X_S quantification.

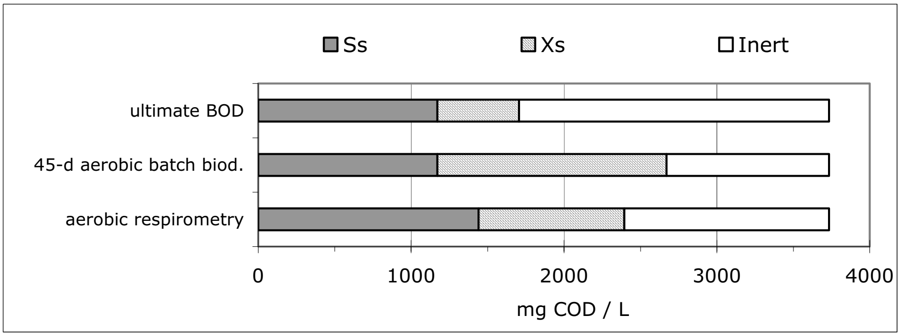

Fig 1. Organic matter fractionation on water-soluble fraction.

After the comparison of the methodologies used on the water-soluble fraction, a comparison of the fractionation on the organic waste and on its water-soluble fraction using respirometry was carried out (Figure 2). Solid respirometry performed on the mixture (sludge and pine barks) indicated that biodegradable OM was composed of 91% and 9% X_S and S_S, respectively (79.6 and 7.5 g O_2/kg). The S_S of the mixture and its water-soluble extract were similar (7.5 g O_2/kg), indicating that the S_S was mainly contained in the soluble phase. In contrast, the X_S part contained in the water-soluble extract was very low compared to the same fraction determined on the mixture by solid respirometry (5 against 79.6 g O_2/kg).

According to this result, the X_S fraction was mainly composed of particulate materials and required a hydrolysis before consumption by the micro-organisms (Mustin 1987).

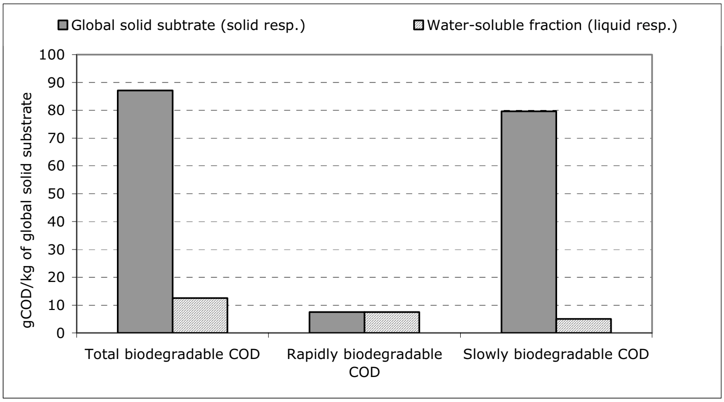

Fig 2. Comparison between the biodegradable fractions determined by respirometry.

Although the measurements on the organic waste or on the water-soluble fraction allowed a similar estimation of the S_S, the quantification of biodegradability of an organic waste was largely dependant of the methodology used, mainly due to the X_S estimation.

References

Boursier H., Béline F. and Paul E. (2005). Piggery wastewater characterisation for biological nitrogen removal process using respirometry. Bioresource Technology, 96: 351-358.

Mustin M. (1987). Le compost, gestion de la matière organique. Ed. François Dubusq.

Roeleveld P.J. and van Loosdrecht M.C.M. (2002). Experience with guidelines for wastewater characterization in the Netherlands. Water Science and Technology, 45(6): 77-87.

Servais P., Barillier A. and Garnie J. (1995). Determination of the biodegradable fraction of dissolved and particulate organic carbon in waters. Annls Limnol., 31: 75-80.

Trémier A., de Guardia A., Massiani C., Paul E. and Martel J.L. (2005). A respirometric method for characterizing the organic composition and biodegradation kinetics and the temperature influence on the biodegradation kinetics, for a mixture of sludge and bulking agent to be co-composted. Bioresource Technology, 98: 169-180.

Assessment of the performances of different mechanical solid-liquid separators for pig and cattle slurries

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Abstract
The separation efficiency of three mechanical solid-liquid separators (centrifuge, rotating and screw press separator) was assessed. The three devices were operated with both cattle and pig slurries characterized by different total solids contents. For all separators it was found that the higher the TS content of slurry, the higher was the separation efficacy. Low slurry input flow rates were required to optimize the separation efficacy with low TS content. The centrifugal separator showed the best performances in terms of separation efficacy (30-70% for total solids, 9-29% for TKN, 60-90% for P_2O_5) both with cattle and pig slurries, but due to the low slurry input flow rate, also the highest power input requirements (4.3-7.9 kWh/kg of separated N). The management costs of the separation process ranged from 0.7€/m^3 (5000 m^3 of slurry/year) to 0.17 €/m^3 when 30000 m^3 of slurry is treated a year.

Introduction
In 2002, the EU Nitrates Directive was adopted at a regional level (Piemonte) by 9/R Directive, introducing limits to the maximum rate of nitrogen to be land applied according to soil characteristics and vulnerability: 170 kg N/ha on vulnerable areas, 340 kg N/ha under all other soil conditions. The requirement forced farmers to look for new lands where to apply the exceeding amount of animal wastes and a convenient solution to transport them. Transport costs can be reduced by separating the manure into a nutrient-rich solid fraction and a liquid fraction (Møller et al., 2000). With the aim to give to farmers some technical and economical indications concerning the separation of slurry, three mechanical solid-liquid separators were tested.

Materials and methods
The three separators (centrifuge, rotating and screw press separator, Table 1) were operated both with cattle and pig slurries characterized by two different total solids contents (Table 2) and were tested with at least

two input flow rates. The main parameters assessed were: TS, TKN and P_2O_5 separation efficiency, energy requirements and management costs. The management costs of the separation process were estimated by considering the machine cost, the power requirements and the annual maintenance cost of the separators.

Table 1. Main characteristics of the tested mechanical separators

Separator	Centrifugal	Rotating	Screw press
Installed power (kW)	7.5	7	12
Max. loading rate (l/h)	4000	30000	40000

Table 2. Main chemical characteristics of the slurries used for the trials

Separator	Screw press		Rotating		Centrifugal	
Slurry	Pig	Cattle	Pig	Cattle	Pig	Cattle
TS (%)	1.7-4.6	5.7-8.5	3.4-3.5	5.72-8.48	1.7-4.6	4.0-6.0
TKN (%)	0.26-0.42	0.34-0.37	0.34-0.43	0.34-0.37	0.26-0.42	0.21-0.36
P_2O_5 (%)	0.05-0.34	0.27-0.65	0.23-0.27	0.27-0.65	0.05-0.34	0.09-0.27

Results

It was pointed out that an increase in the slurry TS content improved the performance of all three equipments. In case of dilute slurries, low input flow rates allowed to get a better separation efficacy than high input flow rates. Among the tested devices, the centrifugal one showed the best separation efficacy (30-70% for TS, 9-29% for TKN, 60-90% for P_2O_5) with both slurries types.

Table 3. Main separation efficacy of the three devices (considering all the variables: slurry types and characteristics and input flow rates)

Separator	Slurry	TS (%)	TKN (%)	P_2O_5 (%)
Screw press	Swine	7.4-57.5	0.8-15.9	10.5-73.7
	Cattle	27.6-77.8	10.4-36.5	32.8-73.7
Rotating	Swine	8.8-36.0	1.7-10.1	9.2-46.7
	Cattle	42.2-58.7	10.4-28.2	44.3-56.2
Centrifugal	Swine	30.6-69.7	8.9-25.7	59.6-84.0
	Cattle	54.1-69.1	20.3-29.2	75.9-93.8

No big differences in terms of separation efficacy were identified between the screw press separator and the rotating one.

The required electrical power was directly linked to the slurry input flow rate. The highest power requirement (4.3-7.9 kWh/kg of separated N) was observed for the centrifugal separator due to the low slurry input flow rate that must be used for this latter device (max. allowed flow rate 4 m^3/hour). In general terms, the mechanical separation of pig slurry required a higher power input as a consequence of a lower separation efficacy compared to cattle slurry (Fig. 1A). The management costs of the separation process were related to the amount of treated slurry per year and ranged from 0.7 €/m^3 (5000 m^3 of slurry/year) to 0.17 €/m^3 when 30000 m^3 of slurry is treated yearly (Fig. 1B)

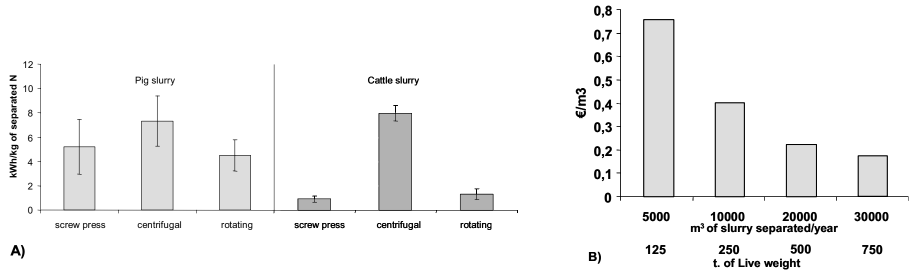

Fig. 1. (A) Energy requirements for the separation of 1 kg of N; (B) costs of the process according to the volume of slurry separated/year

Conclusions

The mechanical separation of both pig and cattle slurries was particularly efficient in terms of separated P_2O_5 (up to the 90%) rather than TKN (max 36.5%). Better performance were achieved with the three separators when fed with cattle slurry, due to its higher TS content. Since the costs for mechanical separation of slurry decrease with increasing volume of slurry treated per year, the possibility for small farms to use separators owned by contractors may be considered. The mechanical separation of slurry may lead to an increase in ammonia losses and GHG emission when compared to the traditional slurry management. Trials are running nearby the DEIAFA to assess also this aspect.

References

Møller, H.B, Sommer, S.G., Ahring B. K., 2002. Separation efficiency and particle size distribution in relation to manure type and storage conditions. Bioresour. Technol. 85, 189-196.

Development of an agglomeration-based technology to transform chicken manure into an user-friendly fertilizer

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The management of manure from chicken production requires special attention since the manure is particularly odorous and may be contaminated with pathogens. Furthermore, not only is it sometimes generated in huge amounts in one place, its handling, transport and storage is also difficult. Quite commonly, no application possibilities are available in the surrounding area. Uncontrolled use may lead to pollution of groundwater and the spreading of diseases. On the other hand, chicken manure is a valuable resource for crop production due to its high nutrient content, especially with respect to phosphorus and nitrogen.

A chicken manure-based fertilizer product should not be odorous, and be easy to handle and store. For transport over longer distances, the mass and volume should be minimised and hygienic aspects considered. Furthermore, its application onto farmland needs to be possible using existing equipment, and should result in a high evenness in distribution. Pellets best fulfil these demands. However, the pelletizing technologies used today require large investment costs and are very energy intensive. Due to their high throughput capacities, they are a suitable option in areas where chicken production is concentrated, often with more than 1 million birds. However, the majority of chicken production facilities are of a medium size with less than 10.000 chickens per facility, so that such techniques are not applicable.

In this study, the feasibility of a more simple option was investigated. This approach is based on the agglomeration principle. Small scale tests in 5-L vessels containing rotating elements, as well as pilot scale tests using a 120-L rotating drum, were carried out. Due to the rotation of paddles in the vessels, round pellets are formed. To allow the transformation of the untreated manure into pellets, the moisture and the rotation speed of the drum or the stirrer needs to be well adjusted. Examples of the pelletizing conditions and parameters used in this study are given in Table 1.

Table 1. Examples for pelletizing conditions and parameters

Test. Nr.	Substrate	Water content (%)	Rotation Time (min)	Output ratio (%)
PTR3	Dried and ground up manure	33	15	96
PTR16	Fresh manure	40	10	100
PTR19	Manure composted with oat husks	57	10	100

The moisture content of chicken manure may range between 13 and 89%, with an average of 65% for layers and 40% for broilers (Mande, 2003). In this study, the optimum moisture content for agglomeration was found to be around 40% for fresh manure and 60% for composted manure. The reason for the higher percentage of the composted manure was the oat husk content, which gave the compost a higher water-holding capacity. Therefore, in most cases, water adjustment measures through drying or moistening need to be carried out.

Pellets of almost spherical shape were formed within 3-15 minutes. The pellet diameter varied according to the agglomeration parameters, and commonly ranged from 2 to 20 mm. The distribution of the pellet size in the aforementioned examples is shown in Figure 1. The uniformity of the pellet sizes was found to increase if the drum was adjusted to an angle of 2.5°. With this adjustment, more than 95% of the pellets were between 2 and 10 mm.

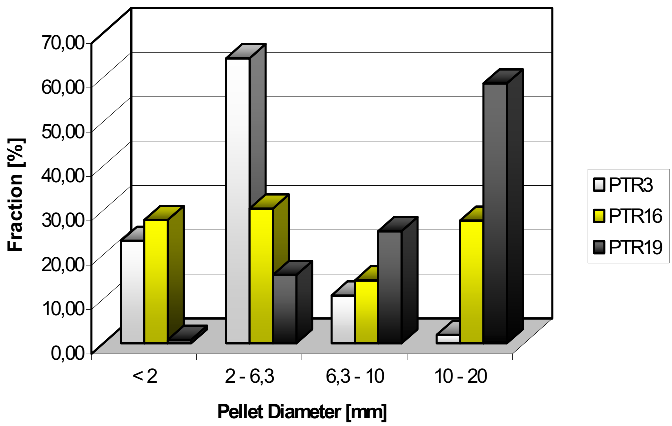

Figure 1. Size distribution of selected pelletizing experiments.

After pelletizing, the pellets were still wet, and the moisture content did not differ significantly from the initial water content. As a result, pelletizing will need to be followed by a drying step. Options include composting using passive aeration, or solar drying if climatic conditions allow.

Drying also affects the total nitrogen content, as seen in Table 2. In this case oven drying at 35°C was applied. No significant total N reduction was ascertained.

Table 2. Average total Nitrogen content during the agglomeration process.

	Pellets (wet) [%] DS	Pellets (dry) [%] DS
Total N	1,65	1,55

The pellets need to be of a high hygienic standard, which can be achieved before or after the agglomeration by composting. Many publications have already shown that composting of chicken manure is possible (e.g. Elwell *et al.,* 1998). To verify if composting of pelletized manure is also possible, simple self-heating tests were undertaken. Thee test series were monitored with different classes of manure pellets. All mixtures resulted in a low degree of degradation which will allow composting of these substrates.

Overall, the following complete treatment options are possible:

1) Composting – Agglomeration – Solar drying
2) Storage – Agglomeration – Composting including drying

In option (1), the moisture content of the manure or manure mixture is reduced through the composting process; hygienisation is included in this step. After the formation of the pellets via agglomeration, they are dried before being marketed or applied to the land. In option (2) the moisture content is adjusted by storing and/or drying; subsequently the pellets are created, and finally composted as they are. The shape of the pellets is not affected by the composting process.

Both options can be adapted to the specific needs of a farm, and they represent a simple approach that can be adopted by small poultry farms.

References

MANDE, ADAS, 2003. Final Project Report. Department for Environment, Food and Rural Affairs, Mansfield.

Elwell, D.L. et al, 1998 Composting Unamended Chicken Manure, Compost Science & Utilization, Vol.6, No.2, 22-35, JG Press.

Electroremediation of heavy metals from liquid manure

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Animal manures are actually one of the main sources of heavy metal (HM) inputs into the environment in many European countries. It concerns in particular copper and zinc and is related to intensive use of feed concentrates in order to accelerate animal growth. Many techniques for the reduction of heavy metal concentrations in soils have already been developed (Mulligan et al 2001). However, it seems that the removal of HM from manure before spreading is to be preferred over soil purification after spreading.

The aim of this research was to develop a HM electroremediation process to obtain an animal fertilizer with an improved ecological value from liquid manure. This joint research between Wageningen University and Research Centre and Agricultural University of Poznań was financed within the Light Manure project (MCF 6th Framework Program).

For the experiments a reactor for liquid manure treatment was developed. The volume of the cathode compartment was 10 dm^3, whereas the manure compartment was 12 dm^3. The reactor was built of Plexiglas. The anode was a fine-grained carbon (CSI 50) plate, whereas the cathode was a steel mesh covered with a titanium layer. Manure used for this research came from a pig farm and was stored at 5^{o}C. Initially, the cathode compartment was filled with water. The current density used during the experiment was 17 A/m^2. The measured parameters were: voltage, pH, conductivity and temperature, as well as volume and mass of the manure and water phases. The HM concentration was determined using atomic absorption spectrometry (AAS) in a certified Chemical-Rural Station laboratory. NPK and NH_4^+, as well as the composition of gases emitted from the reactor were measured in the chemical laboratory of Agrotechnology and Food Innovations, Wageningen.

The results showed a continuous decrease in manure conductivity and a similar increase in the conductivity of the cathode liquid (Fig. 1). The pH of the cathode liquid immediately (within 1 hour) reached a value over 12 and remained at this level during the whole process. The pH of the manure deceased very slowly during 30 hours, and when its buffering capacity was broken the pH dropped rapidly to a level of 1.8-2.2.

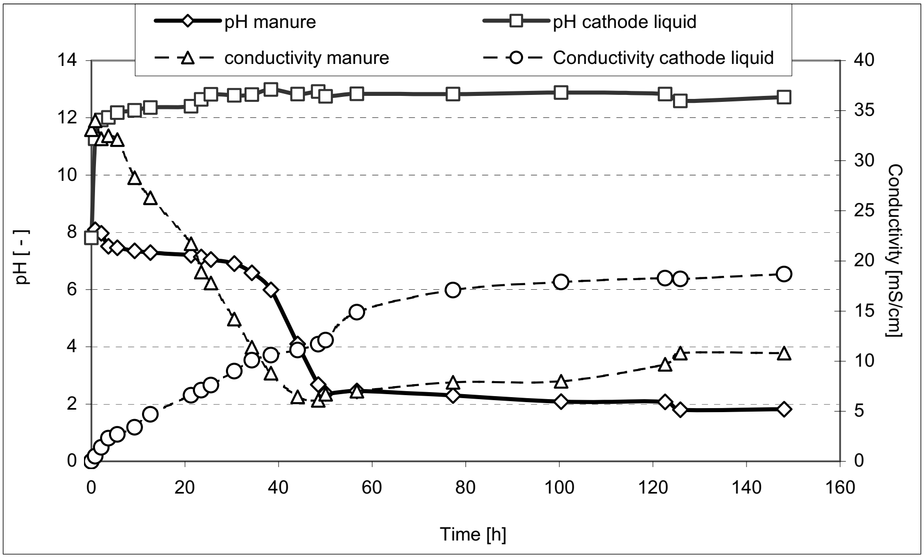

Figure 1. Changes of conductivity and pH during the swine manure electroremediation process.

The decrease of manure pH was closely related to foam formation triggered by a strong release of CO_2. A similar foaming effect could be observed during normal acidification of manure using sulphuric acid. Excessive foaming can create a problem with development of farm-scale technology. During this experiment the addition of a 3 mm layer of liquid paraffin decreased the foam formation. Addition of liquid paraffin prevented also undesired ammonia volatilisation from the cathode liquid.

Other experiments carried out within the Light Manure project using the same reactor have revealed that the decrease of pH in the manure phase depends strictly on current density and dry matter content. The decrease in pH is a main prerequisite for enhancing the electroremediation process (Virkutyte et al. 2002), since the biggest part of HM is bound to organic matter in the manure, and these bonds can be broken down by decreasing the pH to values below 3.5 (Mulligan et al. 2001). In previous experiments where the pH remained above 3.5, the maximum Cu and Zn removal were 24.7 and 25.5% respectively. A further decrease in Cu (76.6%) and Zn (72.2%) concentrations was observed in the current experiment (Table 1). The heavy metals released will pass through the membrane to the cathode liquid where, in the presence of OH^- ions, a precipitate is formed. In this study, almost 85% of NH_4^+ and 95% of K^+ moved to the cathode liquid, which became a mineral NK fertilizer.

Table 1. Changes in liquid manure during the electroremediation process

Compounds	Untreated manure	Electroremediated manure
Cu content (mg/dm^3)		
Average content	18,6	4,3
In liquid phase	7,79	1,1
In sediment	36,4	10,2
Zn content (mg/dm^3)		
Average content	89,5	24,9
In liquid phase	36,4	11,5
In sediment	182,5	56,0
N-tot (g/kg)	6,39	2,182
P-tot (g/kg)	1,051	1,081
K-tot (g/kg)	4,14	0,216
N-NH_4 (g/kg)	4,79	0,776
Dry matter (%)	5,24	4,57
Ash (%)	1,7	0,82

The experiments showed that the setup, in which the anode is placed directly into the manure, provides a simple and efficient way to sufficiently decrease the pH of the manure phase. However, this solution needs a special electrode material, because manure (especially pig manure) treated with electricity becomes a very aggressive mixture for most conductors. The electroremediation process allows the user to obtain two separate anode fractions originating from manure: a sediment and a liquid part with low content of HM, K^+ and N-NH_4. The liquid cathode fraction is low in dissolved HM, but high in K^+ and NH_4^+.

References

Mulligan C.N., Yong R.N., Gibbs B.F. Remediation technologies for metal-contaminated soils and groundwater: an evaluation. Engineering Geology 60, 193-207.

Virkutyte J., Sillanpaa M., Latostenmaa P., 2002 Electrocinetic soil remediation - critical overview. The Science of the Total Environment. 289, 97-121.

Composting of winery and distillery residues: Evaluation of the process by FT-IR

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The winery and distillery industry produces a great number of solid and liquid wastes, whose disposal constitute an environmental problem. Composting could be an effective method for recycling these wastes for agricultural use. FT-IR spectroscopy is a quick and useful method to monitor the composting process. However, any particular composting mixture needs preliminary studies of the spectra. The most appropriate criteria to describe the process (e.g. band ratios, shape and intensity of the nitrate band) should be selected, and the time/peak ratio curves recorded for the compost mixture under study. Afterwards, monitoring of the composting process can be based on the comparison of fresh and mature samples. Also bands of inorganic components are useful for assessing the decomposition process, because they indicate the degradation of the organic matter. Different composts can be distinguished by their fingerprint region (1500-900 cm^{-1}). This region also reveals fresh and partially decomposed materials. The presence or absence of specific bands provides information about the decomposition status of the materials throughout the composting process (Smidt et al., 2002).

In our experiment, Fourier transform infrared spectroscopy (FT-IR) was used to monitor the composting process of winery and distillery residues, evaluate the degradation rate and, thus, ascertain the maturity of the final compost. Three different piles were prepared in a forced aeration composting system (Table 1). The mixtures (about 1800 kg each) were composted in a pilot plant, in trapezoidal piles (1.5 m high with a 2 x 3 m base). Compost piles were turned over when necessary in order to improve both homogeneity and composting process (Table 1). The bio-oxidative phase of composting was considered finished when the temperature of the pile was stable and near to that of the surrounding environment. Then the piles were allowed to mature for two extra months.

Table 1. Characteristics of the composting heaps

	Composition, % fresh weight basis (% dry weight basis)			
	Pile 1		Pile 2	Pile 3
Waste[b]	Initially	After 17 days		
GS	63 (56)	44 (51)	--	--
EGM	25 (28)	18 (25)	70 (80)	70 (79)
GM	12 (16)	9 (15)		--
CM	--	--	30 (20)	--
PM	--	--	--	30 (21)
SS	--	29 (9)	--	--
Turning (days)				
	18-53-86		92	144

[a]Data expressed as; [b]GS: grape stalk; EGM: exhausted grape marc; GM: grape marc; CM: cow manure; PM: poultry manure; SS: sewage sludge

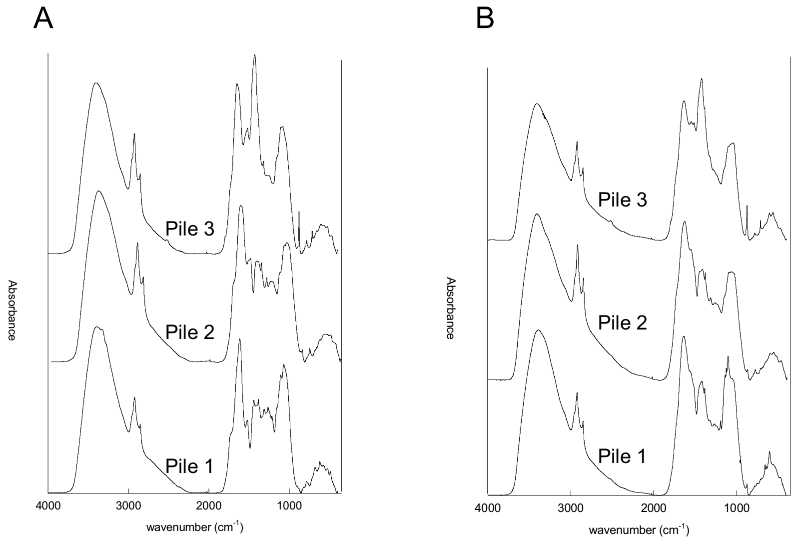

Figure 1. FT-IR spectra of the initial composting mixture (A) and mature compost (B).

In our experiment, the appearance, shape and intensity of the nitrate band at 1384 cm^{-1} were pronounced and evidenced the maturity of the studied winery and distillery composts. In addition, relative decreases of peak intensity in the polysaccharides region at 1037 cm^{-1} were particularly evident in FT-IR spectra of materials after 5 and 8 weeks of composting.

These results suggest the occurrence of degradation and condensation reactions of organic structures.

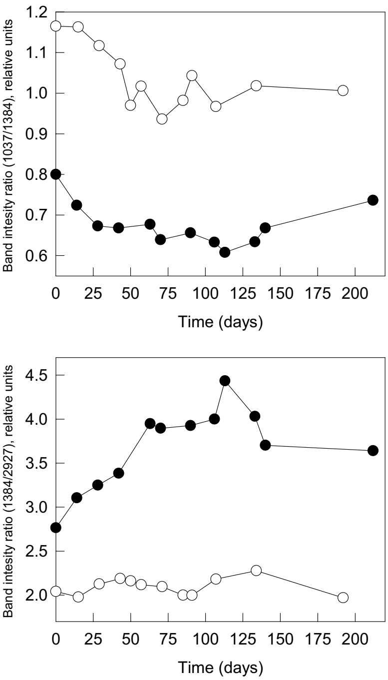

Figure 2. Band intensity ratio time curves (empty circle) for pile 2 and (full circle) for pile 3.

In this study, the ratios between the intensities of the major peaks at 1384, 2927, and 1037 were calculated to characterize the compost maturity. The decrease of the ratios 1037/1384 and the increase of the ratio 1384/2920 indicated the progress of the decomposition process (Figure 2). This is in agreement with the studies of compost FT-IR spectra carried out by Hsu and Lo (1999) and Grube et al. (2005), which showed that easily degradable organic matter components, such as aliphatic chains, polysaccharides, alcohols and proteins, are decomposed, and therefore the mature compost contained relatively more aromatic structures of higher stability.

The presence in pile 1 of a high amount of grape stalk, material rich in lignin that absorbs in the 1300–1400 cm^{-1} region, can overlap the nitrate band (1384 cm^{-1}), and therefore the ratios 1384/2927 and 1037/1384 can become unusable for evaluating the maturity (Grube et al., 2005). In conclusion, although the composition of the input mixture strongly affects the shape of the infrared (IR) spectra, typical bands of components can be selected and used to follow the composting process (Smidt et al., 2002).

References

Grube, M., Lin, J.G, Lee, P.H. and Kokorevicha, S., 2006. Evaluation of sewage sludge-based compost by FT-IR spectroscopy. Geoderma 130, 324-333.

Hsu, J.H. and Lo, S.L., 1999. Chemical and spectroscopic analysis of organic matter transformations during composting of pig manure. Environmental Pollution 104, 189-196.

Smidt E., Lechner P., Schwanninger M., Haberhauer G., Gerzabek M.H., 2002. Characterization of Waste Organic Matter by FT-IR Spectroscopy: Application in Waste Science. Applied Spectroscopy 56, 1170-1175.

Content of nutrients and trace elements in stored manure from laying hens

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Feeding regimes continuously change, thus changing the content of elements in faeces and urine. In manure handling, additives like straw, rainwater, etc. also influence the properties of the manure. Therefore, there is a need to analyse recently sampled animal manure in order to estimate the flow of elements on the farm and in the fields.

In Sweden, production of meat and eggs from hens is carried out on specialist farms that often lack sufficient arable land for spreading the manure. Therefore the manure has become a commodity. In the last ten years, housing systems for laying hens have changed drastically, and systems for production of organic eggs have been developed. Updated quantitative values for plant nutrient and trace element contents of stored manure from laying hens are lacking, although this information is needed to evaluate stored manure from laying hens as a fertiliser, and to avoid unacceptably high amounts of heavy metals being applied to arable land. The aim of this study was to present quantitative mean values of plant nutrient and trace element contents in stored manure from laying hens, to formulate recommendations for balanced manure applications in crop production, and to validate a sampling technique for taking representative samples in solid and semi-solid manure.

Manure was sampled from full storage units of 53 egg production plants using a core sampler developed and validated at JTI (Rodhe and Jonsson, 1999). The manure samples represented A) furnished cage housing systems, B) floor housing systems, and C) organic floor housing systems where the hens had access to an outdoor yard. The manure types involved were solid, semi-solid and slurry. The manure was analysed for dry matter (DM) content, ash content, pH, ammonium nitrogen (NH_4-N) content and total contents of N, P, K, C, S, Mg, Ca, Zn, Cu, Co, Cr, Ni, Pb, Cd, Hg and Se.

There was a significant difference in DM content between manure types, solid > semi-solid > slurry, Table 1. Solid manure from conventional cage housing systems had significantly higher DM content than conventional floor housing systems. The total N and NH_4-N contents were significantly larger in slurry from conventional furnished cages and floor housing systems than in solid and semi-solid manure from these housing systems, Table 1. Possible explanations are lower ammonia emissions during storage of slurry and that larger amounts of litter were used in systems with solid and semi-solid manure. The K content in manure from organic egg production was significantly lower than in manure from conventional egg production, Table 1. The reason could be that different feed components were used in organic and conventional egg production.

The large plant nutrient content of N, P, and K has to be considered in order to fertilise to crop requirements. Therefore a spreading technique capable of applying low rates has to be used. Depending on conventional manure handling system, an application of 170 kg total-N ha^{-1} corresponds to 7 tonnes of solid manure ha^{-1} or 22 tonnes of slurry ha^{-1}. This means a P application of 63 kg ha^{-1} with solid manure or 39 kg ha^{-1}

Table 1. Mean values of dry matter content, plant nutrients and trace elements in stored manure from laying hens. Within DM, means with the same letter was not significantly different ($p<0.001$). Within total-N, NH_4-N and K, means with the same letter was not significantly different ($p<0.05$). Within P, Zn, Cu, Pb and Cd there were no significant differences

	Furnished cages			Floor housing			Organic floor housing	
	Solid	Semi-solid	Slurry	Solid	Semi-solid	Slurry	Solid	Semi-solid
Dry matter (DM), % of wet sample								
DM	60 a	27 c	10 d	45 b	31 c	12 d	57 ab	33 c
Plant nutrients g kg^{-1} DM								
Total-N	53 b	58 b	77 a	42 b	57 b	73 a	31 b	46 b
NH4-N	17 b	30 b	56 a	18 b	26 b	54 a	14 b	25 b
K	24 a	23 a	30 a	26 a	23 a	33 a	19 b	14 b
P	15	15	19	18	17	18	18	20
Trace elements mg kg^{-1} DM								
Zn	410	409	523	417	377	431	376	350
Cu	40	49	73	55	48	62	51	49
Pb	2	3	2	2	3	4	3	3
Cd	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.1

with slurry. Mean annual applications of P larger than about 22 kg ha^{-1} represent a surplus according to Swedish regulations (De Clercq et al., 2001). An application of 170 kg total-N ha^{-1} with manure from laying hens also applies about 1 kg of Zn, 160 g of Cu, 7 g of Pb and 0.7 g of Cd per ha. A build-up in arable soils of Cd in particular should be avoided as this trace element is easily taken up by crops. A grain harvest removes about 0.08-0.18 g Cd, which means that an application of 170 kg total-N ha^{-1} for a 5-year period does not contribute to a net input of Cd to the soil.

References

Rodhe L. and Jonsson C., 1999. Sampling equipment for solid manure. JTI-report No. 252 Agriculture and Industry. Swedish Institute of Agricultural and Environmental Engineering, Uppsala. 15 pages. English summary.

De Clercq P., Gertsis A.C., Hofman G., Jarvis S.C., Neeteson J.J., Sinabell F., (eds) 2001. Nutrient Management Legislation in European Countries. Department of Soil Management and Soil Care, Faculty of Agricultural and Applied Biological Sciences, 347 pages. Wageningen Pers, The Netherlands.

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Availability of P and K in ash from thermal gasification of animal manure

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Introduction

In areas like Denmark where the livestock density is regulated on the basis of manure N content, surplus phosphorus is becoming a key environmental problem, which has to be solved in order to avoid increasing P losses to surface waters in the future. Combustion of animal manure or its solid fraction and the subsequent export of the ash to nutrient-poor areas could be a solution. However, combustion is difficult due to fouling and corrosion problems, and the ash will only be marketable if the fertiliser value of the remaining P and K is acceptable and if the content of contaminants (heavy metals) is sufficiently low. A combined fast pyrolysis and char gasification technique for treatment of biomass has been developed where organic material such as manure is processed in a fluidised bed reactor at temperatures of around 700 °C. After simple separation of a fine textured ash, the cleaned gas is suitable for combustion in a separate unit for energy production. One advantage of this technique is that the temperature can be finely controlled, and temperatures exceeding the melting point of e.g. potassium chloride can be avoided. The low and well-controlled temperature probably also prevents severe reductions in the availability of nutrients in the ash. However, the availability of P and K in the ash remains to be thoroughly tested.

Material and methods

We have investigated the P and K availability in ash derived from gasification of the dried solid fraction from pig slurry separation (pig ash), and in ash derived from gasification of manure from laying hens (poultry ash). For comparison, dried pig manure (comparable to the one used for gasification) and super phosphate were also included in the investigation. The P and K availability was tested by direct analyses of total P, citrate-soluble P, water-soluble P, total K, water-soluble K and ammonium acetate soluble K in the ashes and manures. Furthermore, the availability of P and K after application to soil was evaluated by measuring changes in extractable P and K in two soils with different liming status. The soils were analysed for bicarbonate extractable P (Olsen et al., 1954), water soluble P (Sissing et al., 1971), resin extractable P (Kuono et al., 1995) and ammonium acetate extractable K (Anon., 1994) one week and four months after ash and manure application. All soils amended with manure or ash received similar doses of P, corresponding to 90 kg P ha^{-1} as total P.

Results

The direct manure analyses indicated low availability of P in the ashes with low solubility in both water (less than 1%) and citrate (less than 20%) (Table 1). In contrast, the solubility of P in pig slurry separate and super phosphate was high (larger than 65% in water and 85 % in citrate). Water solubility of K was 100% in super phosphate, pig slurry separate and poultry ash, while it was only 35% in the pig ash, indicating that availability of K in pig ash was reduced by the gasification, while it remained high in the poultry ash.

Table 1. Solubility of P and K in ash and manure products

Product	Total P (g kg^{-1})	Citrate soluble P (%)	Water soluble P (%)		Total K (g kg^{-1})	Water soluble K (%)
Super phosphate	94	*85*	*66*		13	*100*
Pig slurry separate	8	*95*	*97*		7	*100*
Pig slurry ash	53	*11*	*0.6*		36	*35*
Poultry manure ash	50	*40*	*0.2*		77	*100*

The Evaluation of P availability after application to soil showed a different picture: The percentage of applied P from poultry ash, which was extracted by water- or resin-extraction of soil, was almost equal to that of P applied with super phosphate or dried pig slurry separate. Pig ash showed a somewhat lower extractability, but not as low as indicated by the low solubility of P in the direct manure analyses. For all ashes and manures, more of the applied P was extracted after one week than after four months' incubation. Soil pH had little influence on the extractability of fertiliser P. In contrast, the Olsen P method gave quite different results. With this method time had little and sometimes opposite effects on the extractability of P, differences between ash and manure were smaller and inconsistent, and soil pH seemed to have a more pronounced effect on extractable P.

Table 2. Water-, resin- and bicarbonate-extractable P in soil 7 and 120 days after application of ash and manure products to soils with low or medium pH. Within each soil test, soil type and incubation time, numbers followed by different letters are significantly different ($P<0.05$, LSD test) in an analysis of variance.

Incubation time	Product	Water P[$] ($P_W$)		Resin P[$]		Olsen P[$]	
		Soil pH 5.3	Soil pH 6.4	Soil pH 5.3	Soil pH 6.4	Soil pH 5.3	Soil pH 6.4
7	Super phosphate	17^{a}	14^{a}	40^{a}	43^{a}	40^{ns}	15^{ns}
	Pig slurry separate	13^{b}	7^{c}	35^{b}	29^{b}	9^{ns}	10^{ns}
	Pig slurry ash	6^{c}	4^{d}	18^{c}	8^{c}	15^{ns}	0^{ns}
	Poultry manure ash	20^{a}	11^{b}	35^{ab}	27^{b}	20^{ns}	0^{ns}
120	Super phosphate	8^{b}	4^{a}	12^{a}	19^{a}	39^{ns}	16^{a}
	Pig slurry separate	9^{b}	3^{b}	13^{a}	13^{b}	35^{ns}	4^{b}
	Pig slurry ash	4^{c}	1^{c}	0^{b}	3^{c}	24^{ns}	1^{b}
	Poultry manure ash	11^{a}	4^{a}	11^{a}	13^{b}	35^{ns}	14^{a}

[$] Calculated as extractable P from soil after application of manures or ashes subtracted with extractable P from soil without P application as a percentage of the amount of P added with manure or ash.
[ns]: not significant ($P<0.05$)

Conclusion

These results suggest that:

- The availability of P in ashes from thermal gasification of animal manure products may be higher than indicated by traditional fertiliser analyses.
- Further evaluation of methods to determine P availability in e.g. ash is needed.
- The solubility of K in ash varies depending on manure type.

References

Kuono,K., Tuchiya, Y and Ando, T., 1995. Measurement of soil microbial biomass phosphorus by an anion exchange membrane method. Soil Biology and Biochemistry 27:1353-1357.

Olsen, S.R., Cole, C.V., Watanabe, F.S. & Dean, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agric. Circ. 939, Washington, DC.

Anon. 1994. Fælles arbejdsmetoder for jordbundsanalyser. Plantedirektoratet

Sissingh, H.A., 1971. Analytical technique of the Pw method, used for the assessment of the phosphate status of arable soils in the Netherlands. Plant and Soil 34, 483-486.

Co-composting of winery and distillery wastes with manure

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The wine production of the European Community countries represents 40% of the entire worldwide production, Spain being one of the main producers. Grape stalk, grape marc (GM), wine lee and exhausted grape marc (EGM) are the main solid organic wastes produced by the winery and associated distillery industries. The disposal and treatment of these wastes are a problem for these industries because of their seasonal character and high content in phytotoxic and antibacterial phenolic substances. A conditioning treatment of the winery and distillery wastes is necessary to produce a stable and easily manageable end-product. Composting is a widely-used treatment for organic wastes, thus the composting of winery and distillery wastes to obtain organic fertilisers could be an economically and ecologically acceptable way to dispose of them.

In this experiment, three piles were prepared with mixtures of GM, EGM and cow and poultry manures (CM and PM, respectively). The mixtures were prepared in the following proportions, on a fresh weight basis (dry weight basis in brackets):

- Pile 1: 70% EGM + 30% CM (72:28)
- Pile 2: 70% GM + 30% CM (76:28)
- Pile 3: 70% EGM + 30% PM (67:33)

These piles (about 140 kg in each pile) were composted in a domestic thermo-composter (85 cm high with a 70 x 70 cm base and a 350 L volume). The aeration of the mixtures was natural (the air went through holes in the base of the composter) and by turnings. The moisture of the piles was controlled weekly by adding the necessary amount of deionised water to obtain a moisture content not less than 40 %. Excess water leaching from the piles was collected and part of it was added again to the piles. During composting, the evolution of pH, electrical conductivity (EC), organic matter (OM), total N (N_T), NH_4^+-N, NO_3^--N, total organic C (C_{org}), humic acid-like C (C_{HA}), fulvic acid-like C (C_{FA}) and water-soluble organic C

(C_w) contents, C/N, C_w/N_{org} and C_{HA}/C_{FA}, humification index (HI = (C_{HA}/C_{org})x100), cation exchange capacity (CEC) and germination index (GI) of the mixtures were studied and analysed according to the methods described by Paredes et al. (2001).

The pH values increased with time, as a consequence of the mineralisation of proteins, amino acids and peptides to ammonia, except for pile 1, possibly due to the higher nitrate formation (Table 1). However, the EC values decreased during the process in all composts. This fact could be due to the loss of soluble salts by leaching, because leachates were not totally re-added to the piles. OM degradation was greater in pile 1, according to the OM and C_{org} evolution. In general, the N_T concentration increased during the process, probably as a consequence of a concentration effect caused by the reduction in the pile weight, as it has been observed in other composting experiments with winery wastes (Diaz et al., 2002; Alburquerque et al., 2006). The N_T content was greater in pile 3 and therefore, PM was the organic waste which provided the highest amount of N in the co-composting with winery and distillery wastes. The use of EGM in the piles 1 and 3 favoured the nitrification process. However, the higher EC values from the middle of composting process in pile 2 could reduce the NO_3^--N content, because it has been observed in soil that the nitrification process is very sensitive to salinity (McClung and Frankenberg, 1985). In general, all composts reached water-soluble organic C (C_w) and NH_4^+-N concentrations, as well as C_w/N_{org} and C/N ratios within the established limits, which indicate a good degree of compost maturity (C_w<1.7 % and NH_4^+-N<400 mg kg^{-1} (Bernal et al., 1998); C_w/N_{org}<0.7 (Hue and Liu, 1995) and C/N<20 (Poincelot et al., 1974)). In most cases, HI and C_{HA}/C_{FA} fell during composting, possibly due to the alkaline co-extraction and partial acid co-precipitation of incompletely or not humified components of organic matter, such as the polyphenols of the winery and distillery wastes (Iglesias Jiménez and Pérez García, 1992). This fact could hide the real evolution of the humic fraction. So, the humification process was best revealed by increases in the cation-exchange capacity during composting. On the other hand, the germination index indicated the reduction of phytotoxicity during the process (GI>50 (Bernal et al., 1998)).

References

Alburquerque et al., 2006. Process Biochemistry 41: 127-132.
Bernal et al., 1998. Bioresource Technology 63: 91-99.

Diaz et al., 2002. Process Biochemisry 37: 1143-1150.
Hue and Liu, 1995. Compost Science and Utilization 3: 8-15.
Iglesias Jiménez. and Pérez García, 1992. Resources, Conservation and Recycling 6: 243-257.
McClung and Frankenberg, 1985. Soil Science 139: 405-411.
Paredes et al., 2001. Biodegradation 12: 225-234.
Poincelot et al., 1974. Compost Science and Utilization 15: 24-31.

Table 1. Evolution of the main parameters during the composting process (dry weight basis)

Composting time (days)	pH	EC ($S\ m^{-1}$)	OM (%)	C_{org} ($g\ kg^{-1}$)	C_W (%)	N_T ($g\ kg^{-1}$)	NH_4^+-N ($mg\ kg^{-1}$)	NO_3^- -N ($mg\ kg^{-1}$)	C/N	HI (%)	C_{HA}/C_{FA}	CEC[1] ($meq\ 100\ g^{-1}$)	GI (%)	C_W/N_{org}
Pile 1: exhausted grape marc + cow manure														
0	7.9	0.37	88.3	501.7	3.14	22.9	871	20	21.9	5.94	0.84	107.0	60.2	1.42
14	7.5	0.26	86,9	476.4	2.93	27.7	742	30	17.2	7.43	1.06	102.4	63.4	1.09
28	7.4	0.23	86.9	477.6	2.80	26.0	455	82	18.4	6.32	0.96	111.0	75.6	1.10
53	7.4	0.24	85.1	471.4	2.76	25.6	150	221	18.4	5.36	0.76	128.2	56.4	1.09
88	7.2	0.30	81.6	467.5	2.70	26.1	121	334	17.9	3.41	0.58	131.7	59.4	1.05
mature	7.4	0.22	80.7	458.7	1.10	26.4	76	113	17.4	2.52	0.93	173.0	78.2	0.42
LSD	**0.1**	**0.01**	**1.7**	**8.0**	**0.15**	**2.82**	**47**	**23**	**1.9**	**0.83**	**0.13**	**10.5**	**5.5**	**0.14**
Pile 2: grape marc + cow manure														
0	7.1	0.33	90.1	498.7	4.27	23.6	328	16	21.1	9.20	1.20	83.6	48.1	1.82
14	7.5	0.28	88.0	484.9	3.71	25.6	819	84	19.0	9.24	1.30	102.3	49.7	1.50
28	7.8	0.24	88.2	481.6	3.72	25.1	981	67	19.2	9.57	1.13	103.8	56.3	1.54
53	7.8	0.27	86.1	478.8	3.85	24.1	175	112	19.9	9.18	1.27	104.4	46.8	1.62
88	7.5	0.35	83.6	462.2	3.51	26.3	198	72	17.6	8.65	1.28	108.7	51.2	1.35
mature	8.0	0.29	83.6	459.8	1.86	26.9	88	30	17.1	3.11	0.49	105.1	68.4	0.69
LSD	**0.2**	**0.01**	**1.6**	**9.0**	**0.20**	**2.07**	**46**	**10**	**1.6**	**1.17**	**0.20**	**8.3**	**8.5**	**0.15**
Pile 3: exhausted grape marc + poultry manure														
0	7.1	0.30	83.0	452.2	3.29	30.6	1874	< 1	14.8	5.96	1.20	115.0	61.8	1.15
10	7.1	0.28	81.9	441.0	2.86	37.7	9876	< 1	11.7	5.59	0.69	94.6	74.8	1.03
27	7.4	0.25	82.0	454.6	2.84	35.7	8576	53	12.7	7.37	1.13	98.5	74.0	1.05
49	7.4	0.22	80.4	440.9	2.65	31.0	301	297	14.2	4.97	0.79	123.4	46.3	0.87
88	7.2	0.21	77.3	440.9	2.68	31.8	82	226	13.9	4.18	0.60	129.7	48.1	0.85
mature	7.6	0.16	76.7	433.0	0.98	32.2	72	125	13.5	1.87	0.57	150.4	58.4	0.31
LSD	**0.1**	**0.02**	**0.5**	**6.9**	**0.05**	**1.66**	**55**	**14**	**0.7**	**0.61**	**0.11**	**10.5**	**5.7**	**0.04**

[1] Ash-free material.

OM: organic matter, EC: electrical conductivity, C_{org}: total organic C, C_w: water-soluble organic C, N_T: total N, N_{org}: organic N, HI: Humification index, C_{HA}/C_{FA}: Ratio of humic acid-like C/fulvic acid-like C, CEC: Cation exchange capacity, GI: Germination index, LSD: Least significant difference ($P<0.05$).

Development of a pig slurry treatment system with SBR and MBR technology

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Sequencing Batch Reactor (SBR) is basically an activated sludge process where organic pollutants are degraded under aerobic/anoxic/anaerobic conditions in the same tank, which is very convenient for on-farm installation. Treatments focusing on water reuse with total safety (such as animal houses cleaning) are of special interest nowadays. One of the most advanced systems (though not widely used for animal waste treatment) is based on the combination of biological degradation with membrane separation, Membrane bioreactors (MBR). The study and optimisation of these two technologies for pig slurry treatment was the aim of this work.

Materials and Methods

The pilot plant is located in a Swine Research Centre belonging to ITACyL (Agricultural Technological Institute of Castilla and Leon). This centre is in Segovia, one of the Spanish regions most affected by nitrate contamination and higher pig density. From sow houses comes a mixture of straw, solid and liquid. The liquid is separated by gravity from the dunghill and lead to a subterranean pit where it is mixed with the wastewater coming from piglet houses. The collected liquid is pumped through a 0.5 mm sieve and storaged in a homogenezation open-air tank. The pilot plant can be fed both 1) with fresh slurry recently collected from houses, or 2) with stored slurry (previously separated with 0.5 mm sieve) from the homogenization open-air tank. Each influent is pumped via a rotative sieve (0.25 µm) and sent to the SBR (3 m^3). This simple pre-treatment is cheaper than others, like centrifugation for solid-liquid separation (Tilche et al., 1999) or anaerobic digestion (Obaja et al., 2003), used in previous experiments. The effluent is discharged either into an intermediate tank or directly into the membrane tank. Excess sludge is withdrawn at the end of each cycle and sent to the dunghill. The clarified liquid accumulating in the intermediate tank could be filtrated by the membranes (0.4 µm) at any point during the cycle. The plant can also work as MBR: biological process and filtration instead of settlement.

The SBR cycle was conceived after tests with different lengths of nitrification-denitrification periods per cycle and attending literature (Kishida et al., 2003; Obaja et al., 2003; Pieters, 1999; Tilche et al., 1999). A 12-h cycle was found to give the optimal results: nitrification (2.5 h), denitrification (2.1 h), nitrification (2.5 h), denitrification (2.4 h), a last short oxidation-nitrification (0.5 h) which prevents ammonium escape in the effluent and improves COD degradation, and finally 1.8 h settling before the clarified extract and sludge is withdrawn. The study was divided into two phases with different and low HRT (Phase I: 8 days and Phase II: 6.5 days) according to previous works with similar wastewaters (Kishida et al., 2003; Obaja et al., 2003; Tilche et al., 1999; Zhang et al., 2006). Changes in SBR feed were responsible for solids accumulation in the reactor that obliged us to raise the purge on some occasions. The mean SRT (solid retention time) of the system was established as 18.5 and 15 days for Phase I and Phase II.

The effluent obtained was accumulated in an intermediate tank or sent to membrane tank and filtrated during Phase I and II in order to test the filtration capacity of the membranes with different effluents. The filtration unit was operated with stable permeate flow around 60-70 L/h Sampling was carried out for a 3-months period. Analyses were performed according to the Standard Methods (1995). pH, Oxidation Reduction-Potential, Dissolved Oxygen, Temperature, N-NO_3^-, NH_4^+ were continuously monitored in SBR. Microscopic observations of activated sludge and filamentous microorganisms were carried out weekly.

Results and Discussion

SBR was fed with the slurry stored in the open-air tank. Due to the different animals and diets, wastewater characteristics varied greatly among the experiments (Table 1).

In the SBR process, the sludge was very fine, consequently only a reduction around 86% SST was achieved because of sludge escaping with the effluent in both Phases, as it can be seen in Table 1. The filtration improved effluent quality and reduced variations, reaching 100% of solids removal. Although sedimentation was not good, microscopic observations did not reveal filamentous microrganisms. Due to this occasional sludge escaping, the mean COD_s was 650 mg/L for the Phase I and 1223 mg/L for the Phase II. The SBR system was able to remove between 90 and 95% of the COD_s. Tilche et al. (1993) achieved 336 mg/L of total COD,

Table 1. Characteristics of the SBR influent, efluent and permeate for Phase I and Phase II, average values and removal percentages.

		Phase I (HRT 8 days)				Phase II (HRT 6,5 days)			
	SBR influent	SBR effluent		Permeate		SBR effluent		Permeate	
	Average mg/L	Average mg/L	%	Average mg/L	%	Average (mg/L)	%	Average (mg/L)	%
pH	7.54(0.29)	8.34(0.14)	-	8.26(0.23)	-	8.45(0.33)	-	8.36(0.17)	-
SST	6260 (2810)	0.82(0.62)	87	0.06(0.03)	99	0.89(0.56)	86	0.04(0.01)	99
COD_s	12779 (3739)	644(203)	95	301(166)	98	1233(279)	90	474(212)	96
TKN	2068 (470)	89.2(51. 5)	96	18.5(15.9)	99	104.7(38.7)	95	45.5(13.9)	98
$N\text{-}NH_4^+$	1498,2	13.4(7.9)	99	18,0(10,9)	99	16.1(10.6)	99	27.3(10.5)	98
$N\text{-}NO_3^-$	-	11.41(8.06)	-	7.30(4.37)	-	5.36(3.90)	-	5.57(3.24)	-
$P\text{-}PO_4^-$	28.17 (7.91)	6.70(3.00)	61	8.76(3.26)	69	-	-	-	
	(uF/100mL)					(uF/100mL)		(uF/100mL)	
Total coliforms	6.83 E 05					6.83 E 05	97	0.00	100
Fecal coliforms	2.48 E 05					2.48 E 05	96	0.00	100
Streptococci	3.23 E 05					3.23 E 05	95	0.00	100

Average values for 13 samples in Phase I and for 9 values in Phase II. Values in brackets are standard deviation.

although this was thanks to a previous to SBR pre-treatment with centrifuge (25-50% DQO removal). In this work with simple rotative sieves, it would be impossible to achieve this high percentage. Instead, filtration reached 98 and 96% removal, which demonstrate that membrane decreases also COD together with solids in final effluent (Pieters, 1999).

The high influent concentration of nitrogen did not appear to affect the SBR system. Although NH_4^+ effluent mean concentration was low (13.4 and 16 mg/L, respectively, in each phase), and the removal reached 99%, the process could have been probably improved by means of a two-step influent feeding (Kishida et al., 2003; Obaja et al., 2003; Tilche et al., 1999; Zhang et al., 2006). With regard to nitrate and nitrite, final effluent concentrations were below 11 and 1 mg/L, respectively. The membrane treatment did not affect NH_4^+ or NO_3^- elimination, but it removed 99% TKN. Differences between final effluents of Phase I and II were not evident, and they were more related to settlement problems in SBR and solids accumulation in the membrane tank. Another remarkable result from membrane filtration was that microorganisms were completely removed.

Evolution studies of nitrogenous compounds, DO, ORP and pH allowed to detect the end of nitrification ("Ammonia valley") and denitrification ("Nitrate knee"), optimising the design of cycle length and load increase (Kishida et al., 2003; Zhang et al., 2006).

Conclusions

SBR is an excellent on-farm technique to treat pig slurry, because it achieves high removal rates (N, COD, ST, bacteria, etc.) despite the large variations in influent, the use of relatively low HRT and the simple and low-cost pre-treatment employed in the pilot plant. Although the results for SBR were quite good, problems with settlement could be avoided with the use of membranes, and thus the final effluent had a better quality and low variations of SST, COD, NKT and pathogens.

References

Kishida N., Kim J-H., Chen M., Sasaki H., Sudo R., (2003) "Effectiveness of oxidation-reduction potential and pH as monitoring and control parameters for nitrogen removal in swine wastewater treatment by sequencing batch reactors" Journal of bioscience and bioengineering Vol. 96 No 3 285-290.

Obaja D., Macé S., Costa J., Sans C., Mata-Álvarez J. (2003) "Nitrification, denitrificatien and biological phosphorus removal in piggery wastewater using a sequencing batch reactor". Bioresource Technology, Volume 87, Issue 1, March, Pages 103-111.

Pieters, J.G. (1999) Farm-scale Membrane Filtration of Sow Slurry. J. Agric. Engng Res. 73, 403-409.

Tilche A., Bacilieri E., Bortone G., Malaspina F., Piccinini S., Stante L., (1999) "Biological phosphorus and nitrogen removal in a full scale sequencing batch reactor treating piggery wastewater" Wat. Sci. Tech. Vol. 40 Nº. 1 pp. 19-206.

Zhang Z., Zhu J., King J., Li W., (2006) "A two-step fed SBR for treating swine manure" Process Biochemistry 41892-90.

Low temperature anaerobic digestion for swine mortalities disposal and recovery of green energy

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There is an urgent need for more economical and sustainable alternatives for mortality disposal on Canadian swine operations. The objective of this study was to investigate the feasibility of using a low temperature anaerobic process operated under a wide range of conditions to digest mixtures of swine mortality and swine manure slurry.

Anaerobic sequencing batch digesters (6-42 L) were operated at 20 or 25°C. In order to simulate normal farm carcasses disposal procedures, the carcasses were kept intact, that is, including the blood, viscera, visceral content. Fresh manure slurry collected on a commercial swine operation was mixed with the homogenized swine carcasses material prior to bioreactors feeding. The mixture was fed to the bioreactors at an organic loading rate of 3.2 g COD/l-day.

Table 1 gives the experimental design that was used in this study. It identifies for each treatment cycle the operating temperature, treatment cycle length, carcass loading and number of treatment cycle. Feed and reaction period lengths of 1 and 2 weeks each (total treatment cycle length of 2 and 4 weeks) were used in this study.

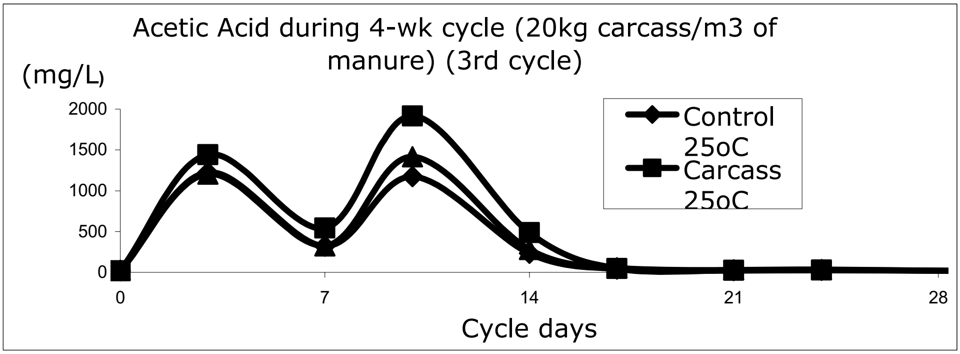
Table 1. Experimental design.

Experimental Run no.	Bioreactor no.	Operating Temperature (°C)	Treatment cycle length (week)	Kg carcass per m^3 of manure	No. of treatment cycles
1	3-4	25	4	0	3
	7-8	20	4	20	3
	5-6	25	4	20	3
2	3-4	25	2	0	7
	7-8	20	2	20	7
	5-6	25	2	20	7
3	3-4	25	2	0	6
	7-8	20	2	40	6
	5-6	25	2	40	6

Table 2. Characteristics of carcass & manure used in experimental test runs 1, 2 and 3

Parameters	Carcass	Manure
Total solids (%)	40,7	4,6
Volatile (organic) solids (%)	38,0	3,2
Volatiles/Total solids (%)	93	70
COD total (g/kg)	867	85
Volatile fatty acids (g/kg)	0,61	18,0
Total Nitrogen (g/kg)	27960	6270
Ammonia Nitrogen (g/kg)	2470	4950
Ratio COD/Total Nitrogen	31.0	13.6

Table 2 provides the characteristics of the swine carcass and manure slurry used in this study. The carcasses had high dry matter (DM) and VS contents of 41% and 38 %, respectively, while the manure slurry had a DM and VS content of 4.6 and 3.2%, respectively.



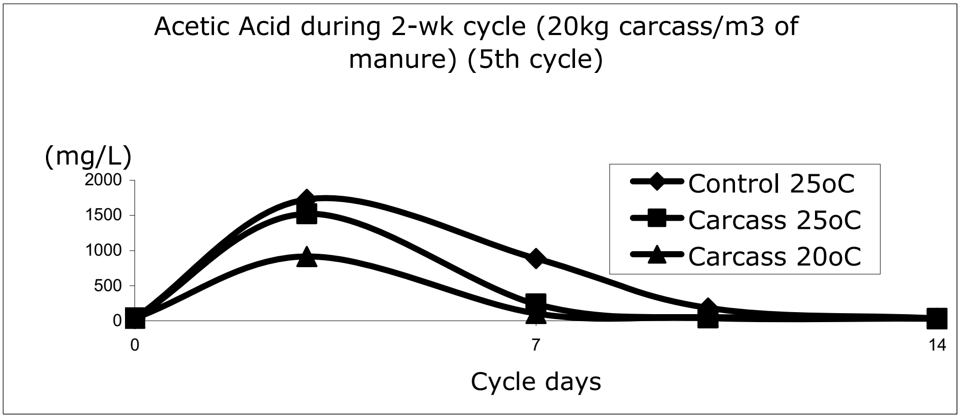


Figure 1. Profiles of acetic acid in test run 1, cycle 3 and test runs 2 and 3, cycle 5.

The addition of swine carcass to the swine manure at the rate used in this study did not affect the stability of the bioreactors. There was no formation of foaming or accumulation of volatile fatty acids in the bioreactors, and the pH and alkalinity remained within an acceptable range for the anaerobic microflora development. All the VFAs were utilised before the end of the treatment cycle. Figure 1 provides the acetic acid profile for one cycle in treatment 1 (4-weeks treatment cycle lenght) and 2 (two-week treatment cycle length). The profile for propionic, butyric, isobutyric, valeric, isovaleric,and caproic acids were similar to the acetic acid profile in all cycles with equivalent treatment cycle length.

The amount of methane produced by the bioreactors fed either swine manure slurry or a mixture of swine carcass and manure slurry ranged from 0.27 to 0.33 l of CH_4 per gram of COD fed. The difference between treatments was not statistically significant. The biogas was of good quality, its methane content ranged from 72.6 to 75.6%. The COD reduction was also similar for all treatments. It ranged between 70 to 82.8%.

The low temperature anaerobic technology provides a year-round sustainable disposal method for swine carcasses and permits recovery of green energy. In addition, this on-site mortality disposal will improve the bio-security on the farm by eliminating the contamination risk associated with the pick up of dead animals by external contractors.

Influence of physical characteristics during composting of the solid fraction of dairy cattle slurry

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Physical characteristics of cattle slurry solid fraction (CSSF) are responsible for the aerobic (or anaerobic) conditions inside composting piles and therefore for their metabolic activity and temperature. When 70% moisture content is exceeded, and this is the case with most CSSF, thermophilic temperatures may not be attained since oxygen movement is restricted. Although turning the pile may provide oxygen for the decomposition process, this can increase NH_3 emissions and reduce the agronomic value of the final product (Hao and Chang, 2001). In the present work the fate of organic matter (OM) and nitrogen (N) during the process of composting CSSF was studied with the aim of maximizing compost quality.

Two CSSF (screw pressed at rates of 1 m^3 h^{-1} and 3 m^3 h^{-1}) with 30% and 24% dry matter (DM) content were collected at dairy farms located in NW Portugal during the winter of 2005. Both CSSF were composted: i) in outside piles with 15 m^3, without turning or with 5 turns, covered either with black polyethylene or with polypropylene (geotextile), which is permeable to the air but waterproof and; ii) inside an unheated greenhouse, in piles with 5 m^3, without turning or with 5 turns, either covered with black polyethylene or uncovered. The 16 piles were periodically sampled for chemical analysis, and compost temperatures of the piles were monitored automatically with a thermistor positioned in the centre of each pile. During composting, the average air temperature was 11ºC outside and 13ºC inside the greenhouse. Compost DM content, pH, electrical conductivity (EC), OM content and $N_{Kjeldahl}$ were determined by standard procedures (CEN, 1999), and compost mineral N was analysed by molecular absorption spectroscopy, after extraction with 2 M KCl. Losses of OM were calculated according to the following equation:
OM loss (%) = $100 - 100[x_1(100-x_2)]/[x_2(100-x_1)]$;
where x_1 and x_2 are the initial and final ash contents, respectively (Paredes, et al., 2000).

Thermophilic temperatures (> 55ºC) were attained soon after separation of CSSF, except for the outside static piles covered with polyethylene, which did not reach temperatures high enough to ensure effective destruction of pathogens and viable weed seeds. Piles covered with geotextile or uncovered reached higher temperatures compared with polyethylene, due to the restriction in oxygen caused by the polyethylene. Pile temperatures declined slowly to air temperature between one and five months of composting, except for smaller static piles where low temperatures were attained 3 months after composting was initiated. The pH of CSSF was alkaline (8-9) during the thermophilic phase of composting, increasing the potential for NH_3 volatilization. Turning frequency, pile dimension and cover type did not affect the pH or the EC of the composts.

Organic matter of initial CSSF decreased from a maximum of 91% to a minimum of 70% after 5 months of composting. The concentration (%) of N increased almost linearly with the OM (%) decrease according to the following equation:

$N = 16.326 – 0.165\ OM$ ($n = 448$; $r^2 =0,897$***).

Mineralization of OM, based on OM losses, followed a first order kinetic equation:

$OM_m = A\ (1-e^{-kt})$;

where OM_m indicates the mineralized OM (%) at the time t (days), A the maximum mineralisable OM (%) and k the rate of mineralization. This rate increased for turned piles (k=0.0277) in comparison to static piles (k=0.0092), but maximum mineralisable OM (63-67%) was similar for all treatments. Initial rates of OM mineralization decreased with increasing pile size, indicating that smaller piles may accelerate the composting process, whereas the static piles with initially 30% DM showed increased rates of composting and took shorter time to reach maturity than the piles with initially 24% DM.

Smaller piles, turning operations, and higher DM content of CSSF were associated with increased rates of OM degradation and N concentrations during the process of composting. An increase from 1.4% to 3.0 % $N_{Kjeldahl}$ (average of 8 treatments) was attained after 2 months of composting with turning in comparison to 5 months with static piles. The use of geotextile, in comparison with polyethylene, increased N compost concentration and improved composting efficiency in turned piles, as indicated by the higher temperatures. The C/N ratio declined with a similar pattern for all compost treatments, from over 35 to a value of 15 towards the end of composting, indicating an advanced degree of stabilization.

Mineral N was characterized by a high NH_4^+ and low NO_3^- content during the thermophilic phase of composting. Towards the end of composting, the content of NH_4^+-N decreased sharply and the content of NO_3^--N increased. Without turning, a higher DM value was associated with lower NH_4^+-N concentration. Therefore, increasing DM may reduce N loss. $N_{Kjeldahl}$ content was almost two- and three-fold greater, respectively, for static and turned piles (when approximately 52% and 65% of initial OM had been lost) than for the initial CSSF. Therefore, it is expected that N losses were small. N leaching risk should be almost nil either during the thermophilic phase of composting, since the NO_3^- content was very low, or during the maturation phase, since moisture content was not enough to leach NO_3^-, particularly for the inside uncovered piles. However, polyethylene, which is impermeable to air, prevented evaporation of water, resulting in more anaerobic conditions with increased leaching risk, although such a cover would also exclude rain and prevent oxygen replacement and, therefore, limit nitrification.

Mature compost can be obtained with raw CSSF after 5 months, as indicated by the low compost temperature, the low C/N ratio and the low amounts of NH_4^+, combined with the increase in NO_3^-. However, to improve compost efficiency and minimize N loss as NH_3 gas, it is recommended: i) to increase CSSF DM by slowing the rate of the screw dewatering mechanism; ii) to reduce pile turning frequency and; iii) to avoid polyethylene covers.

Acknowledgments
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References

CEN, 1999. European Standards - soil improvers and growing media. European Committee for Standardization.

Hao, X. and Chang, C., 2001. Gaseous NO, NO2, and NH3 loss during cattle feedlot manure composting. Phyton-annales Rei Botanicae, 41 (3): 81-93.

Paredes, C., Roig, A., Bernal, M. P., Sánchez-Monedero, M. A., and Cegarra, J., 2000. Evolution of organic matter and nitrogen during co-composting of olive mill wastewater with solid organic wastes. Biol. Fertil. Soils, 20: 226-236.

Anaerobic digestion and composting of the organic fraction of municipal solid waste: process control and quality

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The European Landfill Directive (1999/31/CEE) has caused the development of biological treatment as the clearest alternative management strategy for the biodegradable fraction of municipal solid waste (MSW).

Anaerobic digestion (AD) is often the most cost-effective treatment due to the high energy recovery linked to the process and its limited environmental impact. However, AD effluents are not generally suitable for direct application to land. Thus, it is generally accepted that post-treatment after AD is required to obtain a high-quality, finished product. A combination of AD materials recycling and co-compostage would probably be the best solution in avoiding disposal to landfill as much as possible.

The total amount of MSW generated in Madrid in 2005 was about 3 millions tonnes. Of this, 140.000 tonnes were treated in Pintos plant of Gedesma. The actual production of compost is about 19.500 t/y. This study was designed to evaluate the treatment's effect on the evolution characteristics of the organic fraction of municipal solid waste (OFMSW).

Figure 1 describes in schematic form the MSW treatment process of Gedesma Pintos plant: pre-treatment, AD of OFMSW and co-compostage of sludge. After the separation process of municipal solid waste, a mechanical pre-treatment takes place before the AD to increase the rate of degradation.

The AD (one stage "wet" system) process was performed in two continuous stirrer tank reactors (6.000 m^3 per tank) of first generation and low load and mesophilic range (38 ± 1ºC). The hydraulic retention time (HRT) was 32 days and the organic loading rate 1.3 kg TSV / $m^3 \cdot d$.

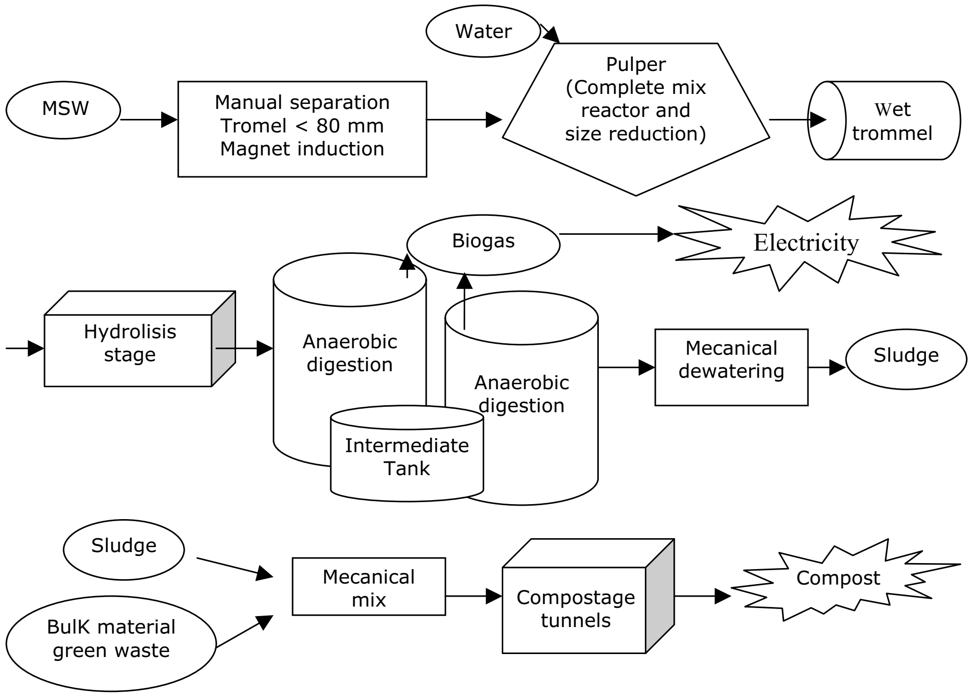

Figure 1. Process diagram of Pintos Plant.

The specific gas production (SGP) was 0.33 m^3 /kg TSV·d and the percentage of CH4 60 ± 5 %.

The most relevant characteristics of the input and effluent substrates of AD process are presented in Table 1.

After AD, a post treatment co-compostage of dewatered (by centrifugation) effluent and green waste as the bulk material (1:1, w/w) produces a high-quality finished product.

This process takes place within 12 tunnels of 500 m^3 for 21 days with forced aeration at 55 ºC. The process finishes with a size selector which supplies homogeneously sized material suitable for use as soil compost. The following table shows the chemical and microbiological characteristics of the final product.

Table 1. Characteristics of the input and effluent substrates of the AD process of OFMSW.

Parameters	Unit Measurements	
	OFMSW Input	SLUDGE Effluent
PH	6.8 ± 0.2	7.9 ± 0.2
Conductivity, mS/cm	28 ± 1.2	3.8 ± 0.6
DBO_5, ppm	7450 ± 420	1200 ± 226
TS , g/kg	41.7 ± 5	298 ± 22
TVS, % TS	60.3 ± 3.1	42.6 ± 3.9
STS, % TS	11.3 ± 1.2	2.9 ± 0.4
TKN, %	6.5 ± 0.3	1.3 ± 0.5
NH_4–N, mg/l	4.4 ± 0.2	0.9 ± 0.1
Ratio C/N	5.4 ± 0.8	19.0 ± 1.9
P2O5, %TS	0.3 ± 0.06	0.64 ± 0.07
K2O, %TS	1.6 ± 0.3	1.1 ± 0.4

Table 2. Characteristics of green waste and compost (dry matter basis).

Parameter	Green waste	Compost
PH	5.5 ± 0.2	8,0 ± 0.2
Conductivity, (mS/cm)	2.3 ± 0.3	1,4 ± 0.3
TS , g/kg	49 ± 2.5	611,0 ± 25
TVS, % TS	81.5 ± 3.3	43,0 ± 2.6
TKN, g/kg	16.4 ± 0.9	21,0 ± 2.0
NH4–N, mg/l	3.5 ± 0.4	5,6 ± 0.4
Ratio C/N	17.4 ± 1.0	11,9 ± 0.4
P2O5, %TS	0.7 ± 0.1	0,5 ± 0.08
K2O, %TS	0.7 ± 0.1	0,8 ± 0.07
Ca, mg/kg	-	3,7 ± 0.2
Mg, mg/kg	-	0,7 ± 0.06
Escherichia Coli, NMP/g	-	400 ± 95
Salmonellas,25 g	-	Absent

Table 3. Limit values of heavy metals for compost.

Heavy metal	Concentration Limits (mg/kg dry matter)			Pintos Compost
	Class A	Class B	Class C	
Cadmiun	0.7	2	3	0,9 ± 0.1
Copper	70	300	400	78,5 ± 3.2
Nickel	25	90	100	14,9 ± 2.1
Lead	45	150	200	78,6 ± 5.8
Zinc	200	500	1000	301.8 ± 9.6
Mercury	0.4	1.5	2.5	0.16 ± 0.02
Total chromium	70	250	300	30,2 ± 4.6
Chomium (VI)	0	0	0	0

The “Fertilisers and Derivatives” Royal Decree 824/2005 establishes threshold values for heavy metals and pathogens and defines types and categories of compost (A, B and C). Table 3 shows that the final Pintos compost corresponds to a class B compost.

Improving the treatment of slaughterhouse wastewaters by reed bed filters

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Introduction

Reed bed filters were first employed for wastewater treatment in 1960 in Germany, by Dr. K. Seidel (*Arceivala, 2002*). These systems consist of waterproof pools inside which various marsh plants, such as reed (*Phragmites* sp.), cattail (*Typha latifolia*), giant rush (*Juncus ingens*) etc. are grown, which increase the efficiency of the cleaning process.
In 1995, over 200 of such wastewater purification systems were in use all over Europe, most of them in Denmark, Germany and Great Britain. Among the East European countries, Czech Republic employs this system on a large scale as an alternative method for cleaning the wastewaters (*Vymazal, 2002*). The use of the reed bed filters is extensive: farms, municipal wastewater treatment plants, slaughterhouses etc. (*Finlayson and Chick, 1983*).

Our study attempted to assess the efficiency of such a system for cleaning the wastewater from a slaughterhouse.

Materials and Methods

The slaughterhouse is situated near Vâlcele (Cluj county) and slaughters a mean of 25 cattle and 120 swine monthly. For cleaning of its wastewater, this slaughterhouse employs a single settling tank, from where the water is evacuated into a minor dried-up riverbed. 180 meters farther, the outflow water enters the Valea Racilor stream.

A pool with a surface of 16 m^2 and a mean depth of 40 cm was established in the riverbed, and cattail was planted (8 plants/m^2). Water samples were taken at the outflow of the pool and at the point were the water reached the stream, both before and 7 days after establishing the reed sedimentation pool.

The following parameters were determined: sediment - with Imhoff cones; total suspensions - by centrifugation method; electric conductivity - with electronic conductivity-meter; dry matter - at 105 °C, after centrifugation; pH - with electronic pH-meter; ammonium - by distillation;
Calcium - by titration, with EDTA; chemical oxygen demand - potassium permanganate method; biochemical oxygen demand - Winkler method; total number of mesophilic germs (TNMG) - with nutrient agar; most probable number of total coliforms and fecal coliforms - the multiple test tubes method, with lactose broth for the presumptive test, and with Levine medium for the confirmation of total coliforms and brilliant bile broth for the confirmation of feces coliforms.

Results and Discussion

The results are given in the following tables:

Table 1. Physical and chemical parameters

Parameter	Without vegetal filter		With vegetal filter	
	Settling tank outlet	Stream inlet	Settling tank outlet	Stream inlet
sediment (ml/L)	0	0	0.4	0
total suspensions (mg/L)	1384	1234	2242	1380
conductivity (μS/cm)	556	635	1313	677
dry matter (mg/L)	716	717	623.4	406.3
pH	7.57	7.50	7.69	7.74
ammonium (mg/L)	7.4	6.2	50.5	18.0
COD-Mn (mg/L)	30.4	22.5	57.2	19.1
BOD_5 (mg/L)	28.4	18.1	48.1	9.7

Table 2. Bacteriological parameters

Parameter	Without vegetal filter		With vegetal filter	
	Settling tank outlet	Stream inlet	Settling tank outlet	Stream inlet
TNMG (cfu/mL)	97300	57500	38800	11000
total coliforms (MPN/100mL)	160900	91800	542000	91800
feces coliforms (MPN/100mL)	160900	27800	542000	91800

Analyzing the results, the following findings can be mentioned:

- low-sediment before, as well as after the reed bed filters were established;
- total suspension decreased with 10% without the vegetal filters, and decreased with 38% with vegetal filters;
- conductivity increased with 14% without the vegetal filters, and decreased with 48% after their usage;
- dry matter had similar values without the vegetal filters, but decreased with 34% with the vegetal filters;
- pH had similar values in both treatments;
- ammonium decreased with 15%, respectively 64%;
- COD-Mn decreased with 26%, respectively 66%;
- BOD_5 decreased with 36%, respectively 79%;
- bacteriological parameters decreased with a percentage, between 40 and 82 without vegetal filters, respectively between 71 and 83 after vegetal filters usage.

Although we have no results from winter season - our research being performed in June – a study by *Rousseau et al* (2004) indicated that the wastewater purification system with reed bed filters is also efficient in the cold season, as the decrease in BOD_5, total suspensions, and phosphorus was independent of temperature. However, low temperatures have a negative influence on ammonium removal (*Vymazal, 2002*).

Conclusions

It was shown that the employment of the reed bed filter considerably increased the cleaning efficiency. This system might be a valuable and large-scale solution for slaughterhouses in our country.

Acknowledgments

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References

Arceivala, S.J., 2002. Wastewater treatment for pollution control. Tata McGraw-Hill, New Delhi.

Finlayson, C.M., Chick, A.J., 1983. Testing the potential of aquatic plants to treat abattoir effluent. Water Research, 17(4), 415-422.

Vymazal, J., 2002. The use of sub-surface constructed wetlands for wastewater treatment in the Czech Republic: 10 years experience. Ecological Engineering, 18, 633-646.

Rousseau, D., Vanrolleghem, P.A., Pauw,N.D., 2004. Model-based design of horizontal subsurface flow constructed treatment wetlands: a review. Water Research, 38, 1484-1493.

Manure management technologies in Poland: costs and environmental impacts

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The previous 15 years has been a period of great changes in Polish agriculture. In the period 1990-99 an introduction of market economy caused up to 70% income decreases per ha. In turn the necessity of application of new norms in the field of environmental protection in relation with the Polish accession to the EU means that Polish farms face succeeding deep changes and investments.

The traditional technology for farmyard manure management on Polish farms consists of anaerobic storage in big windrows usually placed directly on the field. This is related to a lack of platform areas for manure storage which was estimated in the year 2000 to be about 12 mill. m^2. However, anaerobic storage of manure heaps directly on the field will be forbidden in Poland after 2008. The aim of this work was to evaluate the possibility of replacing the traditional technology by aeration, mechanised with tractor aerator and disc spreader in view of the small investment potential characteristic of less developed European countries. This paper presents a comparison between the traditional technology of anaerobic manure storage and the modern method of manure composting.

Materials and methods

The methodology included analysis of changes in physical, chemical and microbiological parameters of cattle and pig manures with both technologies, measuring NH_3, CO_2 and CH_4 emissions (using dynamic chambers and Lockyer's tunnels), and calculating economic costs for using machinery during storage, composting, transport and spreading. The manure heaps were aerated using a tractor aerator and additionally manure spreader for comparing the costs of both machines usage. The cost of technologies was calculated using the methodology developed by IBMER (Muzalewski, 2002). This research was a part of multiinstitutional grant "Gaseous emissions in different technologies of manure management", financed by the Polish government for the years 2001-2003.

Results

The results of experiments carried out on 18 manure heaps showed strong differences in characteristics between manure stored under anaerobic conditions and manure composted with use of a tractor aerator. The decrease of manure heap mass stored under anaerobic conditions was lower (12-28%) than when composted (28-52%). These large weight losses in composted heaps were created by strong vaporisation (dry matter increased about 15-28%) and CO_2 emission from decomposed organic matter (increase of ash content in compost). These effects were related to the high temperature (over 60^{o}C for at least 6 days, including winter conditions) during the composting process.

The average loss of total nitrogen was lower in manure stored under anaerobic conditions (9.7%) than when composted (11.9%). These losses were similar to those obtained by Sommer (2001) for composted deep litter (11.6%) and smaller for compacted manure (18%). Ammonia emission from composted manure was noticed only during the first 3-5 days (with some small increase after second aeration in the case of some heaps), being highest during the first hours after the initial aeration (17-38 g of $N\text{-}NH_4$ from 1 ton of dry matter per hour). Total nitrogen losses were 1.43-3.19 times lower than the decrease of ammonium content, which means that much of $N\text{-}NH_4$ was transformed into organic nitrogen by micro-organisms This was related to the growth of thermophilic bacteria from 4.2×10^{6} to 1.36×10^{7} in composted manure. In manure stored under anaerobic conditions both termophilic and mesophilic micro-organism were reduced in numbers from, respectively, 4.2×10^{6} to 8.5×10^{5} and 4.68×10^{11} to 1.66×10^{8}. However, the relatively smaller decrease of $N\text{-}NH_4$ in manure during anaerobic storage (on average 28%) than in composted manure (80%) suggested that losses of ammonia could occur during transport and spreading of non-composted manure.

The losses of ammonia after spreading of anaerobically stored manure showed a huge influence of weather conditions (cumulative losses between 51% of initial $N\text{-}NH_4$ for summer period to only 5% for an experiment carried out in November). In contrast, the measurement of ammonia emission after spreading of compost using the same Lockyer's tunnels showed no ammonia losses. These results show clearly that total ammonia losses in manure management can be higher with the traditional, anaerobic technology (especially for spreading made during sunny, windy weather) than for manure composted with tractor aerator. This conclusion differs from the results obtained by Amon et al. (1998) using a smaller heap scale and manual manure aerations. The way of aeration, the time and especially surface/volume ratio can have a strong impact on the results of ammonia emissions during storage and composting of manure heaps.

Differently from the anaerobic manure storage, no significant nitrates and potassium leaching was measured from compost heaps because of the fast increase in dry matter content (i.e. drying) and buffer capacity.

The total yearly costs of mechanisation of traditional cattle manure management for a farm with 30 big animal units (DJP) was estimated to be 11146 PLN/year (2933 €). However, for the same farm the costs of aerobic technology reached only 5971 PLN/year (1571 €). This difference was related to the large reduction (reaching 52%) of manure mass during composting which was created mostly by high water vaporisation. This fact decreases strongly the costs of compost transport and spreading. The average cost of spreading of anaerobically stored manure (15.5 PLN/t; 4.01 €/t) was a little bit higher than for compost (12.7 PLN/t; 3.34 €/t). However, the real difference is much higher because the dose of manure spread (30 t ha^{-1}) is twice as high as the adequate rate of compost (15 t ha^{-1}). This is related with the strong evaporation of water during composting and 2-3 times higher content of dry matter in compost than in farmyard manure.

Costs were calculated for a 20-year investment for a manure platform for storage and – as an alternative technology – the costs for a group of 5 type-farms (each of 1200 fattening pig/year) for buying and using a tractor aerator for composting manure directly on the ground. This comparison showed that under Polish conditions the total cost of investment for a manure platform is 4-8 times higher than for composting with aerator. Usage of a manure spreader for aeration would be 8-13 times more expensive due to very low efficiency of this machine compared with an aerator.

Conclusion

In conclusion of the research carried out, the authors would like to highlight that the technology of composting is under Polish farm conditions more economic than traditional manure management technology. This is related to the lower costs for transport and spreading of compost compared with farmyard manure. Unfortunately, unlike some other EU countries (like France), Polish law is very restrictive in this area and forbids to compost manure directly on the ground. However, this and many other studies have proved that this does not create any risk for soil and groundwater.

References

Amon B., Boxberger J., Amon T. Zaussinger A., Pollinger A. 1998 Emissions of NH3, N2O and CH4 from a tying stall for milking cows, during storage of solid manure and after spreading. Ramiran 98. Vol. 1, Cemagref Editions: 279-292.

Muzalewski A. 2002 The costs of machines exploitation (in Polish). IBMER, nr 15.

Sommer S.G. 2001 Effect of composting on nutrient loss and nitrogen availability of cattle deep litter. European Journal of Agronomy 1,4 123–133.

Effect of natural zeolite, a slurry additive, on physicochemical slurry properties and aerial ammonia concentration in the pig farm nursery

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Abstract: The present study was conducted in a control and experimental unit of the nursery on a pig-breeding farm. The commercial preparation, a natural zeolite containing 55% clinoptilolite, was spread directly on the partially slatted floor in a dose of 1 kg/50 m^2, as recommended by the supplier. The aim was to asses its effect on the aerial ammonia concentrations and physicochemical slurry properties. The results showed an aerial ammonia reduction of 15 %. Direct sprinkling of the additive on the slatted floor influenced physicochemical parameters which are indicators for the organic loading, as well as the concentration of nitrogen compounds specially ammonium ion reduction for 16 %.

Introduction

Zeolites are naturally occurring three-dimensional, microporous, hydrated aluminosilicate minerals which remove ammonia and ammoinum ion from slurry by trapping and exchanging them in its crystalline structure. Clinoptilolite has a specific affinity for ammonia, whose aerial concentrations are usually lower in nursery units than in the fattening units. Aerial concentrations pro rata of feces and urine depends on concentrations of ammonium ions and ammonia, temperature and pH in the slurry.

In the present study, the effect of a commercial zeolite preparation, "Pigozen", added to the piglet slurry in a nursery unit, was assessed in terms of aerial ammonia and physicochemical composition of the slurry.

Material and methods

The study was conducted in nursery units of a pig-breeding farm during a winter period. The piglets were housed in two identical nurseries, in boxes each with 30 animals. They were kept under standard keeping conditions for about 50 days.

The additive was spread over the slatted floor of one of the boxes in a dose of 1 kg/50 m^2. Air pollution, i.e. CO_2 and NH_3 concentrations were determined weekly by a Dräger - Acuro gas detector pump with detector tubes. Samples of pig slurry were taken from the channel under the floor. Standard physicochemical parameters were analyzed in accordance with standard methods on an HACH DREL/4000 chemistry/apparatus module.

Results

The results are presented as means of 7 weekly measurements (n=7) in Tables 1, 2, and 3.

Table 1. Microclimatic parameters and air pollutants in the nursery units

Parameter	Control unit	Experimental unit
Temperature ^oC	24.2	24.6
Relative humidity %	70.1	71.8
Air velocity ms^{-1}	0.09	0.08
Carbon dioxide CO_2 % by vol.	0.16	0.19
Ammonia NH_3 ppm	4.04	3.44
Reduction of NH_3 in comparison with control %		15

Table 2. Physicochemical parameters in the slurry from the nursery units

Parameter	Control unit	Experimental unit
Dry matter %	7.1	10.5
Inorganic dry matter %	24.1	32.0
COD - Mn consuming capacity mg O_2L^{-1}	9125	8664
Biochemical oxygen demand mgO_2L^{-1}	6764	6023

Table 3. Level of nitrogen compounds in the slurry from the nursery units

Parameter	Control unit	Experimental unit	Reduction %
Ammonium NH_4-N mgL^{-1}	1880	1572	16
Nitrite NO_2-N mgL^{-1}	6,4	6.9	-
Nitrate NO_3-N mgL^{-1}	2385	1928	19

Discussion and conclusion

The health and productivity of piglets are greatly influenced by microclimatic parameters. Their values, as measured in this study, met the criteria set for the respective animal species and category and were found to be comparable between the control and experimental units. The effect of the slurry additive was reflected in a considerable difference in aerial contamination, especially with ammonia, between the control and experimental nursery units where it inhibited the emission of ammonia from animal excreta, thus improving the housing microclimate. During the study period, the concentration of ammonia in the experimental unit was reduced by some 15% on an average (Table 1).

Zeolite influenced physicochemical parameters in the slurry (Table 2) which differed between experimental groups with respect to pH value, and the dry matter content, which was raised about 3%, as well as its inorganic part. Parameters which are indicators for the organic loading, COD-Mn and BOD_5, did not change significantly. The addition of zeolite to slurry reduced the concentration of ammonium and nitrate ions by about 16% and 19 %, respectively (Table 3).

Accordingly, the addition of zeolite additive to slurry appears to improve the housing microclimate due to reduction of aerial ammonia, which could be the consequence of reducing concentrations of ammonium and nitrate ions in slurry. Our results suggest that a higher additive dosage may be associated with better results as expected, based on the zeolite properties and potential utilization in animal hygiene.

References

Farkaš A.,2004. Natural zeolite as ammonia absorbent. Doctoral dissertation. Faculty of Chemical Engineering and Technology, University of Zagreb, Croatia.

Milić D., Tofant A., Vučemilo M., Venglovský J and Ondrašovičová O.,2005. The performance of natural zeolite as a feed additive in reducing aerial ammonia and slurry ammonium ion concentration in the pig farm nursery. Folia Veterinaria 49, 3 : Supplementum, 23-25.

Nutrient recovery from ash after incineration of organic residues

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Organic residues (sewage sludge, biomass, manure) contain significant amounts of nutrients and organic matter that have justified their cheap disposal on cropland. In recent years, however, many plant and soil scientists, public authorities and food industry companies have called for restrictions on uncontrolled spreading of organic residues on cropland because of constant (PAHs, phthalates) or increasing (PBDEs, Bisphenol A, hormones, antibiotics etc.) concentrations of organic pollutants and heavy metals that are partly accumulated in soils and may be transferred to the food chain. Moreover, intensive cattle and pig farming produces increasing quantities of manure that may lead to over-fertilization of croplands and eutrophication of aquatic bodies.

An alternative and safe disposal route for organic residues is incineration that makes use of the calorific value of organics, yields energy, destroys the organic pollutants and concentrates inorganic pollutants and most nutrients – except nitrogen that is lost to the atmosphere - in the ash. Most sludge-, manure- and biomass ashes contain P and K (15-25%), Ca (20-30%), Si (15-25%), Fe (10-20%) and trace nutrients. Because of their commonly high concentrations of copper, zinc, lead and cadmium and their limited usability as a fertilizer (dust, insufficient nutrient plant availability) untreated ashes are frequently banned from application on crop- or woodland and are disposed of in landfills, where nutrients are lost or may even adversely affect water bodies.

In Europe, more than 10% of P in the anthropogenic cycle is currently lost in ashes disposed of in landfills. Growing utilization of biomass for energy generation will increase the depletion of P, a scarce and non-replaceable resource that is vital for every living organism. Phosphate rock static reserve estimates vary from only 100 to 150 years and sedimentary phosphate rock deposits (87% of global reserves) contain high levels of cadmium (>20 mg/kg) and uranium (>100 mg/kg) that usually are transferred to P-fertilizers and subsequently accumulated in soils.

To minimize adverse effects of biomass-to-energy concepts, ash must be converted to a P-rich fertilizer raw material. The selected technological approach is a thermo-chemical ash treatment at around 1.000°C that removes harmful heavy metals and makes P fully plant available.

During this process, ash is mixed with about 10wt% of chlorine solutions to a slurry from which solid granules are formed. These granules are dried, fed to a gas fired rotary kiln and exposed to a temperature of 900-1.100°C. Chlorine additives and heat induce 85-97% of cadmium, copper, lead and zinc, usually the elements in critical or toxic concentrations, to evaporate in the form of aerosols from which the heavy metals are extracted in a 3-stage gas cleaning system.

95% of the nutrients are transferred from ashes to granules that normally will be used as a semi-finished product from which multinutrient fertilizers (PK, NP or NPK) in accordance with market, crop and soil requirements will be manufactured. They meet the limits for harmful substances set by the most stringent European Fertilizer Ordinances and have much lower cadmium concentrations than standard mineral phosphate fertilizers.

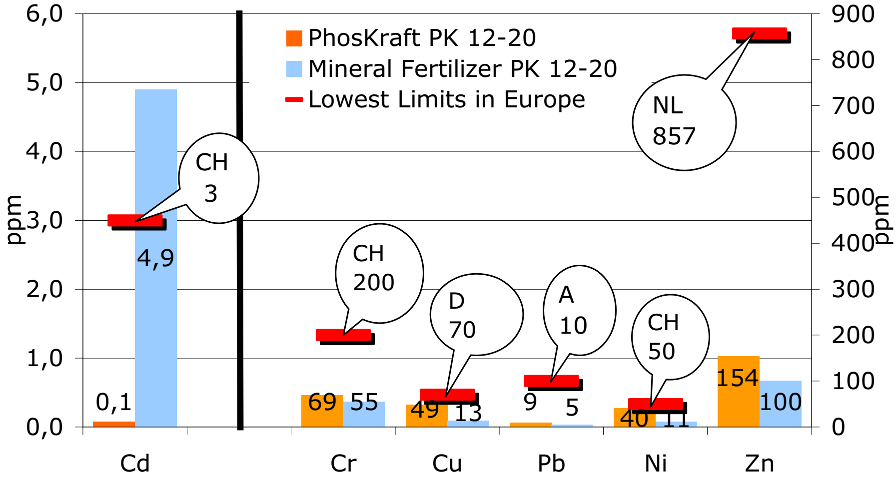

Figure 1. Heavy metal concentrations in a multinutrient fertilizer from sludge ash in comparison to standard mineral fertilizers and most stringent European limits.

The excellent yield and phosphorus plant uptake from the sludge based PhosKraft® multinutrient fertilizer – at same or superior levels compared to conventional mineral fertilizers - has been proven in various pot tests conducted, among others, by the Austrian Agency for Food Security that has licensed the process and the product for regular use on crop- and woodland in accordance with the regulations of the Austrian Fertilizer Ordinance.

The proposed technology can recover 95% of phosphorus, potassium and other nutrients from ash after incineration of organic residues. In regions with high manure and sewage sludge production, more that 50% of phosphate rock imports may be replaced by local resources and on a global scale, up to 30%, without any risk of pollutants being accumulated in soils or transferred to the food chain. As a side effect, significant amounts of cadmium and uranium imports to soils can be avoided.

The technology has achieved industrial maturity and will be commercially implemented in a pilot plant close to Linz, Austria, operational from June 2007.

References

Patureau, D., Laforie, M., Lichtfouse, E., Caria, G., Denaix, L., Schmidt, J.E., 2006. Fate of LAS, NPE, PAH and PAE after sewage sludge spreading on agricultural soils: a 30-years field-scale recording. The Conference Proceedings, IWA Specialized Conference – Sustainable sludge management: state of the art, challenges and perspectives.

Herter, U., Külling, D., 2001. Risikoanalyse zur Abfalldüngerverwertung in der Landwirtschaft. Bericht der Eidgenössischen Forschungsanstalt für Agroökologie und Landbau FAL, Reckenholz, Zürich, im Auftrag des Bundesamtes für Landwirtschaft.

Eriksson, J.,2001. Concentrations of 61trace elements in sewage sludge, farmyard manure, mineral fertiliser; precipitation in oil and crops. Swedish Environmental Protection Agency, Report 5159.

Suntheim, L., Dittrich, B., 2000. Untersuchungen zur Phosphat-Düngewirkung von Klärschlämmen und Komposten. Jahrestagung der Arbeitsgemeinschaft landwirtschaftlicher Versuchsanstalten, Gmunden.

Dachler, M., 2002. Zufuhr von Cadmium durch Mineraldünger – die Situation in Europa. Jahrestagung der Arbeitsgemeinschaft landwirtschaftlicher Versuchsanstalten, Klosterneuburg.

Kratz, S., 2004. Uran in Düngemitteln. Uran-Umwelt-Unbehagen: Statusseminar am 14.Oktober 2004, Bundesforschungsinstitut für Landwirtschaft (FAL), Institut für Pflanzenernährung und Bodenkunde.

Kley, G., Köcher, P., Brenneis, R., Peplinksy, B., 2004. Möglichkeit der Nutzbarmachung von Klärschlammaschen durch thermochemische Behandlung – Ergebnisse experimenteller Untersuchungen. VDI Seminar 43-36-25: Klärschlamm / Tiermehl / Altholz / Biogene Abfälle, 12.-14.Februar 2004, München.

Werner, W., 2003. Complementary Nutrient Sources. IFA-FAO Agricultural Conference « Global Food Security and the Role of Sustainable Fertilization », Rome, 26-28 March 2003.

Prinzhorn, G., 2005. Phosphordünger aus Klärschlammaschen mit thermischer Schwermetallentfrachtung. Schriftenreihe WAR 167, Darmstadt.

Hahn, J. 2006. Neue Klärschlammstrategien dank Phosphorrückgewinnung. Österreichische Abfallwirtschaftstagung, 22.-23.März 2006, Wien.

Behaviour of the organic matter and related methane production during anaerobic degradation of stored slurries

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Natural degradation of livestock wastes during storage leads naturally to the release of methane (CH_4) to the atmosphere. Total CH_4 emissions from livestock wastes storage were estimated to 13.8 $Tg.yr^{-1}$ (Johnson et Ward, 1996). In France, these emissions accounted for 16% of the national CH_4 emissions (CITEPA, 2002). Methane producing capacity of slurries can vary for given animal type depending on its age, and from one animal type to another. These variations could be related to the slurry compositions, particularly to the organic matter characteristics. The positive contributions of volatile fatty acids (VFA), protein, cellulose and hemicelluloses, and the negative role of lignin, were shown by Chandler *et al.* (1980) and Møller *et al.* (2004).

The aims of this work were to study (1) organic matter transformations during anaerobic storage of slurries and (2) the influence of the organic matter characteristics on the CH_4 production. For this purpose, the organic matter fractions of thirteen raw slurries were characterised before and after anaerobic storage. Moreover, the initial organic matter characteristics of these slurries were compared to their ultimate CH_4 production.

Thirteen slurries covering various animal types (pig, bovine and duck), age classes, feed regimes and manure management systems, were studied. Storage of the slurries was simulated in 250-1000 mL glass bottles during 120-150 days at 30°C. During the simulated storage, biogas production was monitored by pressure measurement. Gas samples were collected and analysed for CH_4. At the beginning and at the end of the storage experiments, slurries samples were taken for volatile solid (VS), chemical oxygen demand (COD), organic carbon (OC) and total VFA determinations. Organic fractions characteristics were also determined through van Soest extractions (van Soest and Wine, 1967). The ultimate

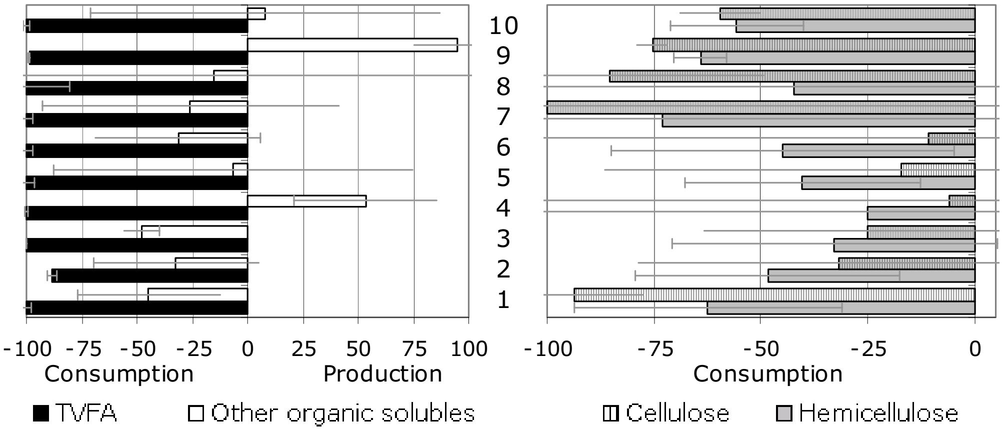


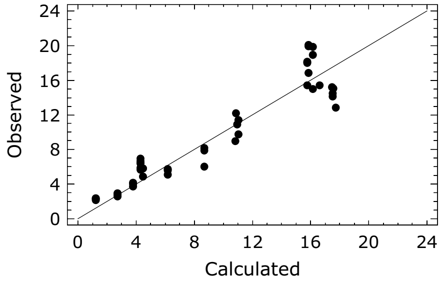
Figure 1. Changes (consumption or production) in the initial biochemical fractions of slurries after anaerobic storage (results are expressed as percentage deviations from the initial content). Slurries 1 to 6 were from swine, slurries 7 to 10 were from bovine.

CH_4 productions of 12 slurries were determined in batch experiments at 30°C after dilution and inoculation of the slurries.

Among the 13 slurries studied, only the 10 slurries presenting a significant CH_4 production during the simulated-storage were used to evaluate the organic matter biodegradation. The total organic matter biodegradation rates (VS, COD, OC) varied from 16 to 58%. All initial TVFA (100%) and over 30% of the carbohydrate contents were consumed with a biodegradation that could significantly reach 94% for cellulose and 64% for hemicelluloses. Other organic solubles can be significantly produced (slurries 4 and 9) and could represent intermediates of particulate organic matter hydrolysis and TVFA production (Figure 1). The lignin content was always stable during anaerobic degradation disregarding extraction uncertainty (data not shown).

A statistical approach allowed us to determine significant relations between the organic matter initial composition and the ultimate CH_4 production. As shown in Figure 2a, the VS contents allowed a good prediction of the maximum CH_4 production of the 12 slurries. Taking into account the organic matter characteristics improved slightly the prediction (Figure 2b). According to these results, TVFA is the more significant

a - VS fraction (r^2 = 96,79%)	**b - van Soest and TVFA fractions** (r^2 = 98,38%)
CH_4-C = 0.16*VS	**CH_4-C** = 0.49*TVFA + 0.27*Other organic solubles + 0.14*Carbohydrates – 0,32*Lignin



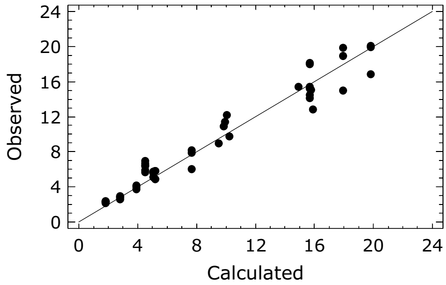


Figure 2. Statistical relation (p<5%) between CH_4 production (in g CH_4-C.L^{-1} slurry) and organic matter content (in g.L^{-1}) : a -with VS and b -with 4 organic fractions (VFA and van Soest).

fraction responsible for CH_4 emissions, while the lignin fraction seems to limit CH_4 production.

The results obtained during this study are in agreement with other works, such as Chandler *et al.* (1980), and allowed us to determine a relation between organic matter and maximum CH_4 production. According to our results, CH_4 production is more strongly connected to the VS content than to its quality, especially for the lower volatile solid content.

References

Chandler J. A., Jewell W. J., Gossett J. M., Van Soest P. J. and Robertson, J. B. (1980). Predicting Methane Fermentation Biodegradability. Biotechnology and Bioengineering Symp. 10: 93-107.

CITEPA. Inventaire des émissions de gaz à effet de serre en France au titre de la Convention Cadre des Nations Unies sur les Changements Climatiques, Format CCNUCC (décembre 2004).

Møller H. B., Sommer S. G. and Ahring B. K. (2004a). Methane productivity of manure, straw and solid fractions of manure. Biomass and Bioenergy 26 : 485-495.

*Johnson D. E. and Ward G. M. (1996). Estimates of animal methane emissions. Environmental Monitoring and Assessment **42**: 133-141.*

Van Soest P. J. and Wine R. H. (1967). Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. Journal of the A.O.A.C. 50 (1): 50-55.

A new technology to process swine manure

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Liquid manure (slurry) contains about 95% water by weight. Slurry has a low concentration of nutrients, and thus the costs of transport and application are high. Application of liquid manure causes many problems during a short growing season in Finland, and in intensive livestock areas the risk of nutrient losses to the environment is high. Also the odour of manure is problematic.

At MTT Agrifood Research Institute in Finland a new microbiology mediated technology is being developed, which effectively decreases the odour of liquid manure and enables fractionation of the processed manure to humus, water and concentrated phosphorus and nitrogen fertilizer (Fig. 1).

Microbial processing is based on an amendment of a selected and enriched soil microbe population. The process chain consists of six incubation chambers, and feedback is used to stabilize and intensify the reaction chain (Fig. 2). During processing, liquid manure is changed to an odourless form. Also, NH_3 is separated and collected, and the organic molecules are changed to a form where they are easy to precipitate and separate. NH_3 formed during aeration is collected and saturated with water or acid. Residence time in each incubation chamber is 12 hours when 3 m^3 of slurry is processed in two days. After the process (and fractionation), the end products are NH_3, separated phosphorus fertilizer, humus and clean water (Fig. 1).

To separate the solid fraction of raw slurry from water is difficult because of many hardly precipitated solids. During microbial processing, water-soluble small molecules (e.g. water-soluble carbohydrates) disappear, and dark coloured humus-like high molecular weight molecules are formed. In this state, 30-50% of the water-soluble phosphorus is precipitated to the bottom of the container and is easy to separate from the liquid to use as a separate P fertilizer. Practically the rest of the water-soluble P is precipitated when, after microbial processing, calcium hydroxide and MgO are added to the liquid manure until pH 9.5-10 is reached to remove NH_3 from the processed liquid in stripping towers. Alkaline liquid manure is run down through the tower, while air is pumped from the bottom through the tower. After stripping, a small amount (1:1000) of ferric sulphate, aluminium sulphate and calcium carbonate is mixed with processed and stripped liquid manure. After this, liquid manure is slowly run through basins (residence time is three days) where organic matter is precipitated. The residual phosphorus is precipitated with the humus and is practically not plant available.

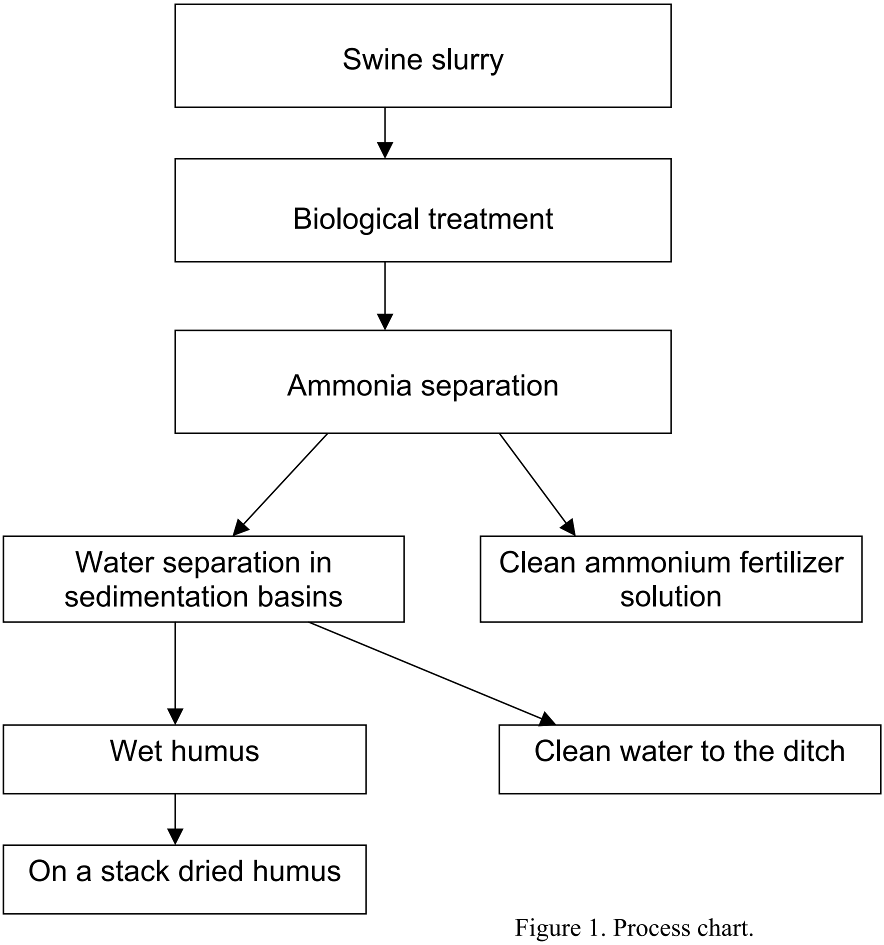

Figure 1. Process chart.

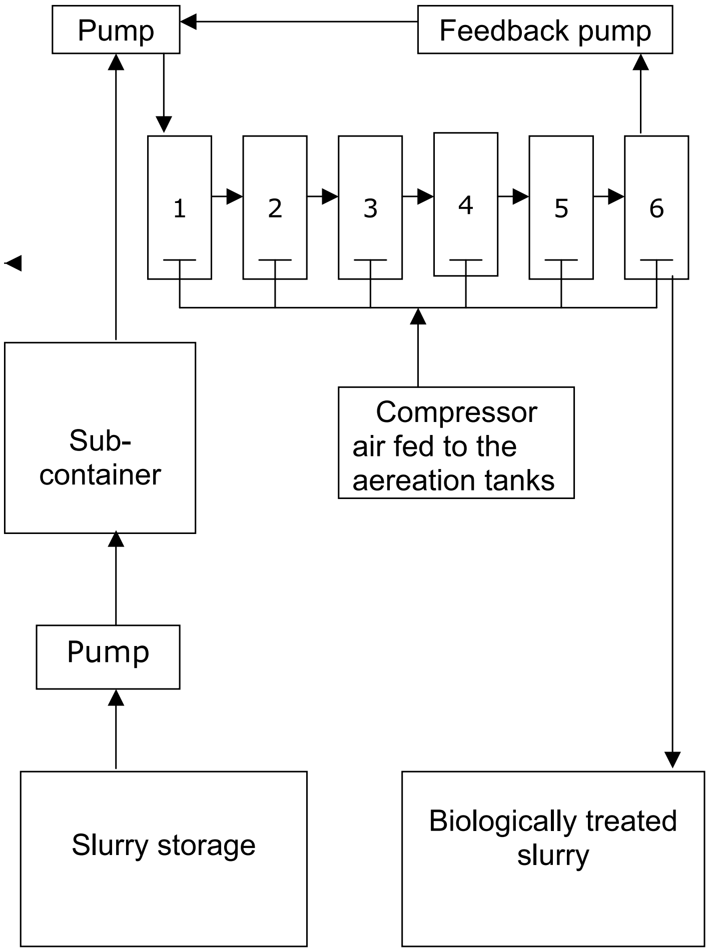

Figure 2. Biological treatment process chart.

The cost of this new technology is not higher than those for the present law provided storage and spreading of liquid manure. Preliminary results show that the quality of separated water is good and fulfils the standards of Finnish waste water obligatory standards. No faecal coliforms are found in the separated water. Separated humus contains considerably less faecal microbes than fresh manure. This new technology is very promising, and farm-scale processing will be started during summer (2006).

Nitrous oxide and methane emissions from unmanaged wet areas of intensive dairy systems

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Introduction

Nitrous oxide and methane are important greenhouse gases (GHGs), with agriculture estimated to contribute 66% and 41% to the UK's nitrous oxide and methane emissions, respectively (Baggott et al. 2006). Current methodologies for estimating GHG fluxes, cf. IPCC, acknowledge emissions from well-defined managed components of livestock production systems. However, they do not take into account the source strength of emissions from unmanaged, wet components of these systems, for example areas surrounding feeding and water troughs, seepage from solid and liquid manures, gateways, tracks and ditches. These wet areas could be significant sources of emissions due to the complex interactions between physical, chemical and climatic factors, e.g. between increased soil compaction and excretal N deposition around water troughs, tracks and gateways. A greater understanding of these interactions and the association with emission of nitrous oxide and methane would aid a) the estimation of the magnitude of these sources and b) the development of potential mitigation options to reduce emissions.

This study aimed to quantify nitrous oxide and methane emissions from unmanaged wet areas on dairy farms, and to examine the relationship between fluxes and the physical and chemical characteristics of these sources.

Methodology

Nitrous oxide and methane fluxes were measured from two commercial dairy farms on contrasting soil types, *viz*. clay loam and sandy loam. Fluxes were measured from within the extent and margins of a number of unmanaged wet areas identified within each farm. In addition, simultaneous flux measurements were made from adjacent pasture land as means of comparison. Measurements were made using the conventional closed chamber technique and gas chromatography. A modified floating chamber was used to measure flux from waterlogged areas. The number of chambers used on each occasion was varied to account for the spatial variation between source areas, and the frequency of sampling was optimised to account for seasonal variation and land management changes that could potentially affect GHG fluxes. After each flux measurement, soil samples were taken from within the flux chamber area and analysed for total nitrogen, nitrate and ammonium, total and soluble carbon, pH, bulk density, moisture content and water filled pore space.

Results

Preliminary results measured over a 12 month period starting May 2005, indicate that fluxes of nitrous oxide and methane from unmanaged areas on both clay and sandy loam can be considerably higher than those from managed pasture (Tables 1 and 2). Areas of seepage from liquid manure stores accounted for the highest nitrous oxide fluxes from both soil types (758 g N_2O-N ha^{-1} d^{-1} from the clay loam, and 191.9 g N_2O-N ha^{-1} d^{-1} from the sandy loam). However, fluxes varied markedly across these areas of seepage, ranging from less than ambient to 8791.0 g N_2O-N ha^{-1} d^{-1} from the clay loam, and from less than ambient to 1609.8 g N_2O-N ha^{-1} d^{-1} from the sandy loam. These variations could be seen both across individual source areas and between sampling occasions.

Table 1. Mean nitrous oxide and methane emissions from unmanaged sources and managed pasture from a dairy farm on clay loam.

	Number of samples	Nitrous oxide (g N_2O-N $ha^{-1}d^{-1}$)	Methane (kg CH_4-C $ha^{-1}d^{-1}$)
Ditch	11	13.8 *(12.1)*	0.7 *(0.5)*
Gateways	87	40.4 *(11.8)*	3.2 *(1.1)*
Seepage - solid manure heaps	45	57.0 *(18.4)*	21.9 *(8.0)*
Seepage – liquid manure stores	85	758.0 *(201.7)*	37.5 *(5.6)*
Tracks	68	2.4 *(1.4)*	9.4 *(2.1)*
Water troughs	77	20.1 *(6.0)*	1.7 *(0.6)*
Woodland	28	105.1 *(107.6)*	31.2 *(20.5)*
Managed pasture	58	2.2 *(1.0)*	0.0 *(0.0)*

Standard error of means in parentheses

Methane emissions were also considerably higher from unmanaged wet areas. On the clay loam, areas of seepage from liquid manure stores accounted for the largest methane fluxes (37.5 kg CH_4-C ha^{-1} d^{-1}) although measurements taken from a woodland used by livestock also showed high emissions (31.2 kg CH_4-C ha^{-1} d^{-1}). On the sandy soil, fluxes measured from gateways, tracks and water troughs were also much higher than fluxes from managed pasture land (Table 2).

Table 2. Mean nitrous oxide and methane emissions from unmanaged sources and managed pasture from a dairy farm on sandy loam.

	Number of samples	Nitrous oxide (g N_2O-N ha^{-1} d^{-1})	Methane (kg CH_4-C ha^{-1} d^{-1})
Gateways	59	173.8 *(69.3)*	3.9 *(2.2)*
Seepage - solid manure heaps	35	66.2 *(28.6)*	9.6 *(3.9)*
Seepage - liquid manure stores	25	191.9 *(78.2)*	7.3 *(3.8)*
Tracks	66	19.4 *(9.0)*	24.3 *(4.3)*
Water troughs	78	182.0 *(60.0)*	7.2 *(2.0)*
Managed pasture	46	13.7 *(8.8)*	0.0 *(0.0)*

Standard error of means in parentheses

Results to date show no significant correlation between fluxes and the physical and chemical characteristics of the soil, although initial results indicate that moisture content, water filled pore space and nitrate concentrations are the most important factors influencing nitrous oxide emission from both soil types. Full analyses of all results on completion of the experimental work should provide a greater understanding of these complex interactions.

Preliminary results demonstrate that unmanaged wet patch areas can be significant sources of GHG emissions. The extent of each wet patch source and the proportional area of unmanaged areas to managed areas are being assessed on each farm, so that total emissions from these sources can be compared to traditionally cited agricultural sources such as excretal returns during grazing, manure spreading and fertiliser applications.

References

Baggott S.L., Brown L., Cardenas L., Downes M.K., Garnett E., Hobson M., Jackson J., Milne R., Mobbs D.C., Passant N., Thistlethwaite G., Thomson A. and Watterson J.D, 2006. UK Greenhouse Gas Inventory, 1990-2004: Annual Report for submission under the Framework Convention on Climate Change. AEA Technology plc, Didcot, UK, April 2006.

Research for climate protection: technological options for mitigation (Reclip:tom)

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Introduction

In 2005 a 3-year research project (reclip:tom) was initiated to suggest options for mitigation of Austria's national greenhouse gas emissions, and for the quantification of their potential and costs. For reclip:tom, Austria's national GHG emissions have been broken down into four sectors: energy, processes, agriculture, and soils. These are being dealt with within individual work packages, with the respective sector experts in charge. The identification and quantification of interactions between emission sectors is given high priority in reclip:tom.

Approach

Reclip:tom assesses the emissions of GHG for the year 2000 based on emission balances as published by the Austrian Federal Environment Agency. A "business-as-usual" scenario for the further development of emissions to the years 2020 and 2050 will be created using available and officially accorded activity projections and extrapolations. In each of the work packages, emission sources and mitigation measures have been identified.

Agricultural sector of reclip:tom

Emission estimates

The "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories" (IPCC, 1997) require emissions from the following categories to be quantified: CH_4 emissions from enteric fermentation, CH_4 and N_2O emissions from manure management, direct N_2O emissions from agricultural soils, and indirect N_2O emissions from N use in agriculture. The Austrian emission inventory estimates include the animal categories "cattle" (dairy cows > 2 years, mother, and suckling cows > 2 years, young cattle < 1 year, young cattle 1 – 2 years, cattle > 2 years), "swine" (fattening pigs > 50 kg, swine for breeding > 50 kg, young pigs < 50 kg), "sheep and goats", and "poultry" (chicken, other poultry). The Austrian emission inventory estimates GHG emissions according to the IPCC reporting guidelines (IPCC 1997) taking Austrian specific data into consideration, rather than default values, where possible (Amon et al. 2005).

Mitigation options and emission projections
A range of potential mitigation options has been proposed, and fed into reclip:tom. This section briefly summarises the most important mitigation options identified.

<u>CH_4 emissions from enteric fermentation</u> - CH_4 emissions from enteric fermentation of dairy cattle may be reduced through an increase in milk production per cow. This is achieved via more concentrate and less roughage feeding. Especially in Alpine regions, the cows´ diet is mainly based on grass, and ecological side effects of an increase in concentrate feeding must be considered. An overall reduction in meat consumption leads to a lower number of cattle and thus a reduction of CH_4 emissions from enteric fermentation. This is, however, only possible if consumers' habits change.

<u>CH_4 emissions from manure management</u> - CH_4 emissions from manure management may be reduced through manure treatment: either biogas production or separation of solids. Biogas production is mainly implemented for energy production reasons. Through slurry separation, organic carbon is mechanically separated. The remaining liquid fraction has a lower carbon content and thus a lower potential for CH_4 losses. With solid systems the aerobic composting of farmyard manure is a possible way to reduce CH_4 emissions.

<u>N_2O emissions from manure management</u> - As with CH_4 emissions, potential mitigation options include a reduction in meat consumption, biogas production, and the mechanical separation of solids. An increase in the percentage of grazing leads to a reduction in N_2O emissions from manure management. A further, very promising option is the matching of the N input in the diet to the animal's requirements. With pigs, this means the introduction of phase feeding.

<u>Direct N_2O emissions from agricultural soils</u> - Direct N_2O emissions from agricultural soils can be reduced through less mineral fertiliser application. N input must meet the crop's demand. A decrease in the number of

animals would reduce N input via animal manure. As with N_2O emissions from manure management, the matching of the N-content of the diet to the animal`s requirements reduces N excretion and consequently also direct N_2O emissions from agricultural soils.

Indirect N_2O emissions - Indirect N_2O emissions can only be reduced if the agricultural N surplus is reduced. It must be an aim to close the N cycle, to improve N usage and to reduce N surpluses.

Emission projections

Emission projections in the agricultural sector will to a great extent depend on the development of animal numbers. For Austria, emission projections until the year 2020 have been set up within the CAFE programme (Clean Air for Europe) of the EU. In Austria, a working group in collaboration with IIASA has projected animal numbers and emissions until the year 2020. They concluded the following general trends: A reduction in dairy cow numbers, a slight reduction in calf numbers, a slight increase in suckling cows, a slight increase in pig numbers, and no or little changes in sheep and goat numbers.

Outlook

Emissions sources and processes were identified and mitigation measures proposed. Possible side effects and interactions were also identified. In a next step, costs and mitigation potentials will be worked out. Extrapolation scenarios for the years 2010, 2020 and 2050 will be produced.

Acknowledgments

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http://systemsresearch.ac.at/projects/reclip.tom

References

IPCC, 1997. Revised 1996 Guidelines for National Greenhouse Gas Inventories, Vol.1: Reporting Instruction, Vol.2: Workbook, Vol.3: Reference Manual. Intergovermental Panal on Climate Change, Edited by J.T.Houghton, L.G.Meira Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs and B.A. Callander, Geneva.

Amon, B., Fröhlich, M., Hopfner-Sixt, K., Amon, T., 2005. Emission inventory for the Agricultural Sector in Austria: state of the art and future developments. In: Emissions from European Agriculture', Kuczynski, T., Dämmgen, U., Webb, J., Myczko, A. (Eds.), Wageningen Academic Publishers, 147 – 181.

Ammonia emission rates after application of slurry by different techniques in dry grasslands and arable fields in the Central Plateau of Spain

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Modern agriculture is the largest source of nitrogen releasing to other ecosystems. In Europe, the ammonia (NH_3) emission to air from agriculture (animal husbandry) is at the same level as the emission of nitrogen oxides from traffic and stationary combustion plants together (Ferm, 1998). Continuous control of NH_3 emissions will make a positive impact on the environment; a first plan has been adopted in the Gothenburg protocol (www.unece.org/env/lrtap/multi_h1.htm). At the same time, NH_3 emissions contribute to the acidification of soils (Moller and Schieferdecker, 1985), eutrophication of terrestrial ecosystems and surface waters (Roelofs, 1986), and constitute a large fraction of the fine particles that can affect human health and the radiation balance.

The land spreading of animal manure represents approximately one-third of the total NH_3 emissions from agriculture, so there has been much interest in the development of abatement measures in this area. There are three main types of slurry application systems in use: (1) broadcast spreader with a splash plate to distribute slurry onto the land; (2) band spreader that discharges slurry just above ground level in strips or bands; (3) trailing shoe spreader with a shoe added to each hose, allowing the slurry to be deposited onto the soil. The aim of this study, financed and coordinated by the Spanish Ministry of Agriculture, Fisheries and Food through a broader project carried out by Tragsega. S.A., was to evaluate the efficiency for reducing NH_3 loss of different slurry application techniques at field-scale on representative grassland and arable soils in the Central Plateau of Spain (Segovia). The application of similar nitrogen load in mineral fertilizer was used as control treatment. To test the reductions of NH_3 concentrations in the air, two experiments at field scale were performed (Table 1). Ammonia concentrations were measured with passive samplers.

Table 1. Experimental sites, located in Segovia (Spain)

Description of area	Treatments	Date
Basardilla -26 ha grassland -Crop height 10 cm -Uniform topography	Four 1200 m^2 rectangular plots (Splash plate, band spreader, trailing shoe, and mineral fertilizer)	02-04/08/2005
Valverde de Majano -20 ha arable soil -Uniform topography	Four 1200 m^2 rectangular plots (Splash plate and mineral fertilizer with and without incorporation within 6 hours)	14–19/09/2005

With the aim to optimize the experimental setup and select a correct plot orientation in both experiments, a meteorological tower was installed one month before the experiments were started at each of the study sites. Meteorological variables were also measured both before and during the experiments (wind speed, direction, temperature and radiation).

The same load of total nitrogen was applied in all treatments, and N-NH_3 concentration of the slurry was determined. To measure NH_3 concentrations in the atmosphere (Table 2), three types of passive samplers were used (diffusion tube with and without diffusion barrier, as described by Sanz et al. (2005), and box sampler type – Ferm type).

Table 2. Experimental schemes.

Experience	Nº sampling points	Sampling distances	Sampling heights	Time Collected	Background distance
Basardilla	30	Up to 200 m	1.8,2.5,3 m	6,12,24,48 h	1300 m
Valverde Majano	30	Up to 200 m	1.8,2.5,3 m	24,48,72, 120 h	1300 m

An approximation of the aerodynamic gradient method (Genermont et al., 1998) was employed to estimate the relative NH_3 emission rates for each plot at the different exposure times. A first approximation was made by considering that the K values were constant in plots, and that no substantial overlapping of the plumes generated by each plot was observed. The aim was not to obtain the accurate absolute emission rate values, but instead to compare emissions between treatments. Based on the relationship between fluxes and vertical concentration gradients, the flux reductions (%) relative to the reference treatment (splash plate) was obtained for each treatment/plot. In both experiments the NH_3 emissions for the mineral fertilizer application were near 0 µg/m^{2}s, whereas the broadcast spreading with splash plates resulted in the highest emissions. In the case of the grasslands, reductions of NH_3 observed within the 6 h after application were 67% for trailing shoe, and 51% for band spreader compared with the broadcast spreader technique (Fig. 1, left). On the other hand, in the arable soil, reductions of NH_3 were 64% for incorporation within 6 hours with 48 hours of exposition time (Fig. 1, right).

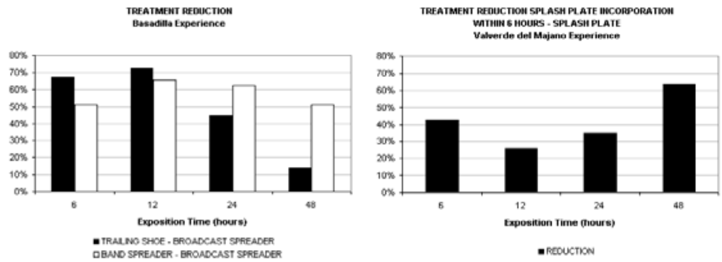

Figure 1. Ammonia rate reduction percentages – Exposition time;
(a) Basardilla – (b) Valverde del Majano

The slurry application systems evaluated were effective in the reduction of NH_3 loss from grassland and arable soils. In other studies, application techniques for slurry (shallow injection, band spreading and trailing shoe), resulted in reductions of NH_3 emission of 70-95% compared with surface broadcast application. However, earlier experiences using field-scale equipment and more recent trials with a small-plot applicator suggest that abatement efficiencies under different conditions may not be so high, according to our results.

References

Ferm, M. 1998. Atmospheric ammonia and ammonium transport in Europe and critical loads—a review. Nutrient Cycling in Agroecosystems 51, 5–17.

Genermont, S., Cellier,P., Flura, D., Morvant, T., Laville. 1998. Measuring Ammonia Fluxes after slurry spreading under actual field conditions. Atmospheric Environment, Vol 32, No 3, pp 279-284. Pasquill, F., 1961. The estimation of the dispersion of windborne material, Meteorol. Mag., Vol. 90,pp. 33-49.

Moller, D., Schieferdecker, H. 1985. A relationship between agricultural ammonia emissions and atmospheric sulphur dioxide content over industrial areas. Atmospheric Environment 19, 695–700.

Roelofs, J.G.M., 1986. The effect of air-borne sulphur and nitrogen deposition on aquatic and terrestrial heathland vegetation. Experimentia 42, 372–377.

Sanz, M.J., Monter, C., Antequera, C.R., Montalvo,G., Bigeriego, M. 2005. Influencia del sistema de aplicación de purines sobre las emisiones de amoniaco a la atmósfera en una explotación agrícola. Porci, Nº 87,55-68.

'Beef and chips' - environmentally friendly overwintering of cattle on woodchip pads

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Introduction

There is increasing interest, in the UK and Ireland, in the use of woodchip pads as an alternative to conventional, straw-bedded housing and concrete yards or the use of 'sacrifice' fields for out-wintering livestock. The many perceived benefits include low installation costs, low labour, reduced pasture damage and improved stock health, welfare and production. Woodchip *"corrals"*, within the original concept, are open-air enclosures, bedded with large woodchips. For the timber industry they constitute a promising outlet for small-sized round-wood and the potential saving in bedding costs is likely to be significant; at current straw costs, estimated at c. €100 per suckler cow, over a 4-month winter.

The woodchip corral is claimed to work as a biological treatment unit, reducing the pollutant load from dung and urine passing through and before entry into the freely drained subsoil. Woodchip *"stand-off"* pads, however, include either a compacted base (clay sites), or installation of a plastic liner. A drainage system collects the effluent for storage or land application, thereby avoiding the risk of direct, surface or groundwater contamination. This paper outlines the distribution and current state of development of pads in England and Wales and associated management benefits and problems, based on the findings of a scoping study commissioned by the Environment Agency during 2004/05. Potential environmental risks are considered, and the needs for further research.

Methodology

Information was collected via regional co-ordinators (in the N, the Midlands and SW England, and in Wales), who exploited contacts with farmers, farmer organisations (e.g. NFU) at local and national level, with other consultancy groups, the Environment Agency and with the farming press. The initial contact provided basic information on pad type, livestock, location, with more detailed data collected using a simple questionnaire and follow-up phone call to a selected sample (c. 30 farms).

Sampling and analysis of effluent, from a large pad in the Midlands stocked with dairy cows, was also undertaken on a weekly basis from January – March 2005.

Results

The study identified a total of 75 woodchip pads used for beef or dairy cattle, although subsequently a projected estimate of about 170 woodchip pads in England has been made based on annual Census data. Woodchip pads were concentrated on the W side of the country, in predominantly livestock areas. From the detailed site information, stocking densities averaged 14m^2/cow on stand-off pads and 16.5m^2/cow on corrals. Costs of construction ranged considerably, from €15/animal to €430/animal for a large corral built entirely by contractors (€150/animal overall), these being rather higher than have been reported elsewhere. However, these estimates did not always appear to include farm labour inputs, or a realistic assessment of the costs of effluent collection or storage. The depth of the woodchip bed ranged considerably (0.15m – 4.0m), with an average depth of 0.51m overall, 0.42m for corrals and 0.60m for stand-off pads (Figure 1).

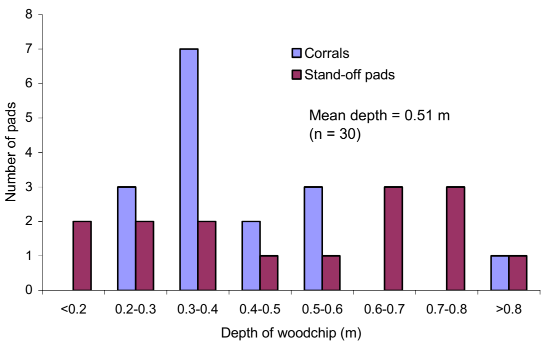

Figure 1. Depth of woodchip layer reported in corrals and stand-off pads

The average pad area was around 1500 m^2, overall, with *"hotspot"* areas (where dung solids are concentrated) noted on about half of these, of typically c. 70 m^2. From farmer comments, these *"hotspots"* are often related to the presence of trees or other shelter features; or, in other cases, to feed areas with restricted access or with concrete pads without adequate slurry management. In the latter case, it is important to provide a retaining lip or kerbstone to the concrete pad so that slurry can be scraped away rather than allowed to drain onto the woodchip.

There is little evidence, from limited research to date, including recently published work (Anon., 2005; French and Hickey, 2001) to substantiate claims of effluent biodegradation in the pads. Average effluent concentrations from the EA site study are shown in Table 1 and compared with other recent monitoring data. These average data disguise a wide variation in analysis; effluent quality failed to approach what might be considered relatively uncontaminated water. These results confirm the need for containment and recycling of the effluent from woodchip pads. It has been proposed that woodchip pads may provide some opportunity for mitigation of gaseous emissions from overwintered livestock; new research is proposed, to evaluate optimum woodchip pad design and management, and potential impact on gaseous (NH_3 and N_2O) emissions.

Table 1. Concentration of nutrients ($mg.l^{-1}$) in drainage collected from stand-off pads (Ireland and England) and corrals (Scotland); also comparison with typical analyses of cattle slurry and dirty water.

Site	COD	Total N	Total P	NH_4-N	BOD_5
Grange – pad effluent[1]	-	-	38.6	880	9856
Staffs – pad effluent[2]	9217	903	36.3	745	846
Staffs – slurry lagoon[3]	-	309	50.9	203	-
Scottish corrals[4]	-	337	94.7	191	-
Typical dirty water	*13500*	*850*	*410*	*460*	*6500*
Typical cattle slurry	*40000*	*4000*	*870*	*2000*	*20000*

Notes:

[1] - Grange, Ireland; average effluent quality, winters 2000/01 and 2001/02

[2] - Dairy unit, Staffs; average effluent analysis, Jan - March 2005

[3] - Dairy unit, Staffs; sampled from slurry lagoon, March 2005

[4] - Corrals in Scotland; average for the sampling period (Dec 2003 – Sept 2004)

Acknowledgement

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References

Anon., (2005). Flow and leachate characteristics of four woodchip corrals in Scotland. Report to the Scottish Executive. Project reference: CRE/001/03. Centre for Research into Environment and Health (CREH).

French P and Hickey M. (2001) Out-wintering pads as an accommodation system for beef cattle, Teagasc, Grange Research Centre.

Ammonia and greenhouse gas emissions from pig slurry – the effect of slurry fermentation, separation of the fermentation product and application technique

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Introduction

Biogas production from manure is an effective means of reducing greenhouse gas emissions from manure storages. In contrast, it is not well known how anaerobic digestion or application techniques affect the emissions after spreading of slurry on fields. In a biogas plant slurries can be refined to different products after the anaerobic treatment, for example by separation. Pig slurry contains more phosphorus than would be needed on livestock farms. Separation of the fermented slurry to a solid fraction with most of the phosphorus and a liquid fraction with most of the nitrogen would allow using the liquid fraction on the farms close to the biogas plant and transporting the more phosphorus-containing fraction cost-efficiently to farms farther from the plant with a P requirement. In this study we measured ammonia and greenhouse gas emissions after the use of the different products of a biogas plant on a barley field.

Materials and methods

Raw slurry (pig slurry + sewage sludge), the fermented product of a large biogas plant, and NPK fertilizer were used as nutrient sources in a field experiment in 2005-2006. The fermentation residue was applied as such, and as separated to the solid and liquid fractions. The amount of applied soluble N was supposed to be 100 kg/ha, but the actual rates varied between 75 and 100 kg N/ha. Two different injection techniques (traditional and injection in wider bands) and band spreading on the soil surface were used. Emissions of ammonia were measured with a chamber technique using the Innova photoacoustic Field Gas Monitor as long as detectable emissions were observed. The emissions were monitored both from plots where the applications were done at the time of sowing, and from plots fertilized two weeks after sowing to the growing crop. Annual emissions of nitrous oxide and methane were measured from the plots fertilized at the time of sowing using a chamber method and a GC. However, the emissions from the solid fraction were monitored only for one month.

Results and discussion

Injection of the slurries proved to be a very efficient means of reducing ammonia emissions, since the emissions from injected slurries were undetectable from the beginning. After band spreading there were ammonia emissions until the slurry was incorporated one hour after the application, but the total emissions were only 30-50 g ha^{-1} day^{-1}. There were no statistical differences between the emissions from different slurries. When the slurries were band spread in the growing crop two weeks after sowing, the ammonia emissions were higher than those on the day of sowing. The lowest ammonia emissions were observed from the raw slurry (Fig. 1). Due to the higher pH of the fermented slurry the release of ammonia was higher from the fermented products. The highest ammonia emissions were observed from the solid fraction of the fermentate, which does not infiltrate into the soil.

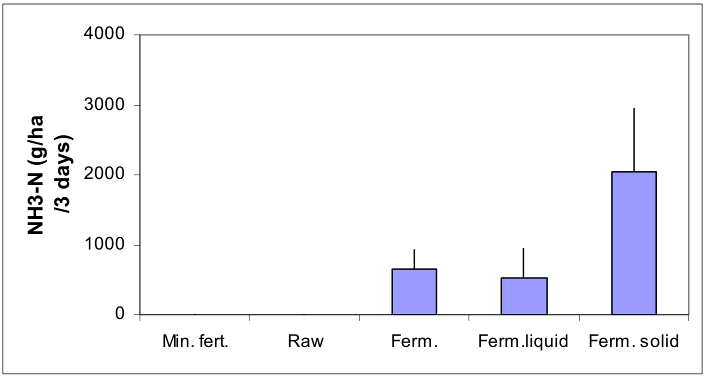

Fig.1. Emissions of NH_3 after spreading of slurries to the growing crop.

On the basis of the results of the first month after sowing, the emissions of nitrous oxide were lower from the solid fraction of the fermentate than from the liquid slurries (Fig. 2). The solid fraction was peat-like material that did not infiltrate into the soil, and thus denitrification of the N in this product was not likely.

There were no clear effects of slurry fermentation on the annual emissions of nitrous oxide (Fig. 3a). Fermentation seemed to lower the emissions compared to the raw slurry one month after injection, but later there were no marked differences between the treatments. The period of methane emissions was about two days, and thus the total amount of methane emitted was low (Fig. 3b). Fermentation reduced methane emissions from slurry spreading.

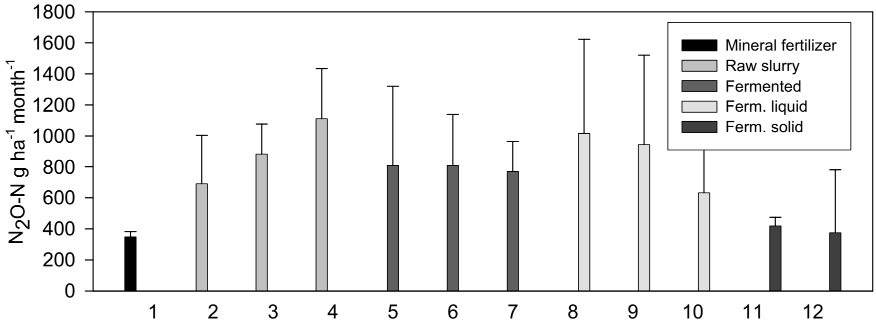

Fig. 2. Annual emissions of N_2O and CH_4 from the field after fertilizing with mineral fertilizer (1), raw slurry band spread (2), injected (3) and injected in wide bands (4), fermented slurry band spread (5), injected (6) and injected in wide bands (7), separated liquid fraction of the fermented slurry band spread (8), injected (9) and injected in wide bands (10), solid fraction of the fermented slurry surface spread (11) and incorporated (12).

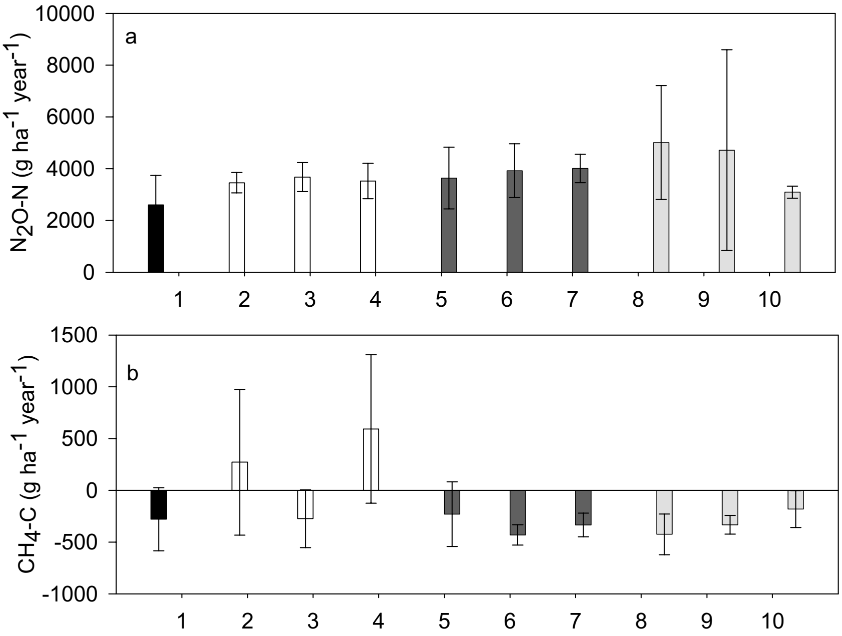

Fig. 3. Annual emissions of N_2O and CH_4 from the field amended with various fertilizer materials (numbers are defined in the legend to Fig. 1).

The effect of cow slurry fermentation and application technique on greenhouse gas and ammonia emissions from a grass field

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Introduction

Anaerobic digestion of manure is receiving increased attention due to environmental problems related to large livestock facilities and possibilities for greenhouse gas emission reduction. In anaerobic digestion manure properties are known to change, thus affecting the availability of nutrients to plants, as well as gaseous emissions. The effect of anaerobic digestion of cow slurry on emissions of the greenhouse gases methane and nitrous oxide and the indirect greenhouse gas and acidifying agent ammonia were studied in a field experiment. The fertilizer value of anaerobically digested manure was studied in a pot experiment.

Materials and methods

The field experiment (randomized blocks) was established in Jokioinen, Finland in 2005. The plots were fertilized with either mineral fertilizer (100 kg/ha) or two different types of cow manure (raw and anaerobically digested, 170 kg tot-N/ha) which were applied to the growing crop using two application techniques: injection and band-spreading.

Greenhouse gas flux measurements were made with a closed chamber method (Regina et al. 2004) during one year. Two replicate gas samples (V=20 ml) were taken with a syringe from the top of the chamber immediately after closing and half on hour later, transferred to pre-evacuated glass vials and analyzed with a gas chromatograph. Ammonia was measured using a photoacoustic field gas monitor (Innova) by closing the chamber, as for the greenhouse gas measurements, and measuring the change in headspace ammonia concentration during 5 min. Ammonia emissions were measured for two or tree days.

The fertilizer value of anaerobically digested manure was studied in a pot experiment with Italian rye grass (*Lolium multiflorum*). Raw and digested cow manure from a farm-scale biogas plant or laboratory scale biogas reactors (1 g N, corresponding to 241 kg N/ha) and three rates of mineral fertilizer (0.3, 0.6 and 1.0 g N corresponding to 72, 144 and 241 kg N/ha, respectively) were applied to plastic pots (V=5 l) before sowing. The effects of the treatments on crop yield were investigated.

Table 1. Treatments used in the field experiment (three replicates).

Treatment	Description
DIG_I	Digested slurry, injection
DIG_B	Digested slurry, band-spreading
MIN	Mineral fertilizer
RAW_B	Raw slurry, band-spreading
RAW_I	Raw slurry, injection

Results and discussion

Preliminary results showed variation between the treatments in both ammonia (Figure 1) and greenhouse gas emissions (Figure 2, Figure 3). One-year cumulative emissions of greenhouse gases showed a different pattern compared to a shorter measurement period. The main reason for that were large emissions of nitrous oxide in the spring after snow melting. Also, most of the methane was released in the beginning of the measurement period. Ammonia emissions were higher from the digested slurry. Slurry injection decreased ammonia emissions, but less in digested than in raw slurry. Nitrous oxide emissions were lowest from the band-spread digested slurry.

Emissions from the same slurry were much higher when the slurry was injected into the soil. It may be that low viscosity of anaerobically digested slurry enables it to better infiltrate into the soil (Wulf et al. 2002) to the location of active nitrifying and denitrifying bacteria. The methane-oxidizing capacity of this soil was low, and thus the cumulative fluxes were positive in most cases, even with mineral N addition. More methane was emitted from injected, digested slurry than from band-spread, digested slurry, possibly indicating that there was some methane production in the soil in addition to the release of dissolved methane from the slurry.
In the pot experiment, anaerobically digested slurries gave better crop yields than non-digested materials, even when the amount of soluble N was the same as in the raw slurry. The reason for that may be the smaller amount of degradable C in the slurry after anaerobic digestion which limits microbial N immobilization and thus improves the fertilizer value of the slurry as suggested by Petersen (1999).

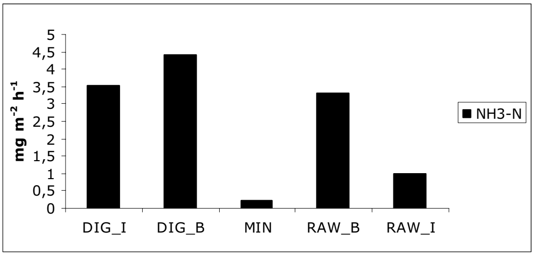

Figure 1. Average NH_3-N production rate during 2-3 days after slurry application.

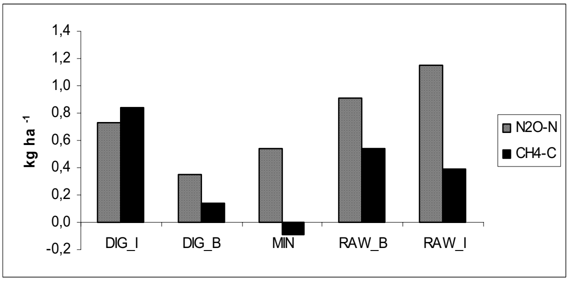

Figure 2. Cumulative N_2O-N and CH_4-C emissions during 4 months.

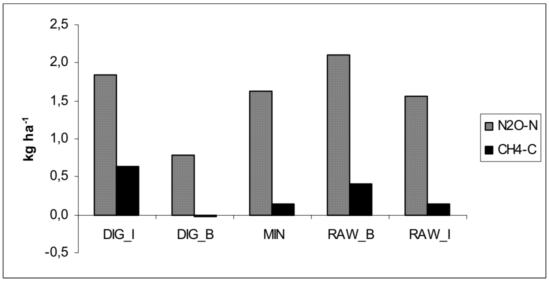

Figure 3. Cumulative N_2O-N and CH_4-C emissions during 11 months.

References

Petersen, S.O. 1999. Nitrous oxide emissions from manure and inorganic fertilisers applied to spring barley. J. Environ. Qual. 28:1610-1618.

Regina, K., Syväsalo, E., Hannukkala, A., Esala, M., 2004. Fluxes of N_2O from farmed peat soils in Finland, Eur. J. Soil Sci. 55, 591-599.

Wulf, S., Maeting, M., Clemens, J. 2002. Application technique and slurry co-fermentation effects on ammonia, nitrous oxide and methane emissions after spreading: I. Ammonia volatilisation. J. Environ. Qual. 31:1789-1794.

Ammonia emissions from swine manure storage tank

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Introduction and literature review

Agriculture is the main source of atmospheric ammonia (NH_3) from human activity (AAC, 1998). The three main sources of NH_3 on farms are animal waste, fertilizers and crop residues. In Canada, manure management accounts for about 80% of agricultural emissions, and the swine industry represents 16% of these emissions (AAC, 1998). Swine manure is generally managed in liquid form and stored in leak-proof storage tanks (BPR and AGECO, 2003). In Quebec, most of those storage tanks are built in concrete (BPR and AGECO, 2003).

Arogo et al. (2003) reported NH_3 emissions from swine anaerobic lagoons varying between 0.036 and 24.2 g NH_3 day^{-1} m^{-2}. Some of the reported emissions were derived from 24-h sampling periods or were measured during specific hours of the day and extrapolated. Liang et al. (2002) and Harper et al. (2004) developed mathematical models to estimate NH_3 emissions form swine anaerobic lagoons. The Liang et al. (2002) model was developed on the classical two-film theory while Harper et al. (2004) developed a regression equation based on the measured flux from swine anaerobic lagoons. Inputs to the models are wind speed and manure characteristics such as temperature, total ammoniacal nitrogen (TAN) concentration and pH.

The objective of this project was to measure NH_3 emissions from liquid pig manure stored in a concrete tank. Combined with a mathematical model, these results were used to estimate annual NH_3 emissions, and to compare with values found in the literature.

Methods

Ammonia emissions were measured during three periods in 2002 and 2003 (spring, summer and autumn) for a total of 79 days. During these days, emissions, air and manure temperature were measured continuously every 10 minutes, 24-h a day. The experiments were carried out on a conventional concrete tank (30.5 m in diameter and 3.7 m in depth). The stored manure came from an 800 grower-finisher pig building. Two floating aluminium chambers were used to collect air samples. The dimensions of each chamber was 152 cm x 25 cm x 20 cm height, and it was attached to a tubing structure to ensure floatation on the manure surface. Inside the chamber, the air volume was 0.044 m^3 and the manure surface was 0.39 m^2. Clean air was pumped to the chamber's inlet at a flow of 90 l min^{-1}. In the chamber, air passed over the manure surface from the inlet to the outlet. At the outlet, the air was exhausted to the atmosphere. An air sample was carried from the outlet of the chamber to an infrared NH_3 analyser (Siemens Ultrtamat 6E) by air pump, solenoid valves and Teflon® tubes.

Results and Discussion

Daily NH_3 emission results obtained in this project varied from 0.61 to 6.0 g NH_3 day^{-1} m^{-2}. Those results are comparable with the values presented by Arogo et al. (2003).

Annual emissions were estimated using the measurement results obtained and modelled data for periods without measurements. Figure 1 presents the average daily NH_3 emissions, manure temperature and depth of manure from April 13 to November 10. During this period, the manure temperature was higher than 0°C; emissions were considered negligible when manure temperature was below 0°C. Ammonia emissions over the missing periods (hatched areas in Figure 1) were estimated from a regression equation relating NH_3 emissions to the manure temperature. An exponential relationship was obtained showing the strong link between the NH_3 emissions and manure temperature (NH_3 emissions = 0.6* Exp(0.08*manure temperature), R^2 = 0.84). In Figure 1 the curve "depth of manure" does not exactly reflect the reality during the emptying phase, because values were estimated. Annual emissions obtained from the integration of the curve in Figure 1 equalled 530 g NH_3 m^{-2}.

Results obtained were also compared with NH_3 emission models found in the literature (Liang et al., 2002; Harper et al., 2004). Input values for TAN and pH obtained from the manure analyses were equal to 1,034 mg kg^{-1} and 7.67, respectively. Wind speed was not measured in this project; an average value of 2.8 m s^{-1} was used for the calculations. For the period between April 13 and November 10, a total of 413 and 240 g NH_3 m^{-2}

were calculated with the Liang et al. (2002) model and the Harper et al. (2004) model, respectively. The NH_3 curves obtained with those two models are included in Figure 1. Ammonia emissions measured in this project were higher than those predicted with the models. This could be explained by the fact that the models were developed with manure stored in anaerobic lagoons instead of a concrete tank. Storage types may affect manure characteristics such as dry matter content, TAN concentration and pH. Meanwhile, the model developed by Liang et al. (2002) seems accurate to evaluate NH_3 emissions.

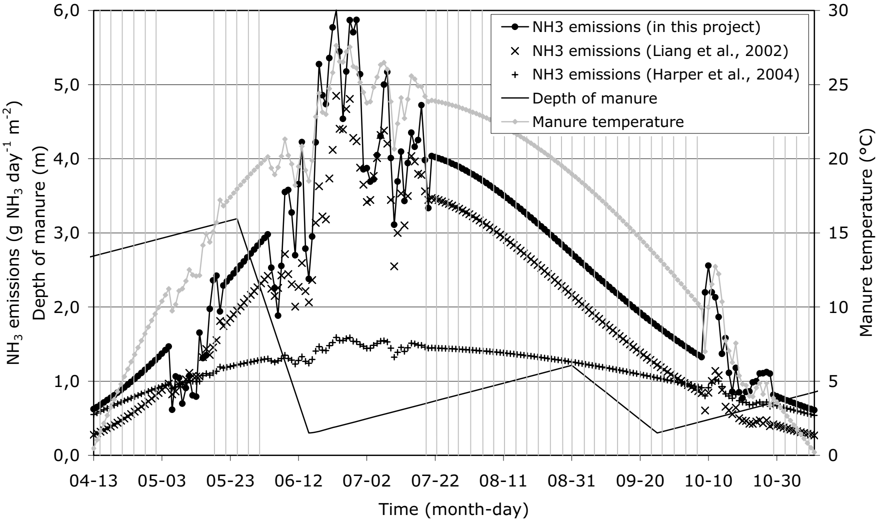

Figure 1. Average daily NH_3 emissions (black circles), manure temperature and depth of manure in the tank between April 13 and November 10. Also shown is model results using two models from the literature (see text).

Conclusions

Average and daily emission results measured in this project varied from 0.61 to 6.0 g NH_3 day^{-1} m^{-2}. The annual NH_3 emissions calculated in this project were 530 g NH_3 m^{-2}. According to the results obtained, NH_3 emissions were a function of the temperature, were comparable with values presented in the literature and, based on the measurement periods, were not influenced by the manure depth.

References

AAC (Agriculture and Agri-Food Canada) 1998. The health of our air: Toward sustainable agriculture in Canada. ISBN 0-662-27170-X. 98 pages.

Arogo, J., P.W. Westerman and A.J. Heber. 2003. A Review of Ammonia Emissions from Confined Swine Feeding Operations. Trans. ASAE. 46(3): 805-817.

BPR and AGECO. 2003. Suivi des plans des interventions agroenvironnementales des fermes porcines du Québec, Année de reference 2001 – Rapport final. Fédération des producteurs de porcs du Québec. 93 pages.

Harper, L.A., R.R Sharpe, T.B. Parkin, A. De Visscher, O. van Cleemput and F.M. Byers. 2004. Nitrogen Cycling through Swine Production Systems: Ammonia, Dinitrogen and Nitrous Oxide Emissions. J. Environ. Qual. 33: 1189-1201.

Liang, Z.S., P.W. Westerman and J. Arogo. 2002. Modeling Ammonia Emissions from Swine Anaerobic Lagoons. Trans. ASAE. 45(3): 787-798.

The effect of cattle-slurry electroflotation on grassland yield

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The climatic conditions of the Basque Country (northern Spain) provide favourable conditions for the growth of grasslands and the development of livestock enterprises. The intensification of the farms is leading to serious environmental risks due to the large production of manures and slurries and their subsequent inefficient management. Usually the fastest and easiest way to get rid of them is the application to grasslands as fertilizer. Their application involves N losses that can lead to pollution. ADE BIOTEC S.L. is developing a process called "electroflotation" with the aim of reducing the volume of slurries from intensive livestock farms. The process consists basically of a preliminary filtering to reduce dry matter. This dry matter can be further composted by usual methods. Afterwards, the remaining slurry is subjected to an electrolysis catalyzed by iron, which leads to the flocculation of solid particles, giving as a final result two different fractions: a solid and a liquid one. The liquid fraction can be used as fertirrigation water, while the solid fraction, which is a sludge reduced in volume, can be applied directly as organic amendment. The objective of this work was to asses the fertilizer capacity of the two fractions obtained by electroflotation by determining their effects on grassland yield and N uptake in comparison to untreated slurry.

The experiment was carried out in a typical permanent pasture [perennial ryegrass (*Lolium perenne* L. var. Herbus), 60%; intermediate ryegrass (*Lolium × hybridum* Hausskn. var. Texi), 32%; white clover (*Trifolium repens* L. var. Huia), 8%]. The untreated slurry (US), the solid phase (SP) and the liquid phase (LP) were all analysed (Table 1) and applied at a rate of 70 kg NH_4^+-N ha^{-1}.

Table 1. Characteristics of the different slurry fractions applied

	Untreated Slurry (US)	Solid phase (SP)	Liquid phase (LP)
Total N (% of fresh wt.)	0.34	0.06	0.03
NH_4^+-N (% of fresh wt.)	0.18	0.05	0.03
C (%)	2.20	0.28	0.10
C:N	6.47	4.66	3.33
DM (%)	5.58	0.88	0.35
pH	7.03	7.57	8.84

Seven weeks after their application to grassland as fertilizers, herbage yield was assessed. Herbage was dried in a forced-air oven at 70ºC for at least 48 h, weighed, and then ground. Nitrogen concentrations were determined on dried and ground herbage using a Macro Kjeldahl method.

Grassland yield increased 30% by the application of both the SP and the LP with respect to the US (Table 2). In accordance with this, SP and LP treatments showed significantly higher apparent efficiencies of the N applied than the US treatment, which showed an apparent efficiency very close to that of 37 kg DM kg^{-1} N described by Estavillo et al. (1996) in the same edaphoclimatic conditions.

Table 2. Dry matter yield (t DM ha^{-1}) of component species and of the total grassland, and apparent efficiencies of the N applied (kg DM kg^{-1} N). Figures within each column followed by the same letter are not significantly different at P<0.10

Treatments	t DM ha^{-1} Clover	t DM ha^{-1} Ryegrass	t DM ha^{-1} Other Species	t DM ha^{-1} Total	Apparent Efficiency Kg DM kg^{-1} N
Control	0.20 a	0.95 b	0.40 a	1.55 c	22.9 c
US	0.12 a	2.04 a	0.27 a	2.43 b	34.6 b
SP	0.21 a	2.55 a	0.40 a	3.16 a	45.2 a
LP	0.36 a	2.55 a	0.24 a	3.14 a	44.9 a

Although herbage N concentration (% N) was not affected by any treatment (data not shown), when N uptake rates were calculated (Table 3), it could be observed that in the SP treatment uptake was 23% higher than in LP and US. This was due to the higher ryegrass uptake. N uptake by clover was also higher in SP and LP treatments than in US, although not statistically significant. Clover is a weak competitor for N with respect to ryegrass. Thus, N application increases in ryegrass the competitive capacity for light and nutrients, and reduces the nodulation and N_2 fixation in legumes (Dunlop and Hart, 1987).

The apparent recovery of the N applied was calculated not taking into account the N taken up by clover, that is, assuming that all the N extracted by clover was due to atmospheric fixation. The application of both products of electroflotation (SP and LP) induced much higher N recoveries than the original untreated slurry (US) (Table 3), in agreement with the higher biomass yields also achieved. This could be due to lower N losses ocurring in SP and LP due to their physic characteristics. Thus, probably the low dry matter content of these slurry fractions favoured the infiltration in the soil.

Table 3. N uptake (kg N ha^{-1}) of component species and of the total grassland, and apparent recoveries of the N applied (%). Figures within each column followed by the same letter are not significantly different at $P<0.10$

Treatments	Kg N ha^{-1} Clover	Kg N ha^{-1} Ryegrass	Kg N ha^{-1} Other Species	Kg N ha^{-1} Total	Apparent Recovery %
Control	6.58 a	27.66 c	9.58 a	44.76 c	-
US	3.80 a	57.17 b	5.30 a	70.20 b	36.05 c
SP	7.46 a	79.87 a	7.65 a	92.92 a	65.17 a
LP	11.88 a	65.90 ab	4.55 a	72.37 b	47.45 b

Electroflotation seems to be a good tool for the management of cattle slurry from dairy farms. By this process slurry volume can be reduced and its products be used as efficient organic fertilizers. Thus, both the solid and liquid phases resulting from electroflotation have shown to induce a positive effect on grassland yield and N recovery.

References

Dunlop, J. and Hart A.L., 1987. Mineral nutrition. pp. 153-183. In Baker M.J. and Williams W.M. (ed) White clover. CAB International, UK.

Estavillo J.M., González-Murua C., Besga G. and Rodríguez M., 1996. Effect of cow slurry N on herbage productivity, efficiency of N utilization and on white clover content in a natural sward in the Basque Country, Spain. Grass Forage Sci. 51: 1-7.

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New parameters for evaluation of environmental impacts from cattle slurry and mineral fertilizer surface-applied to grassland

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Introduction

Potential risks of environmental pollution caused by applied cattle manure increase with stocking density (number of cattle per unit area of grassland) on dairy farms, and the manure should be carefully managed so as to reduce these risks. Since nitrogen (N) is closely involved in grassland dry matter production, as well as in important loss pathways to the wider environment, such as ammonia (NH_3) volatilization, nitrous oxide (N_2O) emission and nitrate (NO_3) leaching loss through soil to ground water, manure N management is particularly important. There is a risk, however, that reducing one form of N losses may simply cause an increase in another form.

The environmental impacts of applied manure should be therefore evaluated by all losses to the environment. In this paper we propose two new parameters, N leakage per unit dry matter production of the grass (NLPP) and net N efficiency of the applied NH_4-N for the production (N_{en}), for evaluating the environmental impacts of manure application to grassland.

Materials and methods

We monitored the N leakage that is the sum of NH_3-N volatilization, N_2O-N emission and N leaching to the ground water (major form of N was NO_3-N), as well as dry matter yield (DMY) of the grassland and N uptake by the grass, in a lysimeter experiment over 3 years. Timothy (*Phleum pratense* L.) sward was established in each lysimeter. We began to use the 12 lysimeters in autumn 2000, based on the following 6 treatments with 2 replicates.

There were 4 treatments, comprising 2 application rates of anaerobically digested cattle slurry (ADCS) and 2 application times (Table 1). The experiment included 2 further treatments; the application of mineral

Table 1. Details of the treatments of the lysimeter experiment, and total applied N for 3 years.

Name of the plot	Application		Total applied N* (g N m^{-2} $3yrs^{-1}$)		
	rate	time	NH_4-N	Org. N	T-N
Ctrl.	-	-	0	0	0
SA	standard	autumn	32	36	68
SS	standard	spring	32	30	62
HA	heavy	autumn	64	74	138
HS	heavy	spring	64	59	123
MF	**	**	48	0	48

*: All plots received 8g N m^{-2} as NH_4-N at establishment of the sward and total 2.4g N m^{-2} as wet and dry deposition for 3 years.

**: Mineral fertilizer was usually applied at the rate of 11g N m^{-2} $year^{-1}$ as NH_4-N after the wintering (late April) and 5g N m^{-2} $year^{-1}$ after first cutting (late June).

fertilizer, ammonium sulphate ($(NH_4)_2SO_4$), to the grass according to recommended rates in Hokkaido, Japan; and a control (no ADCS and no mineral fertilizer).

Definition of the new parameters, NLPP and N_{en}

The new parameters, NLPP and N_{en}, are given by following equations:

$NLPP = N_l/(Y_t - Y_n)$,

where N_l (mg m^{-2}) is the N leakage defined above, and Y_t and Y_n (g m^{-2}) is the DMY of the grass in the treatment where N is applied and no N, respectively. From the definition, the NLPP indicates the N leakage per unit increase in dry matter production due to the total applied N.

$N_{en} = (Y_t - Y_n)/N_{sn}$,

where Y_t and Y_n is as defined above. N_{sn} (g m^{-2}) is net NH_4-N applied from the ADCS or mineral fertilizer, and the net NH_4-N is the difference between the applied NH_4-N and NH_3-N volatilization loss, because NH_3 volatilization loss does not contribute to grass production.

Results and Discussion

The major component of the N leakage from the applied ADCS to the environment was NH_3 volatilization and N leaching loss (Table 2). The N_2O emission loss was much smaller than the other components of the N leakage. The NH_3 volatilization loss, however, was not greatly affected by the rate and time of ADCS application (Table 2). This result suggests that it is very difficult to control the NH_3 volatilization loss from surface-applied

ADCS by application rate and time. Consequently, the N leaching loss plays an important role in reducing the N leakage.

NLPP in the SS plot was the smallest among the ADCS treatments, reflecting the low N leaching loss as well as high N_{en} (Table 2). The low N leaching from the plot means that the N uptake efficiency by the grass was high. This high N uptake efficiency supported the high N_{en} in the plot. The largest NLPP among all treatments was recorded in the HA plot (Table 2), although the N leaching loss was less than that in the HS plot. This was likely due to relatively small effect of N uptake by the grass on the N leaching loss at the heavy application rate compared with that at the standard application rate; at the heavy application, the N supply from ADCS greatly exceeded the N requirement of the grass. It appeared that NLPP in the HA plot was attributed to low efficiency of the applied N for grass production, which was reflected in the lowest N_{en}. NLPP from MF was considerably smaller than that where the ADCS had been applied, because there was no NH_3 volatilization.

The sum of N uptake by the grass and N leakage in the ADCS treatments was less than 50% of the total N applied (Table 2). This suggested that more than 50% of N in the ADCS, especially organic N, accumulated in the soil. Further work is needed to determine the effect of mineralization of the organic N in ADCS on N leakage, particularly on the N leaching loss, as a long-term effect of the ADCS application.

From the data of NLPP and N_{en} we can easily evaluate the standard rate application of the ADCS in early spring as the best strategy both for efficient use of N supply to increase the grass dry matter production, and for reducing environmental risks.

Table 2. Apparent partitioning of N uptake, N leaching, NH_3 volatilization and N_2O emission from total applied N, and the new parameters, NLPP and N_{en}

Name of the plot	N uptake	N leakage			NLPP	N_{en}
		N leaching*	NH_3-N loss	N_2O-N loss	(mg g^{-1})	(g g^{-1})
	(% to the total applied N)					
SA	18.1	7.9	13.1	0.1	25.9	24.1
HA	17.5	10.1	13.6	0.1	37.7	19.3
SS	29.7	6.0	13.2	0.0	15.8	31.6
HS	24.8	12.3	12.7	0.1	26.3	24.1
MF	63.8	11.5	ND**	0.1	3.7	31.4

*:Major form of N was NO_3-N. **ND: not detected.

Agronomic use of exhausted grape marc composts on tomato crop: Yield, biomass production and morphological aspects

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The world-wide production of wine in 2004 was 46.9 millions hL, Spain, together with France and Italy, being the greatest producers (FAO, 2005). Grape stalk, grape marc and wine lee are the main solid wastes obtained during winemaking, while exhausted grape marc is the final solid waste from alcohol distilleries. As an example, the grape marc production in the world could be estimated to about 1 million ton/year. The winery and distillery wastes are characterised by a low pH, similar EC values, high organic matter, P and K contents, as well as low micronutrient and heavy metal contents compared to the values for wastes usually used as organic fertilizers, such as manures and urban wastes. Composting could be a feasible option for recycling these residues, taking advantage of their nutritional and energy properties without causing environmental damage.

This experiment compared the effect of two composts derived from the winery-distillery residues on the yield and biomass production of two varieties of tomato plant (*Lycopersicon esculentum*, var. Muchamiel (traditional) and var. Anastasia (hybrid F1), with the effect of mineral fertilisation (MF, 400:180:600 kg $N:P_2O_5:K_2O$ per hectare). The composts were obtained using the Rutgers static pile composting system, in which air is supplied to the pile by forced aeration. Two different piles were produced by: a) co-composting exhausted grape marc and cattle manure, 70-30% fresh weight (EGM+C); b) co-composting exhausted grape mark and poultry manure, 61-39% fresh weight (EGM+P). The co-composting was established in order to achieve a suitable C/N ratio in the initial mixtures. The composts were applied to soil at two different rates equivalent to 45 (low) and 90 t fresh weight ha^{-1} (high). These application rates implied an input of 78 and 111 kg N/ha for EGM+C, and 157 and 222 kg N/ha for EGM+P, respectively. The experiment was conducted under controlled conditions in a greenhouse with a randomized design, with six replications for each treatment and variety. The yield and biomass production of tomato plants were monitored, determining fresh and dry mass of the fruits, leaves, stems, branches and roots of each tomato plant. Morphological parameters such as root, branch and stem length were also measured.

The fertilisation produced an increment in the yield and biomass production (Fig. 1) compared to control plants, a fact also observed by Montemurro et al. (2005). The effects of some of the organic treatments were similar to that of the mineral fertilisation. This increment was higher in the traditional varieties compared to the hybrid F1 variety. This could be due to the greater efficiency of the hybrid plants in the vegetative steps and, additionally, to the resistance of this variety to different virus diseases, especially Tomato Yellow Leaf Curl Virus (TYLCV), which produced a lesser increment of the fertilisation treatments compared to hybrid controls.

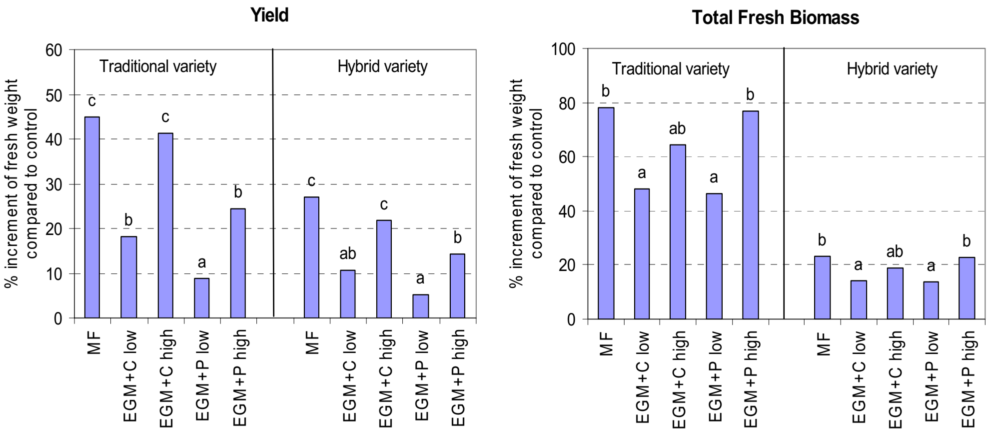

Figure 1. Percentage of increment of the tomato yield and total fresh biomass, compared to the control plants for the traditional and hybrid varieties (F-ANOVA test: sig <0.000 for yield, and sig<0.00 for total fresh biomass in both varieties).

The yield increment compared to the control plants in the two tomato varieties by the highest dose of the compost derived from EGM and cattle manure (EGM+C) was 41,3% and 21,8%, respectively. This was statistically similar to those produced by the mineral fertilisation. With respect to the biomass production, the highest dose of both compost treatments produced the greater effect in the total and not commercial fresh biomass, similar to that of produced by the mineral fertilisation.

The type of compost amendment induced differences in the morphological aspects, obtaining similar increases in most of the studied parameters for the compost derived from exhausted grape marc and poultry manure (EGM+P) and for the mineral fertilisation (MF) compared to control plants. All the treatments induced an increase in the fresh and dry biomass, especially in leaves and branches. In general, the increasing dose of compost application induced higher fresh and dry biomass.

The variety effect was especially significant in the parameters of biomass production (Table 1), probably due to the previously mentioned greater efficiency of the hybrid plants in the vegetative steps, as well as the resistance to diseases, which produced a minor effect of the fertilisation treatments compared to hybrid controls. Moreover, other parameters affected by this efficiency were the fresh and dry weight in stems, branches and leaves. The root was the only part that was not influenced by the variety in any parameter considered.

Table 1. Comparative effect of the fertilizer treatments depending on the tomato variety, referred to unfertilized plants.

Parameter		*F-ANOVA*	Parameter		*F-ANOVA*
Fresh weight	Stem	152.57***	Dry weight	Stem	273.44***
	Branch	43.40***		Branch	74.84***
	Leave	102.66***		Leave	78.59***
	Root	0.47ns		Root	0.00ns
Length	Stem	2.63ns	Biomass production	Yield	9.78**
	Branch	41.91***		Total biomass f.w.	122.39***
	Root	0.72ns		Not commercial biomass f.w.	66.65***

ns: Not significant.

To conclude, despite the higher efficiency shown by the mineral fertilisation in providing the nutrient needs to the tomato plants, the highest application rate of the composts produced using winery and distillery wastes showed similar results to those of the mineral fertilisation. For this reason, this rate of the studied composts could replace a high percentage of the mineral fertilisation.

References

Food and Agricultural Organisation (FAO), 2005. FAOSTAT database. Available from: http://www.fao.org.

Montemurro, F., Convertini, G., Ferri, D. and Maiorana, M., 2005. MSW compost application on tomato crops in Mediterranean conditions: effects on agronomic performance and nitrogen utilization. Compost Science & Utilization 13:234-242.

Reduction in nitrate leaching for a sustainable agriculture

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Nitrogen is one of the most efficient factors in plant production, but is undesirable in groundwater (nitrate leaching) and in the air (ammonia emissions etc. (Sattell et al. 1999)). Nitrate moves with water. It is not retained in soils that are dominated by negatively charged clay and humus colloids. Leaching is an important factor concerning nitrogen losses.

Due to the production costs, nitrogen is an expensive substance. Currently the costs for one kilogram of mineral N in Switzerland amount to 1.5 CHF (≅ 1 EUR). For the production of one kilogram N, two kilograms of mineral oil are necessary. Consequently, economical and environmentally safe use of nitrogen and animal manure is useful, and reduced application of N fertilisers lowers agricultural production costs.

Application of excessive amounts of nitrogen, mostly in the form of animal manure, results in environmental problems (Siegenthaler et al. 2001). Localised high animal counts, mostly pigs or poultry, are the cause of over-fertilising and pollution problems in many European countries or regions. The trial aim is to develop methods for the reduction of nitrate leaching.

Materials and Methods

Over a seven year period (1993-2000), lysimeters (1 m^2 surface, 1.4 m usable depth, filled in 1982 with a low humus, loamy sand soil, pH-value 7.5, C_{org} 1.72%, sand 59.3%, silt 26.1%) at Liebefeld-Bern's Research Station (565 m above sea level, annual average precipitation 1100 mm, average temperature 8.8 ^{0}C) were used to investigate the influence of different plant production systems (crop rotations, grass-clover mixture, china reed [*Miscanthus sinensis "Giganteus"*] and full fallow) on percolated nitrate losses (Stauffer and Spiess 2001).

Mineral standard fertilisation (N,P,K,Mg,Ca), depending the cultures needs were applied. Root crops: 40 t/ha solid cattle manure (4.2 kg N/t; 0.2

kg/NH4-N/t). China reed and permanent grassland: 40 m^3 liquid cattle slurry (1:1 diluted, 1.9 kg N /m^3; 0.9 kg NH4-N /m^3).

Results and Conclusions

- Lysimeter experiments show that only very small quantities of nitrate leach into the groundwater planted with grassland (PG) or other permanently plant covered soils.
- Cultivated catch crops (CR) are a powerful help in reducing nitrate losses.
- Prolonged fallow land periods (FF) during the warm season, when rapid mineralisation and nitrification of nitrogen occur, result in a substantial increase in nitrate leaching.

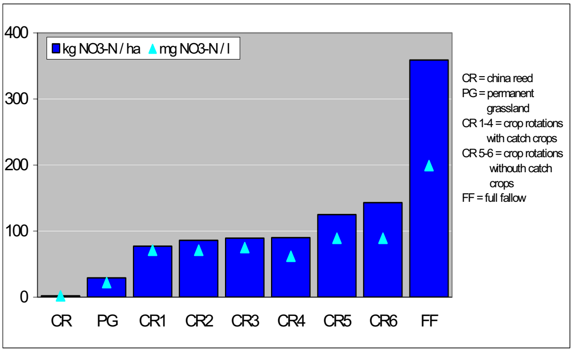

Figure 1: Annual nitrate-nitrogen losses with different crop-rotations and full fallow.

Lysimeters at Liebefeld's Research Station.

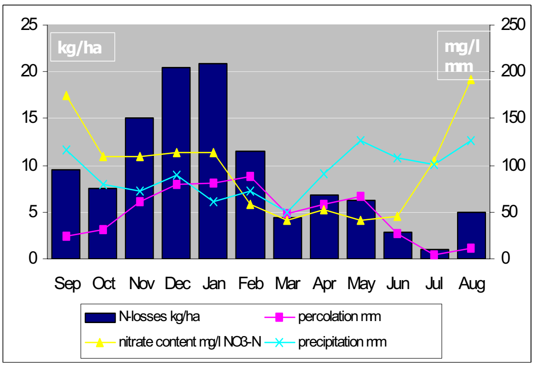

Figure 2: Amounts of nitrogen-losses, nitrate contents, percolation of leaching water and precipitation, (average of 7 years and 6 crop rotations).

- Nitrate leaching due to the amount of water percolating to groundwater was highest on soils without plant (full fallow) during times of heavy-rainfall, and during the cool, wet months from November to February.
- With fertilisation corresponding to plant requirement the risk for leaching and nitrate losses is mostly low.

Measures

The Swiss Government (Lehmann 2006) supports projects to reduce nitrate.

Measures on farm level include:

- Integrated crop production
- Minimum storage capacity for slurry
- Balanced nutrient management
- Correct use of fertilisers and manure
- Limitation of livestock numbers
- Ecological compensation areas (precondition for direct payments)

Measures on field level include:

- Fertilisation according to plant nutrient requirements
- Soil analysis
- Direct seeding of winter crops
- Strip drilling of maize
- Meadows instead of arable land

Conclusions

- Most of the nitrogen leaching occurs during winter: Fertiliser application during winter, especially slurry, increases the nitrate leaching.
- The quantity, time and place for the application of nitrogen fertilisers must be optimised.
- On a 30 ha arable farm with optimised fertilisation, annual savings of up to 9 000 CHF (approximately 6 000 EUR) can be achieved through minimising nitrate losses
- Minimised nitrogen losses result in lower agricultural production costs.
- National support programs to reduce nitrate and protect groundwater can be helpful

References

Lehmann HJ, 2006: personal communication: http://www.nitrat.ch/d/englisch/frameset_e.html

Sattell R., Dick R., Hemphil D., Selker, J., Brandi-Dohrn, F. Minchew, H., Hess, M., Sandeno J., and Kaufman S. 1999: Nitrogen Scavenging: Using Cover Crops to Reduce Nitrate Leaching. Oregon State University Agricultural Experiment Station, EPA, 319 Program.

Siegenthaler Albrecht, Stadelmann Franz X. and Stauffer Werner, 2001: Minimising of nitrate losses in plant production. INRA: 11th Nitrogen Workshop, Reims, 523-524.

Stauffer W. and E. Spiess. 2001: Einfluss unterschiedlicher Fruchtfolgen auf die Nitratauswaschung. Agrarforschung 8, (8), 324-329.

Use efficiency of phosphorus applied with animal manure to organically and conventionally managed soils

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Phosphorus (P) is a limited resource that restricts crop production on large areas worldwide. In contrast, P losses from over-fertilized soils result in eutrophication of water bodies, particularly in areas with high livestock density. Thus P contained in animal manure, which presents the major P source for crops in organic farming, needs to be managed properly. This requires good knowledge of its fertilizer value (Oberson and Frossard 2005).

We studied the use efficiency by ryegrass of P applied with animal manure to soils from a long-term field experiment that was for 22 years under the following systems: bio-dynamic (DYN); bio-organic (ORG); conventional with organic and mineral fertilizers (CON); conventional with exclusively mineral fertilizers (MIN); non-fertilized control (NON) (Table 1) (Mäder et al., 2006).

Table 1. Characteristics of the systems applied since 1978.

	NON	DYN	ORG	CON	MIN
System	Control	Bio-dynamic	Bio-organic	Conventional (integrated)	Conventional (integrated)
Fertilizer	None	Composted manure, slurry, preparations	Slightly rotted manure and slurry	Manure, slurry and mineral fertilizer	Mineral fertilizer
Plant protection	Specific according to guidelines of respective system				
Crop rotation	Same 7 years crop rotation				
Soil tillage	Identical				

The soils were characterized by different available and total P contents and microbial activity (Table 2).

Table 2. Selected characteristics after 22 years of cropping by different systems.

Cropping system	Microbial biomass†	Available P ‡	Total P §
	mg C kg^{-1} soil	mg P kg^{-1} soil	mg P kg^{-1} soil
NON	100 a	0.4 a	563 a
DYN	152 c	1.7 b	640 bc
ORG	141 bc	1.9 b	629 b
CON	128 b	4.0 d	683 d
MIN	92 a	2.6 c	658 cd
F-Test	***	***	***

†Microbial C released by the fumigation-extraction method (Vance et al., 1987); no conversion factor applied; ‡Isotopically exchangeable P during 1 minute (Oehl et al., 2002); §Ignition followed by acid extraction; ***: $P<0.001$

To test whether the greater microbial activity in organically managed soils (DYN, ORG) affects the P use efficiency, we carried out a pot experiment (Tagmann, 2000) using P radioisotope labeling (Fardeau et al., 1996). Soil available P was labeled with ^{33}P and amended with animal manure (cow faeces) or water soluble di-ammonium-phosphate (mineral P) or a zero P treatment. Both fertilizers were applied at 30 mg P kg^{-1} soil. The shoot material from four cuts of *Lolium multiflorum* was analysed for dry matter production, P content and specific activity. The residual and fresh fertilizer values were calculated (Fardeau et al., 1996) and are expressed as i) proportion of P in the plant derived from the fertilizer and ii) percentage of P applied with the fertilizers taken up by plants (coefficient of utilization, CU).

Without fresh P fertilizer application, dry matter production was 5.9 g kg^{-1} soil in NON, 8.9 in DYN, 9.6 in ORG, 10.4 in MIN and 11.7 in CON. This order agreed with the available P contents in the soil. P in the plants derived from residual fertilizer P amounted to 41% for DYN, 44% for ORG, 56% for MIN and 64% for CON. The CU of the residual fertilizers ranged from 9 (DYN) to 15% (CON).

Twenty to 55% of P in the plant was derived from freshly applied fertilizer, with clearly greatest proportion in NON and lowest in MIN and CON. The CU of mineral P ranged from 37 (CON) to 43% (ORG) (Figure 1). For animal manure P, in which 25% of total P was organically bound, the CU was lower (24 to 35%, Figure 1).

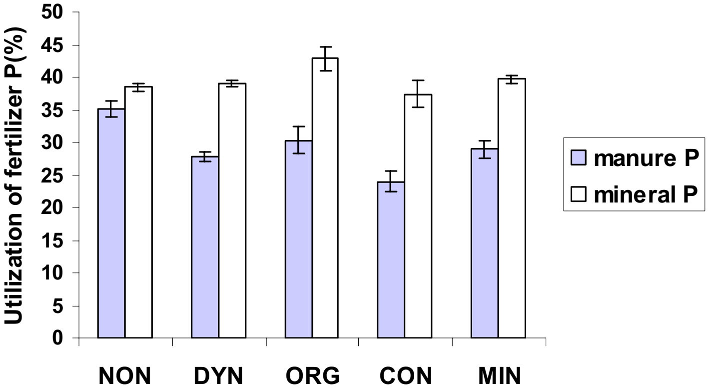

Figure 1. Utilization of animal manure P and water soluble mineral P by ryegrass grown on soils that were for 22 years cropped by different systems.

The CU and proportion of P in the plant derived from the fresh fertilizer were mainly affected by soil available P, with lesser importance of the fertilizer at higher soil available P in conventionally cultivated soils. Differences in soil microbial activity were of subordinate importance in the use efficiency of fresh and residual P fertilizers. Thus, the use efficiency P of manure P was in our experiment not improved by greater microbial activity. Irrespective of the cropping history, animal manure was less available to ryegrass than water soluble P.

References

Fardeau, J.-C., G. Guiraud, and C. Marol. 1996. The role of isotopic techniques on the evaluation of the agronomic effectiveness of P fertilizers. Fertilizer Research 45:101-109.

Mäder, P., A. Fliessbach, D. Dubois, L. Gunst, W. Jossi, F. Widmer, A. Oberson, E. Frossard , F. Oehl, A. Wiemken, A. Gattinger, and U. Niggli. 2006. The DOK experiment (Switzerland), p. 41-58, In J. Raupp, et al., eds. Long term field experiments in organic farming. Verlag Dr. Köster, Berlin.

Oberson, A., and E. Frossard 2005. Phosphorus management for organic agriculture, p. 761-779, In J. T. Sims and A. N. Sharpley, eds. Phosphorus: Agriculture and the Environment. ASA, CSSA and SSSA.
Oehl, F., A. Oberson, H.U. Tagmann, J.M. Besson, D. Dubois, P. Mäder, H.R. Roth, and E. Frossard. 2002. Phosphorus budget and phosphorus availability in soils under organic and conventional farming. Nutrient Cycling in Agroecosystems 62:25-35.
Tagmann, H.U. 2000. Nach- und aktuelle Wirkung von Hof- und Mineraldüngerphosphat in langjährig konventionell und biologisch bewirtschafteten Böden. Diploma thesis, Swiss Federal Institute of Technology (ETH), Zurich.
Vance, E.D., P.C. Brookes, and D.S. Jenkinson. 1987. An extraction method for measuring soil microbial biomass C. Soil Biology & Biochemistry 19:703-707.

Effect of time and rate of cattle-slurry application on nitrate concentration of drainage water in a double-cropping forage system

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Introduction

In the NW region of Portugal a very intensive dairy farming system has been developed based on two silage crops per year (maize plus a winter crop), which has important risks of nitrate leaching losses during the winter season. These soils receive N inputs as high as 600-730 kg N ha^{-1} yr^{-1} resulting from two applications of dairy-cattle slurry just before sowing each crop, and 220-300 kg N ha^{-1} yr^{-1} from mineral fertilizers (Trindade et al., 1997). The objectives of our study were to evaluate the effect of cattle-slurry rate and time of application on nitrate-N concentration of drainage water during the winter crop (*Lolium multiflorum Lam*.) growth period.

Materials and methods

The experiment was carried out at Vila do Conde between May-97 and May-00 in a sandy loam soil representative of the NW region of Portugal. The soil was a deep well-drained sandy loam derived from granite and classified as a RGuo soil, with a pH value of 5.8, OM content of 2.5%, available P_2O_5 and K_2O, of 117 and 157 mg kg^{-1} respectively. Seven treatments were arranged in a randomized complete block design with three replications: a control with no N fertilizer (T0); one application of cattle-slurry at maize planting to supply 138 (T1), or 411 (T2) kg slurry-N ha^{-1} yr^{-1}; two applications, at maize and at ryegrass planting with 536 (T3), and 504 (T5) kg slurry-N ha^{-1} yr^{-1}; treatment T5 received, in addition to the cattle-slurry, 240 kg N ha^{-1} as mineral fertilizer (744 kg total N ha^{-1} yr^{-1}); three applications including a top-dressing at ryegrass tillering representing 478 kg slurry-N ha^{-1} yr^{-1} (T4); and a mineral fertilizer treatment (T6) receiving 240 kg N ha^{-1} yr^{-1}. Details of the fertilizer treatments are give in Table 1. Treatment T5 represents the conventional N fertilization practice on very intensive farms under this double-cropping forage system. Some variation occurred between years in the N rates applied on the treatments receiving slurry (mean ± 10-15%).

The experiment was established in May-97 and the NO_3^--N concentration measurements were carried out between October and May in the 2nd and 3rd year (1998/99 and 1999/00) using six ceramic cup samplers in each plot installed at 1 m depth.

Table 1. Dates and rates of N applied (kg N ha^{-1}) by treatment. N sources are: s = cattle-slurry and m = ammonium-nitrate mineral fertiliser.

Date of application	T0	T1	T2	T3	T4	T5	T6
Maize sowing		138s	411s	327s	210s	300s+50m	50m
Maize top dressed	no N					140m	140m
It. ryegrass sowing				209s	161s	203s	
It. ryegrass top dressed					107s	50m	50m
Total N applied	0	138	411	536	478	744	240

Results and discussion

The time-course of NO_3^--N concentration by treatment in the drainage water during the winter crop growth period is shown in Figure 1.

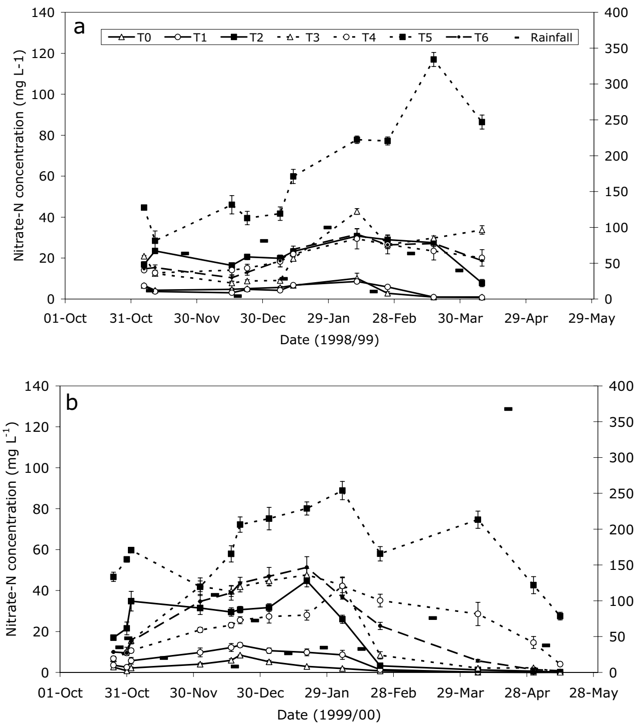

Figure 1. Mean NO_3^--N concentration in the drainage water by treatment, and cumulative rainfall between sampling dates during the winter crop growth period, for the year 1998/99 (a) and 1999/00 (b). The vertical bars represent SEM (n = 3).

The rate of cattle-slurry and the time of application along the year resulted in significant differences ($P<0.01$) between the treatments in NO_3^--N concentration of drainage water. Mean values of NO_3^--N measurements between October and May were 4, 6, 22, 22, 20, 61 and 22 mg NO_3^--N L^{-1} respectively on treatments T0, T1, T2, T3, T4, T5 and T6. Considering the limit of 11.3 mg NO_3^--N l^{-1} established by the EU (EEC, 1980) for drinking water, it is concluded that drainage water from treatments T2 to T6 is far from meeting the minimum requirements. Nitrate-N leaching losses are related to the typical climatic conditions of this region with more than 600 mm of drainage concentrated between October and March, which tended to promote the leaching of all residual NO_3^--N that was present in the soil at harvest of the maize crop (Trindade et al., 1997). In the 2nd and 3rd year of this work, 870 mm and 1370 mm of rainfall fell during the raining season (Set-Apr). Treatment T6 with the application of only 240 kg N ha^{-1} of mineral origin (190 + 50 kg N ha^{-1}, respectively, to the maize and winter crop) showed values of NO_3^--N concentration in drainage water similar or higher than treatments T2, T3 and T4 that received significant higher amounts of N from slurry. Average NO_3^--N concentrations (L_N) in leaching water were exponentially related to the amount of slurry-N (N_{ap}) applied ($L_N = 3.894e^{0.0036Nap}$, $R^2 = 0.98$). An important fraction of slurry organic-N may have been mineralised during the year, with this fraction being proportional to the amount of the organic-N applied (Pereira et al., 2006).

NO_3^--N concentration in the drainage water during the winter period was closely related to the annual rate of N applied in cattle-slurry. Nitrate leaching losses showed also to be affected by N source, since the application of mineral N fertiliser lead to values of NO_3^--N concentration in drainage water similar or higher than treatments that received significantly higher amounts of N from cattle-slurry.

References

Pereira J.L., Trindade H., Coutinho J. and Moreira N., 2006. Nitrogen mineralization in soils receiving different rates of cattle-slurry and cropped with forage maize. Grassland Science in Europe 11: 724-726.

Trindade H., Coutinho J., Van Beusichem M.L., Scholefield D. and Moreira N., 1997. Nitrate leaching from sandy loam soils under a double-cropping forage system estimated from suction-probe measurements. Plant and Soil 195: 247-256.

European Economic Community (EEC) 1980 Council directive on the Quality of Water for Human Consumption. Official J., No. 80/778 EEC L229, 11.

Leaching of organic matter and metals from pig slurry before and after solid-liquid separation

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Murcia is one of the main regions for pig production in Spain, and the accumulation of pig slurry is one of the most important environmental issues related to agriculture. Solid-liquid separation of the pig slurry is considered a suitable technology for recycling this waste (Martínez-Almela and Barrera, 2005). Water content of the slurry is 85 to 99 %, so the separation of the slurry into solid and liquid fractions could allow the use of the liquid as irrigation water and the solid fraction as manure. In this work the movement of organic matter (OM) and metals in the soil due to the use of pig slurry, solid and liquid fractions was studied.

Materials and methods

A pig slurry (PS), solid (SF) and liquid (LF) fractions were collected from a depuration plant based on solids flocculation by a polyacrylamide (PAM) at the Veterinary Farm of the University of Murcia. A non-calcareous Typic xerofluvent soil was used, having pH 4.1, 1.35% organic-C, 0.85% total-N, $CaCO_3$<0.5% and total heavy metal concentrations (mg kg^{-1}) of 36937 Fe, 770 Mn, 113 Cu, 411 Zn, 16.1 Ni, 219 Pb and 2.2 Cd. The soil (736 g) was placed in 40 cm long, 4.5 cm internal diameter columns (bulk density 1.3 g cm^{-3}). The three amendments were added at the soil surface, after saturation of the column with water to field capacity. The following rates were used: 6.8 g kg^{-1} of SF and 40.8 ml kg^{-1} for PS and LF, equivalent to 31.5 t ha^{-1} for SF and 188.7 m^3 ha^{-1} for LF and PS. Unamended soil was run as a control. Then distilled water was supplied from the top of the column at a rate of 320 ml in 24 h (equivalent to 200 mm, minimum annual rainfall in the Mediterranean area). All treatments were replicated two times. The soils (7 depths) and leachates were analysed for NaOH-extractable organic-C (Cext), total-N, NH_4^+-N, organic C (TOC), available-P ($NaHCO_3$ extraction), EC, pH and sequential extraction of Cd, Cu, Zn.

Results and discussion

Available-P was retained in the first 2 cm of the soil in all the treatments indicating its low mobility. All amendments increased the values of most parameters in the first 2 cm of the soil, except for EC, which had lower values in 0-5 cm due to leaching of the soluble salts. The concentration of NH_4^+-N was differently affected by the treatments. In the soil with SF it remained in the first 2 cm (linked with the OM), while NH_4^+-N from PS moved down to 10 cm, and in LF-treated soil the values increased down to 20 cm with respect to the control.

Table 1. Values of pH, electrical conductivity (EC), and concentrations of available-P, C and N in the soil columns after leaching.

Treatment	Depth (cm)	Avail.-P (mg kg^{-1})	NH_4^+-N (mg kg^{-1})	TOC (g kg^{-1})	TN (g kg^{-1})	pH	EC (dSm^{-1})	Cext (g kg^{-1})
Control	0 – 2	21^{a}	35^{c}	13.2^{a}	0.90^{a}	4.6^{a}	0.62^{d}	2.88^{a}
	2 – 5	20^{ab}	44^{c}	14.0^{a}	0.88^{ab}	4.4^{ab}	1.28^{c}	2.37^{a}
	5 – 10	17^{b}	49^{bc}	14.4^{a}	0.62^{abc}	4.5^{ab}	2.03^{b}	1.31^{bc}
	10 – 15	17^{b}	53^{ab}	12.9^{a}	0.65^{abc}	4.3^{c}	2.14^{ab}	1.26^{bc}
	15 – 20	18^{b}	57^{a}	12.6^{a}	0.43^{c}	4.4^{bc}	2.13^{b}	1.01^{bc}
	20 – 30	19^{b}	55^{ab}	12.3^{a}	0.55^{bc}	4.5^{ab}	2.19^{a}	0.84^{c}
	30 – 40	18^{b}	47^{ab}	14.8^{a}	0.69^{abc}	4.5^{ab}	1.35^{c}	1.53^{b}
Pig slurry	0 – 2	115^{a}	216^{a}	20.3^{a}	2.23^{a}	6.6^{a}	0.66^{d}	2.57^{a}
	2 – 5	23^{b}	130^{b}	17.8^{b}	1.30^{b}	4.5^{b}	1.83^{bc}	1.27^{b}
	5 – 10	23^{b}	115^{b}	17.0^{bc}	1.39^{b}	4.4^{b}	2.10^{ab}	1.02^{b}
	10 – 15	21^{b}	48^{c}	15.7^{cd}	1.17^{b}	4.3^{b}	2.39^{a}	1.17^{b}
	15 – 20	23^{b}	48^{c}	15.5^{cd}	1.21^{b}	4.3^{b}	2.27^{ab}	1.23^{b}
	20 – 30	21^{b}	39^{c}	16.7^{c}	1.58^{b}	4.5^{b}	1.93^{ab}	0.87^{b}
	30 – 40	24^{b}	58^{c}	14.8^{d}	1.53^{b}	4.5^{b}	1.36^{c}	1.18^{b}
Liquid fraction	0 – 2	39^{a}	207^{a}	16.3^{ab}	1.78^{a}	5.8^{a}	1.07^{d}	2.24^{ab}
	2 – 5	27^{b}	95^{b}	14.2^{c}	1.50^{ab}	4.5^{bc}	1.17^{cd}	2.44^{a}
	5 – 10	22^{c}	86^{bc}	14.0^{c}	1.22^{b}	4.3^{c}	1.92^{ab}	2.48^{a}
	10 – 15	18^{c}	66^{bc}	14.6^{bc}	1.29^{ab}	4.3^{c}	2.30^{a}	2.22^{ab}
	15 – 20	19^{c}	63^{bc}	14.5^{bc}	1.20^{b}	4.3^{c}	2.25^{a}	1.09^{c}
	20 – 30	21^{c}	58^{bc}	14.8^{bc}	1.12^{b}	4.4^{bc}	2.22^{a}	1.62^{bc}
	30 – 40	20^{c}	52^{c}	17.0^{a}	1.27^{b}	4.6^{b}	1.54^{bc}	1.99^{ab}
Solid fraction	0 – 2	157^{a}	154^{a}	23.0^{a}	2.70^{a}	6.6^{a}	0.85^{d}	4.31^{a}
	2 – 5	21^{b}	33^{b}	14.7^{b}	1.38^{b}	4.9^{b}	1.16^{d}	1.75^{b}
	5 – 10	18^{b}	57^{b}	15.3^{ab}	1.47^{b}	4.3^{c}	2.04^{b}	1.76^{b}
	10 – 15	18^{b}	47^{b}	14.8^{b}	1.44^{b}	4.3^{c}	2.45^{a}	1.78^{b}
	15 – 20	16^{b}	48^{b}	14.5^{b}	1.35^{b}	4.3^{c}	2.21^{ab}	1.94^{b}
	20 – 30	15^{b}	55^{b}	13.5^{b}	1.25^{b}	4.4^{c}	2.11^{b}	0.96^{c}
	30 – 40	17^{b}	59^{b}	12.8^{b}	1.44^{b}	4.4^{c}	1.55^{c}	1.58^{bc}

Values followed by the same letter in the same column do not differ significantly according to the Tukey test ($P<0.05$) for each treatment. The PS, SF and LF had, respectively 6.1, 6.9, 0.8 g kg^{-1} of TOC, and (mg kg^{-1}) 33, 574, 1.8 of Zn, 11, 8.1, 0.8 of Cu and 1.0, 0.2, 0.5 of Cd.

The $CaCl_2$-extractable Zn decreased in the first 2 cm in all treatments with respect to control, due to the increase in pH, but the values in LF significantly decreased down to 10 cm. The NaOH-extractable fraction increased in the first 2 cm of FS and PS treatments, linked to their OM contents. The EDTA-extractable fraction increased in the SF, which contained non NaOH-extractable polymers able to chelate metals. There were no differences between the amount of Zn leached in the treatments and the control (average 4.35 mg). The soluble and exchangeable Cu ($CaCl_2$) decreased in the first 10 cm of all treatments with respect to control. But the fraction linked to the OM clearly increased in the first 5 cm of PS, in all depths of SF, and in the lower layers in LF, at the expense of the residual fraction. This was due to the ability of Cu to form stable chelates with the OM (Ross, 1994), as both materials (SF and LF) led to the greater leaching of TOC (2.1 mg TOC). Cd showed the highest solubility, but PS and LF decreased the solubility in the first 2 cm, shifting Cd to the OM fraction. The PS effect was found at all depths.

All fractions of pig slurry decreased solubility of metals in the soil, mainly in the surface, due to the increase in soil pH. But the addition of OM, and its movement in the soil depth, retained Cu from the residual non-available fraction and Cd from the soluble fraction. The LF showed the highest risk of TOC and N leaching.

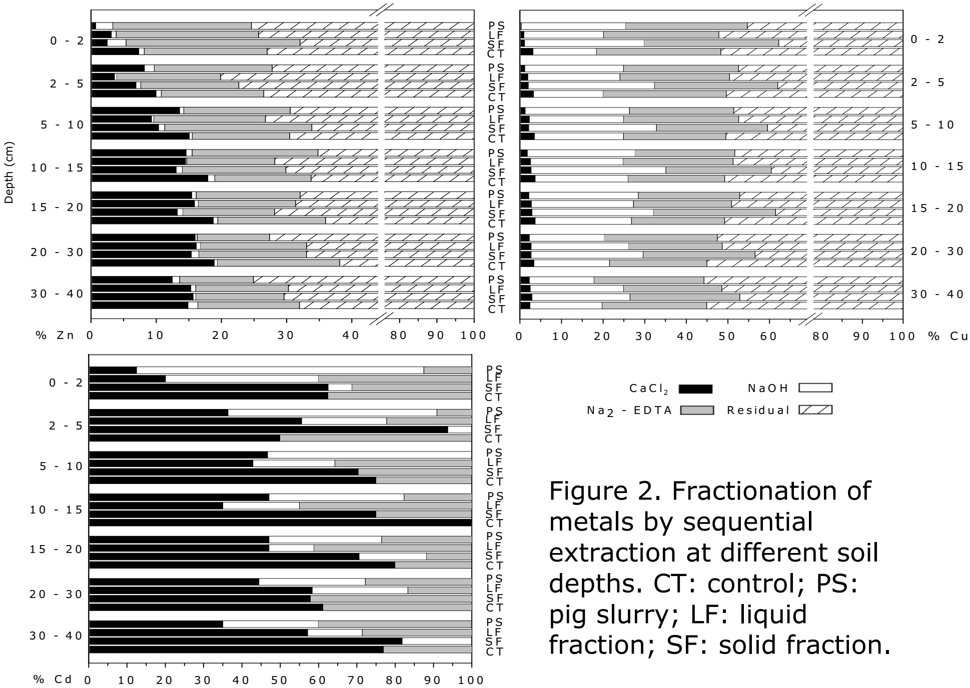

Figure 2. Fractionation of metals by sequential extraction at different soil depths. CT: control; PS: pig slurry; LF: liquid fraction; SF: solid fraction.

References

Martínez-Almela, J., Barrera, J.M. 2005. Bioresource Technology 96, 223-228.
Ross, S.M. 1994. Toxic Metals in Soil-Plant Systems. Wiley, Chichester.

Acknowledgements

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Influence of application rate and method on nitrogen losses from slurry applied to grassland

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Introduction

A number of techniques have been developed to reduce ammonia emissions following slurry application to land, and previous research has shown that band spreading and shallow injection techniques can give significant reductions (typically in the range 30-70%) compared with broadcast application. However, most previous assessments were conducted at application rates in the range 20 – 35 m^3 ha^{-1}. As slurry application rates on UK farms can exceed these levels, there was a need to establish a) the relationship between ammonia loss and application rate, and b) the effectiveness of band spreading/shallow injection at reducing ammonia emissions over a range of application rates. There was also concern that application techniques designed to reduce ammonia emissions may result in greater losses of N via other pathways (e.g. nitrous oxide emission, nitrate leaching) and not necessarily result in greater crop N uptake. This study was designed to address these questions.

Methodology

Field experiments were conducted to assess the influence of slurry application rate and method on nitrogen losses via ammonia volatilisation, nitrous oxide emission and nitrate leaching and also on crop N recovery. The experiments covered a range of soil types and application timings (autumn, spring and summer). In each experiment, slurry (cattle or pig) was applied at 5 target rates in the range 20 – 80 m^3 ha^{-1} by broadcast and trailing shoe/shallow injection, using a specially designed small-plot applicator. Band widths of the slurry on trailing shoe/shallow injection plots were measured to assess overall plot coverage. Ammonia emissions were measured for 7 days following application using a system of small wind tunnels (Lockyer, 1984). Nitrous oxide emissions were measured from the 35 m^3 ha^{-1} application rate over a 3 – 12 month period using static chambers. Nitrate leaching was measured via ceramic suction cups from the autumn applications to sandy textured soils. Fertiliser response curves were included to assess efficiency of utilisation of slurry N.

Results

Preliminary results indicate that while the band spreading application techniques can give significant reductions in ammonia emissions, compared with broadcasting, the magnitude of the reductions is variable. For example, significant reductions in emission (mean across all application rates of 53%) were achieved following shallow injection of cattle slurry (1.2% DM) in June 2004 to a clay soil (Fig 1a). There was no linear relationship between ammonia loss (expressed as a % total N applied) and the application rate for either application method, although losses at the lower application rate (circled in Fig 1a) were significantly greater than those at all other rates. The lower shallow injection emissions (mean across all application rates of 4% of total N applied) were a result of slurry being retained in the 3-4.5cm deep injection slots (9-18% of the ground surface area was covered by slurry) and infiltrating rapidly into the soil. However, no significant reduction was observed following trailing shoe application of cattle slurry (4.3% DM) to a sandy loam soil in November 2004 (Fig 1b), despite the slurry remaining in bands (49-62% of the ground surface area was covered by slurry). Again, there was no linear relationship between ammonia loss and the application rate for either application method, although losses at the lower application rate (circled in Fig 1b) were significantly greater than those at all other rates.

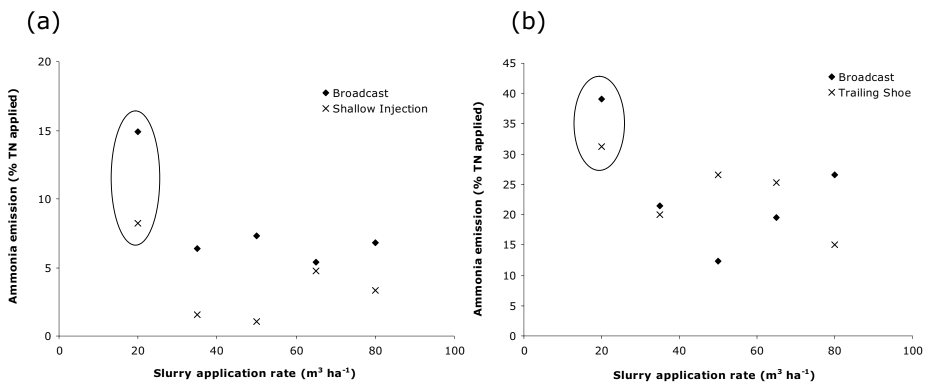

Figure 1. Relationship between ammonia emission (expressed as % of total N applied in slurry) and slurry application rate: (a) broadcast vs. shallow injection, June 2004 application; (b) broadcast vs. trailing shoe, November 2003 application.

There was limited evidence of 'pollution swapping' (i.e. an increase in nitrous oxide emission or nitrate leaching losses) for those applications where emissions were reduced. For example, following November 2003 application of cattle slurry to a clay soil there was a significant reduction in ammonia emission using shallow injection (60% across all application rates), but no significant increase in nitrous oxide emissions (Table 1). However, November (2003) application of pig slurry to a sandy loam soil by trailing shoe resulted in a small (non-significant) increase in nitrous oxide emissions and a significant increase in nitrate leaching (Table 1).

It is hypothesised that factors influencing slurry infiltration into the soil (e.g. hydraulic loading rate, slurry solids content, soil moisture status) influence the effective reductions achieved through bandspread/shallow injection compared with surface broadcast application. Full analyses of all results on completion of the experimental work will highlight strategies for reducing ammonia emissions from slurry spreading with minimal impacts on other N pollution pathways (nitrous oxide emissions and nitrate leaching).

Table 1. Influence of application method on nitrogen losses and crop uptake (all expressed as % of total N applied) from slurry applications (35 $m^3\ ha^{-1}$) to grassland.

	Cattle slurry to clay soil, November 2003 application		Pig slurry to sandy loam soil, November 2003 application	
	Broadcast	Shallow injection	Broadcast	Trailing shoe
Ammonia	12^a	5^b	63^a	32^b
Nitrous oxide	2.2	2.3	0.3	0.5
Nitrate leaching	-	-	10^b	19^a
Crop uptake	53	44	ND	ND

Within experiment, values in rows with different superscripts were significantly different ($P<0.05$); ND, not determined

Acknowledgement
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References
Lockyer, D.R., 1984. A system for the measurement in the field of losses of ammonia through volatilization. Journal of the Science of Food and Agriculture 35: 837-848.

Nitrogen and phosphorus losses following cattle slurry applications to a drained clay soil at Brimstone Farm

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Background

An estimated 47 million tonnes of farm slurry supplying *c.* 210,000 tonnes of nitrogen (N) and *c.* 50,000 tonnes of phosphorus (P) are applied to agricultural land in the UK each year. Current Nitrate Vulnerable Zone (NVZ) legislation (which covers *c.* 55% of agricultural land in England) does not impose timing restrictions on slurry applications to clay and medium textured soils, because these soils are perceived as being 'nitrate retentive'. However, on drained land (which covers an estimated 6.4 million ha in England and Wales) the rapid transfer of water from the soil surface to drains via soil macropores, could potentially lead to high nutrient concentrations and losses in drainage waters following slurry application. The pattern of nutrient losses from arable land is likely to be different to that from grassland, because factors that affect water movement (e.g. ground cover, cultivations, surface compaction, pore size distribution and continuity) differ between the two land use types.

Methodology

This study is being undertaken on a heavy clay textured (60% clay) soil of the Denchworth Association at Brimstone Farm (Oxfordshire). The site consists of 18 hydrologically isolated plots (40m x 48m) which were in arable production for over 20 years until autumn 2001, when grassland was established on 9 plots. Each plot is drained by pipe drains at 48m spacing and 90cm depth, supplemented by permeable fill to within 30cm of the surface and mole drains at 50cm depth and 2m spacing. Cattle slurry (*c.* 40m^3/ha, 115 kg/ha total N and 20 kg/ha P) was applied to the arable and grassland plots in September and December 2004, and March 2005, with three replicates of each application timing. Drainflow volumes were measured continuously and drainage water samples were collected on a flow proportional basis using automatic water samplers and analysed for NO_3-N, NH_4-N, total P (TP), total dissolved P (TDP) and molybdate reactive P (MRP).

Results

On the arable plots, NO_3-N concentrations in drainage waters up to mid-April 2005 were greatest ($P<0.05$) following the autumn slurry application timing and peaked at 70 mg/l NO_3-N after 5mm of drainage. Nitrate concentrations declined on all the treatments to less than 20 mg/l NO_3-N after 30mm of drainage (Fig 1a). On the arable reversion grassland plots, NO_3-N concentrations in drainage waters were low (less than 10 mg/l NO_3-N) throughout the drainage season. There was no effect ($P>0.05$) of slurry application timing on drainage water NO_3-N concentrations (Fig 1b).

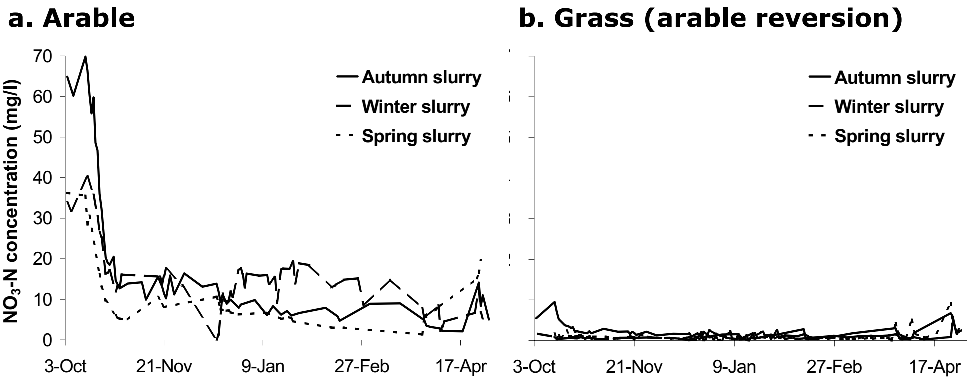

Figure 1. Mean NO_3-N concentrations in drainage waters (2004/05).

Mean NO_3-N leaching losses up to mid-April 2005 (when fertiliser N was applied) were greatest ($P<0.05$) from the arable land at 15 kg/ha, compared with 1.1 kg/ha from the arable reversion grassland. On the arable plots, NO_3-N leaching losses following the autumn and winter slurry application timings (up to the time slurry was applied in the spring) were equivalent to 10 and 6% of the total slurry N applied, respectively. Slurry application timing had no effect ($P>0.05$) on NO_3-N leaching losses from the arable reversion grassland plots, with losses from the autumn, winter and spring applications at 1.8, 0.7 and 0.9 kg/ha, respectively. The low NO_3-N leaching losses from the arable reversion grassland plots were a reflection of the recently established grass sward accumulating N within organic reserves, and of N uptake by the grass crop between slurry application and the start of drainage.

Heavy rainfall (*c*. 30mm in the 7 days following application) after both the winter (16th December 2004) and spring (23rd March 2005) slurry applications resulted in peak NH_4-N concentrations of *c*. 6.3 mg/l from the grassland plots (*c.* 8-fold greater than the EC Freshwater Fish Directive limit of 0.78 mg/l NH_4-N), compared with peak concentrations of *c*. 1 mg/l NH_4-N from the arable plots. Ammonium-N losses were greatest (P<0.05) following the winter and spring slurry applications to grassland (0.89 and 0.68 kg/ha, respectively), compared with losses in the range 0.19-0.33 kg/ha from the other four treatments.

Drainflow MRP concentrations from the arable and grassland plots peaked at 1.3 and 4.1 mg/l following the winter slurry application, and at 0.4 and 4.7 mg/l following the spring slurry application, respectively (Fig 2). Mean MRP losses over the whole drainage period (October 2004 to April 2005) were greatest (P<0.05) from the grassland plots at 0.68 kg/ha compared with 0.11 kg/ha from the arable plots. The elevated NH_4-N and MRP losses from the grassland plots reflected the greater connectivity between the soil surface and drains, as a result of 'by-pass' flow in cracks/mole channels, than on the cultivated arable plots.

a. Arable **b. Grass (arable reversion)**

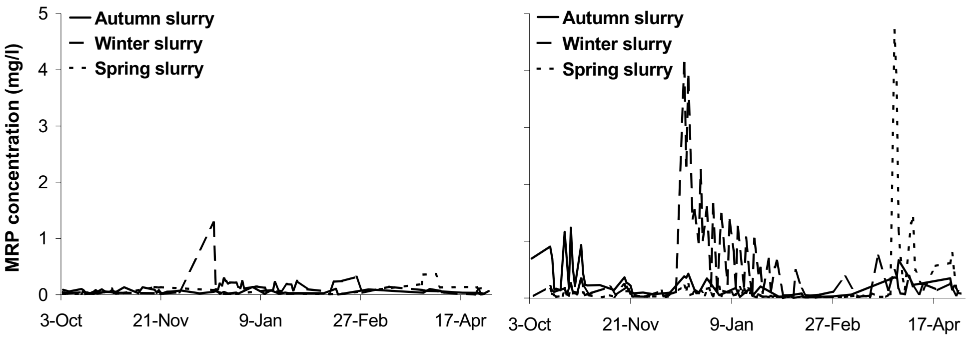

Figure 2. Mean MRP concentrations in drainage waters (2004/05).

Conclusions

These data indicate that drained arable clay soils may not be as retentive of slurry N as had previously been thought, although arable reversion grasslands are very nitrate retentive. Applying slurry to 'wet' drained soils where rainfall follows soon afterwards, is likely to result in elevated drainflow NH_4-N and P concentrations, particularly where there is good connectivity (e.g. grasslands) between the soil surface and field drainage system via cracks/mole channels.

Acknowledgement

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Grass forage yield and soil mineral nitrogen as influenced by fertilization type and slurry application techniques

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In Galicia (North-western Spain), grasslands are closely related to livestock management, and frequently animal manures are used as fertilizers. In the region, intensive farming generates appreciable amounts of slurry for disposal on restricted paddocks of the farms. Traditionally, they are spread by surface broadcasting. Nowadays, is well-known that the use of techniques such as shallow injection, compared to surface spreading, has as advantages: higher nitrogen (N) utilization by plants, lower ammonia losses and lower odour emissions. The objective of this study was to assess the effects of type of fertilizer and slurry application techniques to grass-clover ley in terms of crop yield and soil mineral N content.

A field experiment was conducted during 2005 at the Agricultural Research Station of Mabegondo, A Coruña. Altitude is 10 m, mean annual temperature is 13.3 ºC, and mean annual precipitation is 1128 mm (10-year average). The soil is a Humic Cambisol, characterised by a silty loam texture. In October 2004, at the site, a temporal grass-clover meadow had been sown. The experiment consisted of six treatments: a control (receiving no slurry or mineral N input), a mineral fertilizer (calcium ammonium nitrate) and two slurries, i.e. dairy slurry (D) and liquid swine (S) manure applied in two ways: by surface band application (B) or shallow injection (I) at 5 cm depth. The trial was laid out as a completely randomized block design with three replications. Slurries (Table 1) and mineral N fertilizer were applied three times, at a target rate of 100 kg N ha^{-1} in April and May and at a rate of 60 kg N ha^{-1} in October. Four cuts were harvested during the year (25 May, 19 July, 22 September and 24 November). For each cut, grass dry matter (DM) yield was determined. At the same time, soil samples (0-10, 10-30, 30-60 and 60-90 cm depth layers) were taken and analysed for mineral N (NH_4^+-N + NO_3^--N) contents.
There was a significant effect ($P<0.001$) of fertilizer type on the total DM yield (Figure 1.A). Forage yield was significantly greater for the SI

treatment than for treatments with dairy slurry application (DB and DI) and the control treatment, while there was no statistical difference between SI, SB and M treatments. Although no statistical differences could be demonstrated between the spreading techniques, shallow injection of dairy slurry had a detrimental effect on herbage yield compared to the use of inorganic fertilization. The reduction on first cut yield (Figure 1.B) after injection, independent of manure type, has been reported by most authors. It may have been due to sward damage by the injector tines due to the soil cutting action of the injector. By the second cut, shallow injection increased slightly DM yield and, in subsequent harvests (third and fourth cuts), a slight ($P>0.05$) DM increase was only observed in the liquid swine manure treatment.

Table 1. Date, application rates and some characteristics of slurries used in the experiment.

Date	Rate	Manure	Analysis (g kg^{-1} product)				
	m^3 ha^{-1}		DM	pH	Total N	P	K
6/04	30	Liquid swine	28	8.0	112.8	23.1	54.8
7/04	30	Dairy slurry	85	8.5	40.2	8.8	35.4
27/05	40	Dairy slurry	82	8.7	40.7	8.9	45.7
27/05	30	Liquid swine-injected	54	8.4	59.4	20.1	21.2
2/06	60	Liquid swine-banded	23	8.3	74.3	21.4	37.2
13/10	45	Liquid swine	26	8.3	50.8	14.1	20.3
14/10	15	Dairy slurry	85	8.5	47.8	7.7	65.0

Liquid swine manure was more dilute than cattle slurry (Table 1) and infiltrates more quickly into the soil, which probably resulted in lower rates of ammonia volatilization with respect to dairy cattle slurry and improved N uptake of the crop. With dairy slurry application the potential agronomic benefits due to injection were not observed, maybe it could be due to greater gaseous losses of N through denitrification as a result of higher C to N rate in this slurry compared to swine slurry.

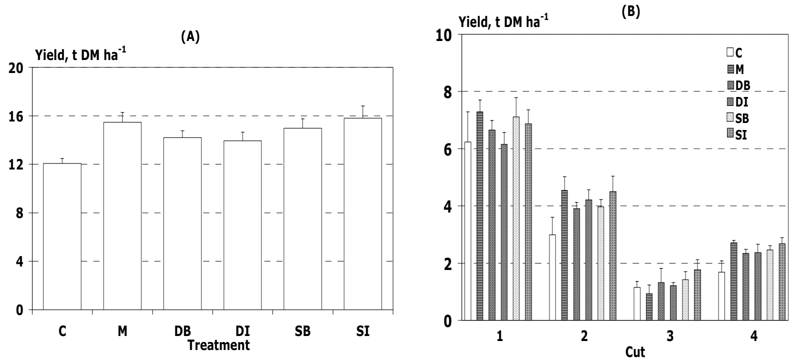

Figure 1. Forage DM yields following fertilizers application. (A) Total DM yield and (B) for the different cuts. C: Control, M: mineral fertilizer, D: Dairy, S: Liquid swine, B: Surface banded, I: Injected.

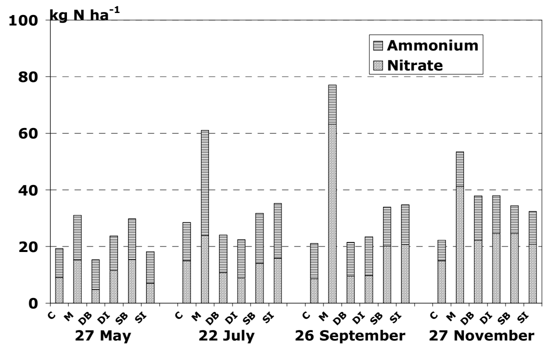

Figure 2. Soil mineral N contents (0-90 cm depth). C: Control, M: Mineral fertilizer, D: Dairy, S: Liquid swine, B: Surface banded, I: Injected.

Residual mineral N contents found in the soil profile (0-90 cm, Figure 2) after forage harvests showed that injection did not lead to increased mineral N in the soil compared with surface application. The largest values were found after inorganic fertilization.

In conclusion, the results show that shallow injection may be a good choice for liquid swine slurry application to grassland; it had not a detrimental effect on forage yield compared to the use of inorganic fertilization. The injection of slurries did not increase the risk of nitrate leaching during winter, whereas data suggest that nitrate losses after mineral fertilization could be higher than after slurry applications.

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Fractionation of copper and lead in a soil column amended with an anaerobic municipal sewage sludge

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Introduction

In recent years, the production of sewage sludge (SSL) has sharply increased in the Basque Country (N Spain) due to the demand for better quality of water and the imposition of more restrictive environmental laws. The application of stabilized SSL to the land has become an attractive option, as with this practice soil fertility can be increased, reducing the need for synthetic fertilizers. At the same time it represents a feasible alternative for waste management. Heavy metals are, however, one of the main concerns for the use of biosolids on land. The environmental impact of these contaminants strongly depends on their mobility and bioavailability. The objective of this study was to describe the fractionation of Cu and Pb in a soil column amended with an anaerobic municipal SSL with the use of a sequential extraction technique, so that information on metal mobility and potential availability could be obtained.

Materials and methods

The soil used in this study was a Dystric Cambisol developed from a mixture of marlstones and sandstones, with low pH (<4.0), low CEC (<15 cmol(+) kg^{-1} below the first 4 cm depth), and low base saturation (<17%), typical of soils located in high leaching environments. Organic C content in the A1 horizon was 93.8 g kg^{-1}, whereas that of the A2 horizon was about 4 times lower (23.5 g kg^{-1}). The concentrations of total N were 3.7, 1.5, and 0.8 g kg^{-1} for the A1, A2, and Bw, respectively, and soil texture was sandy clay for the A1 and Bw horizon, and sandy clay loam for the A2 horizon. Concentrations of native Cu and Pb in the soil were higher in the A1 horizon (13.4 and 61.0 mg kg^{-1}, respectively) than in the deeper soil horizons (depth weighted means: 6.1, and 12.6 mg kg^{-1}, respectively). The chemical composition of the SSL used was as follows:

organic C 20.5%, total N 4.2%, P Olsen 0.07%, pH 7.7, total Cu 456 mg kg^{-1}, and total Pb 151 mg kg^{-1}.

A soil column of 8.8 cm ID was hand packed, maintaining the original layering of the profile, to 53 cm depth, and an anaerobic SSL was applied on top of the column at a loading rate of 69 Mg ha^{-1} (DW equivalent), and irrigated with DD water at a flow rate of 3.6 mL h^{-1}. At the end of the 11-wk experiment, the column was cut into sections and air-dried at 30ºC. The sequential extraction procedure employed is summarised in Table 1. Determinations of total contents of Cu and Pb in soils and SSL were carried out after acid digesting the samples with a HNO_3:$HClO_4$ mixture (85:15; v/v). Analytical determinations were carried out by atomic absorption spectrophotometer equipped with a graphite furnace.

Table 1. Protocol for selective sequential dissolution procedure[1].

Extractant	**Solid:liquid Ratio**	**Temp. ºC**	**Time**	**Fractions associated with**
1. 1*M* $MgCl_2$	1:10	25	30 min	Soluble and readily exchangeable
2. 1*M* NaOAc + HOAc	1:10	25	5 h	Weakly adsorbed
3. H_2O_2	1:10	85	1 h	Organic matter
1*M* NH_4OAc + 0.02*M* HNO_3	1:20	25	Over night	
4. 0.5*M* NaOH	1:25	50	15 min	Al oxides
5. 0.25*M* $NH_2OH\cdot HCl$ + 0.25 *M* HCl	1:20	50	30 min	Fe and Mn oxides
6. 5*N* HF : 1*N* HCl	1:20	80	30 min	Residual

[1] Berna, F., Corti G., Ugolini F. C. and Agnelli A. 2000. Assessment of the role of rock fragments in the retention of Cadmium and Lead in irrigated arid stony soils. Annali di Chimica, 90.

Results and discussion

The distribution of background Cu in the original SSL was as follows: Fe and Mn oxides >> residual > organic matter (OM) >> weakly adsorbed = Al oxides = water soluble and readily exchangeable (Fig. 1A). In the natural soil the highest concentration of Cu was found in the residual fraction with 25%, 47%, and 41% of Cu total in the A1, A2 and Bw horizons, respectively (Fig. 1A). The range of Cu in the more labile fractions, such as water and readily-exchangeable, and weakly-adsorbed fractions, ranged between 2 and 7%. The distribution of Pb in the SSL was as follows: Fe and Mn oxides >> residual >> water soluble and readily exchangeable = weakly adsorbed = Al oxides = OM (Fig. 1B). The residual fraction of Pb in the native soil increased with depth, ranging from 9% in the A1, to 65% in the Bw, at the expense of the water soluble and the easy exchangeable fraction, which decreased from 50% in the A1, to 39%

in the Bw horizon. The amount of Pb bound to Al oxides was non detectable, and the Pb linked to the OM fraction was < 8% of total Pb content (Fig 1B).

At the end of the experiment, a decrease in total soil Cu concentration (from 13.4 to 10.6 mg kg^{-1}) was observed in the A1 horizon in spite of the addition of a Cu source on top of the soil column (456 mg kg^{-1} of Cu). On the other hand, a uniform increment of ~0.1 mg Cu cm^{-1} took place in the following 49 cm of the soil column. The same behaviour was observed with Pb, as the SSL amendment caused a decrease in Pb concentration (from 61.0 to 50.5 mg kg^{-1}) in the A1 horizon, whereas there was an increase in Pb content with depth (from 0.1 to 0.4 mg cm^{-1}), which was found to be mainly associated with OM.

After the 11-wk experiment, and below 4 cm depth, Cu was predominantly in the residual fraction and increased with depth (Fig. 1C), thus, showing an increase of Cu in this fraction relative to the original soil. A general increase of Cu, both in absolute and relative values, was also observed in the OM, and in the Fe and Mn oxides fractions (Fig. 1C). The

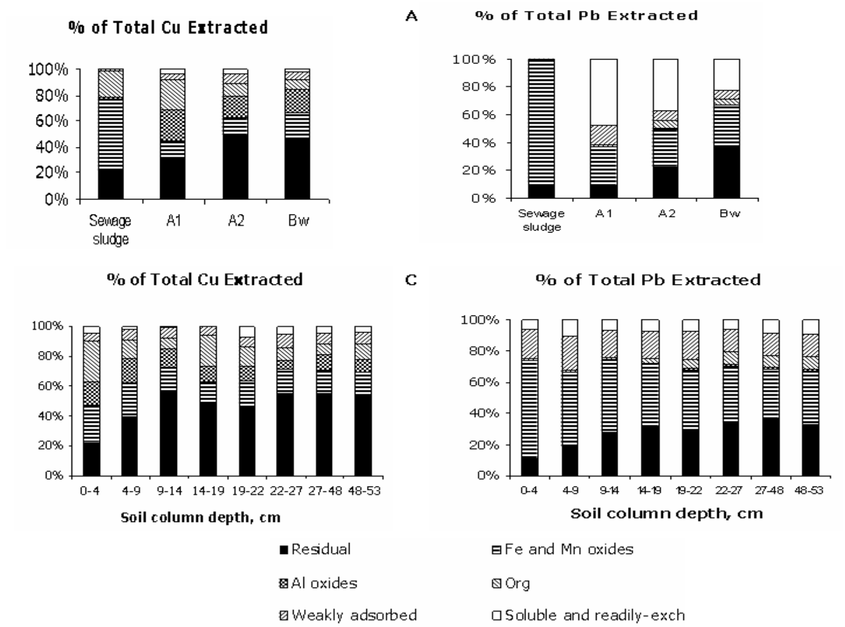

Figure 1. Distribution of Cu and Pb fractions in the initial samples (SSL and soil horizons used in the experiment) (A and B), and in soil columns, at different depths, at the end of the experiment (C and D).

decrease of total Cu detected in the A1 horizon was mainly attributed to a decrease in the Al oxides bound Cu, probably through binding reactions with organic and inorganic ligands added with the SSL and transfer to deeper horizons. A special increase in the OM-bound Cu was observed between 14 and 19 cm depth, thus suggesting the precipitation of organo-metal complexes along with the decrease of the carbon/metal ratio. Finally, a slight increase in the most Cu labile fractions was observed at depth (Fig. 1C), but this fraction remained low.

After the 11 wk experiment, and below 4 cm depth, Pb was predominantly present in the most recalcitrant fractions (Fig. 1D), with a general increase of those fractions bound to Fe and Mn oxides and of the residual fraction relative to the original soil. The main effect of the SSL addition was the noticeable decrease of the $MgCl_2$-extractable Pb, and the increase of the NaOAc-extractable Pb fraction in all horizons, especially in the subsurface horizons, in which their ratio doubled (Fig 1B and 1D). The percentage of Pb in the OM fraction increased considerably in the Bw horizon relative to original soil, probably because of the mobilisation of native Pb - through binding reactions with the organic ligands added with the SSL – to deeper horizons, as suggested for Cu. Finally, the fraction of Pb bound to Al oxides remained low at the end of the experiment (Fig 1D).

Analysis of malodorous volatile organic compounds in the air around dairy cow manure with HS/SPME GC-MS

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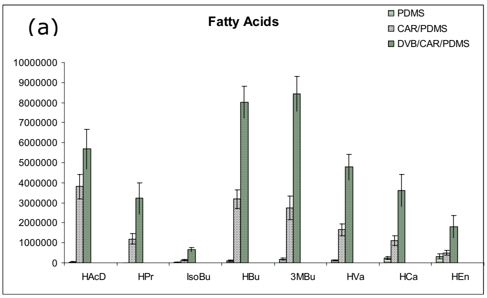
Malodorous volatile organic compounds (volatile fatty acids, phenols and indoles) (VOCs) emitted to the air of dairy farms are an important environmental problem in animal production, since they are regularly a source of conflicts in their neighbourhoods. Volatile organic compounds in the air come from different proteins that are degraded in the large intestine of the animals, and also in the wastes by different microbes.

In order to analyse the air around dairy farms, headspeace solid phase microextraction (HS/SPME) was used for the extraction and preconcentration of acetic acid, propanoic acid, isobutyric acid, butyric acid, 3-methylbutyric acid, valeric acid, caproic acid, enanthic acid, phenol, 4-methylphenol, 4-ethylphenol, indol and 3-methylindol. The determination of compounds preconcentrated by HS/SPME was performed with a gas chromatograph coupled to a mass spectrometer (GC-MS) (Varian Saturn 2200).

Different extraction fibres (30 µm DVB/Carboxen/PDMS, 100 µm PDMS and 85 µm Carboxen/PDMS) were tested to determine their extraction performance.



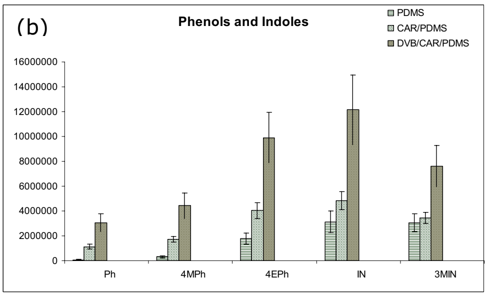


Figure 1. Different fibre extraction results for a) volatile fatty acids and b) phenols and indoles in air.

Based on Figures 1a and 1b it was concluded that 30 µm DVB/Carboxen/PDMS (DVB/CAR/PDMS) fibre was the best one for the extraction of fatty acids, phenols and indoles from the air at ambient temperature.

Different extraction periods at ambient temperature were tested for the chosen fibre. In one sense, the longest time extraction gave the best result for the compounds. However, one aim of the work was also to be able to analyse as many samples as possible per day, so an extraction time of 15 min at ambient temperature was chosen, which was enough to extract the compounds of interest.

Table 1. The relative standard deviation (RSD) within-a-day and among days for the analytes of a synthetic compound mixture.

Compounds	Within-a-day RSD%	Among days RSD%
Acetic acid	1.92	2.30
Propanoic acid	1.27	3.04
Isobutanoic acid	7.88	5.43
Butanoic acid	9.24	6.75
3-methylbutanoic acid	12.91	3.49
Valeric acid	9.18	0.83
Caproic acid	5.01	5.24
Enanthic acid	15.68	13.99
Phenol	8.19	5.04
4-methylphenol	10.69	5.28
4-ethylphenol	11.93	4.38
Indole	14.03	3.08
3-methylindole	14.72	4.18

The repeatability within-a-day and among days was studied, and the relative standard deviations for these values are shown in Table 1. External calibration curves were used for the quantification of the volatile organic compounds. These calibration curves were good enough for the quantification of these compounds in the gas samples.

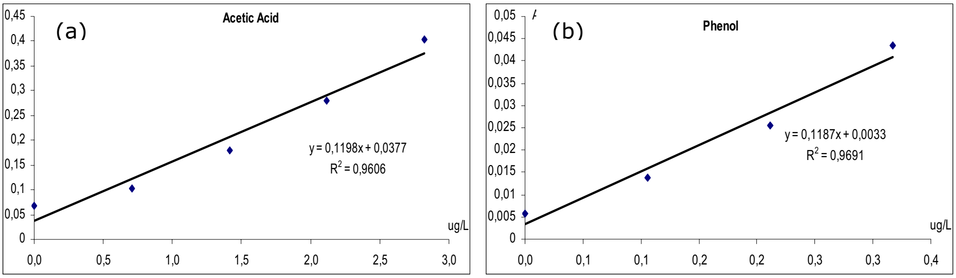


Figure 2. External calibration examples for the (a) acetic acid and (b) phenol.

The calibration curve was prepared in the lab with spherical gas bottles. In the first step, the internal standards (acetic-d_3-acid-d and phenol-d_6) were absorbed by the extraction fibre for 10 minutes, and then the analytes to be quantified were extracted for 15 minutes from the bottles of gas with different concentration. Gas samples at dairy farms were taken in Tedlar bags using a vacuum pump sampler (Supelco). The procedure used to prepare the calibration graphic with internal standard was followed with these samples, i.e. the internal standard were absorbed by the extraction fibre before extracting the analytes from the tedlar bags. The results obtained are shown in Table 2.

Table 2. The results for VOC in two air samples from dairy farms.

Compounds	Sample 1 µg·L^{-1}	Sample 2 µg·L^{-1}
Acetic acid	1.05	0.78
Propanoic acid	0.16	0.13
Isobutanoic acid	0.03	0.02
Butanoic acid	0.08	0.07
3-methylbutanoic acid	0.09	0.08
Valeric acid	0.14	0.14
Caproic acid	0.74	0.77
Enanthic acid	0.31	0.34
Phenol	2.09	2.40
4-methylphenol	0.03	0.02
4-ethylphenol	0.03	0.03
Indole	0.02	0.02
3-methylindole	0.03	0.03

Acknowledgements

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Agricultural value of the spent mushroom substrate

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The rapid expansion of the agroindustry sector during recent decades has led to an increasing production of organic wastes. One of these agroindustries is mushroom industry, which generates two main types of spent mushroom substrate (one for Agaricus bisporus (SMS-AB) and another for Pleurotus (SMS-P)). SMS-AB is composed of a composted mixture of cereal straw and manure (poultry and/or horse manure and/or pig slurry), calcium sulphate, soil and residues of inorganic nutrients and pesticides, whereas the SMS-P only contains cereal straw and residues of inorganic nutrients and pesticides. Great amounts of these wastes are produced in The Netherlands, France and Spain, countries accounting for 51 % of the European mushroom production. SMS has been employed in recent years for different uses, such as air, soil and water bioremediation, feedstuff and energy production, pest control of different crops and as organic fertiliser (Rynker, 2004). However, not enough data are currently available on the agricultural value of the different types of spent mushroom substrate. Therefore, the aim of this work was to carry out a nutrient characterisation of the two types of spent mushroom substrate from the mushroom industry in Spain in order to evaluate their potential fertilising capacity.

In this experiment, 36 different types of spent mushroom substrate (19 SMS-AB and 17 SMS-P) were collected from different mushroom industries throughout Castilla-La Mancha and La Rioja communities, which are the main mushroom producing regions in Spain, during a campaign in 2005-2006. Electrical conductivity (EC), pH, organic matter (OM) content, C/N ratio, N, P, K, Ca, Mg, Fe, Cu, Mn and Zn concentrations were evaluated on the collected samples. These parameters were analysed according to the methods described by Paredes et al. (2001).

As regards the comparative study of these organic wastes, the average pH values in SMS-AB were significantly higher and closer to neutrality than those of SMS-P (6.7 and 5.8, respectively) (Table 1), possibly due to the addition in SMS-AB of calcium sulphate to neutralize the pH of the composting mixture of residues and to supply the suitable level of Ca for mushroom (Pacioni, 1990). EC values were also higher in SMS-AB than in SMS-P, which could be due to the use of other materials together with cereal straw in the elaboration of SMS-AB. Only the SMS-AB samples showed significant differences in the pH values depending on the origin, whereas the EC values were influenced in both wastes by the origin.

Table 1. Agrochemical parameters of spent mushroom substrate for Agaricus bisporus (SMS-AB) and for Pleurotus (SMS-P) (dry weight basis).

	SMS-AB				**SMS-P**			
	Mean	Range	CV	Origin	Mean	Range	CV	Origin
pH	6.7 **a**	6.0-8.0	8	**	5.8 **b**	5.1-7.4	12	NS
EC (dS m^{-1})	8.1 **a**	5.5-10.3	19	*	4.7 **b**	3.1-7.7	26	*
OM (%)	56.3 **b**	34.3-71.1	17	***	86.9 **a**	80.4-91.1	3	NS
C/N	14.0 **b**	11.8-17.1	11	NS	40.8 **a**	25.8-85.1	37	NS
N (g kg^{-1})	22.0 **a**	16.4-27.0	17	***	11.6 **b**	5.0-17.1	26	NS
P (g kg^{-1})	8.03 **a**	3.21-11.94	33	*	0.92 **b**	0.32-1.74	36	**
K (g kg^{-1})	28.7 **a**	20.1-38.1	22	NS	16.7 **b**	11.4-28.4	26	**
Ca (g kg^{-1})	80.1 **a**	58.8-120.8	23	*	16.3 **b**	9.0-26.2	26	*
Mg (g kg^{-1})	6.33 **a**	0.65-10.19	36	***	1.96 **b**	0.82-372	39	NS
Fe (g kg^{-1})	3.73 **a**	0.73-8.47	69	***	1.04 **b**	0.33-2.00	45	***
Cu (mg kg^{-1})	37 **a**	26-51	21	NS	6 **b**	3-9	31	NS
Mn (mg kg^{-1})	321 **a**	208-418	17	NS	104 **b**	35-210	53	***
Zn (mg kg^{-1})	182 **a**	119-224	18	NS	22 **b**	5-41	47	**

EC: electrical conductivity; OM: Total Organic Matter; CV: Coefficient of variation.

*, **, ***: Significant at P<0.05, 0.01, 0.001, respectively, NS: Not significant.

Mean values in rows followed by the same letter do not differ significantly (P < 0.05) between the groups of residues.

The OM content of SMS-AB and SMS-P ranged from 34.3 to 71.1% and from 80.4 to 91.1%, respectively, being this parameter significantly lower in SMS-AB than in SMS-P (Table 1). This could be, on the one hand, due to the lignin-cellulosic character (high C content) of SMS-P, which is only composed of cereal straw, and, on the other hand, because of the fact that this material has not been composted. However, both wastes had higher OM content than the limits established by the Spanish legislation (BOE, 1998; BOE, 2005) for solid organic amendments and organic amendment-composts. The C/N ratio was < 15 in SMS-AB, indicating a good degree of stability of the organic matter (Iglesias Jiménez and Pérez

García, 1989), whereas in SMS-P this ratio was significantly higher, possibly because the cereal straw is a lignin-cellulosic residue with high C and low N contents. Only SMS-AB showed significant differences in the OM content which could be related to the origin, possibly because different manures or proportions of residues were used in the preparation of the compost, depending on mushroom growing area. The C/N values could not be related to the origin with any of the residues.

SMS-AB had also significantly higher concentrations of macronutrients compared with those of SMS-P, especially of N, P and Ca (Table 1). This fact could be due to the use in preparing SMS-AB of calcium sulphate and poultry manure, the last one having high N and P contents (Moreno-Caselles et al., 2002). The influence of the origin on macronutrient concentrations was greater in SMS-AB than in SMS-P, which is possibly related to the differences in the compost preparation depending on the mushroom producer region.

The average micronutrient contents in SMS-AB were for Fe 3.73 g kg^{-1}, Cu 37 mg kg^{-1}, Mn 321 mg kg^{-1} and Zn 182 mg kg^{-1}, whereas in SMS-P they were for Fe 1.04 g kg^{-1}, Cu 6 mg kg^{-1}, Mn 107 mg $kg^{-1}$and Zn 22 mg kg^{-1} (Table 1). The levels of these elements varied greatly (CV $\geq$ 50), being significantly higher in SMS-AB than in SMS-P. This fact could be attributed to the micronutrient content provided by the manures and the soil, which are components of SMS-AB. No significant differences among SMS-AB samples were observed in relation to their origin, whereas in SMS-P the origin influenced in the concentration of all micronutrients, except for Cu.

Compared with other organic wastes, which are commonly used as organic fertilisers, SMS-AB had higher salt content, similar organic matter content, similar or even higher macronutrient concentrations, especially in the case of Ca, and lower micronutrient contents (Pascual et al., 1997; Moreno-Caselles, 2002). SMS-P showed a similar salinity level, higher organic matter content and lower macro and micronutrient concentrations compared to those of manures and urban wastes used as organic fertilisers.

According to this, the residues from the mushroom industry could be used as organic amendment in agricultural soils, in order to improve soil fertility. However, the high contents of mineral salts of SMS-AB could limit its application to land in sensitive areas.

References

BOE, 1998. Orden del 28 de mayo del 1998 sobre fertilizantes y afines. Boletín Oficial del Estado 131: 18028-18078.

BOE, 2005. Real Decreto 82472005, de 8 de julio, sobre productos fertilizantes. Boletín Oficial del Estado 171: 25592-25669.

Iglesias Jiménez and Pérez García, 1989.Biological Wastes 27: 115-142

Moreno-Caselleset al., 2002. Communications in Soil Science and Plant Analysis 33: 3023-3032

Pacioni, 1990. El cultivo moderno del champiñón. Editorial de Vecchi. Barcelona

Paredes et al., 2001. Biodegradation 12: 225-234.

Pascual et al., 1997. Waste Management and Research 15: 103-112

Rynker, D.L., 2004. Handling and using "spent" mushroom substrate around the world (Part two). Available from http://setascultivadas.com/boletin.html.

Assessment of manure management systems in Austria and improvement of the emission inventory

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Introduction

Emission inventories must provide transparent, consistent, comparable, complete, and accurate data on sources and sinks of national emissions and must evaluate the progress towards meeting the reduction commitments. Ammonia emissions are reported according to the methodologies outlined in the EMEP/CORINAIR Guidebook. Greenhouse gas (GHG) emissions are estimated following IPCC methodologies. Emission inventories must not only estimate national emissions as accurately as possible, but also be able to show the annual trends in emissions and the effect of mitigation measures.

Agricultural emissions depend to a large extent on the animal housing, and on the manure management system (MMS). Data on MMS are a mandatory pre-requisite for accurate emission estimates. Mitigation measures can only be reflected in the inventory, if representative data on the MMS distribution are available. The necessity to collect more accurate data on national manure management system distributions is well acknowledged.

The research project presented in this paper assesses the MMS distribution in Austria. The project aims at the following: Detailed overview of Austrian animal husbandry, improvement of the Austrian emission inventory, modelling of typical farms and estimation of their emissions, development of emission scenarios, and proposal of feasible mitigation measures. The Division of Agricultural Engineering (DAE) will closely co-operate with the Swiss College of Agriculture, the Austrian Chamber of Agriculture, the Austrian Environment Agency, the Federal Research Centre for Agriculture in Alpine Regions, and the Statistics Austria.

Survey and questionnaire

Accurate emission inventories should be based on national activity data rather than on default values. DAE has surveyed a representative sample of Austrian farms by sending them a questionnaire that had to be filled in by the farmers. The survey is the basis of the further data processing, emission estimates and proposal of mitigation measures. Special consideration was given to carry out a high quality survey. The questionnaire assesses relevant parameters in all stages of animal husbandry systems: housing and exercise yard, grazing, waste and washing water, manure storage, manure application, animal feeding, and mineral fertiliser application. The Austrian questionnaire was based on a questionnaire that was used in the Swiss DYNAMO project. Austrian experts gave their view on the questionnaire in context with Austrian agriculture and made proposals for necessary adaptations to more specifically meet Austrian farming conditions.

Representative sample of Austrian farms

The sample design and the subsequent drawing of the sample were done in close cooperation with the Statistics Austria. The sample size was 5,000 farms. For the sample design, the Statistics Austria proposed the following criteria:

<u>Region</u> – The survey differentiates three Austrian regions: Eastern Austria, Southern Austria and Western Austria.

<u>Weighing factor, "hv"</u> - Farms with animal husbandry play a greater role in the emission inventory than farms without animal husbandry and should be more often represented in the survey sample. Thus, Statistics Austria weighed arable land with the factor 0.2 and livestock number with the factor 0.8.

Measures to increase the rate of questionnaire return

The survey aimed to achieve a rate of questionnaire return of 40 – 50 %. This necessitated a range of accompanying measures. Special attention was given to an early and comprehensive information to Austrian farmers. Project preparation and questionnaire development were done in close cooperation with the Austrian Chamber of Agriculture and with the Regional Chambers of Agriculture. The joint actions of DAE and the Austrian Chamber of Agriculture increased the project acceptance by the

Austrian farmers and their willingness to contribute to the survey. By the end of June 2006, 2,060 questionnaires had been returned to DAE, which corresponds to a rate of return of 41 %.

DYNAMO – Dynamic Ammonia Emission Inventory

From the questionnaire information, emissions will be calculated with the help of the computer based program "DYNAMO" (Dynamic Ammonia Emission Inventory) which is based on a simple empirical model to estimate ammonia emissions from animal husbandry (Menzi et al. 2003) The model was further refined and can now estimate ammonia losses from the whole manure management continuum. Emission estimates are based on the amount of N in the sections housing, grazing, exercise yard, manure storage and manure application. "DYNAMO" differentiates animal categories, manure management systems and a range of management parameters. Ammonia losses from mineral fertiliser application are estimated as well. "DYNAMO" emission estimation procedures are based on the N flow model as it has been described in the CORINAIR Guidelines. The Swiss College of Agriculture has made the computer based program "DYNAMO" available for DAE. "DYNAMO" parameters will be adapted to Austrian specific conditions. In addition to NH_3 emissions, emissions of the greenhouse gases N_2O and CH_4 will be calculated. Model farms will be defined and emissions calculated based on the survey results. Then, emissions will be estimated for the Austrian provinces and for the whole of Austria. Abatement potentials will be shown and measures for a reduction of ammonia and greenhouse gas emissions will be derived from the results. The project shall be finalised by the end of December 2006.

Acknowledgments

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References

Menzi H, Ruettimann L, Reidy B., 2003. DYNAMO: A new calculation model for dynamic emission inventories for ammonia. Proc. Internat. Symposium "Gaseous and odour emissions from animal production facilities", Horsens, Denmark, June 1-4 2003: 378-400.

Measures to decrease ammonia emission from solid manure storages

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Introduction

In 2003, 27% of ammonia emissions in Sweden originated from manure storage facilities. In the national inventory of ammonia emissions, the emission factor for stored solid cattle manure is currently set to 20%, and for stored cattle slurry to 3% with filling below a stable crust. The emission factor for solid manure storages, however, is based on a very limited number of data often obtained from static pilot-scale storages. On the whole, there is a need for more knowledge about solid manure storages concerning the manure flow in/out of the pad, manure properties and leakage of nutrients from the storage.

The main objective of this study was to quantify the ammonia losses during full-scale solid manure storage with and without abatement measures for ammonia losses. The overall objective was to find an economic and practical measure to reduce ammonia emissions during solid manure storage.

Materials and methods

This study was conducted on a cattle farm with tied system for 67 milking cows and followers. The manure was mucked-out twice a day through two separate rectangular horizontal channels leading to the 400 m^2 pad (Fig. 1). A drainage system on the pad leads liquid to a urine pit. An extra pad was used when the first storage pad was full.

Ammonia emissions were measured from the pad during two seasons (October to May; 182 day period). In the first (control) season, 2003-04, no ammonia reducing measures were employed. In the second season, 2004-05, the most efficient method (addition of peat to bedding) identified in an earlier pilot-scale study (Rogstrand *et al.*, 2004) was implemented. In the first season, the bedding material consisted of 2 kg straw and 1.5 kg sawdust per cow and day. In the second season the sawdust was replaced with 2.5-4.4 kg peat (50% water content).

Three areas with different manure characteristics were identified on the manure pad: 1) stacked manure (in front of the channels), 2) semi-solid manure around the stacked manure, and 3) liquid, consisting of urine, rainwater, and drainage from the stackable manure.

The method used to quantify ammonia during the full-scale trial seasons was an equilibrium concentration method with passive diffusion samplers (Svensson, 1994). On each identified sub-surface, two ventilated chambers and one ambient sampler were placed, and ammonia emissions were measured six (first season) or eight (second season) times per season. By integration over each sub-surface and over time an estimate of the ammonia emissions for the season was calculated. The amount of manure was estimated on each measurement day by registering the area of each sub-surface together with the height of the manure. Manure samples were taken for analysis of properties below the chambers on measurement days.

Figure 1. Measuring the ammonia emissions from three different sub-surfaces with ventilated chambers. The concrete pad was 400 m^2.

Table 1. Average properties of manure (mean ± S.D.). Season 1: n=6, Season 2: n=8

	DM	Total N	TAN	Total C	pH
	%	g kg DM^{-1}		% of DM	
Sub-surface 1, Season 1	20.3±4.1	26.5±4.1	7.4±2.6	42.2±1.0	8.7±0.2
Sub-surface 1, Season 2	20.6±4.1	28.0±3.3	6.6±3.7	42.1±0.8	8.1±0.5
Sub-surface 2, Season 1	16.6±1.2	35.0±6.4	12.2±3.9	42.0±1.2	8.6±0.2
Sub-surface 2, Season 2	17.4±4.3	32.0±3.8	8.7±3.5	40.9±1.4	8.2±0.6
Sub-surface 3, Season 1	1.8±0.4	69.5±21.5	41.4±14.4		7.9±0.1
Sub-surface 3, Season 2	0.7±0.7	85.0±10.9	58.9±5.8	25.2±6.5	8.4±0.3

Results and discussions

The average properties of manure from the three sub-surfaces are presented in Table 1. Eight sub-samples were compiled per analysis.

Figure 2 presents the ammonia emissions per sub-surface for the six measuring times in the first (control) season. Fig. 3 presents the results from the second season where peat was added to the bedding. The surface covered with liquid was the main source of the ammonia emissions during the control season, while the stacked manure was the dominant source in Season 2. In the control season, approximately 640 kg

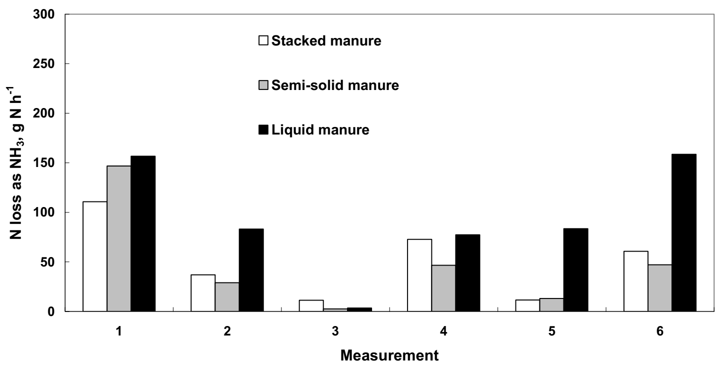

Fig. 2. Total ammonia emissions from the three different sub-surfaces at each measuring occasion, control season.

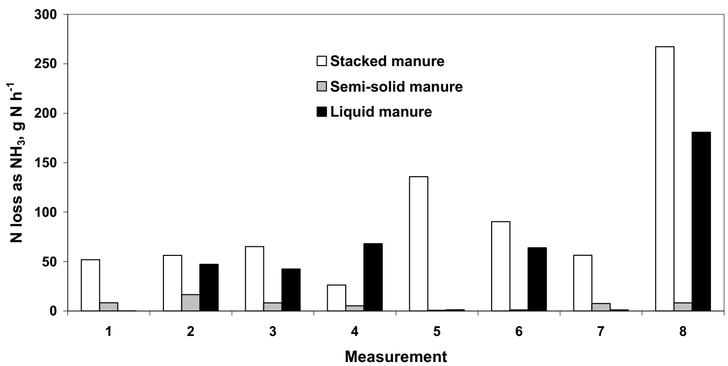

Fig. 3. Total ammonia emissions from the three different sub-surfaces at each measuring occasion, Season 2 with peat added.

N was lost from the main storage during 182 days. Additional 60 kg N was lost in the second storage, which means in total about 700 kg N or about 18% of the initial total nitrogen in the manure. When 2.5-4.4 kg of peat bedding per cow and day was used in the cattle house during the second season, the nitrogen loss was reduced to 14% of the initial total nitrogen in the manure, a reduction of 20% compared with the control season.

Conclusions

The conclusion was that addition of peat in the house reduced the nitrogen losses from solid cattle manure, but the financial gain in form of saved nitrogen was not enough to cover the cost of the peat.

References

Rogstrand G., Rodhe L., Tersmeden M. & Bergström J., 2004. Evaluation of three approaches to decrease ammonia from solid manure storage facilities. Proceedings from Ramiran 6-9 Oct, Murcia, Spain, pp 257-260.

Svensson L., 1994. A new dynamic chamber technique for measuring ammonia emissions from land-spread manure and fertilizers. Acta Agriculturae Scandinavica, Section B, Soil and Plant Science 44(1), 35-46.

Nitrification activity of soil polluted with copper and zinc after intensive pig slurry application

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Nitrate pollution is a big hazard around industrial pig farms. It is possible to manage this problem by the help of soil filtering plots. The SOLEPUR treatment represents a soil purifying system for treatment of pig slurry using soil physical and chemical capacities succeeded by denitrification of nitrogen in leachates. The SOLEPUR process was described in detail in a previous paper (Martinez, 1997). After intensive application of pig slurry, pollution by Cu and Zn is observed. High concentrations of heavy metals can perturb the soil nitrogen cycle (Wilson, 1977). Premi and Cornfield (1969) reported that soil Zn concentrations of 100, 1000 and 10 000 µg Zn g^{-1} (as $ZnSO_4$) showed no, partial and complete inhibition of nitrification, respectively.

The aim of our study was to determine the threshold of heavy metal (Cu, Zn) concentrations in soil of the SOLEPUR treatment facility beyond which nitrification will be inhibited, thereby interrupting the purifying capacity of this soil based system.

Materials and methods

A laboratory incubation study was conducted using ^{15}N to trace the dynamics of $^{15}NH_4$ labelled pig slurry added to soil samples amended with different level of Cu and Zn. The top soil used was a brown silt loam composed of 14,1% clay, 22,9% sand and 63,4% silt. $CuSO_4$ an $ZnSO_4$ were added to soil at rates of 50, 100, 250, 500, 1000, 2500 Cu mg.kg^{-1} soil and 75, 150, 375, 750, 1500 and 3750 Zn mg.kg^{-1} soil, respectively. These levels correspond to treatments T5, T10, T25, T50, T100, T250 (years of SOLEPUR potential operation). The soils were uniformly treated with 200 mg ^{15}N-NH_4 kg^{-1} in pig slurry, incubated at 28°C and ^{15}N-NH_4, ^{15}N-NO_3 and ^{15}N-Norg determined after 0, 7, 21 and 210 days of incubation.

The pig slurry was labelled by addition of ^{15}N labelled urea. Ammonium-N was determined by steam distillation in the presence of MgO, and $N\text{-}NO_3$ in the presence of MgO and Devarda's metal. Organic N was determined by steam distillation and the Kjeldahl method. The $^{28}N/^{29}N$ ratio was determined by mass spectrometry (VG 622 Micromass mass spectrometer) in the Laboratory of Plant and Microbiology Ecology at Research Center Cadarache.

Results and discussion

Only at the highest Cu and Zn rate (2500 and 3750 $mg.kg^{-1}$) was nitrification significantly inhibited. Concurrently immobilization was slightly increased at the same high rate of metal amendments. After 210 days of incubation $N\text{-}NO_3$ in T250 had increased to 28.4% of all labelled N, and $N\text{-}NH_4$ had decreased to 51.2% (Fig. 1). In treatments T5 to T50 slow re-organisation was observed, the relative organic N content increased from 5.5-6.9% to 8.2-10%. In the same period labelled organic N in T250 increased more than 50%.

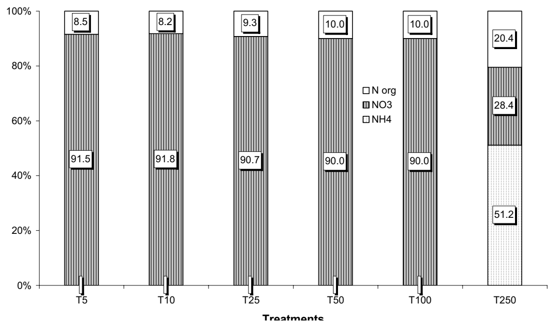
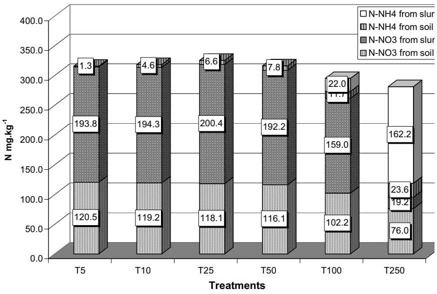


Fig. 1. ^{15}N distribution for 210 days of incubation.

Use of labelled urea permitted us to follow the nitrogen transformations depending of the origin of the N – N derived from soil and N derived from pig slurry. Nitrogen derived from soil was present in nitrate form mainly. A slow rate of mineralization of soil organic matter makes it likely that nitrification was high enough to prevent accumulation of $N\text{-}NH_4$ derived from soil. During the long term incubation the applied fertiliser showed an effect of heavy metals on N transformations in the soil. Soil N was more strongly affected by different treatments than slurry N, perhaps due to a rapid adsorption to soil colloids.



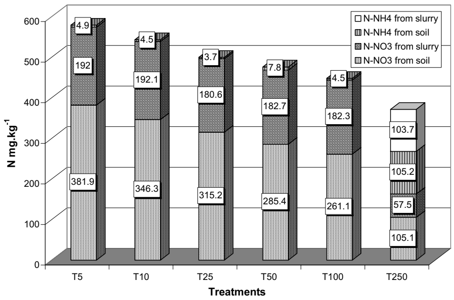


Fig. 2. Nitrogen sources for inorganic nitrogen in soil after 7 days of incubation.

Fig. 3. Nitrogen sources of inorganic N in soil after 210 days of incubation

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Changes of the different forms of inorganic N in incubated soil are shown in Fig. 2. No $N\text{-}NH_4$ was observed after 7 days of incubation in treatments T5 to T50. $N\text{-}NH_4$ content after 7 days of incubation in the T250 treatment was due to suppression of ammonification and to slow nitrification. Increased ammonification was observed after 210 days of incubation. The inhibitory effect of Zn and Cu was very strong, but not total. A similar effect was observed for the $N\text{-}NO_3$ changes in incubated soil. The relatively high rate of nitrification in T250 after 7 days decreased in the next period, 7-210 days. These results are in accordance with Strojan (1978) who also showed that the inhibition of decomposition of organic matter by heavy metals increased with time.

Changes in inorganic N during the period studied showed slower inhibition of N mineralization compared to nitrification. In all treatments inorganic N increased during the incubation period. Ammonification was lower in treatments with higher rates of heavy metals application.

Conclusions

In the presence of high organic matter content in soil and neutral pH, inhibition of N mineralization and nitrification in soil is possible at very high levels of Cu and Zn pollution (more than 1000 mg $Cu.kg^{-1}$ and 1500 mg $Zn.kg^{-1}$). The inhibition of N mineralization and nitrification increased with time.

Acknowledgements

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References

Martinez J (1997) SOLEPUR: a soil treatment process for pig slurry with subsequent denitrification of drainage water. Journal of Agricultural Engineering Research 66:51-62.

Premi PR, Cornfield AH (1969) Effects of addition of copper, manganese, zinc and chromium compounds on ammonification and nitrification during incubation of soil. Plant and Soil, XXXI, 2:345-352.

Strojan, C.J. 1978. Forest leaf litter decomposition in vicinity of a zinc smelter . Oecologia (Berlin) 32:203-212.

Wilson DO (1977) Nitrification in soil treated with domestic and industrial sewage sludge. Environ. Polut. 12:73-82.

A methodology for the sizing of slurry storages, and for measuring nutrient excretion on dairy farms

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Abstract
Proper sizing of slurry storage is the key to good nutrient management, and to avoid water pollution and soil compaction by machinery traffic in wet periods. On intensive dairy farms with high milk production, with the cattle indoor most of the time and with high stocking rates, there is a lot of slurry that must be properly stored. The slurry pit size must be calculated to store all faeces, urine, wastewater, bedding materials and rainfall during the period where slurry must not be applied to the soil, and therefore it is necessary to know the volume of each fraction and of the total slurry that is produced in each period. A methodology to measure the slurry production and nutrient excretion on dairy farms was developed. An equation is proposed to calculate the size of the slurry pit.

Material and methods
A device capable of acquiring, storing and reporting slurry level, rainfall, temperature and air humidity measurements from remote sensors was installed in a slurry pit on a commercial dairy farm.

The slurry pit was a rectangular prism of 133 m^2 made in concrete. The slurry level in the pit was measured with a sampling frequency of 20 times per hour by means of a ultrasonic sensor. A data logger stored the mean value of these 20 measurements. Rainfall was measured with a rain gauge and records stored in the data logger every hour.

The slurry pit stored only the manure produced by dairy cows. About forty seven dairy cows (mean annual) were housed all the time. The annual milk yield per cow was 9200 litres. The farm has 18.3 ha of arable land and therefore the number of dairy cows per ha is 2.57. Milking parlour waste water was measured with a water meter. Bedding material (kg) and number of cows housed daily was registered by the farmer.

Three slurry samples taken in July and December, 2005 and April, 2006, were analyzed. Slurry density was measured with a density meter. The quantity of slurry produced by animals housed during any period of time was calculated from the following expression:

Total slurry production = Slurry level * slurry pit area.

The amount of slurry produced was calculated by cow and day obtaining the mean value from differents periods of time from January, 2005 to June, 2006. The amounts of faeces and urine produced were calculated by the expression:

Faeces + urine = slurry level* slurry pit area*slurry density - rainfall – milking parlour waste water – bedding material

Slurry nutrient content was determined from three different samples. The nutrients available per ha of arable land were calculated by multiplying the cow annual nutrient excretion (kg) by the number of dairy cows per ha of arable land.

Figure 1 shows the evolution of slurry level (height) in the pit from January, 2005 to June, 2006 and the periods of time taken into account when calculating the total amount of slurry produced. The periods were chosen between total or partial slurry emptyings.

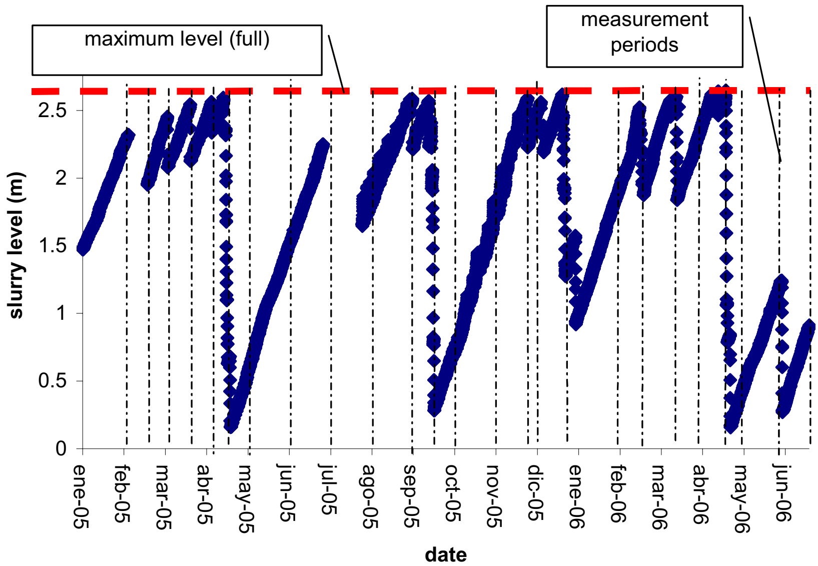

Figure 1. Slurry level (hourly measurement) in the pit, measured by means of an ultrasonic sensor.

Results and discussion

Table 1 shows the total slurry production and the production of the different components including faeces and urine, milking parlour waste water, rainfall and bedding material.

Table 1. Total slurry production and components

	mean	max	min	Std. Dev.	Var. coeffi.
Slurry total (litres/cow/day)	79.3	88.9	67.5	6.37	8.0
Rainfall (litres/cow/day)	5.7	17	0	4.7	82.5
Milk. parlour waste water (litres/cow/day)	16.1	18.3	14.1	1.23	7.6
Bedding material (kg/cow/day)	2.42	7	0.97	2.09	86.4
Faeces and urine (kg/cow/day)	57.7	64.6	50.4	5.49	9.5

Assuming a storage period of four months, the slurry pit size can be calculated by the following expression:

$V=S*h= 73,6*10^{-3} * M*30 + S*P*10^{-3}$,

where V = m^3 cow^{-1} ; S = slurry pit area (m^2); h = slurry pit height (m); $73.6*10^{-3}$ = m^3 cow^{-1} day^{-1} (without rainfall); M = number of months of storage; and P = rainfall (mm) for the period of autumn-winter storage. Considering the Galicia region rainfall zones (Cortizas et al., 2000), a slurry pit height of 2.5 m and 4 months of storage, the slurry sizing will vary from 10.8 to 13.6 m^3 cow^{-1} for uncovered pits, while for covered pits the sizing will be only 8,8 m^3 cow^{-1}.

With respect to nutrient excretion, Table 2 shows the composition of slurry (mean values of three slurry samples analysed for nutrient content).

Table 2. Slurry composition.

DM (%)	OM (g kg DM^{-1})	N (g kg DM^{-1})	P (g kg DM^{-1})	K (g kg DM^{-1})
10.4	70.3	35.5	6.9	38.3

Table 3 shows the annual organic matter and nutrient excretion per cow, and the amount of organic matter and nutrients available for recycling per ha of arable land.

Table 3. Annual excretion per cow, and nutrients available to recycle per ha of arable land.

	Organic Matter	N	P_2O_5	K_2O
Kg cow^{-1} $year^{-1}$	2312	117	52	151
Kg ha^{-1} $year^{-1}$	5469	276	123	357

References

Martínez Cortizas, A. y Pérez Alberti, A. (2000): Atlas Climático de Galicia. Consellería de Medio Ambiente, Xunta de Galicia. 210 pp.

Assessment of nitrate pollution sources in pig-farms producing liquid manure (Case study)

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The polluting effect of liquid manure of a pig farm on soil and groundwater was studied and presented in this paper. The investigated pig-farm is located near the Hármas-Körös River and an oxbow lake of the river; furthermore it is in the vicinity of the Körös-Maros National Park, Hungary. The groundwater can be found at a depth of 2,5-4,0 meters on average. Both the top-layer and the alluvial aquifer are identified as meadow soil with low hydraulic conductivity (1-3 x 10^{-3} m/d). The seasonal change in groundwater level is characterized by a minimum in November and a maximum in March. The annual fluctuation is 0,7-1 m. The covering layer of the main aquifer is at a depth of 50 meters from the surface. To determine the flow direction boreholes were established and their positions were determined by differentiated correction using a TRIMBLE GPS with an accuracy of ±0.5 m. A contour line map of groundwater level was interpolated. The weighting factors of the grid points of interpolated values were determined by krieging based on a linear variogram. Based on the created water surface model the directions of the subsurface run-off was calculated (Figure 1) by SURFER 8.0 software. (Tamás and Bíró, 2002).

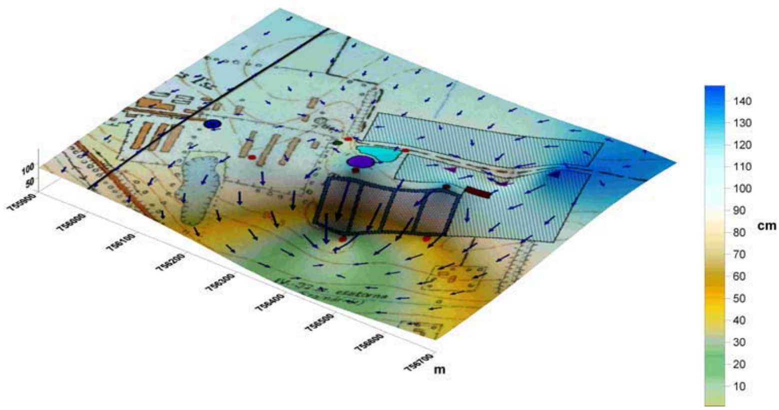

Figure 1. Three-dimensional groundwater model.

The main pollution sources of the pig farm are the structures for storage and transmission of liquid manure. Critical pollution was detected in the surroundings of the transferring sink, where a corroded concrete structure caused a direct pollution. The nitrate content of the soil- and groundwater samples was determined with an ANTHELIC LIGHT spectrophotometer according to the Hungarian standard. The estimated concentration distribution was prepared by krieging according to a previously described method (Keckler, 1995). Pollutant distribution maps were prepared based on the nitrate content of soil and groundwater samples and the groundwater flow model. Figure 2 shows the concentration map of nitrate in the groundwater.

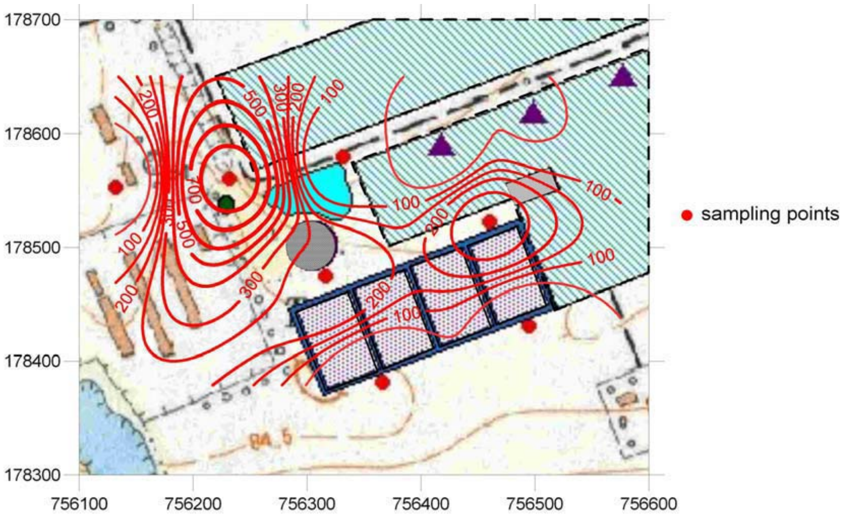

Figure 2. Nitrate distribution (mg/l) in groundwater.

The collective pollutant distribution of soil and groundwater can be seen in Figure 3. Based on the nitrate distribution of groundwater it can be concluded that the effect range of point sources is moderate since the polluted areas are concentrated around the sources. The concentration distribution, which is often inconsistent with the groundwater flow conditions, can be explained with the notably lower horizontal than vertical hydraulic conductivity. This anisotropy could cause the significant concentration differences despite the high hydraulic gradient between the adjacent boreholes.

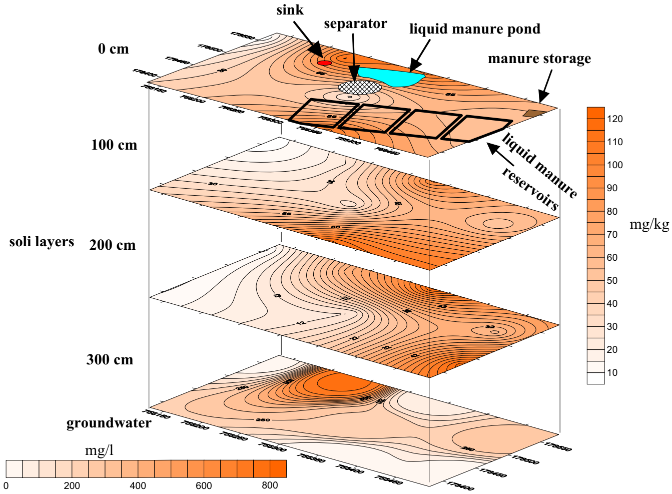

Figure 3. Nitrate concentration layers.

It can be ascertained that pollutant migration is predominantly determined by dispersion instead of convective transport. The highest contamination level on the farm was caused by direct pollution. In spite of the high pollution levels the ammonium concentration in groundwater was low in all samples which could be explained with the restricted flow and simultaneous nitrification. The elevated nitrate level of groundwater near pollution sources was not coupled with high nitrate content in the covering soil-layers, which can be explained by soil properties. The appearance of rifts and cracks - which occasionally reach the capillary zone - in drying soil can serve as tunnels and occasional high intensity rainfalls can wash down significant amount of highly polluted water to deeper layers from the surface. This phenomenon can be explained by by-pass infiltration in soils with an inclination to hysteresis.

References

Keckler, D. (1995): Surfer. Golden Software Inc.

Tamás J., Bíró T. (2002) Vízkészletmodellezés, Debreceni Egyetem tankönyv, Debrecen, 1-200.

Agronomic use of fish sludge

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Introduction

Farmed fish are fed pelleted feed containing nutrients such as nitrogen (N) and phosphorus (P), as well as trace elements to provide a balanced diet for optimum growth rates. However, since fish typically utilise only 30% of dietary N and P, the remainder is voided. Most of the voided N is dissolved, whereas for P, the majority collects in the sediment that settles to the bottom of the tank. Fish sludge, therefore, comprises uneaten fish pellets, faecal material, soluble metabolite products, heavy metals and soil particles and is a valuable source of plant nutrients (Table 1).

Table 1. Typical nutrient contents of livestock manures and fish sludges.

Manure	Dry matter	Total N	Ammonium N	P_2O_5	K_2O	Na
	(%)	(kg/t)	(kg/t)	(kg/t)	(kg/t)	(kg/t)
Cattle slurry	6	3.0	1.5	1.2	3.5	
Cattle FYM	25	6.0	1.5	3.5	8.0	
Pig slurry	4	4.0	2.6	2.0	2.5	
Poultry litter	60	30.0	10.0	25.0	18.0	
Fish (freshwater)	3	2.0	1.2	0.23	0.01	
Fish (marine)	6	0.4	0.1	0.38	0.36	91.0
Fish (marine, thick)	23	6.1	-	23.0	0.48	

Sludge is removed from fish tanks by mechanical filters and pumps in order to maintain high quality water and fish vitality and minimise the risk of disease within the stock. It can be returned to the land to fertilise crops and has the potential to make substantial savings in purchased fertilisers. Sludges may also contain some harmful substances, such as heavy metals and pathogens, which may limit their suitability for fertilising crops. Also, sludges derived from salt water fish farms may contain significant quantities of sodium (Na) which may impact on soil structure and crop health.

AQUAETREAT (Improvement and innovation of Aquaculture Effluent Treatment Technology, www.aquaetreat.org) is a European project examining the feasibility of developing and implementing cost-effective systems for the treatment of aquaculture farm effluent and the potential for reuse of the products and by-products. This paper focuses on the agronomic use of freshwater and marine fish sludge. Four small scale, replicated experiments were conducted in 2005/06 to determine the agronomic value of:

- Marine sludge (turbot) on short rotation coppice willow
- Fresh water sludge (trout) on potatoes
- Fresh water and marine sludge on grass
- Marine sludge (turbot) on sugar beet.

Methods

Experiment 1: Turbot sludge was applied in Spring 2005 to newly planted willow (*Salix viminalis*) rods at rates equivalent to 0, 10 and 50 m^3 ha^{-1}, with an additional application timing for the latter rate only, when the crop was *c.* 30 cm tall. Comparisons were made with inorganic fertiliser (ammonium nitrate) applied at 180 kg N ha^{-1} in 3 equal dressings of 60 kg N ha^{-1}. An assessment was made of crop damage and Na accumulation in the soil, as well as dry matter yield after one season. The experiment is being repeated in 2006. Experiment 2: Trout sludge was applied in Spring 2005 at a rate equivalent to 50 m^3 ha^{-1} in two equal doses to plots each containing 2 rows of potato plants, the first application being made prior to emergence and the second application post emergence. Effects on crop yield and health were determined. A glasshouse pot experiment was also carried out in 2006 using turbot, trout and cow slurries applied pre- and post-emergence. Experiment 3: Trout sludge, turbot sludge and cattle slurry were applied to a recently cut permanent grass sward (*Lolium perenne L.*), in summer 2005 and spring 2006, at 0, 50 or 100 m^3 ha^{-1} in 2005 and at rates calculated to supply 0, 50, 120 or 220 kg N ha^{-1} in 2006. Experiment 4: Turbot sludge was applied to pot grown sugar beet plants in a glasshouse experiment in 2006; 50m^3 ha^{-1} sludge was applied at various timings and repeated applications.

Results and discussion

Experiment 1: Briefly, the Turbot sludge resulted in some shoot damage and leaf scorch of the willow, with a 60% reduction in yield, when 50 m^3 ha^{-1} sludge was applied early, but little detrimental effect was evident at the later application timing (Figure 1). Soil Na content also increased with application rate. Similar results have been recorded in 2006. Experiment 2: Although increased potato yields following sludge applications were apparent, comparisons with the untreated control were not significant ($P>0.05$). Yields were low at <30 t ha^{-1}, which may have been the result of dry conditions. Potatoes have a high demand for P and are considered to be a suitable crop for utilising sludge efficiently, and this application provided <10% of the total crop requirement. The 2006 pot experiment showed that pre-emergent applications of both fish slurries retarded emergence, and post-emergent applications killed off the foliage. In contrast, cattle slurry increased foliage growth. Experiment 3: Despite apparent increases in DM yield, the organic amendments to grassland did not significantly increase yields (Figure 2) or N offtake over the controls in either year. Experiment 4: Pre-emergent applications again posed a problem, either delaying emergence or, at worst, preventing it. However, later post emergent applications showed no problems.

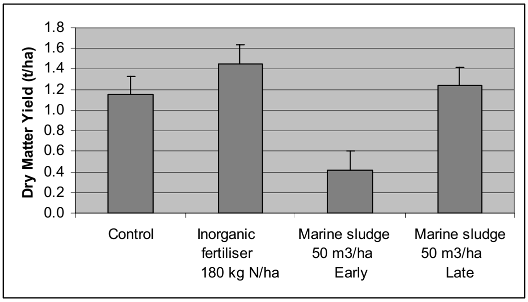

Figure 1. Effect of turbot sludge on willow biomass yield in 2005.

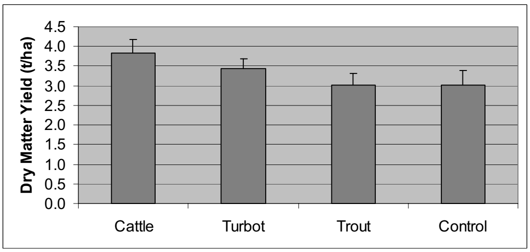

Figure 2. Effect of cattle slurry, turbot and trout sludge on herbage dry matter yield in 2006.

Conclusions

Both fish sludges made significant contributions in supplying part of the optimum fertiliser needs of crops with the potential for significant cost savings of *c.* €50 ha^{-1} for turbot and €60 ha^{-1} for trout sludge.

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Implementation of the IPPC Directive in the Portuguese pig sector. Water use and manure production rates in the account of N, P, Cu, Zn emission factors to water, based on a production site scale methodology

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Objective

This work aimed to determine emission factors to water of the major pollutants *N*, *P*, *Cu* and *Zn* based on production site-scale conditions in accordance with the Portuguese swine production reality.

Introduction

Slurry management based on recycling nutrients in agriculture is a common practice in the swine production sector. However, the Portuguese reality for the majority of the swine farms within the IPPC framework directive is quite different due to the lack of enough land or agricultural production. Therefore farmers are encouraged to join collective treatment facilities or to develop their own farm-scale treatment plant (lagooning systems in most cases). On the other hand, the need to fulfil the EPER (European Pollutants Emission Register) requires updated emission factors to water, to support calculation methodologies. Once treatment systems (solid-liquid separation + lagoons) are well disseminated within the pig sector, references about pollutants removal will be available.

Methodology

To reach this objective, two main aspects were taken into consideration: 1) Measured pollutants content should reflect normal operation; 2) Water consumption measurements should work as much as possible as the slurry production control. A two-year (2004-2006) field study was set up with the cooperation of three swine unit operators, selected from Portuguese IPPC universe according to previous critical planning and facilities constraints, i.e. two Farrow-to-Finish (**FF**) and one Growing-Finishing (**GF**). All operations were established with continuous systems with temporary slurry storage structures for each production stage. All production stages within each operation and operations globally were monitored for water use (with water meters), feeding, slurry production rate (recording the liquid levels in the slurry pits) and pollutants content. Slurry samples were taken inside the buildings from stored slurry of each type of animal, under the slatted floor at the end of the correspondent cycle, and outside in a permanent storage facility. Sampling took place according to routine and volume representativeness criteria, taking into account the specificity of each swine operation production system.

Results and discussion

Tables 1 and 2 show important differences for growing-finishing pigs regarding water consumption and slurry production rates. This is justified by the differences between housing systems and drinking/feeding equipments. The figures achieved for the N, P emission factors were in general lower in Autumm/Winter, nevertheless there is not enough data to define a pattern (Table 3).

Table 1. Daily water use, according to stage of production ($l/a.d^{-1}$) in each pig farm.

	FF 1		**FF 2**		**GF**	
Stage of Production	*Summer/ Spring*	*Autumn/ Winter*	*Summer/ Spring*	*Autumn/ Winter*	*Summer/ Spring*	*Autumn/ Winter*
Lactation	47,44	68,20	55,38	40,57	–	–
Pos weaning	9,04	6,34	5,22	7,94	–	–
Gestation	34,0	22,01	36,06	24	–	–
Growing-finishing	16,9	19,67	11,78	7,35	14,02	7,28
Global[1]	28,22	19,94	16,45	13,26	14,02	–

[1] Total water consumed: includes drinking, wasting, washing and other types of consume;

Table 2. Daily slurry production, according to stage of production ($l/a.d^{-1}$) in each pig farm.

	FF 1		**FF 2**		**GF**	
Stage of Production	*Summer/ Spring*	*Autumn/ Winter*	*Summer/ Spring*	*Autumn/ Winter*	*Summer/ Spring*	*Autumn/ Winter*
Lactation	43.7	57.70	49.84	24.14	–	–
Pos weaning	8.13	4.20	4.7	5.16	–	–
Gestation	25.4	12.00	26.89	13.98	–	–
Growing-finishing	10.82	11.80	5.72	3.71	8.98	5.38
Global[1]	21.65	11.12	10.22	7.43	8.98	7.75

[1] Total slurry production of the pig farm.

A good correspondence was observed between figures for the global slurry content measurements and those calculated by weighted average.

Table 3. Daily specific pollutant emissions, according to stage of production (kg/a.d^{-1}) in each pig farm.

FF1	*Summer/Spring*					*Autumn/Winter*				
Stage of production	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**
Lactation	3.97	7.09 E-02	1.68 E-02	1.06 E-04	3.86 E-04	4.48	4.47 E-02	1.36 E-02	1.19 E-04	3.23 E-04
Pos weaning	0.59	1.37 E-02	3.46 E-03	2.25 E-04	1.69 E-04	0.68	6.51 E-03	2.19 E-03	1.68 E-04	1.49 E-04
Gestation	2.56	4.37 E-02	1.06 E-02	7.24 E-05	2.29 E-04	1.84	4.25 E-02	1.66 E-02	1.49 E-04	5.57 E-04
Growing-finishing	2.39	3.51 E-02	5.21 E-03	9.49 E-05	1.14 E-04	2.33	2.47 E-02	9.91 E-03	4.45 E-04	3.58 E-04
Global [1]M	–	2.37 E-02	7.04 E-03	9.94 E-05	1.72 E-04	–	1.31 E-02	3.64 E-03	1.07 E-04	1.33 E-04
Global [2]C	–	3.17 E -02	5.84 E-03	1.28 E-04	1.54 E-04	–	2.13 E-02	8.21 E-03	3.09 E-04	3.10 E-04

[1] measured on samples of global slurry ; [2] calculated as a weighted average

FF 2	*Summer/Spring*					*Autumn/Winter*				
Stage of production	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**
Lactation	3.62	9.06 E-02	2.87 E-02	8.42 E-05	1.01 E-03	4.98	2.68 E-02	8.01 E-03	5.14 E-05	3.43 E-04
Pos weaning	0.87	1.36 E-02	3.32 E-03	9.25 E-05	5.22 E-04	0.59	8.15 E-03	2.55 E-03	1.82 E-04	6.95 E-04
Gestation	2.61	6.16 E-02	1.14 E-02	4.60 E-05	2.24 E-04	1.84	2.85 E-02	6.90 E-03	4.23 E-05	2.26 E-04
Growing-finishing	2.39	3.51 E-02	5.21 E-03	9.49 E-05	1.14 E-04	2.52	2.59 E-02	5.87 E-03	1.25 E-04	1.52 E-04
Global [3]M	–	3.35 E-02	4.96 E-03	8.52 E-05	1.74 E-4	–	1.98 E-02	5.19 E-03	1.84 E-04	3.05 E-04
Global [4]C	–	3.21 E-02	5.80 E-03	8.92 E-05	2.81 E-04	–	2.11 E-02	5.17 E-03	1.33 E-04	3.61 E-04

Lactation: sows + contribution of piglets

GF	*Summer/Spring*					*Autumn/Winter*				
Stage of production	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**	**Feed kg/a.d^{-1}**	**N_{total}**	**P_{total}**	**Cu**	**Zn**
Growing-finishing	1.76	2.54 E-02	3.47E-03	7.95 E-05	8.76 E-05	2.27	1.80 E-02	5.30 E-03	9.84 E-05	8.44 E-04

Conclusions

The results obtained demonstrate that this methodology was a robust contribution to the determination of N, P, Cu, Zn emission factors to water for each type of animal. A calculation method, taking into account the percentage of these pollutants removal in each treatment operation, can be supported for EPER report purposes.

Summary

Efficient use of agricultural residues and imported waste materials within agriculture is increasingly viewed from a whole-farm perspective.

The 12th International Conference of the Ramiran network in Aarhus, Denmark (11-13 September 2006) considered effects of management and technology on environmental impact and nutrient value of animal manure and other residues recycled within agriculture. Methods to describe and quantify effects of a given strategy or treatment practice at the farm level were discussed.

The Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture (RAMIRAN) is a voluntary, FAO-based research cooperation among scientists involved in research in food or agriculture across Europe.

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