New micro-meteorological techniques for measuring gas emission from stored solid manure

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Livestock manure is a source of atmospheric ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). NH_3 is recognised as a precursor to atmospheric particulate matter and when deposited may cause eutrophication. Methane and N_2O are greenhouse gaseswith a high warming potential. However, accurate estimates of emission of these gases from manure heaps are sparse due the lack of suitable measuring techniques.

In this study the integrated horizontal flux (IHF) and the backwards Lagrangian Stochastical (bLS) dispersion micrometeorological techniques were adapted to measure gas emissions (NH_3, CH_4, N_2O and CO_2) from a manure heap at Research Centre Lethbridge, AAFC. Net horizontal gas fluxes from a heap of composting beeflot manure were determined by mounting passive NH_3 samplers, gas intakes for CO_2 and CH_4, and anemometers on rotating poles that were always located up- and downwind of the pile as controlled by a wind vane. Further, NH_3 emission was estimated with the bLS technique using NH_3 concentration measured with a laser downwind of the heap. Spatial emissions of CH_4, N_2O and CO_2 were determined with static chambers placed on the heap surface.

Table 1**. Gas emission during 0-7 d after establishing a manure heap.**

	NH_3 kg N heap^{-1}	CO_2 kg C heap^{-1}	CH_4 g C heap^{-1}	N_2O g N heap^{-1}
IHF – passive flux samplers	0.77			
bLS-laser *	0.33			
IHF		46.2-54.3	357-600.0	77
Chamber technique		6.40	77.3	10.4

*The measurement with the bLS laser technique was initiated 1.5 h after establishing the heap and the initiation of measurements with the IHF-passive flux sampler technique.

Fluctuations in NH_3 emission measured with the IHF and bLS techniques were similar, but due to differences in measuring period overall emissions measured by IHF were higher than measured with the bLS technique (Table 1). Periodic measurements by taking air samples with syringes and measuring CO_2 and CH_4 concentrations on a gas chromatograph, were similar to continuous measurements with an infrared gas analyser connected to gas intake points up- and downwind of the stockpile. Emissions of CO_2, CH_4 and N_2O measured with the static vented chamber technique were 12-22% of that measured with the IHF technique. The large difference

Assessment of the ammonia abatement potential of different geographical regions and farm types based on a large-scale survey

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Agricultural production is well recognised as the major contributor of ammonia to the atmosphere. As ammonia is responsible for serious negative environmental impacts regulatory measures for the reduction of the emissions have to be introduced. A detailed assessment is necessary to identify the most efficient abatement strategies. The ammonia abatement potential as well as the most effective abatement measures may vary significantly between geographical regions, altitudinal zones and different farm types. Abatement strategies should therefore be adapted to the prevailing regional and farm specific conditions to efficiently abate ammonia emissions.

Based on the results of a representative survey on farm management parameters relevant for ammonia emissions, we performed a detailed assessment of the emission abatement potential using the N-flux model DYNAMO. The stratified survey allowed the differentiation between three different geographical regions, three altitudinal zones and differentiated four main farm types.

Thanks to the stratified structure of the survey, it will possible to perform a highly differentiated analysis of the ammonia abatement potential for each of the 36 different classes and to elucidate the most effective abatement measures specific for the different geographical regions, altitudinal zones and main farm types. This assessment will also allow the preparation of 1) detailed practical recommendations on the most promising abatement measures for different regions and farm types and 2) a strategy of how to identify the most promising measures for a specific farm. As nitrogen input is strictly limited in Swiss agriculture by the agricultural policy, a wide and rapid implementation of the recommendations derived from the project is expected. Detailed results of the project will be available by March 2004.

Ammonia abatement : Effectiveness and costs in two German model farms

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Introduction

By ratifying the UN/ECE Protocol (1999) to abate acidification, eutrophication and ground-level ozone Germany contracted to reduce ammonia emissions in agriculture to 550 kt/y in 2010. In addition Germany has to describe, derive and publish an advisory code of Good Agricultural Practice (GAP) for reducing ammonia emissions. Therefore a national expert group has defined the most acceptable abatement measures in livestock feeding and housing systems for pigs and cattle, as well as measures concerning storage and application of manure. The advisory code of GAP is published as an aid/KTBL Brochure (aid 1545, 2003).

Material and methods

To show the effectiveness of the abatement measures in pig and cattle production, special abatement models for single farm types (pig farm with 1000 fattening places; dairy farm with 70 cows) were calculated.

Results

The most effective abatement measure in the model farm "pig production" is the combination of a slurry tank covered with straw and slurry application with trailing shoes. The ammonia emissions are reduced by about 36 % compared with a non-covered tank and broadcast application of the slurry (reference system). The additional costs are about 0.7 € / kg reduced ammonia emission (1.9 € per pig place). Supplementary N-adapted phase feeding leads to a 54 % reduction of the ammonia emissions, the costs increase to1.4 €/kg NH_3 (5.6 € per pig place).
By using a floating cover for the slurry tank and slurry application with trailing shoes the ammonia emissions can be reduced by about 28 % in the dairy farm model. Compared to the reference system (natural crust on slurry tank, broadcast application of the slurry), the additional costs are 2.9 €/kg NH_3 (40.4 € per cow place).

Conclusions

N-adapted phase feeding in pig production shows to be an effective but cost-intensive ammonia abatement measure. In comparison to pig production higher costs per kg reduced NH_3 are to be expected in cattle production. The most cost-effective ammonia abatement measure in pigs and cattle management is the incorporation of slurry within 1 hour.

European agricultural gaseous emissions inventory researchers network (EAGER)

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Under the Gothenburg protocol, signatories will have to report NH_3 emissions annually. The emission inventory approach must give a true picture of emissions, reliably and reproducibly show changes over time, recognise relatively small changes and take into account all relevant and measurable variables that influence emissions. To allow a co-ordinated implementation of the Protocol, different national inventories should be comparable; at present they are not. A better harmonisation of inventory approaches is therefore needed.

Several countries are introducing legislation to reduce NH_3 emissions. To identify measures and to monitor progress, more reliable emission models will be needed. Co-ordination of model development is advisable, to pool knowledge, create synergies and guarantee good congruency between emission models.

A core group of emission inventory experts has come together to develop a network and joint programme, with the aim of achieving a detailed overview of the present best available inventory techniques, compile and harmonize the available knowledge on emission factors and initiate a new generation of emission inventories that satisfies the new requirements. The purpose of the group is to support harmonized emission inventory activities on the European scale (input for UN/ECE expert group, CORINAIR etc.) and to review and coordinate emission model development activities. The network initially comprises a few members with the greatest experience to allow a rapid initial progress. Later, the experience will be disseminated in a wider group. In its first year the group has compared and evaluated existing approaches. First conclusions are:

- Only models based on N flow can fulfil the new requirements
- Existing N-flow models show a good congruency, but each model has aspects to be checked
- The sharing and pooling of experience provides a large added values to the members and valuable inputs to official European groups and activities.

Can the additive "Effective Micro-Organisms (EM") reduce ammonia and greenhouse gas emissions from slurry stores?

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The additive "Effective Micro-organisms ("EM") is produced and distributed by Multikraft GmbH. EM is widely applied in horticulture, as feed additive in animal houses, as slurry additive, etc. It consists of several micro-organisms and it is anticipated that these reduce NH_3, N_2O, CH_4 and odour emissions from slurry stores. The experiments aimed at investigating the influence of EM on ammonia and GHG emissions from dairy cattle and pig slurry stores.

NH_3, CH_4 and N_2O emissions were quantified in pilot scale slurry tanks. The effect of the following treatment options was investigated: dairy cattle slurry with and without EM, pig slurry with and without EM, and pig slurry where EM had been used as feed additive in the pigs` feed. Emission rates were determined with a large open-dynamic chamber and with high resolution FTIR spectrometry.

Table 1. NH_3, CH_4, N_2O and greenhouse gas emissions during storage of dairy cattle slurry with and without EM

Treatment	CH_4 [g m^{-3} slurry]	NH_3 [[g m^{-3} slurry]	N_2O [g m^{-3} slurry]	GHG[a] [kg CO_2 Eq. m^{-3}]
cattle_withoutEM	894.2	152.7	60.0	37.4
cattle_withEM	910.1	121.9	50.1	34.6

Table 2. NH_3, CH_4, N_2O and greenhouse gas emissions during storage of pig slurry with and without EM and of slurry from pigs where EM was used as feed additive.

Treatment	CH_4-C [g (kg VS)$^{-1}$]	NH_3-N [g/ (kg Nt)$^{-1}$]	N_2O-N [g/ (kg Nt)$^{-1}$]	GHG[a] [kg CO_2 Eq./ (kg VS)$^{-1}$]
pig_withoutEM	97.9	51.9	4.3	4.83
pig_withEM	99.8	58.7	5.3	5.37
pig_EMfeed	22.8	31.6	3.3	2.24

When EM was added to cattle slurry at the beginning of slurry storage, NH_3, N_2O and GHG emissions during storage significantly declined. CH_4 emissions were not influenced.

Addition of EM at the beginning of pig slurry storage had no or negative influence on NH_3 and GHG emissions. This is probably due to the fact that the pig slurry that was used in the experiments had a very low dry matter content (1.95 % DM). In summer this year, experiments will be repeated with pig slurry with a higher dry matter content. EM application as feed additive significantly reduced NH_3 and GHG emissions during subsequent slurry storage.

Quantifying odour emission from composting

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Abstract

Techniques for quantifying odour from composting need to be developed in order to assess new composting methods and to aid odour control. The method used for measuring odour concentration or offensiveness is based on human odour panel validation (olfactometry). In addition the chemical profile was determined using gas chromatography-mass spectrometry (GC-MS) and colorimetric gas detector tubes. These were compared and major odorants were identified from samples obtained from 10 different composting yards. A polypyrrole based 'electronic nose' was also investigated for odour quantification.

Sulphur containing compounds were found to be the major contributors to compost odours. There was a close correlation between the compost emissions as an olfactory response as odour concentration m^{-3} (OC) and the combined hydrogen sulphide (H_2S) and dimethyl sulphide (DMS) concentrations from gas detector tubes. A range of other sulphides and volatile compounds were detected by gas chromatography mass spectrometry (GC-MS) after pre-concentration on an adsorption media, because concentrations were close to their odour detection thresholds. The electronic nose produced positive sensor responses to ammonia (NH_3) at concentrations of less than 2 ppm and negative responses to H_2S and DMS above concentrations of 50 and 20 ppm. The electronic nose could distinguish anaerobic odours from composts with OCs of above 50,000 (typical of anaerobic zones in windrows) from less odorous compost sources. For most on-site measurements, H_2S and DMS detector tubes are more appropriate and can be transposed as an olfactory response within 80% accuracy. The chemical profiles of emissions from turned compost are also presented.

Key words; odour, compost, olfactory, chemical composition,

Measurement and abatement of ammonia emissions from hard standings used by livestock

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Recent research findings suggest that hard standings may account for 10% of the ammonia emission from UK agriculture. However, this current estimate is subject to much uncertainty, due to insufficient information on the frequency of use and stocking densities on hard standings, and the fact that data are limited to a small number of farms. The aim of this project was to carry out additional measurements on commercial farms to address these uncertainties. In addition, experiments were carried out to assess potential abatement measures that could be applied to hard standings.

Ammonia emission was measured on 12 commercial farms (dairy, beef and sheep) at different times of the year to reflect seasonal changes in conditions and usage of the hard standings. Emission measurements were made using the equilibrium concentration technique (employing a system of small dynamic chambers). In order to assess abatement strategies a series of measurements were made on concrete yards at IGER North Wyke to which a group of beef cattle had controlled access. The treatments were:

- No cleaning
- Daily scraping
- Daily washing and scraping
- Use of urease inhibitor and daily scraping
- Reduced area allowance per animal

Each treatment was imposed on the hard standing for a period of one week, with ammonia emission being made on the final two days. Effectiveness of abatement measures was compared against a 'control' yard which was subjected to daily scraping, the most commonly used method for cleaning hard standings.

Preliminary results from this study indicate that scraping in combination with daily washing or use of a urease inhibitor may be effective abatement strategies on hard standings. Further measurements will be conducted on commercial farms to assess both the effectiveness and practicality of these potential abatement measures. Results of the study will be available for presentation at the RAMIRAN 2004 conference.

Ammonia emission from FYM heaps and cattle and swine slurry stores

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Ammonia emission during animal waste storage are estimated to range from 15% to 25% of the total ammonia losses from livestock activity (Svennson, 1991). In Italy, even tough during the last years the volume of stored slurry increased, measurement of ammonia emission from cattle and pig slurry stores (and from manure heaps as well) has not attracted the same interest of other sources such as soil after land spreading. With the aim to collect data from such sources in the national environmental conditions, measurement of ammonia emission were performed from pig and cattle slurry circular tank and from manure heaps. The measurement from slurry stores were performed by means of a specific system consisting of a 13,8 dm^3 captor, a trap containing 400 ml of a 1% boric acid solution, a vacuum pump, an interceptor trap, a volume meter and a flow-meter. The device is arranged to suck the air from the captor with a flow rate of 9 l/min. The ammonia present in the air is then fixed by the boric acid solution into ammonium borate and its concentration can be rapidly determined by titration with 0,1 N Sulfuric acid. The captors were mounted on a special polystyrene and wooden floating frame and placed on the slurry surface. The captors are let free to float on the slurry surface so that the area subjected to the measurement changes continuously. Measurements of ammonia emission from manure heaps were performed by means of an open Large Dynamic Chamber. The trials, carried out in different seasons (summer, winter and autumn) on cattle (8%TS) and pig (3-4% TS) slurry stores, and on manure heaps (autumn, winter) pointed out ammonia losses up to 1.6 $gNH_3.m^2$ and 2.5 $gNH_3.m^2$ per day respectively. First results of ammonia emission measured from FYM heaps showed emission closed to 2.5$gNH_3.m^2$ per day.

Integrated management practices to minimise losses and maximise crop nitrogen value of broiler litter

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Ammonia (NH_3) emissions from UK agriculture have been estimated at 265 kt of NH_3 each year, with losses from the storage and land spreading of solid manures making an important contribution to total emissions. The objective of this study was to quantify the effects of contrasting manure storage methods on NH_3 emissions from solid manure heaps and the effect of NH_3 abatement strategies during storage and land spreading on nitrate leaching losses and crop N availability.

In spring 2001, broiler litter was stored for 6 months at ADAS Gleadthorpe, Nottinghamshire, U.K. There were 5 different storage treatments: conventional, sheeted, turned, 'A-shaped' and roofed. NH_3 emissions during storage (measured using polytunnels) and N losses in store leachate were quantified. After storage, the manure from each storage treatment was spread to loamy sand soil at a target rate of 250 kg total-N ha and the land sown with grass. NH_3 emissions (passive diffusion samplers) and nitrate leaching losses (porous ceramic cups) following land spreading were measured and grass yields and N offtake determined.

NH_3 losses were greatest (P<0.05) from the roofed heap (19 % of total N into store) and least (P<0.05) from the sheeted heap (1 % of total N into store), with intermediate emissions from the other heap treatments (13 – 16 % of total N into store).

Storage and incorporation methods both had significant effects on NH_3 emissions at land spreading (P<0.001). Emissions from the surface spread sheeted manure were equivalent to 26 % N into store and were greater (P<0.05) than from surface spread conventionally stored manure at 11 % N into store. To conserve the retained N during storage rapid soil incorporation was required, which reduced emissions by 15 – 87 % compared to surface spreading. Ploughing the manure into the soil 4 hours after land application increased (P<0.05) nitrate leaching losses from the sheeted manure (losses equivalent to 14 % N into store) compared with 4 % N for the surface spread manure. Incorporation method also had a significant effect on grass N offtake, with ploughing within 4 and 24 hours after application producing greater (P<0.05) grass N offtakes compared with surface spread manure.

This study has shown that NH_3 emissions abatement methods at storage and land spreading can result in important 'pollution swapping' effects that need to be considered as part of an integrated solid manure management policy.

Dynamic modeling of ammonia biofiltration from waste gases

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Ammonia is a highly odorous gas produced by organic waste treatment facilities and other industrial sources. Common air pollution control processes for polluted emissions are physical and/or chemical. However biological treatments have become an effective and inexpensive alternative to conventional treatment systems. In particular biofiltration has been successfully applied for treating low ammonia loads.

Biofiltration is a complex process that involves physical and biological interactions. Several works have been developed for modeling biofiltration, most of them for steady-state conditions. Nevertheless dynamic models are more suitable since biofiltration operation is often carried out under varying load conditions. More realistic models are necessary to improve knowledge and functioning of biofiltration systems. In addition, many works have established bacteria inhibition as one of the factor affecting performance of ammonia biotreatment but inhibition kinetics have not been included in biofiltration models so far.

In this work a dynamic general model for biofiltration has been proposed considering most of phenomena that occurs in biofiltration. The model was validated by experimental results obtained in a biofilter scale plant. The process was modeled with general mass balances which take into account axial dispersion, advection (convection), absorption, adsorption, diffusion and biodegradation (reaction). The model includes detailed biokinetic expressions for ammonia considering all biological inhibitions occurring in the nitrification process. Model parameters were determined from both experimental data obtained from a pilot-scale biofilter and previous works.

The set of partial differential equations was discretized in space along the bed height and

Evaluation of Three Approaches to Decrease Ammonia Emission from Solid Manure Storage Facilities

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A pilot scale study was carried out with the aim to evaluate and compare three principal methods to lower ammonia emission from solid manure storage facilities. The tested methods were 1: Covered manure heap, 2: Improved drainage and 3: Amendment of the manure with peat.

Five open cargo containers, 6 m long, 2.5 m wide and 1.5 m high were used as a pilot-sized simulation of a full-size manure pad with walls on three sides. The containers were each loaded with 3.7 tons of solid manure, which was stacked against the front wall while the back was open to provide free passage of draining fluids. All, except one container had an incline of 1:100, which is consistent with the recommended incline of a full-size manure pad. The particulars of each treatment are explained in the table below.

Table 1. Description of the different treatments in the pilot trial

Treatment	Description
1. Covered storage	The container was covered with an EPDM-rubber sheet
2. Improved drainage	Increased incline to 1:50
3. Amended manure	An additional 10% (weight base) of peat was added to the manure
4. Control	No measures taken to limit ammonia emissions

A micrometeorological mass balance method was used to measure the ammonia emission. This method was described in Schjørring et al. (1992) and applied by Karlsson (1994). The emission were measured at three separate occasions while the volume and ammonium content of the draining fluids was measured continuously. The total duration of the pilot study was three months, from October to December.

The expected result of this study includes a better understanding of the relative effectiveness of coverage, improved drainage and amendment as means to limit ammonia emission. All data will be collected and analysed by March 2004. This pilot trial is an important part of the initial phase of a larger three-year project aiming to develop an effective and economically sound approach to lower ammonia emission from solid manure storage facilities. The most promising of the principal approaches examined during the pilot study will therefore subsequently be tested in full scale.

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Gaseous emissions (NH_3, N_2O, CH_4 and CO_2) from a biological aerobic treatment unit of pig slurry

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The biological aerobic treatment of the pig slurry is one of the measures to limit the land-application of manure in the vulnerable zones where organic nitrogen load is higher than 170 kg of nitrogen per hectare. This kind of treatment removes a part of the nitrogen compounds into nitrogen gas by nitrification and denitrification. However, this treatment could generate gas emissions such as nitrous oxide (N_2O) and ammonia (NH_3). Moreover gaseous emissions (NH_3, CH_4, N_2O, odours...) could be emitted during the following management of the by-products (aerated slurry, biological sludge, separated liquid fraction,….). Within this framework, NH_3, N_2O, CH_4 and CO_2 release from a biological aerobic treatment system of pig slurry was investigated under field conditions. The aerobic treatment unit consisted of a centrifuge decantation of the pig slurry followed by an intermittent aeration of the separated liquid fraction. The quantification of the gaseous emissions by different methodologies (dynamic chamber, micrometeorological technique,…) allowed to quantify the gaseous fluxes from the different products of the biological aerobic treatment unit (raw pig slurry, separated solid fraction, aerated slurry, biological sludge and separated liquid fraction). The integration of these emission factors within a model on the flows of products enabled us to consider gaseous flows on the farm scale. The results showed that the fluxes emissions of CH_4, CO_2 and NH_3 were more important for the storage of no aerated effluents (raw slurry and separated solid fraction) than for the storage of aerated effluents. The total gaseous emissions of NH_3, CH_4 and CO_2 were closed to 390 kgN, 3300 kg C and 9000 kg C per year respectively. The majority of the emissions occured during the storage of the separated solid fraction (56% of CH_4) and the raw slurry (36% of the NH_3 and 28% of the carboneous emissions).

Effects of separation and anaerobic digestion of slurry on emission of odour and ammonia following land application

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Land spreading of slurry causes significant environmental impact in form of ammonia volatilisation and odour nuisance. Loss of ammonia and odour substances from land applied slurry occurs while the slurry is exposed on top of the soil surface and is expected to cease after the slurry has infiltrated into the soil. The rate at which slurry infiltrates into the soil is enhanced by lower dry matter content. Therefore, as anaerobic digestion and separation of slurry reduce the dry matter content of slurry, these technologies may reduce the potential for odour and ammonia volatilisation. The aim of the present study was, therefore, to study how anaerobic digestion and separation of slurry influence ammonia loss and odour nuisance following the subsequent land spreading.

Freshly produced pig manure was either anaerobically digested (AD), separated (Sep), anaerobically digested and separated (AD+Sep) or left untreated (Untreat) before applied to experimental plots (36m × 36m) by a trailing hose slurry spreader. The ammonia volatilisation following application was estimated by micrometeorological mass balance technique. Odour nuisance was estimated by sampling the air leaving the slurry treated soil surface into a static ventilated chamber 20 and 240 minutes after application. The odour concentrations (OU m^{-3}) of the air samples were estimated by an olfactometric panel.

The ammonia volatilisation following land application of slurry was reduced by both anaerobic digestion and separation (Table 1). Separation of slurry was observed to be more efficient for reduction of ammonia volatilisation than anaerobic digestion. Lower emission of odour following land application was observed from both separated and anaerobically digested slurry compared to untreated slurry (Table 1).

Table 1. Dosing and composition of the differently treated slurry types and emission of ammonia and odour following land application.

Treatment	Dose	Comp. of slurry			Ammonia loss		Odour conc., (OU m^{-3})	
	Slurry (t ha^{-1})	PH	DM (%)	NH_4-N (kg t^{-1})	NH_3-N loss (kg ha^{-1})	NH_3-N loss (% of N applied)	After 20 minutes	After 240 minutes
Untreat	26	7.2	3.3	2.4	30	48	300	1000
Sep	28	8.6	1.5	3.9	18	16	n d	n d
AD	27	8.1	2.8	2.9	28	35	250	450
AD+Sep	28	8.2	2.2	3.4	21	21	150	150

Comparison of gas and odour emissions from swine manure management with and without treatment facilities in Québec

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According to a recent document published by the Canadian government, agriculture as a whole could account for 9.5% of the total Canadian greenhouse gas (GHG) emissions, with N_2O and CH_4 contributing 61% and 38% respectively. It is also estimated that 42% of the agricultural GHG emissions originate from livestock operations and that one third of these are associated with manure management. The manure manage is also an important source of odour emissions. The objective of this paper is to compare the total gas and odour emissions from a complete manure handling cycle, with and without manure treatment processes (storage and land application). manure management with and without treatment. Emissions used in the assessment are from manure storage, treatment facilities and spreading operations. GHG and odour emissions were measured over a two-year period from a liquid swine manure storage facility and from three different swine manure treatment facilities. Floating open chambers were used to collect air samples on top of the manure. GHG were measured continuously, during two weeks and over each season by a gas chromatograph. Some air samples were also collected using syringes and stored in evacuated glass containers. All GHG emission data were expressed in terms of mass of CO_2 equivalent to allow for direct comparisons and additions of the emissions for the three different GHG. Air bag samples were collected and odour concentrations (in odor units per cubic meter of air, OU/m^3) were measured in laboratory by a dynamic dilution olfactometer with five panelists. Odour intensities (in ppb equivalent of 1-butanol) were measured on site by a dynamic dilution olfactometer with four panelists. Literature data are used to asses the emissions from the manure spreading periods. Results show that treatment facilities emitted less CH_4 but more N_2O and CO_2 than liquid manure storage facilities. However, the complete handling cycle incorporating a treatment system reduces emissions over storage and spreading periods. Global GHG and odour emissions will be assessed and included in the conference.

Ammonia and greenhouse gas emissions from a straw flow system for fattening pigs

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Animal welfare and environmental protection are increasingly important. Housing systems must be found that offer animal welfare and emit little ammonia and greenhouse gases. The straw flow system is an animal friendly housing system for fattening pigs. The pen is separated into a lying area and an excretion area. In the lying area, straw is used. The pigs keep the lying area dry and clean and excrete on slats in the rear of the pen. The system can be operated economically efficient on commercial farms. It was to be investigated, if this animal friendly housing system offered environmental benefits and if it emitted less ammonia and greenhouse gases than a conventional fully or partly slatted slated system.

Emissions of NH_3, N_2O, CH_4 and VOC are measured at a commercial farm. The animal house consists of three fully separated compartments. Each compartment is forced ventilated by a central exhaust fan. The compartments are separated into 16 pens that hold 10 – 12 pigs.

Concentrations of NH_3, N_2O and CH_4 are measured with high resolution FTIR spectrometry. VOC are analysed by a flame ionisation detector. Ventilation rate is recorded in the central exhaust fan. Measurements are carried out continuously 24 hours a day. The measurement period lasts from 2003-07-01 to 2004-01-31. It covers all seasons: hot – mild – cold and all stages of fattening.

At the conference, results from the full measurement period will be available. Emission factors for the straw flow system will be derived. An evaluation of the environmental impacts of the straw flow system will be possible.

Modelling ammonia and nitrous oxide emissions from slurry-amended soils

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Gaseous emissions arising from the management of livestock manure are a cause for environmental concern. Agriculture accounts for c. 80% of ammonia (NH_3) emissions to the atmosphere in the UK which, following atmospheric transport and subsequent deposition, can cause damage to fragile ecosystems. Agriculture is also a major source of nitrous oxide (N_2O) emission to the atmosphere in the UK, a greenhouse gas implicated in global warming. Application of manure to agricultural land is an important source of emission of these gases and much research has been conducted investigating the controlling factors. Few studies have included concurrent measurements of both however. This is important when considering mitigation strategies because of the phenomena of 'pollution swapping'.

The work conducted in this project addresses this gap through the development of a model for the prediction of NH_3 and N_2O emissions from slurry-amended soils. A key element will be the development of a sub-model describing slurry infiltration into soil. A series of laboratory experiments have been conducted in which slurry infiltration into soil columns was measured using time domain reflectometry. These data together with measurements of slurry and soil physical characteristics will be used for the parameterisation of the infiltration sub-model. The infiltration sub-model will link two other models: one for ammonia volatilisation from the surface slurry pool and one for describing carbon and nitrogen transformations within the soil leading to N_2O emissions. These two sub-models will be derived largely from existing published models.

The overall model will be validated using data from a series of laboratory experiments in which measurements of NH_3 and N_2O emissions and N transformations within the soil are made from slurry-amended soils. The model will be used for predicting NH_3 and N_2O emissions from slurry applications to soil for a range of soil/climate/management scenarios.

Coupling Composting and Biofiltration for Ammonia and Volatile Organic Compounds Removal

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At present, bad odour and atmospheric pollution are the most common problems associated with composting of organic wastes in large-scale facilities. Among the available options for air treatment, biofiltration has proved to be an effective low-cost technology. In a biofilter, a contaminated/odorous gas stream passes through a biologically enriched layer of a filter material such as soil, wood chips, compost or mixed materials, followed by a biodegradation of the absorbed/adsorbed contaminant.

In this study, the efficiency of the biofiltration technology for the removal of ammonia and volatile organic compounds (VOCs) from the exhaust gases of the composting process is studied.

Source-selected organic fraction of municipal solid wastes was composted in a 30-L laboratory reactor equipped with forced aeration. The exhaust gas from composting was passed through a biofilter filled with mature compost. Biofilter dimensions were: diameter: 0.2 m, height: 0.3 m, resulting in a total bed volume of 9 L and a gas retention time of 60 s. Ammonia and total VOCs concentrations and biofilter properties were monitored during the composting experiments according to standard procedures.

Maximum levels of ammonia in exhaust gases were 150-200 mg $NH_3 \cdot m^{-3}$ during the first days of composting in the thermophilic range of temperature (65-70ºC). An average ammonia removal efficiency of 80% was obtained in the biofilter for a loading rate range of 175-225 g $NH_3 \cdot m^{-3}$ biofilter$\cdot d^{-1}$. No delay or start-up phase in the biofilter was observed for the removal of ammonia, probably due to the high ammonia absorption capacity of the compost media.

VOCs emission in the composting process reached a maximum value of 120 mg $C \cdot m^{-3}$ again during the thermophilic phase. Average removal efficiency of the biofilter was 60% for a loading rate of 150 g $C \cdot m^{-3}$ biofilter$\cdot d^{-1}$.

Finally, monitoring of the biofilter properties only showed slightly variations. It is worthwhile noticing that moisture content of the biofilter (one of the main properties associated with biofilter performance) was steady throughout the composting experiment, as a consequence of the high humidity of exhaust gases from composting.

According to these results, biofiltration technology using compost as biofilter media can effectively remove part of the ammonia and VOCs contents from the composting process.

Greenhouse gas and ammonia emission abatement by slurry treatment

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NH_3, CH_4 and N_2O emissions from the manure management continuum "storage" and "field application" were quantified in pilot scale slurry tanks. The effect of the following treatment options was investigated: untreated slurry, mechanically separated slurry (emissions from the slurry and from composting of the separated solids), anaerobically digested slurry, slurry covered with a layer of chopped straw, slurry aeration. Emission rates were determined with a large open-dynamic chamber and with high resolution FTIR spectrometry. Measurements were carried out with dairy cattle and with pig slurry and in winter and in summer. After storage, slurries were applied on grassland with band spreading techniques. Emissions were followed with the large open dynamic chamber (NH_3) and with closed chambers (N_2O and CH_4).Ammonia emissions mainly occurred after field application. Promising mitigation options are low trajectory application techniques and proper timing of application. Anaerobic digestion is an effective means to reduce greenhouse gas emission. Straw cover and slurry aeration showed negative environmental effects and should not be implemented on commercial farms.

Table 1. NH_3, CH_4, N_2O and greenhouse gas emissions during storage and after field application of dairy cattle slurry

Treatment	NH_3		CH_4		N_2O		GHG[a]	
	[g m^{-3}]	%	[g m^{-3}]	%	[g m^{-3}]	%	[kg CO_2 Eq. m^{-3}]	%
untreated	226.7	100.0	4046.9	100.0	23.9	100.0	92.40	1000
separated (liquid and solid phase)	402.8	177.7	2363.3	58.4	28.6	119.7	58.51	63.3
anaerobically digested	229.9	101.4	1344.5	33.2	31.2	130.3	37.90	41.0
straw cover	320.4	141.3	4926.2	121.7	52.5	219.5	119.73	129.6
slurry aeration	422.6	186.4	1739.3	43.0	54.2	226.5	53.32	57.7

Table 2. NH_3, CH_4, N_2O and greenhouse gas emissions during storage and after field application of pig slurry

Treatment	NH_3		CH_4		N_2O		GHG[a]	
	[g m^{-3}]	%	[g m^{-3}]	%	[g m^{-3}]	%	[kg CO_2 Eq. m^{-3}]	%
untreated	210.9	100.0	865.8	100.0	56.2	100.0	18.1	100.0
separated (liquid and solid phase)	313.8	148.8	248.6	28.7	41.3	73.5	1.6	50.6
anaerobically digested	262.9	124.7	217.2	25.1	77.2	137.5	4.4	80.1
straw cover	254.4	120.6	906.4	104.7	167.5	298.2	18.9	199.4
slurry aeration	728.2	345.3	1328.2	153.4	558.6	994.5	27.8	564.8

[a]*GHG = greenhouse gas emissions*

Influence of different levels of covering on greenhouse gas and NH_3 emissions from slurry stores

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Slurry storage contributes considerably to ammonia and GHG emissions. Before mitigation options can be recommended, the key controls of emissions must be understood. There is a considerable lack of such basic knowledge for dairy farming. Experiments aimed at quantifying the effect of different slurry storage conditions on ammonia and GHG emissions from untreated and anaerobically digested dairy cattle slurry. Emissions were followed from storage of untreated slurry with and without a wooden cover and from anaerobically digested slurry without any cover, with a layer of chopped straw and with a layer of chopped straw and a wooden cover. Experiments were carried out under cold winter and under warm summer conditions to cover the year-round range in temperatures.

Table 1. Cumulated CH_4, NH_3, N_2O and greenhouse gas emissions measured in the winter and in the summer experiment

Treatment	*winter experiment*				*summer experiment*			
	CH_4	*NH_3*	*N_2O*	*GHG*	*CH_4*	*NH_3*	*N_2O*	*GHG*
	[g m^{-3}]	[g m^{-3}]	[g m^{-3}]	[kg CO_2eq. m^{-3}]	[g m^{-3}]	[g m^{-3}]	[g m^{-3}]	[kg CO_2eq. m^{-3}]
untreated_crust	164.3	72.5	44.0	17.10	3591.2	110.5	48.7	90.52
untreated_cover	142.0	52.2	38.2	14.83	2999.0	60.0	58.6	81.13
biogas	111.3	62.0	40.1	14.76	1154.2	222.5	72.4	46.70
biogas_straw	114.5	49.6	39.9	14.79	1191.9	125.7	75.7	48.51
biogas_straw_cover	81.1	48.7	40.7	14.31	1021.4	78.1	61.4	40.50

[a]GHG = greenhouse gas emissions

Anaerobic digestion was found to be an effective mitigation option for methane and greenhouse gas emissions from slurry stores. A wooden lid placed on the slurry tank reduced CH_4 and NH_3 emissions, whereas NH_3 emissions from uncovered anaerobically digested slurry were high due to the high NH_4-N content and pH value. It is recommended that slurry tanks, and particularly those used for storage of slurry treated in biogas plants, are equipped with a cover. This will reduce CH_4 release into the atmosphere, as well as NH_3 emissions. Full environmental benefits of anaerobic digestion can only be exploited, if all tanks are covered.

Technique for determination of ammonia emissions in urine diverting wastewater systems

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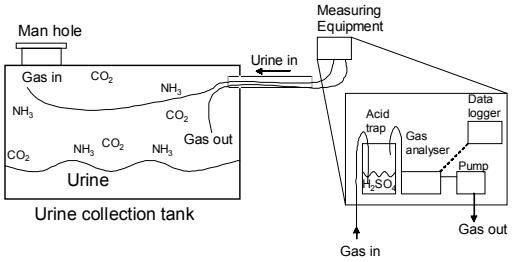
Urine diverting wastewater systems are used for lowering the load of nutrients to the water treatment works and water recipients and to produce an clean organic fertiliser. One concern when collecting the urine, which contains 2.5-7 kg N, m^{-3} mainly as NH_3, is the risk for ammonia emissions. The aim of the study was to develop a method for determining the ammonia loss in urine collection systems.

The measurement technique developed was based on the fact that the collection of human urine is performed in closed systems, mainly in subsurface tanks. Carbon dioxide was identified as a proper gas for determination of the air exchange rate in the tanks. The methods accuracy was tested beforehand in a completely sealed small lab scale system (25 litre tank with 5 litres of urine) to assure that the CO_2 decrease was not caused by absorption into the urine. The CO_2 concentration was digitally logged every minute, complemented with GC analysis of samples manually taken out at pre set intervals.

The ammonia concentration in the gas phase of the tank was determined and then PE-pipes connected to the measuring equipment were installed (Figure). CO_2 was added and thoroughly mixed to a level of 5000 ppm in the tanks gas phase. The CO_2 level in the tank was monitored until the surrounding level was reached or for a maximum of seven days. Samples for GC analysis at the lab was taken manually after 0.5h, 1h, 5h, 1d, 3d and 7 days. The correlation between the CO_2 concentration by the digital gas analyser and the GC analysis at the lab was good, proving that the continuous analysis was accurate.

The equation from the decrease in CO_2 concentration gave the air exchange rate. This combined with the initial ammonia concentration was then used to determine the ammonia loss in the system. Thereby, the method of monitoring the CO_2 decrease showed to be appropriate for determine the ammonia loss in a closed urine collection system.

Key words: ammonia emission, gas emissions, measurement technique, urine collection system



Ammonia, Methane, Nitrous Oxide and Particulate Matter emissions in two different buildings for laying hens

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Ammonia, methane, nitrous oxide and dust concentration as Particulate Matter ($PM_{2.5}$ and PM_{10}), were monitored in two different buildings for laying hens in Italy, both breeding approximately 60000 hens each. The first unit has a in-house prolonged droppings storage (deep-pit), the ground floor is the manure storage, in the first floor the hens are housed. The second unit has a manure removal system with a lower environmental impact, in which the droppings are dried on ventilated belts.

The data were collected continuously in six periods of approximately 1 week each, during a whole year, using a photoacustic detector (Bruel&Kjaer) to measure NH_3, CH_4 and N_2O and a on-line instrument to measure PM. The ventilation rate was also continuously recorded so that emissions could be assessed.

In **Table 1** the yearly averaged emission factors (expressed per bird place) are summarised.

Table 1 *– Laying hen houses: average emission factors.*

Emission factors				
Unit	**NH_3**	**CH_4**	**N_2O**	**CO_2**
Deep-pit				
kg y^{-1} bird $place^{-1}$	0.162 ± 0.101	0.02 ± 0.03	n.d.	51.4 ± 7.4
Ventilated belt				
kg y^{-1} bird $place^{-1}$	0.063 ± 0.018	0.08 ± 0.10	n.d.	77.5 ± 14.1

The ammonia emission factors resulted 0.162 kg y^{-1} hen $place^{-1}$ for the deep-pit system and 0.063 kg y^{-1}hen $place^{-1}$ for the ventilated belt.

The emission factor for the deep-pit house is in good agreement with the value assessed by Italy within the IPPC-TWG (0.154 kg y^{-1} hen^{-1}), but much lower than the Dutch value (0.386 kg y^{-1} hen^{-1}) for the same technique. This result confirm that this technique can achieve lower ammonia emissions in countries with warmer climate, where higher temperatures and higher ventilation rate enable to reach a faster and higher drying of the manure in the pit.

The ammonia emission reduction factor of the ventilated belt technique, compared to the deep-pit technique, was 62%.

A method to assess the reduction of ammonia and methane emissions by application of BAT in Intensive Livestock Farming

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Application of IPPC in Intensive Livestock Farming requires the estimation of the quantities of foreseeable emissions from the installations into each medium as well as identification of significant effects of the measures taken to reduce these emissions.

A mathematical model to attain these objectives has been set up and can be used via Internet.

Calculation of methane and ammonia emissions are performed taking into account the amount of Nitrogen and Organic Matter excreted by the animals, feeding strategies, designs of floors and manure management in the different housing systems, on-farm treatments, type of storages, characteristic of the land concerned when applying manure.

The different technique that are BAT (Best Available Techniques) and that can be applied at the different stages in the manure management can be evaluated and selected according to their efficiency in reducing the emissions from the whole installation.

The calculation program has been calibrated on the reality of some Italian Regions, but can be implemented to work in different climatic conditions, land use and agricultural practices. The proposed calculation method is an useful tool for farmers to evaluate the convenience to select a technique instead of another and to apply for the IPPC permit requested by the competent Authorities.

Management practices for the minimisation of nitrogen losses during the storage of broiler litter

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Ammonia (NH_3) emissions from UK agriculture have been estimated at 265 kt yr^{-1}, with *c*. 18% of this total originating from the *c*. 46 Mt of solid manure stored and spread annually. The objective of this study was to quantify the effects of contrasting solid manure storage methods on NH_3 emissions. The study also investigated any N 'pollution swapping' effects that NH_3 abatement strategies may have had, through the additional measurements of N_2O emissions and N losses in store leachate.

Broiler litter was heaped on 15m^2 concrete pads at IGER and stored for six months. Four storage treatments (three replicates) were investigated; conventional, sheeted, turned, and roofed heaps. Total N, NH_4^+, NO_3^- and uric acid content, together with manure mass, were determined at the start and end of the storage period. Emission hoods were used to measure NH_3 emission rates over six discrete two-hour measurement periods during the first month of storage, and at subsequent monthly intervals. Additionally, N_2O emissions were measured from the conventional-open and sheeted heaps. Leachate from each heap was collected and the N content determined.Lowest NH_3 emissions were from the sheeted heaps (average rate of emission for the 6 month storage period was 177 g NH_3-N / m^2), with emissions reduced by 68% compared with conventional-open storage. Greatest NH_3 emissions were from roofed storage (893 g NH_3-N / m^2), 63% greater than from the open heap. Table 1 shows the cumulative losses of N from the heaps. Losses of N as N_2O were small in comparison to those lost as NH_3, but losses of N in leachate were of a similar magnitude.

Table 1 Losses of N from broiler litter heaps.

Treatment	Losses of N as % of total N into store		
	NH_3-N emissions	N_2O-N emissions	N in leachate
Conventional	5.9ab	0.7	8.8c
Turned	7.0b	-	4.2b
Sheeted	1.8a	0.2	8.0c
Roofed	9.1b	-	3.1ab

Different letters denote differences significant at the 5% level

Sheeting manure heaps was the most effective method of minimising N losses during storage. However, it is also necessary to consider 'downstream' impacts. The benefits of management practices that retain N during storage will only be realised if they do not exacerbate losses following land application. This is currently being investigated in this study.

Ammonia emission from land applied farm yard manure – First results

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Animal waste spreading represents a critical moment of their management strategy since it influences the nutrients availability for the crops (Jarvis and Pain, 1990) and it is considered as the main source of ammonia emission to air (Meisinger and Jokela, 2000). Few data are nowadays available on ammonia emission from land applied solid manure especially for south European countries. In order to cover this gap of information a number of trials were carried out. Ammonia emission were measured from land applied FYM (two degree of rotting) with three air velocity conditions (1, 2 and 3 m/s) and three application rates (20, 40 and 60 t/ha) by means of three Open Large Dynamic Chambers. Each device is made up of a ventilated chamber (24m^2), a fan connected to a galvanized sheet iron pipe 10 m long -equipped with an internal flow rectifier-, and an air sampling system positioned at the end of the pipe. Two anemometers measure air velocity within the pipe and under the chamber. The measurements were carried out in two different temperature conditions (autumn and winter). First results of the trials carried out in autumn conditions pointed out a significant effect of air velocity on ammonia emission, while a partially significant effect of the application rate. Nitrogen lost as ammonia ranged between 10% and 28.6% of the amount spread with manure.

Natural crusting of slurry storage as an abatement measure for ammonia emissions on dairy farms

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Collaborative research on the incidence and effectiveness of natural slurry crusting as a means of ammonia emission abatement was initiated with the collection of information about the farm, slurry management and storage from a sample of 50 dairy farms across the major dairying areas in England. Further visits were undertaken on some of the farms, with studies on slurry crusts facilitated by a specially designed safety cage fitted to a hydraulic inspection platform. Complementary studies were undertaken, both at a pilot- and on a small-scale. A range of factors affecting the formation and retention of slurry crusts and their impact in reducing ammonia emissions, were investigated.

Slurry crusting was found to be commonplace across a large proportion (80%) of stores, despite the fact that 68% of farms claimed to undertake regular store mixing and agitation. Observations provided information on the impact of a range of factors on the potential for crust formation. Major factors were slurry solids, surface area:volume ratio of the storage, livestock diet, slurry management (agitation) and, particularly, weather conditions (evaporation and rainfall).

Mean ammonia emissions were 0.48 g NH_3-N m^{-2} d^{-1} and 2.55 g NH_3-N m^{-2} d^{-1}, for crusted and non-crusted slurry stores, respectively; these were comparable with estimates currently used in the UK ammonia emissions inventory for crusted cattle slurry stores of 2.2 g N m^{-2} d^{-1} (range 0.4 – 5.7 g N m^{-2} d^{-1}). Where direct comparisons between crusted and non-crusted slurry were possible, a reduction in NH_3 emission of about 50% was typical. Assuming that natural crusting is effective in reducing emissions, an objective assessment of crust integrity needs to be developed to assist with effective implementation of mitigation policy. A type of 'crustometer' could be developed, at least partly based on a falling weight technique tested briefly within the field studies.

Characterization of organic packing materials in the removal of ammonia gas in automated biofilters

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Biofiltration is the most commonly used biological gas treatment technology and is extensively used for the treatment of polluted air with gas flow rates. It involves microorganisms immobilized in the form of a biofilm on a porous carrier, such as, peat, soil, compost, synthetic substances or combinations of them. The carrier provides to the microorganisms a favorable environment in terms of pH, temperature, moisture, nutrients and oxygen supply. Testing of carrier capability for serving as appropriate packing material in biofilters needs of well-controlled experimental conditions at lab/pilot scale.

The paper focuses on the construction and automation of a pilot biofilter for determining the suitability of coconut fiber as packing material for treatment of ammonia. Special attention was paid to the construction of the pilot biofilter to come up with a versatile and robust setup that includes a Programmable Logic Controller (PLC) and a computer where a monitoring and control program is implemented using Siemens-WinCC. Parameters such as ammonia concentration, relative humidity and temperature are continuously monitored for assessing reactor performance. Details of biofilter automation will be provided in the full-paper.

The reactor was packed with a mixture of coconut fiber divided in three modules. A fourth model of wood chip was also used. Physical and chemical characteristics of the packing materials such as specific surface area, density, organic matter content, porosity, elemental composition, pH or buffer capacity were also determined. Biological activity and packing capabilities related to ammonia treatment were determined during the operation of the biofilter for several months under different steady-state and transient conditions of airflow and inlet ammonia concentration. Results show the suitability of this material for ammonia treatment reaching treatment capacities larger than those obtained at a full-scale biofilter using the same packing material.

Performance characterization of a full-scale biofilter at an organic waste treatment plant

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Organic waste from food industry, cattle breeding, chemistry industry, wood industry and composting facilities amongst others generate polluted airflows. These airstreams contain a great variety of compounds, which are noticed as annoying odours. Odorous compounds are mainly organic, even though ammonia and hydrogen sulphide are often present at organic waste treatment facilities and also responsible for these annoyances.

Ecoparc Barcelona is a facility located in Barcelona, Spain, for the integral treatment of 300,000 tons/year of domestic residues that have not been collected in specific containers for glass, paper and cardboard of Barcelona and its metropolitan area. Activities at Ecoparc Barcelona include separation of received material and composting of the organic fraction from domestic waste, which are known as odour emitting activities. Ecoparc Barcelona has a 2700 m^2 total surface compartmentalized biofilter designed for treating 345,000 m^3/h of waste gas from 38 composting tunnels and from the rest of the facility. It holds coconut fiber and wood chip as filtering materials. The aim of this research was the characterization of the performance of Ecoparc Barcelona's biofilter.

Characterization of the biofilter performance included monitoring of several parameters such as airflows, concentration of ammonia and hydrogen sulfide as target compounds, relative humidity, temperature, air velocity, and percolate composition. Maximum and minimum levels, periodicity, profiles, etc. were determined according to the schedule of the facility. Data was used for the evaluation of the biofilter performance. Performance parameters such as removal efficiencies and elimination capacities over 1 year of operation will be discussed at the conference coupled with some findings such as unbalanced air velocities or ammonium accumulation in the biofilter.

Nitrogen Efficiency and Environmental Impact at Different Strategies for Management of Green Manure Leys

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Annual green manure leys are important nitrogen sources in organic farming systems without animals. The aim of this project is to elucidate the magnitude of ammonia emissions and leaching losses from cut plant material and the factors affecting these losses under field conditions.

In the project, ammonia emissions and leaching from cut plant material are measured in randomised block trials during 3 years. Frequent cutting (4 times per season) is compared with a strategy with less frequent cutting (2 times per season). Ammonia emissions are measured continuously during two weeks after each cutting with passive diffusion samplers (PDS) exposed in ventilated chambers and in the ambient air. When measuring the leaching losses, precipitation water having passed through the cut plant material is collected and analysed for total N, P and C.

Results from the two first years of trial (table 1) show that both the progress over time and the level of ammonia emissions are strongly dependent on weather conditions. Ammonia emissions seem to appear primarily in conjunction with decomposition of organic material during and after moist and warm periods.

Table 1. Results from the two first years.

Year	Nitrogen loss via ammonia emission (kg ha^{-1})	Leaching from cut plant material to soil (kg ha^{-1})		
		N	P	C
2001	Ca 10	32-38	7-11	640-680
2002	29-37*	45-52	13-15	480-510

* Uncertain value due to many wet samplers

With exception of nitrogen in the year 2001, the leaching losses have so far been biggest in the treatment with frequent cutting. This cutting regime has also given rise to a less efficient utilisation of the growth potential and nitrogen fixation capacity of the ley.

Study of NH_3 emissions during slurry storage in small -scale tanks

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The main objective of this work is quantify the effects of slurry store characteristics and weather conditions on the concentration of total N and total ammonium-N in stored slurry in order to produce a simple predictive model that can be applied to slurry stored on commercial farms.

Two consecutive experiments were carried out changes during slurry storage; first with pig slurry and then cattle slurry. Slurries were obtained from two sites for each experiment and the slurries were delivered to all sites within three days. At each site, three treatments from each slurry were prepared: whole slurry and the same slurry diluted with water to 75% and 50% of its original concentration. Each was replicated three times in tanks of 1 m diameter x 0.8 m high.

Meteorological data was recorded at each site in order to calculate evaporation rates from the slurries and to relate the wind speed measured over the surface of the tanks to that at 2 and 5 m height. Temperature probes were installed in three slurry tanks at 10 and 30 cm depths (representing each slurry dilution from one source) to help to calculate mineralization rates.

The tanks were sampled at the beginning and end of each experiment and analysed for total and volatile solids, organic and ammoniacal N as well as P and K. Slurry depths were measured weekly and a note made of any crust formation. The results should quantify the effects of rainfall, wind speed and other environmental variables on mineralization and ammonia volatilisation and hence the balance of organic and ammoniacal-N in stored slurries.

Results of the experiments will be presented at the Conference.

The effect of storage and rapid incorporation on N_2O emissions following the application of pig FYM to land

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Around 46 million tonnes of the animal manure in the UK is in a solid form and is frequently stored before spreading onto land. Following the application of solid manures to arable land, rapid incorporation has been identified as an effective measure to abate ammonia (NH_3) emissions. The reduced NH_3 loss, however, conserves nitrogen which may subsequently be used in the production of nitrous oxide (N_2O). The UK has agreed to reductions in greenhouse gas emissions of 12.5 % of 1990 levels by 2008-12. It is, therefore, important that measures implemented to reduce NH_3 emissions do not result in the increased loss of N_2O. The objectives of this Defra funded study are to quantify and compare N_2O emissions from fresh and stored pig farmyard manure (FYM) following land spreading and to quantify the effect of rapid incorporation.

The replicated (3 per treatment) plots (12 m by 4 m) were located in winter wheat stubble, on a loamy sand soil at ADAS Gleadthorpe in central England. Pig FYM (fresh or stored for 12 months, either conventionally or with added straw) was spread at a target application rate of 250 kg N ha^{-1} and either left on the surface or ploughed after 4 hours. Additionally, a control treatment was included where no manure was added. Following manure application in spring 2003, measurements of N_2O were made over a 3 month period using static chambers (2 per plot) and analysis by photo-acoustic infra-red spectroscopy.

Preliminary results showed that N_2O emissions following the surface application of pig FYM and from the control treatment were consistently < 5 g N_2O-N ha^{-1} d^{-1}. Peak emissions measured from the ploughed treatments were, however, up to 19 times larger and followed the order; stored with added straw (7 g N_2O-N ha^{-1} d^{-1}) < conventionally stored (13 g N_2O-N ha^{-1} d^{-1}) < fresh (95 g N_2O-N ha^{-1} d^{-1}). The greater N_2O emission from the ploughed treatments was probably a reflection of the lower NH_3 loss increasing the soil mineral N pool potentially available to nitrifying and denitrifying micro-organisms. Similarly, the application of fresh manure is likely to have stimulated N_2O emissions due to its higher NH_4-N content (*c*. 1.7 kg t^{-1}) compared to that in stored manure (*c*. 0.1 kg t^{-1}). The results indicate that ploughing may increase N_2O emissions, however, storage may be an efficient management strategy to reduce N_2O losses at spreading because of the reduction in manure available N content.

Ammonia emissions from poultry manure management systems: housing, storage and land spreading losses

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Around 4 million tonnes of poultry manure are produced annually in the UK, with ammonia (NH_3) losses estimated at 45 kt NH_3 in 2000 (equivalent to *c*.17% of estimated ammonia emissions from UK agriculture). As part of the EU directive on Integrated Pollution Prevention and Control (IPPC) member states are required to prevent or reduce pollution from large poultry units in order to achieve a high level of protection for the environment. This study assessed the potential to reduce ammonia emissions by altering the management of poultry manures during housing, and measured ammonia losses from individual components of the whole manure management cycle (housing → storage → land spreading).

Ammonia losses were higher ($P<0.05$) from winter-housed broilers on straw than woodshavings, but there were no differences in emissions from the different litter types/rates during storage and following land spreading. For the summer-housed flock, there were no differences between the litter types/rates at any part of the manure management cycle. The overall balance of ammonia emissions from the broiler litter studies during housing, storage and following land spreading was 28, 15 and 57%, respectively.

Ammonia losses from weekly belt-scraped layer manure's were more than double ($P<0.05$) those from daily belt-scraping, with twice weekly belt-scraping estimated to reduce ammonia losses by *c*.50% compared with weekly cleaning. The overall balance of ammonia emissions from the layer manure studies during housing, storage and following land spreading was 41, 4 and 55%, respectively.

The findings of these studies have indicated that strategies to reduce ammonia emissions from poultry farming would be most effective if focussed on housing and land spreading practices.

Modelling ammonia emissions from field-applied slurry

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There is increasing pressure for countries to document the effect of measures taken to abate ammonia emissions. The effectiveness of abatement measures relating to field-applied slurry will vary with climate, soil and crop conditions. With limited resources for conducting field experiments, models offer a way to estimate these ammonia losses across a range of conditions. A model of ammonia volatilisation from field-applied slurry has therefore been developed that uses climate and soil input data that are commonly available at national or international scales.

The model only considers that part of the field that actually receives slurry. For slurry applied using a broadcast spreader, this is the whole of the field area, whereas for slurry applied in bands, it only considers the area within the bands. The model potentially distinguishes three emitting surfaces; slurry on soil not covered by a crop canopy ('exposed soil pool'), slurry held on the canopy of the crop ('canopy pool') and slurry on the soil beneath the crop ('covered soil pool'). In the absence of a crop, there is only one emitting surface, the exposed soil pool. If a crop is present and the slurry application technique leads to the canopy becoming contaminated, all three pools are present.

Using two application techniques (broadcast and band spreading) and two application times (early morning and midday), the paper will show how the emission abatement achieved with band spreading, relative to broadcast spreading, varies with the timing of application.

Gaseous emissions from alternative housing systems for laying hens

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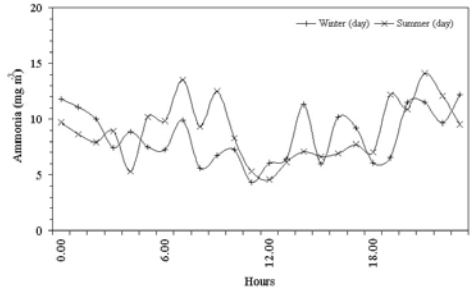
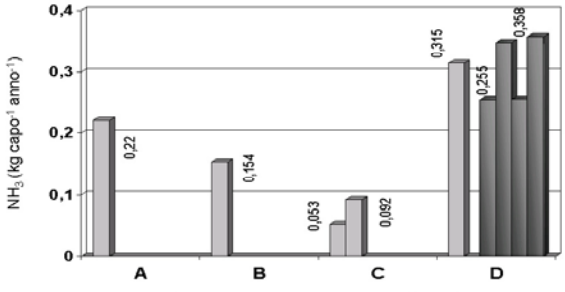
The Directive issued in 1999 by the European Union Council (Dir 99/74/CE), which does not allow to build new livestocks where laying hens are housed in traditional cages will have a great impact over the egg market. The alternative systems, ordered by the directive, are conceived to improve laying hens welfare, trough a lower animal density, the use of litter and nests, so they could express their natural behaviours. Nevertheless recent researches have pointed out some negative aspects. In fact some studies on furnished cages have shown a greater number of broken eggs and/or lower quality than traditional cages, due to dirty eggs laid on litter.The Department of Agricultural and Environmental Science of Udine University, in the frame of a research project co-financed by the Italian Minister of Instruction, University and Research, carried out a lot of experimental trials in alternative houses with floor system, in order to evaluate different aspects such as productive levels and enviromental impacts of the systems.

Research results showed a comparable egg production like traditional cage systems, however hygienic, behavioural and management problems were pointed out. In fact in alternative houses high ammonia and dust concentrations were found. Gas concentrations in houses were used to calculate gaseous emissions from houses, and higher emissions than from traditional cage systems were found (see Figures).



Ammonia concentration measured in alternative housing systems at different hours during summer and winter days.



Ammonia emission measured from alternative housing systems (experimental trials), in comparison with emissions from cage systems (Bat Reference Document, final draft, 2003).