Nuffield Farming Scholarship Trust

IPPC Legislation and Ammonia Mitigation Techniques for the Poultry Industry

A BEMB Trust Award

By

Matthew Davies
2008 Scholar

Contents

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Declaration

The views expressed in this report are my own and not necessarily those of the Nuffield Farming Trust or those of my employer or my sponsor. Every attempt has been made to ensure the information reported is accurate but legal and financial details are subject to change and to interpretation and therefore should not be taken as the definitive.

Abbreviation

IPPC: Integrated Pollution Prevention and Control
BEMB: British Egg Marketing Board
BRC: British Retail Consortium
EA: Environment Agency
NE: Natural England
SSSI: Special Site of Scientific Interest
SAC: Special Areas of Conservation
VOC: Volatile Organic Compounds
Alum: Aluminum Sulphate
NH_3: Ammonia
N: Nitrogen
DDGS: Distillers Dried Grains and Soluble
FCR: Feed Conversion Ratio
BAT: Best Available Techniques
PHD: Pile it High and Deep
VEB: Vegetative Environmental Buffers
BPC: British Poultry Council
BEIC: British Egg Industry Council
NPA: National Pig Association
NFU: National Farmers' Union

Executive Summary

Faced with IPPC legislation, some farms in the UK have been threatened with closure. I set myself the challenge of travelling the world to identify an assortment of the best techniques for reducing agricultural ammonia emissions.

Principally, my research demonstrates that Pre-Excretion routes; what goes into the animal, offer the most promising ways to abate ammonia. Through correct more focused feeding and ongoing genetic improvements, most farms should find their ammonia outputs reduce with no extra costs incurred.

Post-Excretion methods; what comes out of the animal, have also been seen to be highly effective, although are generally more expensive. The poultry sector is already making inroads on improving its ammonia output inadvertently with the cage ban coming into effect on the 1st January 2012. The cage ban will mean the UK's entire intensive layers flock will be in new accommodation, of which all of it will be BAT. In addition, other techniques I have seen on my travels that appear to provide ways of further reducing ammonia emissions in the UK include methods such as; fitting simple external manure driers, using wet air scrubbers in manure stores, piling manure high and deep and also introducing Vegetative Environmental Buffers onto farms.

My scholarship has shown that in the vast majority of cases there are several routes that should not be too costly, or involve large infrastructure changes to comply with IPPC legislation. For those farms presently residing on the closure list, a combination of Pre-Excretion and Post-Excretion methods should see ammonia emission rates drastically decrease. I see no reason why any farm should have to even consider closure with the methods presently available and those being researched.

Personal

When I started my Nuffield Scholarship I was employed as a trainee manager on my family's poultry farm, helping run production and a packing centre. During the course of my scholarship I have taken on the full responsibility of managing the packing centres, production and rearing. We have now embarked on improving our own standards; becoming a top level British Retail Consortium (BRC) registered facility, dealing with all the major multiples. As a company we have grown over this period and have built a new state-of-the-art facility to take us beyond the 2012 cage ban.

My Nuffield experience has made me a well-travelled man, travelling to Australia, America, North East Asia and Europe. I have made many friends in these countries and seen more of the egg industry than I would have deemed possible.

The contacts I have acquired over the last two years have proved invaluable to my scholarship. I have spoken with many obliging people who have extended my understanding of Integrated Pollution Prevention and Control (IPPC) and agricultural ammonia release.

Stemming from my scholarship, I now also sit on the Environmental Emissions Committee (EEC) for the British Poultry Council which is attended by large-scale meat bird producers, BEIC, NPA, BPEX, NFU and some large pig producers.

A bonus to my travels was learning to say “Hello” and “Cheers” in many languages as well as getting engaged.

Background to my study subject

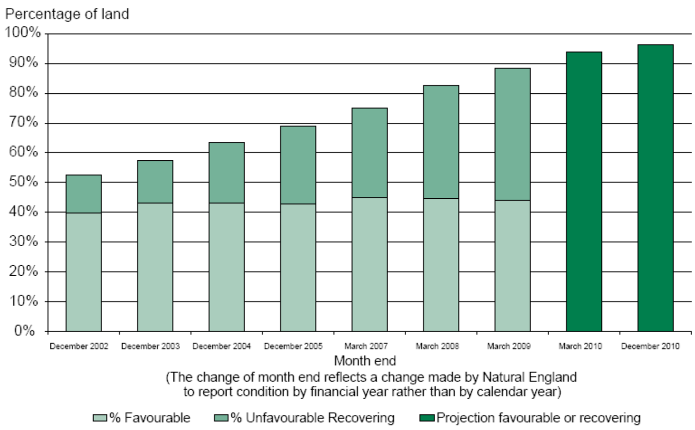
The pig and poultry sectors face many issues over the coming years; one of which is the IPPC legislation is being rolled out across Europe. This predominantly concerns the intensive aspect of these farming sectors, specifically sites with over 40,000 chickens, 750 sows and 2000 pigs; the purpose being to reduce emissions from agriculture to the local environment.

The principal concern for most is ammonia deposition onto statutory designated sites throughout the European Union and especially in the UK. These range from Sites of Special Scientific Interest (SSSIs), which comprise of the country’s most valuable wildlife, and geological interests, to other areas of international biodiversity importance with Special Area of Conservation (SACs) status. SSSIs cover some 2,343,750 hectares of England, Wales and Scotland split over 6589 SSSIs, whilst there are 613 SACs in the UK covering 2,631,415 hectares (Defra, 2009).

The objective of the IPPC legislation is to protect the rarest flora and fauna that find it more difficult to survive in the wider countryside, often under pressure from pollution, climate change and unsustainable land management. The damaging nature of ammonia in these situations coupled with emissions from agriculture, which can be ammonia rich, means that monitoring and reductions of gaseous ammonia maybe necessary for levels to be deemed as sustainable and passive to the local environment. The Environment Agency (EA) have been tasked with setting up and policing IPPC for England.

A National Audit Office report has revealed improvements in English SSSIs stating that Natural England is on track to reach the government target of bringing 95% of SSSI into favourable or recovering condition by 2010 (**Figure 1**)(NAO, 2008).

Figure 1: Percentage of land in target condition



Natural England reduced permissible ammonia levels to one third of their original just before IPPC was enforced across the UK. The effects of which resulted in legislation becoming more air quality driven than had originally been planned, possibly to achieve the targets above. Other aspects covered by the IPPC legislation are odour, noise, vibration, fugitive emissions to air or water and environmental accidents. These cover dust and volatile organic compounds (VOCs) to air, run off from operational or storage areas and potential for leaks or spillages to land or water, including problems with pests, litter or mud. Leaks to the environment from oil or the potential for pollution from fires also fall under this legislation.

As a result of the IPPC legislation, 12 UK farms have been threatened with closure due to a combination of close proximity to SSSIs, SACs and livestock numbers.

Objectives

My research targets likeminded farmers and academics worldwide who share the industry's concerns about IPPC. This report is intended to suggest techniques for reducing ammonia production from poultry. Information has been gathered from field visits, research papers, conferences, interviews and personal experience.

In preparing this report my focus has been on witnessing the world's best available techniques for minimising ammonia release, whilst questioning if such methods could be used in the UK.

My chief objective for this report is to present to poultry farmers effective techniques for reducing their ammonia outputs without increasing costs, or involving large capital investments.

My Study Tour

I chose to travel to 12 countries looking for others struggling with similar environmental legislation.

Australia

My scholarship commenced in Melbourne during February 2008 where I attended the Nuffield Conference and took the opportunity to extend the trip to see the poultry industry down under. In Australia similar legislation is being introduced through the National Pollution Inventory. Notably, all of the new farms I visited used tunnel ventilation with dust chambers, although the older units were curtain sided and naturally ventilated.

Whilst visiting Pace Farms I was shown a system where wastewater was recycled to drip irrigate woodland. There were enough trees planted to deem the farm carbon neutral and the eggs were marketed as environmentally sound. All of these sheds were fitted with air-cooling pads giving a cool and even temperature inside whilst it was over $40^{O}C$ outside.

There was no further processing of manure from laying hens, other than leaving it to dry in the heat, as rain was not an issue. Broiler litter is treated differently and burnt to produce power similar to some places around the UK. One method being trialled in Brisbane was still waiting to have a patent granted but had already been given a sizable investment by one of the UK leading retailers as a method of producing green energy.

Kinross Farm, Melbourne

Pace Farm, Sydney

Darwalla, Brisbane

Europe

I toured Spain with the Nuffield Poultry group in October 2008. Here it became apparent that there is no real issues from agricultural emissions due to there being very few sensitive sites, either Spanish SSSIs or European SACs. There did not seem to be much movement towards the 2012 cage ban so ammonia mitigation appeared lower on the agenda. Nonetheless, forced air-drying of manure was implemented across most farms and manure was removed at least twice weekly in order to avoid complaints from neighbours.

In October 2009 the same group then toured France visiting farms, producer groups, industry bodies, genetics firms and research centres. In France IPPC has had the greatest impact in Brittany. This is due to Brittany being home to the bulk of the French poultry and dairy industries. As a result, these sectors have opted to export their manure and any by-products to other regions of France and across Europe to avoid closures.

On my travels I also learnt of the Dutch Green Label Scheme. I understand the scheme incorporates an elected panel of academics, industry representatives, manufacturers and government bodies. The purpose of the panel is to allow producers with initiative to suggest ammonia abatement techniques used outside of the Netherlands, and apply to trial the system. As a reward to the producer, the panel decide on an appropriate emission reduction figure that the trial technique should aim to achieve. It is then up to the producer to finance the project. If the system is found to work then accurate emissions data is assigned to it and others are permitted to use the method. If the system fails then no one else is allowed to adopt it.

I visited farms in Italy with Techno and Valli. I was most impressed when touring a site in northern Italy, where they were employing two manure drying systems as a result of complaints from outlying villages. Their solution was two fold, firstly a manure drying system had been retrospectively fitted in the poultry units attaching to the egg belts. Secondly the manure was further dried using external manure drying. This was highly effective, reducing the manure from 40% dry matter to dust.

At Big Dutchman in Germany I observed dust, feather and air scrubbing systems capable of reducing emissions for large intensive setups. I also visited Uniqfill in the Netherlands who manufacture bespoke air-scrubbing chambers capable of reducing emissions to near zero.

Whilst in north-western Germany I discovered that they, like the Brittany producers, were the heart of the national poultry and pig sectors. Again IPPC presented problems that were overcome by transporting manure, produce and by-products to southern Germany. However the most extreme of these forms of manure export I witnessed was in Holland where Dutch producers were loading large shipping containers with dried poultry manure and shipping it to fertilizer companies in China.

Nuffield Poultry Group, ISA, France   *Big Dutchman, Germany*

North-East Asia

My choosing to travel to North–East Asia was driven by meeting several poultry producers through the International Egg Commission, who seemed to be bettering anything being done in Europe as far as environmental emissions were concerned. This was not due to environmental legislation but instead was because of large populations living in close proximity to farms. Here odour was the main concern, policed by the local government who fine for odour emissions.

Other motivators that were being used in Asia were foreign investors insisting on European style environmental management and monitoring as a part of the investment criteria.

Each Asian country has its own way of thinking when it comes to "smell" reducing inclusions within the livestock diets, with formulations ranging from coal and yeast (which are subsidised in Korea).

Air scrubbing of exhaust gases is not unheard of and is used on the majority of large pig units in Taiwan, Korea and Japan. These vary from some amateur on farm constructions to high investment versions imported from Europe.

When discussing the British use of manure as a fertiliser spread direct to the land it seemed alien to them that the government required no further processing, whereas all the farms visited in Korea (All) and Japan (Akita Co) were running successful composting ventures as part of the farming business. Accompanying these large scale composting plants were air scrubbers and bio filters ensuring that no odours were being emitted from the composting process.

Interestingly, DQY farm in China was running to EU welfare and environmental standards, undertaking environmental auditing and generating green energy from the manure. This was all part of their investment agreements. DQY also ran a unique scheme tied in with their on-site biogas plant. This involved local maize producers supplying maize to DQYs feed mill in return for discounted manure digestate and slurry. Commendably any unused biogas is also being piped to local villages as free cooking gas.

All the poultry units visited in these Asian counties were tunnel ventilated with a dust chamber at the rear or at least netting, similar to those systems found in Australia. In Taiwan I was particularly impressed to find one farm monitoring ammonia internally and externally, which was controlled by the ventilation system. This was being employed as a marketing tactic for improved welfare.

DQY, Beijing *Hanwei, Dalian* *Akita Co, Tokyo*

USA

During my travels through America I saw production on a scale I had not imagined. Whilst the farms I visited were not all new, they were each run superbly and in very different manners, all with the same goal in mind - to reduce cost effectively.

I took the opportunity to meet with Professors from Iowa State University who have been working on a number of future abatement routes such as genetic selection and feed additives.

It became apparent that whilst America does not have IPPC legislation as such, it does have an equivalent policy similar to that found in Australia, dealt with by local government rather than at a national level like in the UK.

Interestingly, I saw a wet flushing system for removing manure at a 4 million bird farm. During the process water was flushed under livestock housing, removing manure and forming slurry. The slurry passed into settling pits where the solids were separated from the dirty water. Water then filtered into large lagoons for irrigation and re-flushing. This system was being implemented in poultry, pigs and dairy units across Mississippi where water is plentiful. Notably there were no foul smells and no fly issues at any of the sites I visited.

In Missouri I toured a newly built farm housing 1.2 million layers. The development's planning consent required the manure from this farm to be dried, and mixed with manure from other older systems owned by the company. The mixed manure product was then sold outside of the county. Another planning condition was for every bird that was placed on the new farm, one had to be removed from an old farm. This ensured that the company's effect on the environment was decreasing without diminishing bird numbers. Accompanying this, the farm had signed up to annual ammonia and dust monitoring as well as installing dust-catching chambers for fan outlets from poultry buildings.

The USA broiler industry dealt with their litter in a different manner to the UK and Australia, using a method known as de-caking. De-caking is the process of breaking up the crust on the litter formed by the last flock and mixing it with the better litter below. A large quantity of ammonia is emitted during the process, which is combated by spraying the litter in Aluminium Sulphate (Alum) solution.

A highlight of the USA trip was visiting a company in Iowa that owned a site accommodating 3 million hens, with planning permission to expand to 7 million. The fascinating fact about this farm was that not one egg left the site in its shell.

Calmain, Mississippi

Centre Fresh, Iowa

Moark, Missouri

My Findings

I have split my findings into two sections based around the livestock. The first section is Pre-Excretion; what goes into the animal. This looks at how adjusting inputs affect both the livestock and ammonia output. These methods require the least investment however are poorly documented because the livestock industries are the experts.

The second section is Post-Excretion; what comes out of the animal. This includes housing, manure and exhaust gas treatments. These methods require the highest investments but are well documented, with academics as the experts.

Pre-Excretion

1. Dietary Manipulation

There are several very quick routes that will reduce ammonia release as a result of manipulating the diet. These manipulations can be done through phase feeding livestock rather than supplying the same ration throughout the life cycle, in order to meet the needs of the bird but not exceed them. For example a day old chick does not require the same feed as a laying hen, and a hen at peak production does not require the same nutrition as an end of lay hen. Another aspect to consider is feeding the bird correctly for the amount it is eating.

By way of an overview, ammonia is made up of Nitrogen and Hydrogen (NH_3). The main source of Nitrogen (N) available to livestock is protein within the diet, and this is why reducing protein, reduces ammonia. If you limit the amount of available N in the diet so there is enough for nutrition but with as little excess as possible then this limits the quantities of ammonia that can be produced.

$$\text{Manure (Urea)} + \text{Water} \xrightarrow{\text{enzyme release}} \text{Ammonia} + \text{Carbon Dioxide}$$

$$(NH_2)_2CO + H_2O \xrightarrow{\text{enzyme release}} 2NH_3 + CO_2$$

So by limiting the amount of urea in the manure, ammonia is reduced. Alternatively limiting the amount of water present curbs ammonia production, also justifying manure drying.

Reducing crude protein within the diet (such as wheat and soya) drastically lowers ammonia release, with a 1% reduction in crude protein equating to a 10% ammonia reduction (McGahan et al, 2002 & Le et al, 2008). The method of achieving this is by adding synthetic amino acids. Proteins are organic compounds made up of amino acids; each protein has its own unique amino acid sequence that is specific to it, and some can be synthetically manufactured. Adding synthetic amino acids allows excess vegetable protein, taken in the diet from wheat, soya or maize, to be removed. Protein levels can easily be dropped by a quarter, equating to a crude protein decrease of about 6-9% within the diet in my experiance. The concentrations of ammonia in gas and litter decrease by 90% and 50% respectively from using reduced crude protein and enhanced amino acid diets (McGahan et al, 2002).

The aim of feeding protein to livestock is to meet the animal's genetic potential. When trying to feed trace amino acids found in standard rations, either higher protein levels are required or alternatively synthetic amino acids can be added. By feeding this way excess and costly protein can easily be cut from diets in favour of these synthetically manufactured alternatives.

Increasing dietary fibre also reduces ammonia release. A 1% increase in dietary fibre gives a 3% reduction in ammonia (Xin et al, 2009).

2. Feed and Water Additives

Supplements to both feed and water have been found as an effective means of reducing ammonia release rates. One addition (to feed stuffs) is Ecocal, containing calcium sulphate and zeolite, and achieving a 46% reduction in ammonia (Xin et al, 2009).

During the same trial distillers dried grains and solubles (DDGS, a by product of bio ethanol production) were added to a diet, making up 10-15% of the final ration. This accounted for a 29% reduction in ammonia (Xin et al, 2009).

Importantly, these additional feed inputs have caused no significant change to feed costs as demonstrated by Iowa State University. In fact the DDGS ratison costs 1% less than the standard ration used for the experiment, and neither supplement affected flock performance.

In Asia similar work was being carried out to this effect; for instance in Korea the addition of yeast to feed stuffs is subsidised by the government. Elsewhere, farmers are experimenting with coal supplements and some feed companies are promoting the use of probiotics to reduce odour emissions from pigs and poultry units. There is however no data to show effectiveness of these particular supplements.

Acidifying feed or water is another effective means of reducing ammonia release. Nitrogen can exist in different forms depending on the pH. Acidic manure retains more nitrogen as ammonium rather than ammonia, which is not released as a gas. The same principle works when adding an acid to manure once in the manure store. This method also reduces the incidence of salmonella within poultry. As a result, many farms acid feed or water as an insurance policy against salmonella. Any flock in Europe found to be salmonella positive must be slaughtered under present legislation.

3. Genetics

Currently Hy-Line and Iowa State University are carrying out research into the effects of genetics on ammonia production from laying hens. The experiment involves monitoring white birds that have been selected for their unusually low feed conversion ratio (FCR), consuming 90 grams of feed per day compared with 114 grams for the present generation of laying hen.

Monitoring the inputs (feed, water and ventilation rate) and the outputs (manure and air) has enabled clearer understanding of bird performance, including ammonia production rates.

The table below demonstrates the genetic advancement that is on-going within the poultry industry. Notably, with each new generation of laying hen come environmental benefits. The data is based on hens being fed the same diets, over the same laying period, in the same accommodation.

Poultry Efficiency Improvements			
Year	*Feed Intake*	*Egg Produced*	*FCR*
1994	43.5 kg	19.6 kg	2.22kg / kg
2008	41.6 kg	20.3 kg	2.02 kg / kg

It is clear to see that modern hens are laying more and require less feed to do this. Logically, if there is less feed going into the hen and more eggs being produced, there will be less manure excreted as more of the nutrients have been utilised by the hen.

Post-Excretion

4. Livestock Housing

Livestock housing has been shown to have a drastic effect on ammonia emissions from poultry through the implementation of new technologies. The move from deep pit poultry sheds to belt cleaned systems provides an 88% reduction in ammonia for the same bird numbers (BAT, 2003).

Whilst this is the most expensive solution it is also one of the most practical as the impending cage ban (2012) is a chance for those who are continuing egg production to upgrade to Best Available Techniques (BAT). The 88% reduction figure is only for a change in system; further gains can be made with the addition of manure drying both internally and externally.

These manure drying systems can also be retrospectively fitted allowing for more flexibility. In-house manure drying is an expensive process requiring large motors to power the fans, whereas the external version uses the exhaust air from the poultry units to dry the manure, at no extra running cost.

5. Manure Storage

Whilst at Iowa State University I discovered the true meaning of PHD; manure should be piled high and deep (PHD), decreasing the surface area of the manure heap.

Removing manure daily or twice weekly also significantly reduces the quantities of ammonia released, as it has not had time to brew before removal. If the manure is being removed to a store then further treatments can be done. Sealing the building with either a non-permeable or semi-permeable liner can reduce ammonia escaping and give ammonia emission reductions of up to 15% (Simpson et al, 2008). Further, air scrubbing gases from manure buildings can reduce ammonia emissions to 4% (Melse et al, 2005).

6. Manure Processing

In North East Asia all manure is further processed either into power as biogas (as at DQY), into compost (some of which is subsidised) or into calcium rich fertilizer pellets (also partly subsidised).

The processes themselves do not reduce ammonia as open compositing actually increases ammonia. However, the bio-scrubbers fitted to closed composting systems are found to be very effective.

A number of simple solutions have been developed by several poultry equipment manufacturers, one of which is external tunnel drying for manure. This is where the manure is collected on perforated cascading belts, located next to the unit's exhaust fans. Warm air from the shed is then blown through the manure, drying it to almost a dust, giving an ammonia reduction of 70% (BAT, 2003).

Ammonia build up in litter systems or manure heaps can be combated by spraying the litter in Aluminium Sulphate (Alum) solution. The treatment works by acidifying the litter and holding the ammonia in its non-volatile form (ammonium). Other similar treatments used include Sodium Bisulphate, Acidified Clay, Calcium Sulphate, Magnesium Chloride, Calcium Chloride and Magnesium Sulphate (Simpson et al, 2008). These litter treatments can account for up to a 50% reduction in ammonia output over the course of a flock.

The photos below illustrate three manure processing techniques. From left to right are; Manure Pelleting at Akita Co, Japan; Closed Composting at Hy-Line, Korea; and External Manure Drying with Techno, Italy.

7. End of Pipe Techniques

End of Pipe Techniques are exhaust treatments designed to reduce ammonia levels within exhaust gases. There are many different methods, some designed to reduce dust and odour whilst others remove ammonia.

Biocurtains (netting around fans) and biomass walls (straw walls built around fans) are two of the most economical solutions, capable of reducing dust and odour emissions by 17-20% and 40-90% respectively (Xin et al, 2009), but neither is so effective in ammonia removal.

Bio filtration is a method where the exhaust gases are passed through damp wood chippings (pine) or damp straw. These have been shown to reduce odour by 70% and ammonia by up to 60% (Simpson et al, 2008).

Vegetative environmental buffers (VEB) such as tree borders can reduce dust by 49% and ammonia by 46% (Malone et al, 2006). VEBs reduce emissions by intercepting and diluting particulates and ammonia in the turbulent area between units and trees before moving downwind (Colletti et al, 2004). They have little effect on odour but do bring the added advantage of natural screening to any farm.

Air scrubbers are a very effective way of washing ammonia (96% reduction) from the air, with the draw back of feather clogging within poultry units (Melse et al, 2005). That said scrubbers are well suited for pig units and manure storage, although the system would require very high maintenance in a poultry unit to sustain its efficiency.

8. Remodelling

As part of the EA's policing role of IPPC legislation in the UK, they were tasked with taking farm information and modelling ammonia release rates to ammonia sensitive sites (SSSIs and SACs). The results of these models have since been used to enforce IPPC legislation, leading to some farms being threatened with closure due to excessive emissions taken from the model.

A major concern shared by the poultry and pig industries is that present EA models do not take into account local topography, localised weather patterns, and surface roughness (as trees are rougher than grass) as well as ventilation rate, heights and types. All such factors affect the accurate recording of ammonia release rates from farms. Alarmingly, the EA are also basing their ammonia release rate figures on old emissions data.

In response, Natural England have been tasked with re-assessing all effected SSSIs and SACs for proof of model accuracy, based on the suspicion that ammonia from agriculture is not being deposited at the rates initially suggested and modelled by the EA.

I would therefore greatly stress that before investing resources into implementing any of the ammonia abatement techniques discussed in this report, the model produced by the EA must be accurate and site specific to each farm.

Discussion

Whilst in Iowa I had a eureka moment, realising that not only is Pre-Excretion the most important route to solving the ammonia in agriculture dilemma but it is also by far the most sensible and affordable option. I owe that moment to Professor Hongwei Xin who took my thinking away from the expensive equipment.

Looking at manipulating livestock diets as a Pre-Excretion method, it makes logical sense to phase feed livestock with nutrition specific to the animal's lifecycle requirements. Correct phase feeding on lower protein diets are not only environmentally sound but also carry cost savings, which I have already implemented. This goes a very long way to alleviating our problems.

Unfortunately the DDGS available in the UK presently does not have a set level of consistent nutrients, unlike that found in the USA. If the consistency in UK DDGS improves then adding more fibre to the diet by the addition of DDGS may be an option to further reduce our ammonia outputs. The Ecocal trial that was run by Iowa State University also provides a lot of promise showing that simply adding a calcium sulphate and zeolite supplement to the standard ration reduces ammonia successfully and at no extra cost when compared with that of the standard ration.

Notably, as part of the EA's emission modelling no investigations were carried out into protein levels within livestock diets. As this is the most influential factor affecting ammonia release, with potentially drastic savings to be had by reducing crude protein by just a percent or two, it is of paramount importance that livestock diets are not overlooked in modelling ammonia release rates.

Importantly, all farmers regardless seek to improve their livestock through breeding, and this is certainly happening across the world within the commercial poultry sector both for meat and egg production. The commercial bird has an improving FCR and this alone stands as the easiest way of reducing ammonia output. Unfortunately the same can not be said about old and rare poultry breeds as the research has to be based on improving the commercial bird through breeding.

Taking the above into consideration, it appears to me that the industry is already making positive steps towards curbing ammonia release, through ongoing genetic improvements and acidifying techniques (employed to combat salmonella). If combined with correct feeding, most farms should find that they could reduce their emissions at no extra costs.

Nonetheless, Post-Excretion methods are also undoubtedly highly effective, although generally more expensive. The poultry sector has been making inroads on improving their ammonia output inadvertently with the cage ban coming into effect on the 1st January 2012. The cage ban will mean the UK's entire intensive laying flock will be in new accommodation, of which all will be BAT.

Given that manure itself releases ammonia, the storage and processing of manure is key. One of the effects of the 2012 cage ban has been the general movement away from deep pit systems to belt cleaned systems in livestock housing. Belt clean systems offer an 88% saving on ammonia outputs for the same bird numbers, with the added benefit of reducing the incidences of flies and rodents without the need to manage the manure heap. I would suggest that all farmers farming beyond 2012 should consider belt clean systems if for no other reason than getting more birds in the same volume, when compared to a deep pit system.

As regards effective manure storage, from my travels I observed that those practicing good farming methods did not leave the manure in field heaps, but instead opt for sealed, waterproof storage, as seen in the USA, Korea, and Japan. Despite being efficient for reducing ammonia outputs, sealed storage methods will only be effective in England once the hostility of keeping manure on site is resolved. This issue stems from the EA penalising farmers for keeping manure on farms in close proximity to a SSSIs. However the cheapest and simplest method of storing manure that I would advise all farmers follow is to pile it high and deep.

Specifically addressing manure-processing systems, I have seen biogas electricity production and air scrubbed close composting run as viable businesses. Both of these were hugely impressive but require massive investments, the likes of which I am not suggesting. However the most realistic and feasible manure processing addition for UK farmers is simple external manure drying. I witnessed such a system in Italy, which was fitted years after the farm was erected and the manure was dried down to a fine dust. The manure is dried to ensure most of the water is driven off presenting less of an ammonia risk.

I was also quite taken by the Americans use of Alum on litter to reduce its pH. This method could work very well in the UK and easily added to manure through spraying during removal. Further, farms already treating manure for fly larvae could put these systems into use on the Alum application.

The last of the Post-Excretion ammonia abatement methods to be discussed are the end of pipe techniques. The technique I have been most impressed by are the VEB methods as "If people can't see it, they don't tend to complain about it", a statement that has come from dozens of sources. Not only do trees have a positive effect on reducing dust and ammonia, they act as a natural screen in any situation and give off the impression that an effort is being made. Furthermore there is the added benefit of grants being available for planting native woodland.

The most expensive method available solely for reducing odour and ammonia output are wet air scrubbers, as used in Holland, Germany and Asia. Whilst they are very effective when used within pig barns or manure stores they are not as good when placed within poultry units, due to feather and dust clogging. The large maintenance commitment that would be required to manage such a technique within poultry means that I would only ever consider using air scrubbers as a very last resort at the threat of farm closure, and only on manure stores. A cheaper alternative is a biofilter as seen in South Korea; good at reducing ammonia, dust and odour but does require initial investment, regular filter changes and general maintenance.

One of the more interesting finds from my scholarship is that other nations are dealing with very similar environmental issues, but instead are turning them into further business opportunities. Notably:

- In Australia, Pace Farms Eco branded eggs sold exceptionally well and was a model farm;

- In Japan, Akita Co has a very successful and lucrative compost division;
- In Taiwan, Great Mountain Poultry actively monitor their ammonia production as a partial marketing tool for improved welfare;
- In China, DQY adhere to European environment and welfare standards as a marketing strategy;
- In USA, Moark and Iowa State University were trialling feed additives that cost no extra but gave significant environmental savings.

It appears thinking outside the box is somewhat required to solve the pressing environmental issues faced by farmers. A way of stimulating this in the UK is by considering an arrangement similar to that of the Dutch Green Label System. I believe there is great benefit to be had by bringing together farmers, academia and government bodies to make use of the breadth and depth of knowledge and experience across these sectors, as a reckoning point for the EA.

Conclusion and Recommendations

Faced with IPPC legislation some farms in the UK have been threatened with closure. I set myself the challenge of travelling the world to identify an assortment of the best techniques for reducing agricultural ammonia emissions.

Not every country had ammonia at the heart of its environmental agenda, however all were motivated in some manner to reduce emissions from poultry to the wider environment albeit to curb odour, dust or ammonia.

Specifically pinpointing ammonia reduction, a combination of both Pre- Excretion and Post-Excretion methods are currently being employed worldwide. My scholarship has shown that in the vast majority of cases there are several Pre-Excretion routes that should not be too costly, or involve large infrastructure changes to comply with IPPC legislation.

For those farms presently residing on the closure list a combination of Pre-Excretion and Post-Excretion methods should see ammonia emission rates drastically decrease. I see no reason why any farm should have to consider closure with the methods presently available and those being researched.

On a personal note, after 2 years of Nuffield I have adopted some of the Pre and Post-Excretion techniques that I have witnessed on my travels. There is now a stricter phase feeding regime that actively monitors feed intake and adjusts the ration accordingly. We have also started using more synthetic amino acids, although this has partially been driven by high soya prices. We have ensured that all new poultry housing is belt cleaned with manure drying. We have also left adequate space outside the buildings for external manure drying, if later required. However my favourite change has been planting trees surrounding our farms, which has added to screening and amenity value.

Looking forward, I feel the UK should look to match the efforts presently being carried out in the USA in investigating the Pre-Excretion techniques. In doing this I would recommend a particular focus on dietary manipulation and also the effects of genetic advancement, to assess the extent of environmental benefits that are to be gained. The UK would also benefit from adopting a similar strategy to the Dutch Green Label Scheme.

However before significant investments are made, all of the EA models need to be ratified independently until both industry and government accept the models. Farmers must then start the strategic selection of appropriate ammonia abatement techniques on a site specific basis.

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Appendix I

Persons met during my travels:

Name	Positiion	Organisation
Australia		
David Bree	Production Director	Darwalla, Mt. Cotton, Queensland
Albert Benfer	CEO	Darwalla, Mt. Cotton, Queensland
Ron Dullaway	CEO	Golden Cockerel, Mt. Cotton, Queensland
James Kellaway	Managing Director	Australain Egg Corporation Ltd, Sydney, NSW
Frank Pace	CEO	Pace Farm, Minchinbury, NSW
Paul Pace	General Manager	Pace Farm, Minchinbury, NSW
Joe Pace	Site Manager	Pace Farm, West Wyalong, NSW
Philip Szepe	Managing Director	Kinross Farm, Kinglake West, Victoria
Dr David Witcombe	R & D Manager	Australain Egg Corporation Ltd, Sydney, NSW
China		
	General Manager	DQY
	Production Director	
Gu Qing	Finance Director	
Linlin Han	General Manager	Hanovo Foods, Lvshunkou District, Dalian
France		
Benoit Pele	Director of Sales	Hendrix - ISA
Tix Hendrix	CEO	Hendrix - ISA
Veronique Gonnier		CNPO
Pascale Magdelaine		ITAVI
Germany		
Ulf Meyer	Sales Director	Big Dutchman, Vechta, Germany
Italy		
Marcello Valli	President	Valli, Galeata, Forli
Guliano Maltoni	Director	Valli, Galeata, Forli
Pepi	Director	Techno, Marsango di Campo, S.Martino
Japan		
Shogo Akita	Vice President	Akita Co, Fukuyama-shi, Hiroshima.
Yoshiki Akita	President	Akita Co, Fukuyama-shi, Hiroshima.
Haruhito Fujii	Production Division	Akita Co, Fukuyama-shi, Hiroshima.
Hiroaki Ohta	Director	CAF Laboritories, Fukuyama, Hiroshima.
Daisuke Osania	President	Hokuryo Co, Chuo Siroisi-ku, Sapporo.
Katsuyoshi Takada	President	Uchinami Co, Shibadaimon Minato-ku, Tokyo.
Minoru Takeda	Managing Director	Akita Co, Fukuyama-shi, Hiroshima.
Korea		
Li Chean Han	Vice President	Yun Farm, Pyungtaek City, Kyunggi-do.

Young-sik Kim	Site Manager	Ye San Poultry Farm, Yeasan-kun, Choong nam.
Yun-Ho Kim	Vice President	Korean Poultry TS Co, Icheon-si, Gyeongi-do.
Han Ki-Seok	President	Raindow Farm, Chngju-si, Chungcheongbuk-do.
Park Sung-Hwan	Managing Director	Cheonggyewon Inc, Incheon-si, Gyeonggi-do.
	Spain	
Pedro Guillen Gomez	Director of Production	Huevos Guillen, Quart de Poblet, Valencia
Ben Guillen Gomez	Site Manager	Huevos Guillen, Quart de Poblet, Valencia
Bienvenido Rios Sanchez	Comercial Director	DAGU, Cabanillas del Campo, Guadalajara
	Taiwan	
Richie Chen	General Manager	Great Mountain Poultry, Hsin Hua, Tainan
Benjamin Huang	Production Director	Sung Sing Industrial Co,Linluo, Pingtung.
	UK	
Dr Diane Mitchell	Chief Environmental Advisor	NFU
Charles Bourns	Poultry Board Chairman	NFU
Mark Williams	Chief Executive	British Egg Industry Council
Malcolm Sharp	Environment & Design	SAC
Nichoals Sparks	Head of Avian Science Research Centre	SAC
Alan Stewart	Senior Lecturer	Harper Adams University College
Robert Cocksworth	Managing Director	HyLine UK
Louise Butler	UK Marketing Manager	HyLine UK
Alison Holdsworth	IPPC team	Environment Agency
	USA	
Dr Neil O'Sullivan	Director of Research	HyLine International
Tom Dixon	Director of Sales	HyLine International
Dr Jesus Arango	Researcher	HyLine International
Prof Hongwei Xin	Agriculture & Biosystems Engineering / Director	Iowa State Unviersity / Egg Industry Centre
Jim Dean	Center Fresh Egg Farm	Sioux Center, Iowa
Fred Adams	Managing Director	Calmain Foods
Matt Arrowsmith	Vice President	Calmain Foods
Timothy Dawson	Chief Financial Officer	Calmain Foods
Vernon Freelend	Layer Farms Manager	Moark