NUFFIELD FARMING SCHOLARSHIP TRUST

WASTE APPLICATIONS TO LAND - OPPORTUNITY OR THREAT?

A report on a study tour by
John Davies
2008 Scholar

Sponsored by the

NFU Mutual Trust Charitable Trust
Nuffield Award

Contents

1. Acknowledgements

I would like to thank all the people who supported me in the completion of this scholarship.

I am indebted to my wife Emily who kept my business and home in order while I was away during my Nuffield Tour, especially after the birth of our second child, and my daughter Esme, whose phone conversations kept me grounded whilst I was away.

Considerable thanks must go to the NFU Mutual Trust Charitable Trust and the Nuffield Farming Scholarship Trust. Without their funding and support I would not have been able to undertake this life changing experience.

To Patricks Recycling and Boynton Farms - thanks for your encouragement and support; and my clients who probably didn't see me as much as they should have done while I was away.

Views expressed in this report are all my own and for them I take full responsibility. They do not constitute a recommendation and are not the views of the NFU Mutual Trust Charitable Trust or the Nuffield Farming Scholarship Trust.

2. Technical Summary

If we have at least 100 million tonnes of waste with a potential to recycle to land and 5.7 million hectares of land available for recycling, why aren't they all being used as a source of nutrition and organic matter?

In the United Kingdom we have a poor track record of waste application, get concerned over contamination, get confused by the legislation, and often are reluctant to embrace new practices. This all has an impact on why we are not taking advantage of these wastes.

We are living in a changing world with finite resources, climate change issues, energy supply issues and uncertainty of when oil production will reach its peak. Can we defend the apparent waste of nutrition, such as the estimated 57000 tonnes of phosphate entering landfill in Europe every year? Surely we should be as efficiently utilising all the locally available nutrition we have before we manufacture and mine fertiliser from distant countries.

To study this topic further I visited countries that fell into two groups. The first group were those with low population density, plentiful mineral resources and reserves, who can bury waste without it offending anyone. Secondly, well developed countries with limited resources, limited land area and a high level of public awareness of these issues.

In the UK several options exist to improve the use of organics recycling. We need to focus on many solutions and dispel the myths, use science to define what the real risks are, improve the image and methods of application and use proactive marketing (especially on the improvements to the soil that this brings).

Anaerobic digestion is also a significant solution to this problem. It provides a self financing route to process food and livestock waste. It also removes pathogens, removes odours and provides storage for waste. Finally, it produces digestate, an inorganic fertiliser substitute, which ultimately supplies a product with an improved public image for application to land.

All waste products can safely be recycled to land, all the assumed issues with these products do not exist and simple solutions of biosecurity, analysis and best practice can ensure that the full agricultural benefit of all these products can be achieved, but this can only succeed if the mindset of 'waste disposal' is removed and it is replaced with 'nutrients utilisation' and 'soil organic improvement'.

3. Introduction

Personal Background

I grew up on my family farm near Llandrindod Wells in Powys, an upland livestock farm producing pedigree Hampshire Down sheep, commercial fat lambs, store cattle, and free-range eggs. Value is added wherever possible.

This provided a rounded agricultural knowledge for my further studies at Harper Adams Agricultural College. Graduating in 1992 I pursued a career in Farm Management which then led to becoming self employed in 2000 and focusing on agronomy and farm business advice. A strong theme in my management positions was environmental stewardship and this continued in my advisory role. Working in Herefordshire and Powys is a privilege and farm structures are suited to my style of management.

My sympathy for the environment and the concept that "if you protect the environment you protect your wallet" has always been the basis for my advice. If you over apply phosphate and it is lost in soil solution by runoff you have to replace not only the phosphate but you lose the soil forever.

You can imagine my enthusiasm when approached by local waste disposal firm (Patricks – based at Marlbrook, Leominster) in early 2007 to help try to reduce their disposal costs by changing the normal route of disposal away from sewage treatment works, to land application.

This allowed me to bring together many of my skill areas of Agronomy, Business Advice, Environmental Stewardship, and Farm Management with my pet topics of increasing soil organic matter and reducing the cost of inputs. A client of mine is often heard telling people that he uses me as his agronomist and adviser because as a Welsh hill farmer I am very reluctant to recommend anyone to spend money unless it is absolutely necessary!

Realising that using these wastes could reduce the purchased fertilizer usage on my client's farms seemed too good to be true. What was the catch? At the risk of you not reading any further, I still haven't found a reason not to apply these wastes onto land, but there are many issues to consider in the process. The diversion of sewage sludge, compost, food waste, plant tissue, poultry shed washings, wood chips, chocolate, jam, septic tank waste, beverage by-products, whey, vegetable waste, and many others from landfill is also an important reason for using them to apply to land.

It is routine for applications of chocolate to fertilise maize, septic tank to fertilise grass, and sewage sludge to fertilise cereals. This usually results in clients not spending any money at all, but saves them between £120 and £170 per ha.

Origins of the Study

Applying for a Nuffield Scholarship forced me to focus on what I needed to achieve from the travels that may result. Answers were needed to the questions of contamination, odour, nutrient content, public awareness, application options, and to identify if any products were not applicable to land application.

The relevance of my topic hit home when I started looking for land on which to apply wastes. I either had strong objections to it or immediate support for it. The extremes of views were immense. Those against its application quoted “contamination”, “legislation”, “it was all banned, wasn’t it?”, and those who received it without question seemed content to apply it into livestock fields and did not even implement sufficient biosecurity withdrawal periods.

I could see that in order to keep applying the wastes I would need to find answers for both groups of people to ensure for myself and for Patricks that we were not causing issues with: soil contamination; farm biosecurity; bad publicity; or at the extreme, a risk of prosecution.

4. Background

4.1 What is Waste?

In order to legislate something it must first have a definition. The Environment Agency defines waste as “any substance or object which the holder discards or intends or is required to discard”, this is where the problems begin. All products are branded with the ‘waste’ title which instantly produces an image of toxic materials which have a damaging effect on both humans and the environment. To make a point, the same volume of gypsum, for example, could be both waste and/or fertiliser depending on the circumstances in which it was produced and why it changed hands. This is one of the main reasons that many people find waste a difficult subject to fully understand.

When visiting Germany, Holger Meyer (K Nord, Ganderkesee) made what was a defining statement for me. He said "waste is simply a resource that was in the wrong place". His business of waste decontamination, depackaging, composting, anaerobic digestion and supplying anaerobic digestion feedstocks using novel equipment and processes, showed how relocating and processing these wastes turned them into reusable and useful products.

I completely accept that it will always be waste legislation that needs to regulate the land application of these products, but it does nothing to help with the image issue.

4.2 Waste Disposal

When I visited Severn Trent Sewage Treatment Works, near Kinver, it became apparent that massive underinvestment is hampering improvements at these treatment works. At least 65000 tonnes of sewage passes through this plant daily and yet the incinerator on site is inoperable and the anaerobic digester plant is small and ineffective so with the continuous waste from 1/4 million people all the benefits are not being utilised other than Biosolids being taken from the site and applied to land. So reliable large quantities of wastes are arriving at treatment plants daily and only biosolids are being produced, a shame when electricity could be produced and sold and heat utilised as well.

Since Victorian times this waste has been going to land albeit unregulated. This is often forgotten when discussing the effect that waste applications have on the land they are applied to. You could argue that we are in a more industrialised age but knowledge has on balance reduced the impact that we have on our immediate environment.

The historical lack of regulation had the effect of producing a disposal attitude which was considered the norm until the early 1990's. The basis of many people's resistance to land application could result from this period when locally they may well have observed examples of obvious bad practice.

I have always applied waste to land using best practice application rates which ensure that all the available nutrients are used up by crop demand. It seems pointless over applying these wastes as it simply loses available nutrition by leaching or atmospheric loss and reduces the area of land that could benefit from these applications.

With 5.7 million hectares of land in the UK available for land spreading out of a total of 9.1 million hectares (Nicholson et al. 2008) why would you want to over apply this waste?

Being spread annually on this land is around:

- 7 million tonnes (fresh weight) of industrial wastes
- 4 million tonnes of Sewage Sludge
- 1 million tonnes of compost
- 91 million tonnes of Farmyard Manures

(Source Chambers and Chadwick, 2008).

This only equates to around 330 tonnes per farm in the UK, it sounds easily achievable to me. The secret lies with how we apply these wastes and how we utilise the nutrients and how any successful offsetting of manufactured Nitrogen fertiliser will benefit business finance and the global environment significantly.

It is my personal belief that there are actually more wastes available than the 100 million tonnes that is often quoted which due to contamination or cost of recovery is not included in this list, a rising cost of nutrition may well change this.

4.3 Waste Applications to Land

The disposal mindset had a "shot across the bows" with the exemption system introduced under the European Waste Framework Directive. This allocated a permit for individual waste products to be applied to individual areas of land of up to 50 has in size. It has not been without its problems but has helped improve the image of waste applications to land and certainly helped the Environment Agency to effectively police the application process.

Under a disposal regime background micro contaminants were never seen as important compared to the disposal of waste which would have had limited storage available on the sites on which they were generated. You can understand some of this bullish approach when dealing with waste generators. They only see the issues as far as the "factory gate". They often have a 'fire brigade' approach to waste disposal (last minute and large volumes) and are often not prepared to work with farmers to simplify the process. They either want large quantities to be removed immediately or they want small quantities removed regularly. The waste disposal firms are responsible when applications have a health or environmental impact but no one considers the pressure being exerted on them to dispose of products as quickly and as cheaply as possible. The lack of collaboration is completely different to the community and farmer led integrated waste handling that we see in Germany and Sweden as well as many other countries.

Patricks, Marlbrook Leominster, Trailed tanker with splash plate and showing return trip to headland to fill up.

Until the start of my Nuffield studies, liquid slurries were applied by a splash plate on the back of a tanker as per much of standard farm slurry application equipment. Field tankers are refilled from a 'nurse' tank located on the headland of the fields. This buffered the often erratic movement of liquid slurries from waste suppliers. This type of system has two inherent problems, firstly compaction of the land caused by repeated trips back to the 'nurse' tank, and loss of nutritional value and increased smell from the aerosols produced from the splash plate. Looking back it is no wonder the public had concerns and this type of approach had to be phased out. Compaction and soil structural damage must be prevented at all cost.

In Holland, Henk Eggink, the owner of Slootsmid Agricultural Machinery Dealership in Laren, assured me this was the right decision. This was an unplanned visit after passing the dealership and seeing slurry injection and handling equipment on the forecourt I decided to call in. Henk Eggink was involved on "The Panel" advising the Agricultural Minister on Slurry applications to land and went out of his way to assist me including arranging a visit to a farmer client of his, Jan Eggink, who also advised the same minister. Jan Eggink outlined that their government now approached the environmental impact of farming with a carrot rather than stick approach. Farmers in Holland are allowed to increase the output from their farms if they can prove how efficient they are at utilising nutrient. This sounded very logical to me.

In Ireland, a similar visit to SlurryKat also helped with choosing alternative equipment to improve my application systems. A dribble bar was chosen following this meeting as the running costs were lower than a trailing shoe, the expected machine life was also longer and the environmental losses were not significantly different. It was refreshing to see Garth Cairns producing slurry application equipment specified from practicality and reliability perspectives coupled with "testing them almost to destruction" in the contracting arm of the business.

4.4 Legislation

Since 1994 England and Wales has had to comply with the European Waste Framework Directive (WFD) which requires member states by law to intervene to protect the environment and human health through a system of permits and exemptions from the need to permit (Environmental Permitting). These exemptions have developed into 2 main types – simple and notifiable. The majority are simple and require only notification. Notifiable exemptions require more information to be submitted and carry an annual charge and re-registration fee. Low risk Regulatory Position Statements allow certain wastes to be spread to land for agricultural or ecological benefit in the absence of an Environmental Permit.

Waste Protocols help define when certain products cease to become a waste and no longer need regulatory controls, the assumption is that they will have been processed to an acceptable standard i.e. PAS 100 – Compost, PAS 110 – Anaerobic Digestate. In reality these standards are not that easy to achieve and the level of compliance is similar to Environmental Permitting requirements. Online tools have proved difficult to use and the level of work required is little different to an Environmental permit application.

Environmental Permitting sounds as if it has all the bases covered but in fact gaps still exist, safe products exist that have no route to land, and some products have no legislation against them due to being low risk (Septic Tank and Poultry shed washings). Hopefully the revised Environmental Permitting system that is currently under consultation will address these low risk products that have no recycling to land permission.

4.5 Attitudes to Waste

A report on the disposal or reuse of sludge in the South West (Surfers against Sewage, 2006) was conducted by individuals visiting “The Eden Project” in Cornwall. It makes interesting reading. It was concerning that 20% of individuals questioned had never heard of Sewage Sludge before, and 51% of them assumed all Sewage Sludge was dumped at sea, but, on a more positive note, 68 % of individuals were not intending to avoid eating crops that had been fertilized with treated sludge if it had been applied in accordance with all the legislation and guidelines that were in place to protect consumers.

As part of this survey individuals were given a presentation on the processes involved in the disposal and reuse of Sewage Sludge and it showed that, considering most people are uninformed on this subject, when presented with unbiased facts they do see that the utilisation of this product as a fertiliser is a positive thing. Even though 45% of those surveyed indicated that their preferred route for disposal was onto non food crops these same people did not disagree with the application of Sewage Sludge to food crops. The report also concluded that “The more information that people have available to make an informed decision increased the likelihood of support for the use of sludge on food crops, and it was felt

that to ensure public support is maintained for this route, more information on sludge treatment and use should be made available to the public".

It would appear that the solution is simply to educate the public and get on with it. This is correct in part but a much more complicated problem exists!

5. Waste Contamination

As the "Surfers against Sewage" survey showed uninformed people are very likely to assume that wastes should not be applied to land because of the contamination that is likely to be found within it. Is there any truth in this?

During September 2009 I visited Bjorn Vinnerås in Sweden at The SLU (Swedish Agricultural University, Uppsala). I had met him previously at the International Fertiliser Society Conference in Cambridge in December 2008. The paper he presented (Non-metallic Contaminants in Domestic Waste, Wastewater and Manures: Constraints to Agricultural Use) is so pivotal and he appears to be leading the way in adding a scientific based approach to this emotive issue. I am very grateful to the time both he and his department spent discussing the issues of contaminants in waste products.

These issues can be a problem in specific batches of waste but in general terms they do not pose as great a risk as livestock manures do especially those produced in intensive, housed environments. Bjorn and his colleagues showed me that the major sources of heavy metals are related to livestock feed supplements. Incidentally, in this form they are much more available than from industrial sources.

5.1 Pathogens

Bjorn also works 50% of his time for SVA (Swedish National Veterinary Institute) and his specialisation is in "pathogenic control within human and livestock manures". He told me that there are simple solutions to minimising the impact of pathogen control even where *Clostridium Botulinam* (causes Botulism in cattle) and Salmonella are involved. These can be controlled by using Urea treatment of waste to create ammonia which is the only reliable break in these pathogenic lifecycles. His research has been taken up by the Swedish Government and this is now one of the recommended methods to ensure Sweden maintains its Salmonella free status.

People should remember that sewage sludge is treated prior to its application to land, as is the case in Sweden, Holland, Germany and elsewhere. So it is a low risk. Unfortunately the bulk of livestock manure is untreated. *Clostridium Botulinam* and spore forming bacteria are not controlled during digestion or pasteurization and are viable even in post anaerobic digested manure according to Bjorn.

This has really hit home the importance of biosecurity to me and I have decided to implement my own extended grazing withdrawal time on forage fields which have had wastes surface applied of up to 28 days depending on the risk status of the product applied. Under DEFRA (Department Environment, Food and Rural Affairs) animal by-products regulations 2003 you cannot graze or harvest the crop for 2

months in the case of pigs, and 3 weeks in the case of other farmed animals, these form the minimum safe exclusion periods.

But what about Septic Tank waste which can be applied to land untreated? Should we be concerned? Again, no. Bjorn states that the levels of pathogens are still significantly lower than those found in livestock manures, and as long as basic biosecurity is in place the risks are low.

5.2 Other Contamination

Micro contaminants are an area where globally no work appears to have been done to ascertain if a build up is occurring within our soils and if this is causing a problem. Antibiotics and hormones are the biggest issues with possible antibiotic resistance and "gender bender" tendencies coming to the fore. Livestock veterinary treatments and the use of Soya (which contains large quantities of oestrogen) are the main causes of this.

In developed countries ibuprofen and fire retardants also appear in domestic wastes and with no removal of consent to discharge likely, land application with its slow degradation and high microbial activity is still the best option. Bjorn told me that 1 m3 of soil contains the same microbial content as 1 km3 of water, proving that as long as land application is carried out correctly and water contamination does not result this is the best way to ensure a product's safe breakdown.

This highlights the significance of water contamination especially from Nitrogen and the more damaging Phosphate. Both occur in urine and the problem starts when we add 2 litres of urine to 200 L of flush water and industrial wash water, with the latter adding micro contaminants and potentially pathogens. It makes the problem 100 times larger and makes any leak within the system more likely to contaminate water.

In Sweden, housing estates (Understenshőjden and Bjőrkhagen Estates) have been fitted with dual system toilets where the yellow water (urine) and brown water (faeces) are kept separate. The brown goes into the existing sewage system and the yellow is exported and used as a crop fertiliser. The public have embraced this and there has been no objection to the yellow water being applied directly to crop especially as Bjorn et al research shows that after 1 week of storage it has a low pathogen load but would still benefit from not being applied to food crops eaten raw. This highlights the low impact of untreated septic tank waste applications.

Full analysis should be done on all waste streams including all relevant parameters. Paragraph 7 exemptions require a given specification of analysis and expect this up to date analysis to be attached to the form. I like this approach as it monitors heavy metal build up, and Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) issues that are likely to have an impact on soil microbial activity. Again this is the accepted standard in all the countries visited.

5.3 Incineration

In Germany incineration provides a useful route for contaminated organics, but we do not have this option in the UK. Nothing creates such a poor image as organic waste spreading to land as when they

are contaminated with plastics etc. This is technically "disposal to land" which is an offence under Waste Framework directive. Without the incineration option we need to try and separate out this contamination and apply the remainder of the product to land.

5.4 Composting

In California, the City of San Diego Composting Facility (Part of organised Biocycle International Conference 2009 - Waste Diversion, Composting, and Renewable Energy) showed me the huge scale of whole city composting operations. They were also supplying the increasing market for colour coded wood chips for people to match to their homes which are just the sort of innovation you find in California!

Dr Les Kuhlman from Resource Recovery Systems International, Sterling, Colorado spent two days showing me around a selection of his clients' farms showing me the variety of composting systems that they had in place. They all were enthused about composting, and the benefits of raising organic matter were recounted many times.

I was, however, unhappy with the levels of contamination that was present in some of the compost made from source separated waste. Levels would have been unacceptable on my own client's farms. This criticism was of course not relevant to livestock manure based systems. The only way this contamination is likely to improve is through the public embracing the separation of wastes at source.

Compost contaminated with plastics - Sterling, Colorado

The problem with the composting process was the finer they work the windrows the harder it is to differentiate between the contaminants and the compost, causing the whole bulk to pass over the final screen when loading the compost for dispatch. They also use this contaminated screening from one windrow to act as the starter mix for a subsequent windrow, further reducing the contaminants in size and thus making it even more difficult to separate. This is however no different to the situation here in the UK and why I have not used large amounts of compost originating from source separated waste.

It seems that in the USA as a whole the composter does not generally get too much interference from the national and regional Environmental Protection Agency which does leave a lot of the responsibility with the farmer to do the right thing, the exceptions being states such as California where industrialised agriculture is co existing with high environmental impact from odour, nutrients and runoff etc and a tighter system is required and being pursued.

6. Agricultural Benefits

6.1 Crop Nutrition

Andre Capelle (Nagele, Holland) showed me how maize can be grown using only sewage sludge and potatoes with only slurry or digestate. He designs, builds and operates machines that apply slurries and wastes into the growing crop. He is routinely using a lightweight tined harrow to apply products into wheat; a dribble bar applicator into potatoes, maize and cereals; and a tined cultivator into growing potatoes and also dribble bar placement into planted potatoes. He actively develops new methods as circumstances dictate.

Waste being applied into Maize by Andre Capelle

Waste being applied into potatoes (note tied pipes to match row widths)

Wastes being applied into potato seedbed

We know it can be done because rather than applying manures in the autumn and losing significant quantities from leaching and atmospheric loss, they are applied at or close to crop demand. The environmental impact of this is significantly less. The secret in the UK situation is not to focus on Nitrogen to decide your application rate but base it on supplying the lowest denominator, straights can

be used to balance out crop need allowing the waste to be applied to an even greater area. This will prevent, as with historical applications of poultry manure, the Phosphate indices rising unchecked.

It makes sense that any fertiliser supplied as waste does not need to be purchased. In my own calculated examples a client of mine saved around £150-00 per hectare using chocolate waste dribble bar applied under maize another saved around £170-00 per hectare using sewage sludge applied to stubble before drilling spring cereals, and another around £120-00 per hectare using septic tank waste injected into grassland. In all countries I visited fertiliser prices were fluctuating and were relatively expensive as well, so a benefit from reducing the amount used was relevant wherever.

6.2 Soil Organic Matter(SOM)

In America, Australia, and even Europe, intensive mechanised agriculture coupled with 'thinner' soils has increased the importance of soil organic matter replacement and this is why we are seeing the upsurge of composting sites, where even fallen stock are composted in order to supply this valuable commodity. The driver here is mostly water retention but in San Diego I saw compost being used to re-establish native species in the Re-vegetating Canyon Preserve project with mulch and compost from the city of San Diego Greenery composting facility. This was mainly due to invasive European plants removing SOM so preventing the native species from germinating.

Dr Les Kuhlman's (Resource Recovery Systems International) clients in Colorado all praised organic resources as a good source of organic matter and appreciated the increased water retention of soils and yield of cereals that had compost applied to it. Wes Selvidge, Buttonwillow Land and Cattle Company, California saw it as a necessity especially where root crops were in the rotation and where water retention was fundamental to good crop yield and quality.

As in California and Colorado, the UK Soil Organic Matter (SOM) levels have been falling for at least a 15 year period. Soil analysis carried out in 1995 by the soil survey of England and Wales, found on average an 18 % fall in levels had occurred since the last survey in 1980, with some soils falling by as much as 50%.

Dr Les Kuhlman has seen an increase in SOM in Colorado from compost applications and it has had a positive effect on soil nutrient levels, the Cation Exchange capacity (Capacity of nutrients held to soil) and water holding capacity (capacity of water held in soil) both increasing further justifying the diversion of all organic materials away from landfill.

7. Reducing Environmental Impact

7.1 Landfill Diversion

So where has this waste been going? Disposal options are now more limited, disposal at sea is no longer acceptable and incineration has not got a good image. Consequently planning applications for incinerators are very difficult because of 'not in my backyard' resistance. How different the German approach is where electricity generation from incineration of imported and home produced waste makes the country one of the largest importers of waste in the world.

Currently a significant proportion of waste goes to landfill but landfill is under pressure. We are a comparatively small, urbanised island and people are usually fairly resistant to landfill sites in their neighbourhood being filled with everybody else's rubbish, especially when we have insufficient capacity to cope anyway.

Landfill costs have risen up to around £70 plus VAT which includes Landfill Tax and all wastes must be treated before they can go into landfill anyway, a natural disincentive if ever there was one.

7.2 Landfill Allocation Scheme

In order to reduce quantities sent to landfill the Biodegradable Municipal Waste Target (Landfill Allocation Scheme) was set up to ensure only 5 million tonnes goes into landfill by 2020, a 60% reduction in the quantities they currently receive. It will be hard to achieve, especially when reinforced by potential European fines if they are not met.

The only economic solution for diverting a significant quantity of material is land application; no other financially viable options exist, but EA permitting only allows a specific list of organic resources to be accepted for application to land. Some potential products are amalgamations of products and it is proving very complicated to get other resources added to this permitted list. I am discussing the addition of various products with the Environment Agency.

7.3 Manufactured Fertiliser Substitution

Inorganic N has a large impact on the environment; it produces huge CO_2 emissions during the manufacturing process as well as other Green House Gases and the calculation of these levels usually does not take into account the environmental cost of shipping it across the world to the areas where it is ultimately used.

As already discussed, maize is being grown in Holland having all of its nutrition supplied by two applications of slurry timed at greatest crop demand. This did not need any additional manufactured N and it will also receive other nutrients from within the slurry. They are also using digestate applied into cereals post stem extension using applicators manufactured and operated by Andre Capelle. All of these systems can significantly reduce the quantities of manufactured fertiliser.

7.4 National Nutrition Balance Sheet

Jan Eggink (Laren, Holland) was keen to tell me that Dutch farmers purchase nutrients equal in content to that found within their own manures and organic resources. They were even keener to point out that in the UK we purchase around five times what we have available within our own manures and resources; an indication of the inefficient way we use them. The figures may be slightly weighted due to the density of livestock in both countries, but it is still a worrying trend.

I am not suggesting we do without inorganic nitrogen; at least one third of the world's food supply would disappear if we did, just that we should efficiently use the resources that we have first! Their

comments got me thinking about what the actual figures are in the UK. The quantities of elemental fertiliser usage are as follows:

1,008,000 tonnes Nitrogen
224,000 tonnes of Phosphate (P_2O_5)
317,000 tonnes of Potash (K_2O) (AIC 2007/08)

These manufactured or mined fertilisers are collectively worth around 1.2 billion pounds with the estimated total organic wastes in the UK being at least 100 million tonnes. If all of the nutrition were used efficiently this would replace up to 1/2 of the purchased fertiliser within the UK amounting to a saving per farm in the UK of £2100-00. Farm infrastructure would probably not allow this to happen but it is certainly worth striving for.

7.5 Local Waste to Local Land

Local solutions will always work best. The environmental impact is reduced and the nutritional benefits are not spoiled by the high cost of transportation. In the UK we have been lucky enough to have the National Industrial Symbiosis Programme (NISP), started in 2002, which is a funded method of allowing businesses to add their waste streams to a database which is viewed by people who can recover, reprocess, and reuse those resources within their own businesses. The concept is that "waste is a resource that is in the wrong place". The free membership allows both big and small businesses to use the programme maximising its benefits to everyone. More than 10,000 businesses have registered to date across its 12 regions nationwide and are thought to be the only national scheme of its type in the world. I have certainly not heard or come across any similar schemes being operational on this scale elsewhere. For once we have developed a scheme that everyone should be proud of, and certainly it has had a significant effect on waste reduction already.

Opportunities exist for landowners with close proximity to waste producers. Disposal costs will be less as you will not need to transport the wastes for long distances and often the waste producers will pay for any permitting or transport that is required.

8. Renewable Energy - Anaerobic Digestion

8.1 Waste for Energy

The use of waste to generate energy from renewable sources is set to become more important as our energy demands increase and the sources of power generation decreases, and as a consequence more processed waste can ultimately be applied to land.

These processes can include burning, gasification, Landfill gas and Anaerobic Digestion (AD) where waste materials are converted into electricity from gas or into energy in the form of heat. The cleanup of the gas into a usable fuel or the use of the heat directly into a heating main can also be an option. An example of an engine is shown below which can run on gas and more importantly they have been running reliably around the globe for many years.

Gas engine running on Biogas generating electricity (Man Rollo)

Increases in landfill charges and the exclusion of unprocessed waste into landfill, points you in the direction of waste recovery and reuse as an alternative solution. All of these systems have their own benefits but the most holistic approach is AD where food waste or organic wastes are digested in an closed airless vessel which produces a 'biogas' which is a mixture of around 60% Methane and 40% Carbon Dioxide and some trace gases.

This gas can be cleaned up to produce road fuel, or eventually injected into the national grid or more commonly burnt to produce electricity and heat in a Combined Heat and Power unit (CHP). This is an acoustically enclosed compound where a gas fuelled engine powers an electrical generator feeding the electricity supply network and features a system to recover heat from the engine

In Uppsala, Sweden, it was interesting to watch the majority of buses running on Biogas, and having the system of linking up sewage treatment plants and Anaerobic Digesters to Gas Cleaning units which convert the Biogas to road fuel and then pump it back to the town treatment plants where it can be used to fuel the buses.

Not surprising when you consider the national support for renewable technology and the normal approach for district heating systems where domestic and industrial heat is generated in large efficient centralised boilers which removes the inefficiency of numerous small boilers. The key is to minimise your energy usage in the first place and so triple glazing has replaced double glazing and heat exchanger

technology ensures a minimum amount of energy is used by individual homes and businesses in the first place.

With AD the energy balance is critical as only around 40% of the energy can be converted into electricity while the remainder is mostly lost as heat, to truly maximise this technology a use for the heat will always make the projects more viable.

HOST AD, Holland, Plant showing Electrical Compound, Control Room, First Stage Digester and Digestate Storage

The gate fees (Payment received by the importer of waste calculated on a per tonne basis) that this type of waste attracts can produce some extremely short payback periods for AD plants. However, the reluctance of the banks to lend for periods more than the agreed waste contract periods can make borrowing quite difficult unless you can tie into a waste stream for a long period. This, coupled with the increased demand for the waste, will mean the gate fees will probably not last that long as we move towards the competitive German model where many wastes cost around £15-00 per tonne plus delivery.

A market for this waste generated gas is available. The UK Government's initial analysis suggests that the anaerobic digestion of some 100 million tonnes of material such as food waste, manure and slurry, and Sewage Sludge to produce biogas could contribute significantly in producing 10-20 Terawatt hours (TWh) (1 TWh = One million watts) of heat and power by 2020. This represents around 3.8 – 7.5% of the renewable energy that is estimated to be required.

This hardly surprises me as the technology and approach is only the same as has been operating in European and Scandinavian countries for many years. Scandinavians are pragmatic about the reasons why we are lagging behind in renewable technologies and energy efficiency. Bjorn Vinnerås and others say simply that their countries did not incur the enormous cost of rebuilding basic infrastructure after the Second World War and that the 20-30 years we are behind simply this.

AD should be considered as a reliable mature technology, gasification would not have this pedigree, and it is worth remembering that investment in these systems should be safer than some of the developmental alternatives that are currently being promoted.

8.2 The Benefits

In support of this environmental technology, a DEFRA report, "Anaerobic Digestion – Shared Goals", states that "Anaerobic Digestion has significant potential to contribute to the UK's climate change and wider environmental objectives……capturing the biogas from one tonne of food waste will save between 0.5 and 1 tonne of CO_2 equivalent", so this type of technology is accepted to have a positive environmental impact.

I personally believe that there has been an over estimation of food waste production in the UK. The figures have been based on the quantity an adult has produced in an urban environment and I suspect rural neighbourhoods will not be producing anything like these amounts. Even so it is still important that every available tonne is recycled. Essentially as the strap line of the Biocycle Conference 2009 in San Diego suggested "there is no longer 'away', in throw it away".

8.3 The UK Situation

Due to delayed investment renewable energy has been on the backburner in the UK. We are ahead of the USA but behind most of Europe.

AD has experienced a great deal of interest recently. In our energy market there is an obligation for energy suppliers to supply a minimum of 20% of their electricity from renewable sources by 2020. Over the next ten years one third of the country's electricity generation capacity will have to be replaced with the closing down of major gas, coal fired and nuclear power stations leading to an expected shortfall of 3000MW by 2017.

The Department for Energy and Climate Change (DECC) has set out a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050 (34% by 2020) to be achieved through action in the UK. AD can reduce businesses' GHG emissions by capturing methane and nitrous oxide emissions from the breakdown of organic materials. These gasses have a global warming potential that is 21 and 310 times respectively greater than carbon dioxide.

8.4 Public Perception

One of my Nuffield eureka moments came when in Germany and Holland I realised that the general public embrace digestate produced as a result of Anaerobic Digestion as a 'Biofertiliser' even if the AD plant is running on feedstock that they would not like to see applied to land, such as Abattoir Waste and Animal by Products. This means that the public either accept the pathogenic control that these AD plants achieve even without pasteurisation, or that they do not correlate the two. We hope it is the former and this highlights the huge potential route of organics back to land in the UK.

The holistic approach of AD inspires me with the landfill diverted waste, farm by-products, and energy crops being converted into electrical energy which prevents Green House Gas (GHG) emissions, produces a by-product of heat which can be used or sold, and produces digestate which is a balanced nutrient available fertiliser and can be applied in growing crops. This digestate fixes carbon into the soil and replenishes some organic matter.

Many of the renewable technologies have holes in their concept; wind turbines create holes in power generation that has to be plugged by standby diesel or gas fired generators. Gasification is a very untried technology; tidal and hydroelectric are both some way from being economical and others have alarming payback periods. Anaerobic digestion provides you with all these benefits and an income 24/7, reliable operation, breakdowns and servicing permitting. This technology also has a very good public image, as does renewable energy in general, as long as it does not impose on people's homes or immediate environment.

8.5 Digestate

The Environment Agency is supporting the use of AD as one of the ways of diverting biodegradable wastes from landfill, recovering value from them and reducing emissions of greenhouse gasses. They recognize that digestate produced from AD has improved fertilising properties and has less of an environmental impact than undigested manures and slurries.

Digestate is the hidden gem in the AD story. 10 tonnes of digestate can replace around:

0.25 tonnes of Ammonia Nitrate,

0.035 tonnes of Triple Super Phosphate,

0.10 tonnes Muriate of Potash,

Around 5 kg's of elemental Sulphur as well as 5kg's of Magnesium (important with Sulphur deficiency now relevant to nearly all of the UK) is also supplied.

With the fluctuating prices this could be worth over £300-00 (Jan 2010 figures). This will help margins affected by poor global commodity prices significantly. In Germany this digestate is often part of the negotiations when farmers supply feedstock's (maize, grass, slurry, etc) to run AD plants, with the returning crop nutrition potentially reducing input costs in their other enterprises.

My own use of digestate supports all of the above statements. It is a product with high availability of all its nutrients, which binds well to soil and organic matter, so minimising loss to the environment, and still

having a balanced analysis (high in Nitrogen and Potash) well suited to soils on the western side of the UK. It's almost too good to be true!

The reduction in odour that occurs also helps with the general public's aversion to smell. It is a product that lends itself well to be applied by dribble bar into a growing crop, but, an investment of £150,000 to £200,000 would need to be made to commission a self-propelled applicator to spread to 24 metres and run in existing tramlines. I would suggest this is not a viable exercise until the quantities of digestate increase within the UK and demand for this type of service increases, but umbilical application into the crop pre stem extension may well be an immediate solution.

The disadvantage of bulky slurry-like material is that it is difficult to apply into the growing crop due to the volume and weight needed to be tankered around. One of my focus areas after looking at AD plants in Germany and Holland is separation, reverse osmosis, and polymer use to condense nutrients into lower volumes allowing the application of less bulk which applies the same quantity of nutrition. This can be taken a stage further with drying and pelletisation. A product can be produced for application into the growing crop using existing twin disk spreader technology.

This area is a minefield and visits to businesses such as UTS Pumps in Lippetal, Germany has helped me to understand the particle flows, and separation by a whole host of mediums that enable the correct product to be produced from a specific waste. Their knowledge of wastewater treatment also helps with solutions to problems with digestate management.

8.6 The Future

The UK Government is supporting the establishment of on farm AD systems to help reduce greenhouse gas (GHG) emissions from agriculture nationally, to divert biodegradable wastes from landfill and improve local energy supplies.

Under the Energy Act 2008, from 1st April 2010, electricity feed-in tariff (an incentive to support the development of AD by paying a bonus on each kW of electricity produced) for small-scale low-carbon electricity generation will be activated, this will replace the existing Renewable Obligation Certificates (ROCS) system. This will further secure the long term future of renewable electricity. It will provide support for installations up to 5 megawatts – which will include most anaerobic digesters. Currently negotiations continue on this one but it looks likely that this will improve the viability over the current system. As I write this report it is expected the details, which are to announced on the 3rd February 2010, are to include banding on a per kW output basis to support smaller schemes which ultimately have greater greenhouse gas reduction potential.

From 1st April 2011, the Government will develop a renewable heat incentive. This will allow generators of renewable heat to claim financial support for that heat, again improving the financial returns in the long term. They will also layout the framework for gas cleaning and injection directly into the gas grid.

Localised generation of renewable electricity strengthens the national grid and reduces grid transition losses as only one substation is required to reduce the voltage to supply levels. Large power stations are often in remote areas; when this power is used within the grid they assume a 12% grid loss of power making local generation a much more efficient option. Nuclear will fall into this category but lengthy

construction times and the unpopularity of this type of generation all detract from them being set up. Local generation is now preferred reducing grid losses and supplying the immediate locality which also helps with energy security.

Large capital investment, planning constraints and public perception are some of the limitations to establishing an AD unit, but I believe that there is a secure future within AD in the UK. All of these areas are improving with time, plant costs seem to be falling, and planning may well be relaxed for on farm situations and public opinion is rallying.

Since completing my Nuffield Travels I have developed a business offering a one stop solution to the facilitation of Anaerobic Digestion. Uptake has been rapid and there has been a great deal of interest in this technology.

9. Smart Solutions

9.1 Good Application and Good Image

Frau Grasshorn's business (Agretec Grassorn, Hatten, Germany) has developed an application system where the spreader is loaded directly from the lorry and the application is carried out straight away. The waste application is completed and field cultivations are carried out immediately. Frau Grasshorn has worked out that the temporary field heaps alerted the public to something happening which they did not completely understand and so were concerned about. This type of planned application prevents the long term odour issues but does complicate the process and inevitably will result in a greater cost per tonne of biosolids applied.

I do like the approach, but biosolids contracts come up infrequently and although I do use them as a fertiliser source, I do not act as the contractor. It is my intention to tender for upcoming contracts promoting the improved image of the German style application process as well as the improved environmental impact. It will be interesting to see how water companies acknowledge the importance of what appears in their 'mission statements' as compared to accepting a higher tender on environmental grounds for biosolids applications.

9.2 REVAQ

REVAQ an assurance scheme for Biosolids treatment and Application is being adopted by water authorities in Sweden. It was started as a study to see if the assurance of Sewage sludge would help with the image of this material being applied to land.

They have found this has improved consumer confidence and more importantly food retailer confidence in waste applications. You can detect in Sweden that the public fully support farmers especially if the standards they work to are documented, enforced, and there contents widely known. In the UK we need this type of scheme as at present it is down to the standards of the individual operator, and quite frankly some of the standards are very low.

9.3 Anaerobic Digestion

AD does offer a real diversification opportunity for farmers, but they need to survive the high capital start up costs coupled with the low income during commissioning and familiarisation. Too many people seem blinkered by the potential returns and do not focus on the high technical competence that is required to run these plants. If you intend to run your own remember that bureaucratic support may well now be in place but the system is less than simple and a far cry from normal farm activities.

If you intend to build your own plant, beware the fragility of food waste and waste contracts. If you are going to use it include any uncertain feedstock's as a limited proportion of the diet. Also build flexibility into your plants so that in the event of a loss of feedstock you can shut down engines to match the output of the digestion process.

Anaerobic Digestion will be a huge user of waste and this will generate a large quantity of digestate (estimated to be in the region of up to 10 million tonnes if speculation for plants is reached). Many of the large plants processing food waste may well have limited land on which to apply this digestate. If you hear of one of these plants being constructed near you try to negotiate to receive this digestate.

AD schemes only truly make sense when there is a use for the heat, so think carefully before you conceive a project to ensure its location offers you the best feasibility.

Reverse osmosis, polymer treatments and pelletisation will provide solutions to digestate applications into the growing crop. Separation of the solid from the liquid will also remove a disproportionate amount of Phosphate held within the solid which if P indexes are high on your land may well be a way of exporting the Phosphate without losing the majority of Nitrogen and Potash.

If you intend to pursue AD on your own farm beware of the true meaning of the word "Turnkey" installation. No AD Plant supplier manufactures all of its own components so there is a significant amount of outsourcing, directly sourcing these components yourself can reduce costs although this comes with an increased project management load as these components need to be procured, connected and commissioned. A turnkey solution may be preferred by some installations but it does come at a price and often the ability to personalise the equipment within the plant is often not an option.

Cooperation with other businesses can provide many benefits for all parties involved. These benefits can include land to grow crops, receive digestate, and help with Nitrate Vulnerable Zone compliance (This legislation sets limits for Nitrogen applications and loadings to land). It can also provide feedstocks, electricity purchase agreements, heat uses and sales.

Collaboration is good but do not try to over complicate the process, simple is always best. German models of integration may not work here.

10. Conclusions

Waste

- Waste application onto land is an opportunity not a threat as long as it is applied and used with best practice in mind. We have sufficient land area and we should not be wasting finite mineral resources into landfill at all.
- A variety of equipment exists for all wastes to be applied in all situations, they are generally slurry or manure handling equipment that are fairly common on UK Farms. Cropping and timing will be the biggest restriction.
- Waste generators are often part of the problem as they can have inadequate or insufficient storage and seem unable to work with the farmer to minimise their disposal costs. Opportunities exist for ex dairy or livestock farms that still have slurry and manure infrastructure in place.
- The use of umbilical systems or low ground pressure equipment is essential to ensure minimal soil damage results from all applications. The nutritional benefit is quickly eroded away if lots of structural conditions have to be rectified.
- Waste contamination is not the problem it has been made out to be and can often be solved in the case of large physical contamination. Wastes pose no greater risks than livestock manures when applied to land. Cleaning up contaminated waste and using the nutrition is a safe reliable process. I have already secured grant funding on behalf of Patricks, my waste application specialists, to install a modified sewage treatment plant to separate contamination from septic tank, poultry shed washings and other liquid wastes to ensure their safe land application.
- Odour can be controlled by using a surface placed (dribble bar or trailing shoe), or a shallow injection method of application. Splash plate is obviously the worst culprit for producing odours.
- All waste that can be permitted is acceptable to apply to land. Usually you can receive these wastes at no cost with all the permitting completed and paid for by the exporting company.
- Untreated septic tank waste and poultry shed washings are acceptable for applying to land, they require no permitting and supply agricultural benefit to the land they are applied to.
- The permitting process will identify individual batches of waste that should not be applied to land. Zinc is an important heavy metal that affects the activity of soil microbes. High application

levels will have a detrimental effect on soils but the permitting process does prevent this happening.

- Biosecurity measures should always be put in place to prevent pathogenic issues - an extended withdrawal period can be the safest method. Injection of waste (or ploughing) coupled with a reasonable period without livestock is obviously the best scenario.
- Some products exist that cannot be permitted but could be applied to land, we must lobby the Environment Agency for their acceptance.
- It would be better if the Environment Agency approached waste utilisation with a "carrot" rather than "stick" approach.
- REVAQ style treatment and application assurance has improved the public image of waste applications in Sweden, food retailers also trust it, and we need this approach in the UK.
- Education and discussions with the public will remove nearly all their issues with the applications of waste.
- Wastes increase organic matter and therefore nutrient and water retention characteristics of the soil.
- Escalating landfill costs and permitted loadings are reducing wasted organic matter quantities.
- Many countries are relying on the nutrition within waste as a fertiliser replacement - we as a country need to catch up.
- Utilising all available organic wastes could provide £2100 worth of benefit to every farm in the UK, amounting in total to over 1 billion pounds.
- As a waste producer use NISP (National Industrial Symbiosis Programme) to improve the efficiency of waste utilisation. It is extremely good at connecting waste producers and waste users.
- Opportunities exist for people with local waste producers, think outside the box, and start negotiations now.
- Avoid the long term temporary storage heaps of Biosolids in agricultural fields as this escalates the concerns the public may have.
- Never deal with less than scrupulous waste disposal contractors, it is your reputation that will be affected.
- Approach a local food processing company or waste producer. You may be surprised that you can significantly reduce their disposal costs especially if you have a licensed local waste disposal firm that can transport and apply it for you.

- Have a tour of your local area to see if there are any waste products that you can receive the incentive of reducing the waste generators disposal costs and your fertiliser costs at the same time can be quite compelling when negotiating.

It is fair to say that human derived waste and other waste creates the same amount of public concern in all the countries that I have visited. If the public are fully informed about the processes that are in place we can overcome these issues.

I am personally intending to continue my proactive approach to informing the public and key stakeholders of all the implications and problems that may occur as part of the process. This can have two outcomes they will either accept that it is a low risk process and let things proceed or completely refuse for the application to take place, as Frau Grasshorn informed me "a made up mind cannot be changed" but at least an even worse situation can be avoided.

Anaerobic Digestion

- AD has huge potential for waste recycling back to land, even abattoir waste and fallen stock (legislation allowing), through the reliable nutrient source that digestate supplies.
- AD should be treated as an established reliable technology, as they do in Sweden and Denmark, rather than the innovative technology impression we get here.
- AD plants perform better financially if there is a use for all outputs including the heat. I have seen some diverse solutions including bedding recovery and district heating schemes being used to recover heat, consider all the options
- Turnkey operations may not be the best solution to building a plant.
- Do not rely on gate fees being around for any significant time, in Germany all waste will command a fee, from you, not to you!
- Our delay in starting our own AD industry is a knock on from rebuilding post war basic infrastructure not because the financial or technological model does not work.
- Food waste quantities are certainly over estimated don't use them as significant proportions of your feedstock diet. Waste contracts are notoriously fragile, don't use this as a basis for your plant design. Likewise, potential quantities of waste that could be applied to land are likely to be underestimated.

- AD is one of few farm diversification opportunities that operates on a 24/7 process and will help cashflows in any farm business, but don't be taken in by manufacturers claims of performance, take independent advice.
- 10 tonnes of Digestate could be worth over £300-00 at current nutrient prices. Can you afford not to use it within your system?
- Bureaucratic support of AD will ensure that it will soon be a common feature within the UK.
- The one disadvantage of digestate is its bulky nature, separation, reverse osmosis and polymer use coupled with drying and pelletising are all part of the solution to this problem.

AD may be one of the biggest potential growth areas in the UK today (as are all renewable technologies) but be warned it is not automatically viable on all farms or businesses, careful feasibility work needs to be done to assess its relevance and remember in countries such as Germany, Denmark, and Sweden many AD businesses have failed due to poor financial performance.

11. Itinerary - relevant to report

Holland - January 2009

Jan Eggink
Hauterweg 74, Laren, Netherlands

Henk Eggink
Slootsmid B.V., Zutphenseweg 31, NL-7245 NR LAREN, Netherlands

Andre Capelle
Brandsmaweg 13, 8308RT Nagele, Netherlands.

MAN Rollo BV, Koraalrood 17, 2718 SB Zoetermeer
December 16-17th 2009.

Germany - January 2009

Frau Monika Grashorn
Dingsteder Strasse 54, 26209 Hatten, Germany
(January 27th 2009

Biogas Nord
Michael Ogundare
Wernigshof 2-4, D-33719 Bielefeld, Germany

Kompostsysteme Nord GmbH
Holger Meyer
Industriepark 6, 27777Ganderkesee, Germany

UTS Pumps
Hubert Otto Herlitzius
Lippborger Strasse, 10a, D-59510 Lippetal, Germany
(January 20th 2009)

UTS
Simon Ford
Muhldorfer Strasse 25, D- 84419 Schwindegg, Germany

Envitec
Ferdinand Borsje
Boschstrasse 2, - 48369 Saerbeck

Denmark - January 2009

Aarhus University, Nordre Ringgade 1, DK-8000 Aarhus C, Denmark

USA - April 2009

Wes Selvidge
Buttonwillow Land and Cattle Co., 7540 Tracy Avenue, Buttonwillow, CA 93206-9742

Les Kuhlman
Resource Recovery Systems, 511 Pawnee Drive, Sterling, 8751-8661 Colorado

UC Davis
David Bartell, Onsite Power Systems Inc, 216 F Street No 3, Davis, CA 95616.

Biocycle International Conference
San Diego Town and Country Resort, 500 Hotel Circle North, San Diego, CA 92108
April 28-30th 2009

Sweden - September 2009

Bjorn Vinnerås
Swedish University of Agricultural Sciences, Department of Energy and Technology, Box 7032, SE-750 07, Uppsala, Sweden.

Uppsala Town, Sweden

Ireland/Northern Ireland - October 2009

SlurryKat
Garth Cairns
44 Lowtown Road, Waringstown, Craigavon, Co. Armagh, Northern Ireland, BT66 7SJ

Hillsborough College
Peter Frost
Agri-Food and Biosciences Institute
Greenmount Campus, Hillsborough College, Newforge Lane, Belfast, BT9 5FX.

U.K.Visits

International Fertiliser Society
P.O. Box 4, York, YO32 5YS, UK.

Severn Trent
Roundhill Sewage Treatment Works
Gibbet Lane, Kinver, South Staffs.
(April 8th 2009)

Greenfinch
Milton Parc,, Milton Ernest,, Bedfordshire, MK44 1YU
And
The Business Park, Coder Road, Ludlow, Shropshire, SY8 1XE

Andigestion,
Holsworthy Biogas Plant, Holsworthy, Devon, EX22 7HH

Freenergy
Lodge Farm, Commonwood, Holt, Wrexham, LL13 9TE