# Biosolids Reuse

# Investigative Tour

# June 2002

## France, England & Switzerland

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## Abbreviations

| | |
|---|---|
| STW | Sewage Treatment Works |
| EP | Equivalent People |
| SIAAP | Interdepartmental Sewerage Association for the Paris Region |
| BRC | British Retailers Consortium |
| SSM | Safe Sludge Matrix |
| DEFRA | Department for Environment, Food and Rural Affairs |
| EA | Environmental Agency |
| NVZ | Nitrate Vulnerable Zones |
| BSE | Bovine Spongiform Encephalitis |

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### Copyright



### Important disclaimer

# Executive summary

***(This executive summary has been submitted by Daryl Stevens, Jim Kelly, Cliff Liston and Darren Oemcke to the AWA Water Journal for publication)***

# Introduction

Biosolids use in Australian agriculture is currently developing at different rates (Figure 1). Regulatory and environmental pressures are directing treatment plants away from unsustainable practices (e.g. sea dumping and stockpiling) and towards the development of more beneficial and sustainable options. A study tour to England and France was designed to give people involved with biosolids in Australia an opportunity to experience, first hand, how biosolids are managed in these countries, ultimately improving our management of biosolids in Australia. The tour formed part of the communication strategy for the Australian National Biosolids Research Program. The program has the overall aim of developing a sound scientific approach to assessing and implementing realistic guidelines for agricultural use of biosolids, suitable for a wide range of Australian soils and environmental conditions (see http://www.awa.asn.au/NSIG/bio/index.asp).

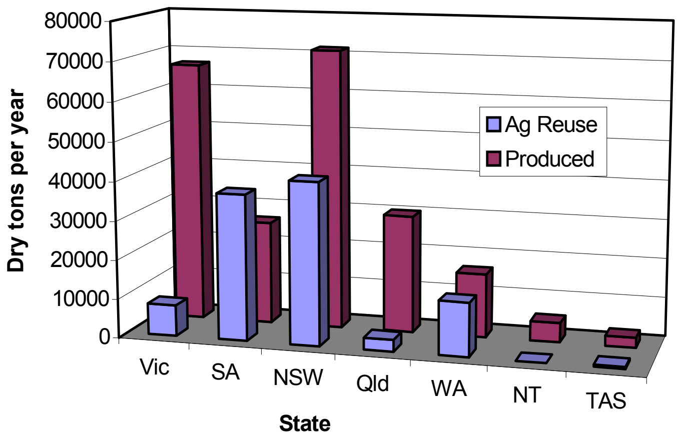


**Figure 1. Estimated biosolids production and use in Australian agriculture, on a state-by-state basis. Use greater than production is being achieved in SA due to the availability of a large stockpile of biosolids.**

The tour aimed to give participants an overview of the regulatory components of biosolids (sewage sludge) management in England and France, including the logic and science that currently underpins regulation and guidelines, as well as looking at possible changes to European regulations in the future. The tour group also looked at how these guidelines have been developed, how they are implemented, and how this has changed the technology for treatment of biosolids. A critical aspect that was also studied on the tour was the public perception of agricultural use of biosolids in relation to scientific assessments of risk.

During the tour we visited a broad range of processing sites, where we observed: sludge incineration; energy recovery; wet air oxidation; thermal hydrolysis; centrifuging and lime stabilisation; belt pressing; open composting; enclosed composting; and land application. We also visited research sites of Vivendi and Thames where we were presented with research on enhanced anaerobic digestion and thermal hydrolysis. What follows is a brief summary of the tour.

# Factors driving options for biosolids management

During the tour a broad range of factors were observed to influence the management of biosolids. These factors included political, environmental pressures, regulatory change, changing social attitudes, changing markets, changing economics, and developments in science.

## *Political*

The UK Government viewed agricultural use as the best practical environmental option in most circumstances, however, they also realised that this was not always possible or practical. Environmental groups and the general public tended to perceive agricultural use better, or more environmentally friendly, than incineration or landfill, and political views reflected this. In both countries agricultural application dominated residuals reuse.

## *Environmental*

Landfill, stockpiling, ocean dumping, land application and incineration have previously been considered acceptable routes for disposal of biosolids. All these routes are now under pressure due to environmental concerns and social change. For example, during the tour we saw examples where landfill has become increasingly expensive, stockpiling was no longer considered acceptable, sea dumping was not allowed and land application and incineration was more carefully regulated.

## *Regulations*

In all countries visited, guidelines relating to agricultural use of biosolids were continually being reassessed and regulations tightened. All the utilities visited expected a lot more discussion in the future on the application of biosolids, green-waste and other residuals to soils throughout Europe.

The current EU directive (86/278/EEC) relating to biosolids reuse on land regulates: banding and soil limits; withholding periods after use; sampling and analytical recording requirements; codes of practice for agricultural use of sewage sludge and waste management licensing regulation. In the future, metal concentrations will be revised (lower), additional metals added (e.g. chromium) pathogen control will be stricter and controls will be placed on adsorbable organohalogen (organochlorine) compounds (AOX), linear alkylbenzene sulphonates (LAS), Di-(2-ethyhexyl)phthalate (DEHP), nonylphenol ethoxylates (NPE), polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and dioxins (PCDD). As a result, technical details will change.

A dinner presentation by the UK's Department for Environment, Food and Rural Affairs highlighted several concerns for the future of biosolids. These included:

- metal limits may be over stringent;
- organic contaminants that need to be included in the guidelines need to be reassessed; and
- use of a prescriptive list of treatment processes was considered inappropriate as this will not cover new processes that evolve.

## *Social*

In both France and England there is growing concern in some sections of the community about the use of biosolids in agriculture. This is, in part, due to other non-biosolids related food scares involving bovine spongiform encephalitis (BSE) and salmonella.

Consequently, research work had focused on the sanitation side of biosolids use, primarily a result of the public's health concerns.

To address and overcome many of these health concerns, the UK developed the Safe Sludge Matrix (discussed further below), which seemed to be initially driven by consumer perceptions and limited scientific understanding. This has led to a conservative and precautionary approach to managing biosolids application to agricultural soil, but with a better scientific understanding. There appears to have been no scientifically established link between sewage sludge use and the occurrence of disease through food or water contamination, when current guidelines are followed.

### *Markets*

In both France and the UK, all the water authorities visited considered agricultural use to be an effective option for biosolids management. Pasteurisation or stabilisation with lime seemed to be the preferred processes, although biosolids composting was also popular.

In both France and England, farmers pay a nominal charge for biosolids. The water company's view is that if it is provided free of charge, the customer will perceive it as waste. All the water companies visited aimed to encourage recycling of this valuable resource and they recognized that repeat business required a quality service. Thames Water provides a one-stop shop for the farmer customer to encourage biosolids use and Vivendi operates long-term regional arrangements with growers. The value of biosolids is dependent on many factors, and the aim of the water authorities is to ensure biosolids use is a sustainable practice at the lowest overall cost.

After approximately 10 years of marketing and use, demand for biosolids is now stable, at approximately 60% agricultural use in both England and France. The biggest threat to the market for agricultural use of biosolids seems to be consumer perception (particularly Sainsburys Supermarket in the UK). We understand that limited structured research has been undertaken to assess the public's perception of biosolids use in agriculture.

### *Economics*

As the cost of landfill increases, the option of agricultural use becomes more attractive. Liquid sludge injection appeared cheaper at the sewage treatment plant end of the process, but transport and application costs are high. Such a practice was also higher risk than higher-grade biosolids. Incineration could be used to provide heat and power, with approximately 13-20% of the original solids requiring disposal or further development for beneficial markets. Some possible alternatives for disposal or use of the incineration ash are in cement or for use as road bases. In Switzerland (extra visit by one author) biosolids are used as fuel for cement kilns and provided energy savings and no waste (see below). Use in cement kilns may be the most economically viable alternative to agricultural use of biosolids, especially for those situations where highly contaminated biosolids are deemed inappropriate for agricultural use.

We also saw at Vivendi Water (France) some research assessing the economics of biosolids hydrolysis (discussed below) being extended to sludge minimisation in activated sludge processes.

### *Science*

In France, there is wide variability in the arrangements and the constraints involved with the agricultural use of biosolids. The industry is very conscious of the need to address environmental and consumer perception issues if they are to ensure the long-term

sustainability of agricultural use of biosolids. The French Government and Water Industry are putting considerable research efforts into this area. The French Government has allocated $1.6 million annually to agricultural research for biosolids use.

The English Government is supporting their preference of using biosolids agriculturally, with $2.1 million in government funding for research in the next 3 years. Research projects are focusing on risk assessment of pathogens, reducing contaminant levels in sewage sludge and pathways of heavy metals in sewage sludge and their effects. The overall aim is to ensure appropriate controls are put in place to protect the environment, human and animal health.

During the tour, we were given the impression that on-going research will be undertaken to monitor new chemicals of concern that could potentially be found in biosolids and determine their regulatory requirements.

# Options for biosolids management viewed on the tour

## *Incineration*

At Colombe, on the outskirts of Paris, primary sludge and thickened waste activated sludge is fed to centrifuges, achieving a dewatered sludge cake of approximately 30%TS (total solids). Some of this sludge is lime treated and used in agriculture, but the majority (approximately 90%) is fed to a fluidised sand bed incinerator. Ash from the incineration process is recycled in road engineering and cement production. Exhaust gases are extensively treated to comply with strict emission limits. Part of the energy produced in the incinerator is recycled in the combustion process to incinerate the sludge without necessitating additional fuel.

## *Energy Recovery*

Until 5 years ago sludge produced at the Beckton and Crossness treatment plants in the UK was anaerobically digested, dewatered and then dumped at sea, via barges. However, following a decision to abandon sea dumping, digesters at both plants were decommissioned and incinerators installed. Currently, raw sludge is mechanically dewatered prior to incineration, using filter presses at Beckton and centrifuges at Crossness. Dewatered sludge is typically in the range of 30 to 32%TS however, the centrifuges at Crossness produce a slightly thicker sludge (1 to 2%TS higher) and a more consistent product. Fluidised sand bed incinerators are used at both plants and natural gas provides supplementary fuel for combustion. Ash from the incinerators is disposed of in landfill however, the plant operators are in the process of seeking approval to recycle it in brick making and aggregate production. Exhaust gases are treated to remove particulates, dioxins and heavy metals while concentrations of carbon dioxide and sulfur dioxide were also reduced. Excess heat from the incineration process is used for on-site power generation, via turbines and the recovered energy provides approximately 50% of the power demand for the sewage treatment plant.

## *Wet Air Oxidation*

The tour visited a large pilot scale sludge treatment plant at Toulouse (south of France), using a wet air oxidation process called ATHOS. This plant has been in operation for about 1 year. The ATHOS process provides low-temp oxidation of raw sludge and involves the following stages:

- initial thickening of raw sludge to about 4%TS;

- preheating of thickened sludge to approximately 235°C and then addition, with oxygen, to a pressurised plug flow reactor (approx 50 bar) for 30 to 120 minutes;
- cooling of treated sludge and then dewatering; and
- treatment of flue gases before release to atmosphere.

Outputs from the process are:

- inert sludge that can easily be dewatered to about 55%TS (without the need for polyelectrolyte) and then disposed to a landfill or used in construction materials or civil works;
- exhaust gases that are simple to treat and as they contain mostly water, carbon dioxide and nitrogen; and
- a liquid that can be recycled to a treatment plant for further biological treatment.

The process can achieve 50 to 95% COD reduction, 10 to 20% nitrogen reduction and is largely self-sufficient from an energy point of view, with external fuel only required for preheating of the sludge on start up. Compared to incineration costs are similar, it is more compact, it offers simpler flue gas treatment and has lower energy requirements.

## *Thermal Hydrolysis*

A large-scale pilot thermal hydrolysis plant (CAMBI) was visited at Chertsey in the UK. This plant has been in operation for about 3 years and is being used to treat sludges from nearby wastewater plants. The CAMBI process essentially involves the oxidation of sludge under elevated temperatures (typically 160°C) and pressures (7 bar). Under these conditions pathogens are destroyed and cell structures in the sludge broken down, releasing energy rich compounds, which dissolve in water. Odorous gases are also produced and require treatment before release to the atmosphere.

Sludge from this process, when fed to an anaerobic digester, readily breaks down. This results in the destruction of high volatile solids (approx 65%) and significant biogas production (up to 50% more than from conventional anaerobic treatment). The CAMBI process offers several benefits, including:

- production of a Class A quality sludge for agricultural use (6 log pathogen reduction)
- production of a highly stabilised sludge with significantly increased biogas yields
- ability to treat difficult sludges
- final product easier to dewater
- enhances existing digester capacity
- easy integration with existing treatment plants

Thermal hydrolysis is being extended to sludge minimisation in activated sludge processes in research being undertaken at Vivendi Water in France. This developmental work involves applying the techniques of Wet Air Oxidation/Thermal Hydrolysis to sludge minimisation, rather than sludge treatment, to improve the cost effectiveness of sludge management programs.

## *Enhanced Anaerobic Digestion*

We also received a presentation on research being undertaken in the UK to investigate and develop enhanced anaerobic sludge digestion processes such as:

(a) Temperature Phased Anaerobic Digestion (TPAD) which involves a short duration (2 to 3 days) thermophilic digestion phase (55°C), followed by a long duration (about 10 days) mesophilic digestion stage (35°C). Benefits of this process are high volatile solids destruction (up to 65%), high bio-gas yields and high pathogen destruction (approximately 6 log).

b) Acid/Gas Phase Digestion which involves a short duration (2 to 3 days) medium temperature (32°C) digestion phase, conducive to the production of high concentrations of volatile acids, followed by a long duration (about 10 days) medium temperature (35°C) digestion phase, conducive to the formation of methane generating bacteria. Benefits of this process are high volatile solids destruction (up to 60%) and high biogas production. This process achieves pathogen destruction of approximately 2 log.

## *Composting*

Two composting facilities were visited, one at Dune (southern France) and the other at Little Marlow Waste Water Treatment Plant in the UK. The facility at Dune was an open-air facility, located in a rural area and involved use of static piles. Dewatered biosolids (15 to 25%TS) were blended with wood chips, green-waste or corn waste and aerated under positive pressure via ventilation pipes beneath the piles. The final product was sold for agricultural use in corn and sunflower crops.

The facility at Little Marlow is a static bay composting facility, contained within a building to reduce odour impacts on the nearby community. Wood chips are used as the bulking agent and carbon source. The final product is a bagged compost (also mixed with green-waste compost and coconut husks) which is marketed to the garden and landscaping industry. The product is seen to have a significant marketing advantage over its main competitors as it is peat-free and Safeway wants to be peat free in years to come. There is growing environmental concern in the UK in regards to the taking of peat, to produce composts, is damaging bird habitats.

It is worth noting that it is getting more difficult to obtain a composting licence within the UK, owing to concerns associated with odours and truck movements.

## *Disposal of Biosolids*

The tour found that ocean dumping of biosolids, once practiced in the UK, has been banned for environmental reasons. Although landfill is currently a cheaper option for disposal of biosolids, it is considered an unsustainable practice (Landfill Directive). Incineration is one alternative for disposal, if the 13-20% residual of the dry biosolids is amendable for use in cement or as a road base. In the UK and France, the development of this use seems to be in its infancy and most incineration residuals are still being transported to landfill. However, several cement-works in Switzerland were found to use biosolids as a part of their fuel source and silica input. Although there are difficulties in using biosolids in the kilning process, the benefits of the biosolids calorific value and silica content make their use economically attractive.

## *Agricultural Use of Biosolids*

The enthusiasm of the French public for recycling is reflected by approximately 60% of the biosolids produced by Vivendi Water being used in agriculture, with markets ranging from broad acre to intensive horticulture. One of the potential barriers for agricultural use of biosolids seems to be public perception of the risks involved with using biosolids (Table 1).

Similar enthusiasm for recycling is evident in the UK, where approximately 1.1 million tonnes dry solids of sewage sludge is produced in the UK annually: 0.6 million tonnes (55%) is recycled to agriculture; 0.17 million tonnes (15%) is used for land-fill and land reclamation; and 0.23 million tonnes (20%) incinerated.

**Table 1. Positives and negatives for using biosolids in European agriculture.**

| Positives | Negatives |
|---|---|
| Nutrients (N, P, S) | Heavy metals |
| Organic matter | Transport problem |
| Trace elements | Odour |
| Nutrient release characteristics | Soil compaction during application |
| Recycling a valuable resource | Timingof production and application<br>-liquid sludge injected<br>-stock pile of cake |
| | End user perception |

The limiting factor for agricultural use of biosolids, in both countries is the nitrogen concentration. Excessive concentrations potentially lead to contamination of groundwater.

In the UK a safe sludge matrix (SSM) was developed due to lack of regulation for pathogens, concern with the perceived risk and quantification of the actual risk (Table 2). The actual risk involved with growing crops with biosolids is considered very small but, after experiences with BSE and GM food scares, Sainsbury's (major UK supermarket chain) wanted to provide the public with the science to substantiate the safe use of biosolids in agriculture. Sainsbury's also wanted to provide the consumer with a process that everyone perceived as safe, before agreeing to use foods grown in soils where biosolids are applied. Sainsbury's have now accepted the content of the SSM and support the sale of produce grown in soils where biosolids are applied.

**Table 2. Safe Sludge Matrix (SSM) (Anon 2001).**

<table>
<tr><th>Crop Group</th><th>Untreated sludges</th><th colspan="2">Conventionally treated sludges (>99% path kill)</th><th colspan="2">Enhanced treated sludges (>99.9999% path kill)</th></tr>
<tr><td>Fruit</td><td>X</td><td>X</td><td></td><td></td><td rowspan="4">10 mth harvest interval applies</td></tr>
<tr><td>Salads</td><td>X</td><td>X</td><td>30mth harv.</td><td></td></tr>
<tr><td>Vegetables</td><td>X</td><td>X</td><td>12mth harv.</td><td></td></tr>
<tr><td>Horticulture</td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td>Combinable and animal feed crops</td><td>X</td><td>√</td><td></td><td></td><td></td></tr>
<tr><td>Grazed crops</td><td>X</td><td>X</td><td rowspan="2">3 weeks harv. and no graze</td><td></td><td rowspan="2">3 weeks harv. and no graze</td></tr>
<tr><td>Hay crops</td><td>X</td><td></td><td></td></tr>
</table>

Application of biosolids to land can be by:

### *a) Injection*
In the UK, liquid sludges are approximately 5-6% solid when injected into the soil. Crops grown using raw sludge are only industrial crops, like oil canola (glossy magazine production, glad wrap). Digested sludge is usually applied around 200m$^3$/ha to 260 m$^3$/ha on newly treated soil with an 18 month interval of application before growing food crops (e.g. oilseed rape this year and wheat in the following years). As application is year-round (when not too wet), tractors with tracks are used and heavy tanks of liquid sludge are not carried on the injection equipment. A 400m long hose connected to a stationary tank is used to pump biosolids to the injection equipment.

### *b) Aerial spread dried and/or wet biosolids*
Terra Ecosystems, the agriculture reuse company of Thames Water, has 2500 farmer customers, they treat 15,000 ha of land annually with 455,000m$^3$ of biosolids cake and 700,000 m$^3$ of liquid sludge (5-6% dry solid). Biosolids is usually applied 1 year in 4, at relatively high application rates. The type of sludge applied depends on the quality of the biosolids, soil, cartage, topography, etc. The major crops grown in the UK are industrial crops (oil seed), cereals and fodder.

Crops grown with biosolids in France are typically corn and sunflowers. Biosolids are not used on vines as the wine industry is very sensitive to the method of grape production (e.g. region, soil type, etc) and they believe the market would not look upon biosolids use favourably. However, it is acceptable to use biosolids as a pre-planting fertiliser for the establishment of a vineyard. Research is currently underway to address some of the wine consumer perceptions.

Both England and France have fairly densely populated agricultural areas where their biosolids are applied. Consequently, one of the biggest difficulties with agricultural use of biosolids is the odour released when in close proximity to housing, from stockpiling on individual farms and during application.

## *Biosolids as an Energy Source: Heat/ Power Generation and Methane Production*
Excess heat from the incineration of sludge can be used to produce steam for electricity generation. The two largest wastewater plants in London have recently been converted to perform this process.

Many treatment plants throughout the world anaerobically digest their sludge, producing methane to generate power via gas engines or turbines. The increased cost of power and increased interest in renewable energy sources is making this approach more attractive to water authorities. Furthermore, processes that improve the efficiency of digestion and provide higher biogas yields, such as CAMBI, TPAD and A/GPD, are also gaining interest.

## *The future for biosolids use in England and France*

From the people and places visited during the tour, it seems that biosolids management in the UK and France is under pressure from social perceptions, environmental responsibilities and regulators. At present, agricultural use of biosolids is the most popular option for biosolids management, yet the industry and regulators are continually refining these options. In some cases, agricultural use is impractical or impossible and other options will always be required, especially if contaminants entering the influent sewage stream cannot be decreased.

It is interesting that many of the same pressures exist in Australia, for example:

- Transport issues, such as noise and dust and a desire to minimise truck movements,
- Issues of business, regulator and public perceptions impacting on the business, and
- Regulations being constantly tightened requiring capital improvements and process innovation.

Clearly, there is a wide-range of options available for biosolids management and Australia will see significant technological changes in the future in this area. This is parallel to increasing land application to meet the requirements of regulators and society's desire to recycle, reduce and reuse residuals.

# Paris, France.

## *Paris Sewer Tour*

### History

Until the Middle Ages, the drinking water in Paris was taken from the River Seine. At the same time, wastewater was poured on the fields and unpaved streets and this eventually filtered back into the river. Around 1200 AD, Philippe Auguste had the Parisian streets paved and incorporated a drain for wastewater in their middle. In 1370 Hugues Aubriot, a Parisian provost, had a vaulted, stone-walled sewer built in the “Rue Montmartre”. This sewer collected the wastewater and took it to the “Menilmontant” brook. However, the wastewater was still drained in the open air. Under the reign of Louis XIV, a large ring sewer was built on the right bank and the Bievre River was used as a sewer for the left bank of the River Seine.

Under Napoleon I, the first Parisian vaulted sewer network was built (30 km long). It was only in the 1850 that Baron Haaussmann, Prefect for the River Seine, and Eugene Belgrand, an engineer, designed the present Parisian sewer and water supply networks. Therefore, more than a century ago, a double water supply network (drinking and sewer water) and a sewer network was built, the length of which was 600 km in 1978.

**Figure 2. Sewer tour of Paris. Old wooden pig that was used to clean sewers.**

From 1914 to 1977, more than 1000 km of new sewers where built. The Paris sewer system now has 2100 km of tunnels and houses, in addition to drinking and non drinking water mains, telecommunications cables, pneumatic tubes and more.

### Paris’s Sewer today

Everyday 1.2 million $m^3$ of wastewater is collected and 15,000 $m^3$ of solid waste removed and disposed of via the sewers of Paris. The capacity of the Acheres sewage treatment plant, which currently services much of Paris, is 2 million cubic meters/day.

## ***Dinner speaker***

*Pascal Bonne, Director of Technologies, Vivendi Water.*

### Background

The Interdepartmental Sewerage Association for the Paris Region (SIAAP) is the syndicate that manages the Paris sewage systems and water treatment facilities.

### Biosolids

Sixty percent of the biosolids produced by Vivendi are reused in agriculture, ranging from broad acre to intensive horticulture. Most of the biosolids can be applied at rates that do not exceed the guideline values. The biggest problem for biosolids reuse in agriculture is the perception of its use and the risks associated.

### Contact details


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## Toulouse, France.

### *ATHOS*

### Background

**Figure 3. ATHOS demonstration plant, Toulouse, France.**

At Toulouse, tour participants where shown a demonstration ATHOS plant which had been in operation for approximately one year. Vivendi were able to secure a large project in Germany by demonstrating that the AHTOS technology works at this plant. One of the significant advantages of the ATHOS process is the compact infrastructure (Figure 3). Vivendi always test their technology on a large scale, on home-turf first, making sure the technology works efficiently prior to installing it in other countries. Because of the preliminary work and the demonstrated abilities of their treatment plants, Vivendi have many other countries interested in the supply and manage of this new type of technology.

Generally, Vivendi develops contracts with third parties so the participating city is always owner of the asset. However, Vivendi retains operational management, to ensure the asset works efficiently and if any problems arise they can be fixed in-house.

### The treatment process

The ATHOS treatment process can destroy up to 60-70% of the sludge. The ATHOS process is now at the final stage of development with patent pending. The objective of ATHOS is to transform sludge into reusable by-products. The basic principle is oxidation of thickened sludge at a moderate temperature (~235$^o$C) while under applied pressure. The theory is to mineralize the organic matter at high temperature and pressure. The pressure needs to be 10 bars higher than atmospheric pressure in order to achieve oxidation/reduction. The organic part of the sludge is transformed to $CO_2$, oxygen and water. The mineral solids remain and require disposal. Sludge can be treated at 70-80% volatile solids. All PCBs (Polychorinated Biphenol) and hydrocarbons are destroyed in the process. The organic nitrogen (N) is converted to ammonia and nitrate. Phosphorus (P) is precipitated with calcium and all other metals are left in the sludge. A minimum of 5% dry solids is required for the ATHOS process.
The main advantages are:

- Process is flexible and compact (Figure 3)
- Solid residue is inert and reusable
- Simplified flue gas treatment and no nuisance emissions
- Liquid recyclable for use by treatment plant
- Small scale dewatering facility

### Contact details

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# SEDE Environment, Composting green waste and biosolids

## The composting process

Sludge is collected from 12 municipal wastewater plants around the region and composted at the location visited. This is a simple composting process and the plant receives about 12,000 –14,000 tons of sludge per year. Dry content of the sludge is between 12% and 25% solid when received. With sludge at 12% solids, the process uses one ton of sludge and one ton of additional product (ratio 1:3 volumes) for the composting process. Additional products sometimes added include wood chips (wooden pallets), green-waste and corn waste.

**Figure 4. SEDE composting piles**

Compost piles are placed on a bitumen base and are about 5m wide, 3m tall and 20m long (Figure 4 & Figure 6). The composting process takes approximately 3 months. The first month is an initial fermentation period, where the pile is aerated by pushing air through ventilation pipes beneath the pile (Figure 5). A relatively low density of the compost mix is maintained to allow the air to pass through the composting pile. Controlling the airflow through the pile regulates the fermentation temperature.

Polishing or maturation then takes another 2 months (minimum), prior to application or storage of the compost. As spreading of composts only occurs in spring and autumn, some storage is required. Storage is beneficial to the process as the stored polished product is used to inoculate the new fermentation stages.

## Managing odour

One of the major issues with a composting process is odour emission. Odour problems are worse during the initial blended step of the composting process. Odour has been found to travel a maximum of 1.5 km at this site.

**Figure 5. Air blowers used for regulating composting process**

SEDE are developing methods to minimize odours and the long-term aim is to reduce odour movement off-site, to nil.

Two types of treatment are used to stop the odours:

a) destroy sulfur and ammonia odours
b) mask the odour.

Odour control sprays are currently manually operated, but eventually they hope to mask odours automatically with wind-activated sprays, strategically placed on all sides of the composting plant.

## Use in agriculture

Crops grown with biosolids in France are typically corn and sunflowers. Biosolids are not used on vines as the wine industry is very sensitive to the method of grape production (e.g. region, soil type, etc) and they believe the market would not look upon biosolids use favourably. However, it is acceptable to use biosolids as a pre-planting fertiliser for the establishment of a vineyard. Research is currently underway to address some of the wine consumer perceptions.

The Ministry of Health controls biosolids application in France. Biosolids application has recently been classified as discharge of waste, rather than a fertilizer. Sludge was initially sold to farmers based on the benefits to production, but when its definition was changed to waste (with the change in legislation) farmers' felt they should be paid to take it. There is an increasing trend to compost biosolids, especially in regions where the metals are low and can be kept low by treatment of waste prior to entering the sewer.

Land has been identified for biosolids application where there is no aquifer that can potentially be polluted and/or there are no houses where odours may cause issues. Farmers need to be registered in the initial scheme, to be able to use it now and this requirement will remain for the foreseeable future.

The limit of discharge is 30 dry t/ha/year for ten years and the average is, at present, approximately 30 t/ha/3years. Farmers pay a symbolic €1 per a ton (AUD$1.65). The composting company monitors 7 heavy metals in the soil and the rate of biosolids application is always within the heavy metal limits specified by the EU. Often, this requirement is made even more stringent by the industry syndicate responsible for compost production. Specified heavy metal limits assumed there were none in soils, but soils were also analysed and the metal in the soil considered in calculation of the application rate of the biosolids.

If producers are growing vegetables, there is a mandatory 18 month period between the last biosolids application and the growing of crops. If the compost is applied at 40 t/ha, the nutritional values are approximately; 40 kg/ha of N; 200-300 kg/ha of available P; 150 kg K/ha; and 800 kg Ca/ha. A typical analysis of the final composted product was listed below (Table 3).

## Quality control

- All biosolids are analysed when delivered to the composting site. Heavy metals are monitored closely (Table 1) so biosolids high in metals can be identified and directed to more appropriate management strategies (i.e. incineration). 7 PCBs are monitored and are required to be < 0.03 ppm individually and the sum of them < 0.21 ppm.
- Pathogen levels are not monitored however, the processing temperature is > 70-80$^{o}$C for 2 weeks, which provides sufficient control.
- At the end of the composting process, a total analysis of the final product is always completed.
- Plastic rubbish, etc, from green-waste causes problems with aesthetics and the only way to stop this is to make sure they are prevented from entering the green-waste.

**Table 3. Typical analysis of composted material and regulatory limits for biosolids used in compost.**

| Parameter | Unit | Compost Concentration | Limits |
|---|---|---|---|
| Moisture | % | 50 | |
| pH | | 8.1 | |
| TKN | % | 3.28 | |
| Ammonium -N | % | 0.23 | |
| $P_2O_5$ | % | 2.82 | |
| $K_2O$ | % | 0.74 | |
| MgO | % | 0.56 | |
| CaO | % | 8.4 | |
| $Na_2O$ | % | 0.07 | |
| $SO_3$ | % | 1.09 | |
| Cr | mg/kg | 19 | 1000 |
| Cu | mg/kg | 159 | 1000 |
| Ni | mg/kg | 15 | 200 |
| Zn | mg/kg | 446 | 3000 |
| Cr+Cu+Ni+Zn | mg/kg | | 4000 |
| Cd | mg/kg | 1.3 | 15 |
| Pb | mg/kg | 100 | 800 |
| Hg | mg/kg | 0.8 | 10 |
| Se | mg/kg | | 100 |

## Ongoing monitoring of metals on farms

Documentation includes a provisional statement (intent) of the compost and levels to be applied to the farm, plus a statement of what was actually applied after the event. The ground is then analysed before use and on going analysis is completed as requested by the farmer. Additional fertilizers are added directly to the soil to balance crop nutritional requirements. The target for the compostor is not to sell a lot of compost, but to ensure a very good quality product.

## Processing costs

~€60 per ton as delivered.

## Contact details

Near Dune ~2 hrs from Toulouse.
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**Figure 6. SEDE composting piles and process (picture extract from SEDE brochure)**

**Participant's Comments**

The ATHOS wet oxidation process is a practical option as a plant of a size that makes it economical for 50,000 to 500,000 people – or if land application or agricultural use was not practical. Capital costs would be very high and unsuitable if the plant was close to residential properties. Biosolids use for agriculture is the most viable option for Australia.

The day was very useful as it stressed that the use of biosolids will not be easily resolved. There is no uniform answer and each case has to be analysed in regard to:

- Availability of land
- Buffer areas
- Community issues
- Capital & operating costs
- Overall plant lifecycle cost

Incineration is not likely to be practical in Australia due to cost and perceived environmental damage.

Environmental solutions need to be tailored to local conditions, i.e. 100% reuse may not be economically viable for large communities and dilution may be acceptable if the community accepts the environmental outcomes.

It was useful to see, first hand, that the same regulatory barriers and public perceptions apply with respect to biosolids application on land in France, as in Australia.

The odour will be with us for the rest of the trip!

# Achères

## Background

The Achères Sewage Treatment Works (STW) is a 10,000,000 equivalent people (EP) classical plant with activated sludge (Figure 7). The Paris sewers are combined sewers and storm water. In a heavy storm, twice the normal flow can occur through the plant, which is approximately 4,000,000 $m^3$/day. This extra flow previously by-passed the STW and was sent directly to the River Seine. However, a high-speed settling process has recently been installed to cope with the by-pass water (Actiflo).

**Figure 7. Classical component of the Achere STW.**

## The treatment process

The Actiflo process is a physicochemical process combining the benefits of weighted flocculation and lamella settling. It was installed immediately after the fine screening and degritting stage. Its compactness and quick start up makes Actiflo particularly well suited for storm water peaks, saving in combined sewer/storm water costs and infrastructure.

There are three stages in the process:

1. Coagulation, where ferric chloride is injected into the screen and grit removed.
2. Flocculation, where suspended solids and micro sand, both conditioned by the polyelectrolyte, attach themselves to each other following the induced collisions. The dense sand then ballasts the newly formed flocculate. The flocculate is then thickened and matured before entering the decantation stage.
3. Decantation, the flocculated water enters the counter-current lamella settler, the treated water is drawn off at the top of the lamellae via a system of collectors that ensure an equal distribution of flow. The sludge and micro-sand are precipitated at the bottom of the settler and collected by scrapers or hoppers prior to being pumped to the hydrocyclones. The hydrocyclones separate the sludge from the micro-sand, which is then recirculated back to the flocculation stage.

When the plant is fully operational it filters approximately 4,000,000 $m^3$/day (4 GL/day). 120 KL/day is the capacity of the DAFF plant at Bolivar, SA. The Actiflo plant can be up to 20 times better than many conventional clarifiers.

The Actiflo process removes more than 80% of the suspended solids levels with levels as low as 30 mg/L achieved. In addition, using ferric chloride as the coagulant effectively removes phosphate from effluent (Table 4).

The River Seine flows into Paris from this plant and the contribution of STW to the Seine's flow is probably around 10%. The Colombe plant (Page 29) was designed to alleviate the demand on this STW.

**Table 4. Selected water properties of effluent water before and after Actiflo treatment**

| | SS (mg/L) | Total P (mg/L) | DOC (mg/L) | BOD (mg/L) | TKN (mg/L) |
|---|---|---|---|---|---|
| Storm flow | | | | | |
| Inflow | 227 | 4.4 | 283 | 87 | 24.5 |
| Outflow | 20 | 0.4 | 63 | 9 | 19 |
| Normal flow | | | | | |
| Inflow | 42 | 3.5 | 112 | 28 | 29.5 |
| Outflow | 9 | 1.1 | 65 | 10 | 25.5 |

The Actiflo plant is fully enclosed with considerable attention been given to odour control (Figure 8) and cosmetics (architectural design). For example, the suburbs of Paris are within sight of the plant and residents approved the exterior design of the structure.

When there is no storm flow Actiflo is used for tertiary treatment of the classical treatment plant component of STW, so it is continually in use. During wet (rainy) conditions, the overflow from the rest of the plant is put through the Actiflo and then disposed of in the Seine. There is no tertiary treatment of the classical plant inflow during this period. As the Sewers house both storm and sewer water, when there is a greater flow to the plant water quality is increased. This is due to sewage was being diluted with a considerable amount of storm water. Phosphorus removal is probably increased during storm flow events as there is more P in the ionic form (Table 4).

**Figure 8. Odour scrubbers**

When fully installed, the final design will have 12 Archimedes screws, each capable of pumping 45 $m^3$/second into the Actiflo plant (Figure 9).

This plant was a “design, build and help operate” (DBHO) contract. The syndicate (SIAAP) negotiated directly with Vivendi as they were the only company with the technology appropriate for this project. As yet, there is no disinfection of the water yet however, this may change if there is a risk of disease identified. At present, a continuation of the natural process (final disinfection in the river) is encouraged in France.

## Water costing

Cost of water in Paris is 2.7 € /m$^3$ water (~ $4.50 AUD , 25% of this is taxes and of the remaining 75%, 65% is the cost of potable water and 35% is the cost of waste water). Everything is paid as part of the cost of potable water. Reclaimed water will be sold at approximately half the cost of potable water.

## Contact details

Paris's Major sewage plant
Jean-Marie Brun
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**Figure 9. Archimedes Screws for lifting water into the Actiflo treatment plants, Achères.**

**Participant's Comments**

The size of Achères WWTP and the amount of money spent on the plant and processes was astounding. It was interesting to see that they had two different pilot plants (from Vivendi and Lyonnaise) for the N removal at the plant.

Surprised that there was no N removal or effluent disinfection before it was discharged to the river. I was very surprised at the high cost of water compared to Australia. I was extremely surprised at the apparent lack of regulation on effluent quality levels within the plant operation.

Currently there are two Actiflo units either being built or have been built in Australia. One at Beenleigh in Queensland, which has been in operation for over 12 months, and the other currently being designed/built for the Wollongong STP.

Much better funded plants and more attention paid to aesthetics/architectural aspects of the buildings/structures.

# Paris.

## *Colombe Wastewater Treatment Plant (Seine Centre)*

### Background

Seine Centre is set in an urban environment, in the town of Colombe, in the western suburbs of Paris. This plant treats the wastewater discharged by a million inhabitants. The plant cost $350 million USD to build and employs the most modern technologies, both in terms of wastewater treatment and the treatment of sludge and flue gases.

The plant features a compact space saving design, with a total surface area of 3.5 ha, two thirds of its entire volume is underground. Given its urban setting and proximity to the River Seine, much effort was devoted to landscaping the site and integrating the plant into its surroundings.

### Statistics

Capacity 1,000,000 EP

- Dry weather flow rate
  240 ML/day (2.8 $m^3$/second). Discharge – BOD 25 mg/L, total N 10 mg/L, P 1 mg/L
- Wet weather flow rate
  730 ML/day (8.5 $m^3$/second). Discharge – BOD 30 mg/L, TKN 15 mg/L, TSS 30 mg/L
- Storm flow rate
  12 $m^3$/second over an 8 hour period.

### The treatment process

Wastewater treatment is conducted in various phases. The initial phase is pretreatment and is conducted in two steps.

1. Grit and grease removal; grit is recovered from the bottom while grease and oil are skimmed from the surface.
2. Primary lamella clarification; the lamellae allow for an increased settling surface thus speeding up the pretreatment process.

Following the initial stage, wastewater enters the biological treatment phase (i.e. BIOSTYR). The BIOSTYR process employs a floating granular medium to which bacteria become fixed. These micro-organisms assimilate and dissolve pollutants. The BIOSTYR process meets the most rigorous water purification standards in terms of nitrification, denitrification and carbonaceous pollution treatments. It is also twice as efficient as conventional processes, while greatly simplifying operating conditions.

The BIOSTYR process consists of up-flow filtration through a submerged and floating thin granular media called BIOSTYRENE. Air is injected into the base of the bed or the media itself. In the latter case, the filter can simultaneously nitrify and denitrify. It is capable of eliminating all biodegradable pollutants: carbon pollution (COD and BOD), suspended solids (SS), ammonia ($NH_4$) and nitrates ($NO_3$).

The bacteria, in the effluent to be treated, attach themselves to the BIOSTYRENE, which simultaneously acts as a filter. The pollution is broken down into cellular material that is retained in the filtering bed by physical means.

## Sludge treatment

Figure 10. Lime stabilized sludge disposal point.

The sludge is thickened and dewatered using centrifugation to increase its solids from 3.5 to 30%. The sludge by-product (60 to 350 t/day of dry matter or 270 to 1300 $m^3$/day of limed sludge - Figure 10) is discharged via barge (Figure 11) or truck to be reused in agricultural applications or incinerated in PYROFLUID incinerators.

PYROFLUID incinerators (Figure 12 & Figure 13) have biosolids injected into a fluidized bed of sand that ensures a maximum reduction in the volume of residual sludge. The fly ash from this process is recovered in a solid form, enabling it to be used for road engineering or as a mixture in the production of cement. Today in France, the reuse of fly ash is regulated by a 'Circular' (10 January 1996). Fly ash's metal contents must be below the limits set in this circular (Table 5). If the metals in the ash are higher than those specified in Table 5 then it must be stored in a category 1 or 2 dump.

**Figure 11. Barge for transportation of limed stabilized sludge for agricultural reuse**

Part of the energy produced in the incineration process is recycled in the combustion process to incinerate the sludge without necessitating additional fuel. Excess energy, in the form of heat, can be distributed for use outside the plant (for industrial equipment or housing applications) or even transformed into electricity to meet the plant's own energy needs (Not done here though). The simultaneous production of electricity and heat is a practical option for all large-scale wastewater sludge incineration units or whenever steam could be integrated into a pre-existing co-generation facility.

The combination of these processes ensures that sludge is always removed from the site. This is very important, as there is little-to-no room for sludge storage on the 3.5 ha site.

**Table 5. Maximum metal concentration allowed in fly ash when reused in roads or cement.**

| Metal | Maximum metal concentration (mg/kg) |
|---|---:|
| Mercury | 2 |
| Cadmium | 20 |
| Arsenic | 25 |
| Chromium | 600 |
| Lead | 3000 |
| Zinc | 5000 |

**Figure 12. Four Pyrofluids (Incinerators) at Seine Centre**


**Figure 13. Diagramatic representation of Pyrofluid (Biosolids Incinerator)**

## *Maisons-Laffitte Research Centre (Anjou Recherché)*

### Background

The Maisons-Laffitte Research Centre, created in 1983, is the group's main water operations research facility. The Centre develops practical management tools to prevent and control water resource pollution, as well as assist with decision-making for the efficient management of the entire water cycle. Anjou Recherché also develops innovative technologies for treating drinking water, as well as municipal and industrial wastes.

Vivendi's Central Analysis Laboratories are located at this site and carry out more than 500,000 tests annually. In collaboration with European laboratories, Anjou Recherché is developing new methods to meet consumers' increasingly stringent demands, in terms of human health and the environment.

### Research

All work undertaken at the research centre involves waste water, biosolids or water control. Their research is sometimes difficult, as the study often requires a continuous feed of the medium being trialed. The centre works mainly on secondary treatment processes and products and therefore needs to access water with some level of pretreatment. There are two pipelines entering the research centre, one used to obtain drinking water from the Seine River and the other sources influent from the sewer system.

Much of their work is on membrane technology and disinfection. Recently, their work in the area of disinfection for drinking and wastewater has been increasing rapidly. A lot of their research involves optimising energy recovery or minimise energy consumption of technology that already exists. Much of the work is in collaboration with the suppliers for both the water treatment system and the electrical power system.

A reasonable level of the work is conducted off-site, because the capacity of their pilot plants is larger than usual. They use large pilot plants as there is an increasing demand to operate them as normal commercial plants, ensuring successful operation when they finally go full-scale.

More recently, the centre has begun working on biosystems. For example, there may be a problem with the cost of the energy required for a full backwash, so they started to investigate biosystems and use alternative filter material that was very light. The total storage weight of the filter material is now much less and significantly less energy is required to backwash.

The centre is also addressing the need to maximize the removal of selected nutrients and pollutants. Research efforts are being put into nitrogen removal and now, increasingly, into carbon removal.

### New Research

A new study recently began looking at drinking water distribution systems. The distribution system is currently the main problem with potable water (from the tap). A study will be carried out, in the future, on the materials used for distribution of this water.

The main problem at present is lead. There were many trials conducted several years ago aimed at alleviating the lead problems, but the centre wishes to pursue this further and look at the impact of biosystems on lead. Biosystems could also remove some of the degradation products of plastics that are found in the drinking water system (originating from plastic pipes). Another developing area of research is wastewater for industry use. Several of their plants are working on the problems of cleaning membranes.

## Interaction of research with practice

To ensure the smooth transition of research to practice, they worked with Vivendi Water from project initiation and worked more collaboratively as the project progressed toward the first commissioning of a plant. For biosolids, the smallest pilot plant is 1000 EP, and the largest 50 000 EP. It is rare that a project that evolved from pilot to full scale, is not successful.

## Biosolids research

Lucie Patria is in charge of work focusing on characterisation of biosolids, their risk and quality assessment. Lucie's research focuses on anything dealing with agricultural supply and use and the restriction/reduction of biosolids loads.

Increasingly, the general public is becoming concerned with the use of biosolids in agriculture, due to basic food problems like BSE or salmonella. Consequently, they wish to know the composition of biosolids and whether or not they are safe to use on crops and land. Therefore, research work is becoming more focused on the sanitation side of biosolids reuse.

Another concern is related to micro pollutants (metals and organics). The French are operating with the knowledge that application of biosolids, or anything else, to soils throughout Europe will be thoroughly scrutinized in the future. At the same time they are keen to reduce the amount of material going to landfill. The current trend appears to be to pasteurise any organic waste including biosolids. There seems to be a lot of confusion and constraints involved with the reuse of biosolids. All questions need to be clarified to ensure the long-term sustainability of biosolids reuse practices. In France, agricultural reuse is considered to be one solution, using biosolids from pasteurisation and/or stabilized with lime.

Another research focus is on reducing the total amount of biosolids produced, using ATHOS or similar biological reduction techniques. The research is basically a global approach for risk assessment and minimisation. There are many studies currently running that deal with the transfer of micropollutants from soil to plants.

Lucie's group has also been taking samples from 60 STW to monitor micro pollutants and is working with the government to monitor known micropollutants of concern and test for possible future micropollutants. The idea is to characterise the situation now and determine where regulation might go in the future. The water industry has been proactive in considering these changes and time they have been developing analytical methods for some of the new chemicals of concern, as they don't currently exist.

A PhD student recently studied the transfer of trace metals to soils and crops. The student found no problem, at this stage, with the levels of metals in biosolids and the loading rates being applied to land in France.

## Wine production with biosolids

There is also a more global project where the end users are wine producers. Currently in France, the producers of wine want a good vintage and don't wish to try anything that may ruin the result. The research group is working on a project to demonstrate to the producers that green-waste compost, used in vineyards in France, will not be detrimental to the vintage. Initially, they would like to demonstrate that it is in the interest of the grape grower and winery to utilise green-waste (and perhaps biosolids in the future), because of the fertilizer and soil conditioning value. Secondly, they want to show that monitoring/regulation is strong enough to ensure no environmental or quality problems, particularly to the vintage or end-user.

Initially, the grape growers were extremely cautious, but now they are starting to see the benefits and their confidence in the compost (green-waste) has increased to the point that they are actively participating in the research. Some of the findings have shown that, in some cases, the compost has had a positive effect on the organic matter content of the soil. Studies with straight biosolids have not been undertaken and, as yet, no studies on the perception of biosolids use have been conducted.

The main focus of the study was on the impact of any type of compost to the soil and for different crops. At present, biosolids are only applied to vines prior to planting in France.

## Other research

There is also a research project on growing trees in biosolids amended soils and they are also looking at the impact of biosolids on the microflora and microfauna in these trials. So far they have found that trees grow faster with biosolids, however, so do the weeds and one of the outcomes of the research was to identify if the weeds became competitors for the tree.

Soon, there will be new research into sanitation and pasteurisation of biosolids to reduce odour. Manipulation of biosolids, whether for composting or spreading, releases odour which can be one of the biggest problems for biosolids reuse, especially in a densely populated country like France.

## Research summary

The centre has been working for a few years on sludge production reduction. By the end of the year they hope to have a process to sell and there are a few orders that may arise from the market in the next few years. However, they are still looking primarily at agricultural use, because it is more rational to close the nutrient cycle by returning it to agriculture, than to destroy the sludge. Agriculture is also a more cost efficient use. Currently, the funds allocated to agricultural research in France are approximately $1.6 million annually.

## Contact details

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**Participant's Comments**

The Biostyre process has the potential for application in Australia for sites with limited land or for retro-fitting in existing plants.

The fundamental treatment processes were the same, but the emerging technologies better. Trends and perceptions of biosolids use in agriculture in both countries appeared to be uncertain and perhaps even in decline.

Certainly in the case of Western Water, the size of this plant/design was not required. However, if the existing plant could be retro-fitted to the existing infrastructure for odour control, it may be economically viable in the long term.

The answers to biosolids' reuse in agriculture are still not encouraging. Incineration is still the accepted disposal technology.

The sludge drying process, to 30% solids was rare in industry to my knowledge.

My opinion is that Silviculture has a role to play in the industry, particularly in land rehabilitation of quarries and freeways as well as landscaping, however land application for agriculture seems more sensible. Public perception (acceptance, education) is the driver for success.

## Paris

## Traveling to London, UK.

Initial meeting with Thames Water.
Paul Lloyd
Client Relations Manager
Thames Water, London.

## After Dinner Speaker

### *Biosolids in the USA; Hamish Reid*

A summary of the overheads is listed below for your information.

#### Presentation outline

- Overview of CFR Part 503 rule
- Los Angeles biosolids management
- Management issues – water businesses
- Potential changes in contaminant management?
- Potential changes in pathogen management?

#### CFR 503 rule

- Self implementing legislation;
- Risk assessment limits for heavy metals, 'unrestricted grade limits and ceiling /loading limits;
- No limits for organic contaminants;
- Class A (pathogens) range of methods e.g. temp/time, PFRP, direct monitoring, pathogen criteria;
- Class B – basically digestion, PSRP $2*10^6$ faecal coliforms;
- Limitations on use depending on pathogen grades, agronomic application, EQ grades.

#### LA County Sanitation Districts

- Five STPs, 500,000 wet tonnes per year, dominated by one plant, meso-digestion;
- 65% land application (Class B), 25-30 US$/t; 3 contracted sites, 5-19,000 acres;
- 30% compost, 30-35 US$ t;
- 5% incineration (cement kiln), limited capacity for expansion and unreliable;
- 5% landfill to maintain option 20 US$ t;
- Future considered to be compost.

#### LACSD – contract management

- 'Transfer' risk to contractor at delivery to truck;
- One contract point to cover transport (80% of cost); application and farm management;
- Contracts for defined land area, agricultural requirements and inspection/audit program;
- 5-10 year contract with minimum quantity and rate, plus flexibility;
- LACSD 'burnt' with energy recovery.

## Hyperion Treatment Plant

- 800 wt/day – activated sludge, meso digest. centrifuge to 30% with polymer, Class B
- 3 land application contracts, 1 lost due to county ban (1 ban upcoming), 1 farmer 'bluffed' county with 'right to farm' (150 miles, $US23/t);
- Purchase of 5,000 acre farm for wheat, cattle;
- Future – upgrade to thermoph. digest., (public = amenity!!! (+ drying); composting, well injection;
- EMS was vehicle for public consultation.

## Synagro

- Sludge management with compost focus, range of products including bagged;
- Sludge + horse bedding in windrow 15-30 days, daily monitoring for PFRP;
- Difficulties with green-waste, odour from encroaching community, previous stockpile;
- Future – indoor facility, CAFOs
- Range of regulatory impositions

## Californian regulation of biosolids

- US EPA – 503 regulations, guidance documents and overview of annual reporting;
- State regulators – oversight??
- State and regional water quality control boards – surface and groundwater issues, establish guidelines (soil restrictions, buffers), permits;
- Local counties –influenced by local politics, can establish requirements, permits and ban;
- Community and commercial interests.

## Contaminant issues – US EPA

- Comfort with metal limits;
- Undertook Round II assessment and identified dioxins as being of concern;
- Still heading to 300 ppt TEQ as limit, based on HEI of home farmer;
- Focus has been on human health protection, may not hold for ecosystem effects e.g. LAS, nonyl-phenoyl.
- NAS undertaking review of 503 rule, expect implementation to be identified as issue.

## Pathogen issues – US EPA

- Updating prescribed test for pathogens, concern at lack of uniformity and QA;
- Comfort with protectiveness of Class B (anecdotal) and Class A (lack of pathogens);
- Concern at 503 allowing ND as Class A;
- Class A = 3 log virus reduction and 2 logs helmiths, difficulties with initial numbers and obtaining equivalency;
- Future development of water catchment 'risk assessments' and method reviews, NAS review.

# Thames Water Reading.

## *Paul Lloyd*

### Background

Thames Water has a turn over of ~US$2 billion annually. Approximately 2 million samples pass through its laboratory each year. They operate the largest biosolids incinerator in the world, located at Beckton and Crossness (suburbs of London; Page 49) the incinerator can treat up to 373,000 tonnes of dewatered sludge /yr. It recovers heat (13.5 Mw) during this process that is used to heat the STW.

**Figure 14. Thames Water, Reading.**

Thames Water spends approximately US$10 million on Research and Technology annually. The focus of R&T is to develop a global knowledge store, improve products and performance and meet industry requirements for the changing environment, regulations, etc.

They offer products and services, properties, consulting service, operation maintenance contracts anywhere in the world.

**Figure 15. Lectures at Thames Water, Reading.**

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## *Manocher Asaadi*

Biosolids Research and Development Projects Manager

### Background

Thames water has 33 Sewage Treatment Works (STW):

- 3 lime stabilising
- 28 anaerobic
- 1 thermal hydrolysis and digestion
- 1 composting plant

There are two sludge power generators, a more friendly term than incinerators.

In total 1100 tonnes dry solids /day (2000 – 2001) are produced. This was:

- 54% digestion cake
- 32% raw cake to incineration
- 7% digestion liquid

Approximately, £1.2 million (AUD$3.12 M) is spent annually on water, wastewater and sludge technology research. The main research and development focuses on STW – wastewater and biosolids, with a lot of work on biosolids digestion and dewater, monitoring/ assessment, etc.

### Research areas

They had a pilot plant for screenings (which had a 300-500ºC feed into a furnace), without air, to obtain a compostable gas, which could be used for energy production. Landfill would not take the screenings, so they are looking at alternative options.

Digestion processes are currently being evaluated:
Anaerobic digestion - 75% of total biosolids treatment
Conventional digestion - 40% destruction of volatile solids (DVS)
Enhanced digestion - 55-60% DVS

Biosolids pre-treatment is the preferred process. This could be thermal hydrolysis, mechanical hydrolysis or biological sludges e.g. thickening centrifuge, high powered ultrasound. A Biological Pretreatment using thermophilic anaerobic digestion could increase DVS by 35% in 2.5 days at 55ºC. An acid-gas phase digestion, which runs for 1-2.5 days at 32ºC (mesophilic temperature range), is also being tested at full scale.

A large proportion of the research is focused on meeting the requirements of the Safe Sludge Matrix (SSM, Page 46). Thames Water found no correlation with organic loading and E.coli removal in digestors. They are now looking at alternate methods for production of SSM compliant biosolids. For example, alternative methods include: chemical treatment (short term); pre-pastuerisation; and biological processes (medium to long-term). There is also a project investigating static bay composting and external projects investigating heavy metal removal by biological and chemical methods.

## *Eco Systems*

### Background

Eco Systems (the recycling arm of Thames Water) was formed in 1989, even though there was a history of biosolids reuse pre 1900's. Eco Systems employs staff with agricultural backgrounds, operates under the name 'Cingaro' (organic spelt backwards) and is 100% statutory compliant.

The reuse arm was developed and operated to help sell sludge independently. In all recycling areas Thames comes together to form Terra Eco. They specialise in talking the farmer's language and focus on providing solutions for biosolids reuse. The Terra Eco group talks with the public, pressure groups, wastewater customers, customers, agronomists, regulators, academics, end users (supermarkets) and landowners to ensure the smooth, open and acceptable operations of biosolids reuse in the UK.

### Spreading

Their aim is to develop long-term contracts for spreading/carting biosolids. These types of contracts are considered much better than short-term contracts as the operators are familiar with the process and have the correct equipment to do the job properly. Furthermore, the operator can invest in new equipment if they have long-term contracts.

Terra Eco has 2500 farmer customers and they treat 15,000 ha /annum with 455,000$m^3$ cake and 700,000 $m^3$ liquid. Biosolids are applied 1 year in 4 at relatively high application rates. The type of sludge applied depends on the quality of the biosolids, soil, cartage, topography, etc. For example, the quality of East London sludge was once lower than others as it was previously discharged to sea and there were no pressures on the STW to reduce metals. As a result of its high metals, incineration was then preferred to agricultural use.

The urban sprawl to the west of London is making it difficult to recycle to agricultural land because of the cartage factor. However, in the UK recycling to land is the preferred option wherever possible.

### Marketing biosolids for agriculture

Farmers pay a nominal charge for biosolids, the theory being that if provided free of charge, the client would think there are problems associated. Terra Eco's aim is to encourage recycling of this valuable resource. They recognise that repeat business requires quality service and have provided a one-stop-shop for the farmer customer. Terra Eco built long-term relationships with contractors and took a proactive approach with stakeholders by removing the aggravation from the use of biosolids, at the farmer and community level. The value of biosolids is dependent on many factors and their aim is to ensure it is a sustainable practice at lowest overall cost (Table 6).

One of the biggest problems with agricultural reuse of biosolids is the odour involved with stockpiling and application. The odour stops when stock piles crust over, but when spread starts there is significant odour release. Stockpiles on farms are usually 1000 $m^3$ and there are 2 to 3 per farm.

**Table 6. Positives and negatives of using biosolids in UK agriculture.**

| Positives | Negatives |
|---|---|
| Nutrients (N, P, S) | Heavy metals |
| Organic matter | Carting problem |
| Trace elements | Odour |
| Nutrient release characteristics | Soil structural damage during application |
| Recycling a value resource | Timing of production and application<br>-liquid sludge injected<br>-stock pile of cake |
| | End user perception |

## Regulations in EU(86) and UK(89)

The EU directive 86/278/EEC regulates:
- Banding and soil limits.
- Withholding periods after use.
- Sampling and analytical recording requirements.
- Code of Practice for Agricultural use of sewage sludge.
- New requirements in early 2003.
- Waste management licensing regulation.

In the future:
- Metals concentrations will be revised (decreasing), and additional metals added e.g. Chromium.
- Pathogen control will be stricter
- Organic controls will be placed on adsorbable organohalogen (organochlorine) compounds (AOX), linear alkylbenzene sulphonates (LAS), Di-(2-ethyhexyl)phthalate (DEHP), nonylphenol ethoxylates (NPE), polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and dioxins (PCDD); and technical details will change.
- Technical details will change.

Europe is starting to look at waste streams as a whole.

## General perceptions

Good:
- Friends of the Earth (an Environmental Group) perceive agricultural use of biosolids better, or more environmentally friendly, than incineration.
- Generally considered by public that agricultural use was a great thing.

Bad:
- There were thoughts that customers may have concerns about biosolids reuse in agriculture.
- Scotch Whiskey Distillers had concerns about biosolids being used in agriculture that produces its grain for fermentation as this may reflect poorly on the 'natural' 'clean' image of their final product.
- Demographics: Farmers that use biosolids are generally not the top producers. The better farmers have good returns ($) and don't want the problems (potential or otherwise) involved with biosolids use. Thus, farmers that use biosolids are concerned that consumers or wholesalers will not buy their product and will prefer produce grown without biosolids.

Codes of Good Agricultural Practice (GAP) were now being used across the UK. However, the water industry still believes it is wise to have alternative methods for biosolids disposal developed as a back up if agricultural reuse is stopped for some reason. The limit factor for agriculture reuse of biosolids, in the code of practice, is usually N (< 250 kg N/ ha/ year).

## Recent Issues

Some recent issues that have not been directly linked to the correct reuse of biosolids, but can influence the perceptions of its reuse in agriculture were:

- Salmonella
- BSE
- Food poisoning E.coli 0157
- Country Land Association concerned about a decrease in land value
- Organic farming cannot use biosolids
- Public perception

The Safe Sludge Matrix (SSM; Table 9) was designed to overcome the poor perception of biosolids reuse in agriculture for the end user. It is recognised that the science of the reuse studies are fine, but perception of biosolids reuse needs to be addressed. As a result of this, Advanced Treatment will be developed and utilised in the future. The SSM was produced by the British Retailers Consortium so a competitive advantage could not be gained by any one retailer - as they all agreed that biosolids are safe to use.

## *Managing the Northern area of London's Biosolids application*

Henry Grace

Henry's role is to ensure monitoring, sales and data management of biosolids application for the northern area of London is maintained and increased.

Biosolids reuse is monitored, managed and coordinated using an extensive database developed by Thames Water. The database system for supply and spreading is digitised on GIS with intensive field sampling (1 core/5ha). The major restriction at the moment is Nitrate Vulnerable Zones (NVZ; Figure 16).

To date (1998), 68 NVZ's have been defined in England and Wales, covering an area of approximately 600,000 ha. This is subject to reviews and the area is forecast to increase under each review. Farms that fall within the defined NVZ must:

- Keep accurate field records of their farming practices related to fertilizer use.
- Not exceed crop requirements when applying nitrogen fertilizers. Taking into account the soil supply of nitrogen from organic matter, crop residues, and organic manures.
- Adhere to application restrictions (Table 7)
- Adhere to spreading controls (Table 8)
- Ensure that adequate safe storage is available for slurry and storage facilities that conform to regulatory requirements.

**Figure 16. Location of Nitrate Vulnerable Zones in the UK. (Map taken from EA brochure).**

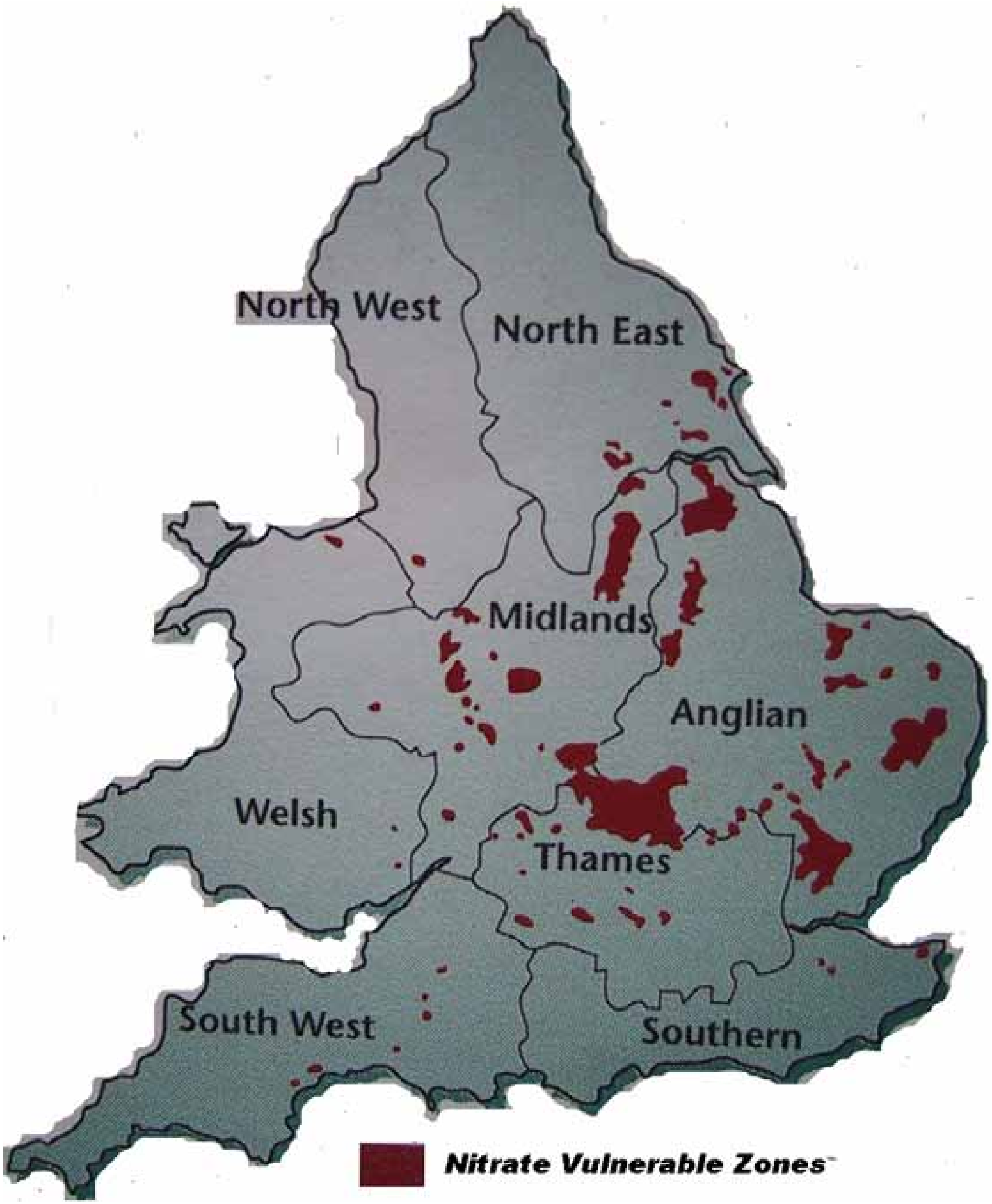

**Table 7. Nitrogen application restrictions for Nitrate Vulnerable Zones.**

Closed Period

| | Arable | Grassland |
|---|---|---|
| Manufactured N Fertiliser *(unless specific crop requirement)* | 1 Sept – 1 Feb | 15 Sept – 1 Feb |
| Organic Manures *(with high available N on sandy/shallow soils only)* | 1 Aug – 1 Nov | 1 Sept – 1 Nov *(includes land sown with autumn crops)* |

Nitrogen limits apply to any 12 month period

| Organic Manures | Arable | Grassland |
|---|---|---|
| Whole farm area within NVZ *(includes that directly deposited by grazing animals)* | 210 kg/ha total N *(170 kg /ha after 19 Dec 2002)* | 250 kg/ha total N |
| Individual Field within NVZ *(Does not include that directly deposited by grazing animals)* | 250 kg/ha total N | 250 kg/ha total N |

**Table 8. Spreading controls for nitrogen fertilizer application in Nitrate Vulnerable Zones.**

| | |
|---|---|
| 1 | Do not apply manufactured nitrogen fertilizer or organic manures when the soil is waterlogged, flooded, frozen hard or snow covered. |
| 2 | Do not apply organic manures within 10 m of watercourses |
| 3 | Do not apply manufactured nitrogen fertilizers in such a way they that enter into a watercourse. |
| 4 | Do not apply manufactured nitrogen fertilizer or organic manures to steeply sloping fields. |
| 5 | Spread manufactured nitrogen fertilizers and organic manures evenly and accurately. |

Spreading is very well planned - considering risks, potential problems, and farm distances to allow the workload to be distributed within the organisation. At end of the process farmers are given a letter outlining what was actually done on their property.

After the initial soils tests, a 10 year soil sampling protocol is used. By calculating the metal loading sampling requirements can be flagged for areas where metals are calculated to be approaching limits. Generally, the calculated soil metal concentrations after 10 years is greater than the total metal concentration analysed (presumably due to losses from leaching and plant uptake). The database is in-house and updated automatically as biosolids are applied to paddocks.

## *Dinner Speaker*

## *Alec Kyriakides*

Sainsbury's Supermarket Ltd.

Approximately four years ago, Sainsbury's became concerned about the use of untreated sludge application to land for food production. Initially, these concerns were perceived to be accurate as there was little research to provide the sound scientific base for the acceptability of the practice. At that time, pathogens in biosolids were not monitored or regulated.

Working with the British Retailers Consortium (BRC) the Safe Sludge Matrix (SSM) was developed. This is now being combined with Hazard safety assessments. SSM was developed because of the lack of regulation for pathogens, the quality of biosolids and a concern with the perceived risk (Table 9). The actual risk involved with growing crops with biosolids amended soils is very small. However, after BSE, GM food, foot and mouth etc. in Europe, Sainsbury's felt customer's perceived there was still a high risk. Sainsbury's now believe there is the science to substantiate safe biosolids use in agriculture and feel more comfortable with the practice. Involving the BRC meant that no organisation could gain a competitive advantage of biosolids grown crops, as they all agreed that it is safe.

**Table 9. The safe sludge matrix (Anon 2001).**

<table>
<tr><th>Crop Group</th><th>Untreated sludges</th><th colspan="2">Conventionally treated sludges (>99% path kill)</th><th colspan="2">Enhanced treated sludges (>99.9999% path kill)</th></tr>
<tr><td>Fruit</td><td>X</td><td>X</td><td></td><td>√</td><td rowspan="4">10 mth harvest interval applies</td></tr>
<tr><td>Salads</td><td>X</td><td>X</td><td>30mth harv.</td><td>√</td></tr>
<tr><td>Vegetables</td><td>X</td><td>X</td><td>12mth harv.</td><td>√</td></tr>
<tr><td>Horticulture</td><td>X</td><td>X</td><td></td><td>√</td></tr>
<tr><td>Combinable and animal feed crops</td><td>X</td><td>√</td><td></td><td>√</td><td></td></tr>
<tr><td>Grazed crops</td><td>X</td><td>X</td><td rowspan="2">3 weeks harv. and no graze</td><td>√</td><td rowspan="2">3 weeks harv. and no graze</td></tr>
<tr><td>Hay crops</td><td>X</td><td>√</td><td>√</td></tr>
</table>

Interestingly, consumers have no problems with animal manures or other waste used in agriculture that could potentially be a higher risk. The biggest risks are generally across-species transfer of pathogens, not within-species. However, we are trained from childhood that our excrement is 'bad' and we must wash our hands after going to the toilet for our health. The reality is that it is for the health of others, so you don't spread your germs to others through touching food, etc. The risk of infection from your own excrement is very low (pers. comm. Vaughan, 2002).

Alec suggested that it is difficult to survey the perceived risk, as doing so can sway or bias the results by promoting the perception. Sainsbury's now operates on the market theory of supplying the customer with 'what they want', not convincing them of 'why they want it' and then selling it to them. Thus, if the customer perceives that food grown with biosolids is bad and won't buy it, then the bottom line is that Sainsbury's will not sell it.

Sainsbury's felt they needed to be proactive so they could answers if and when consumers/industry asked, with an estimate of the actual and relative risk. Generally, acceptable risk is 1-in-a-million but, the calculation of risk is complicated and varies considerably depending on the starting point and pathogen considered. Risks are currently being quantified by Thames Water in respect to biosolids and animal manure reuse in agriculture. Sainsbury's are comfortable with chemistry regulation, but pathogens and other emerging issues are a concern (e.g. organic pollutants).

Even though a lot of research has been undertaken and the risk is understood to be low, Sainsbury's still believe the public (consumer) will have concerns in the future regarding biosolids use in agriculture. This will be largely due to perceived risk promoted by pressure groups. Key pressure groups are not community or Green Peace, rather, it is the media pushing their cause through Sainsbury's. The disappointing thing is that pressure groups often don't represent the majority view of the community and/or scientific knowledge.

The difference between the US and the UK, seems to be that if the regulatory and appropriate government bodies (e.g. USDA) give approval, the community believes and trusts that the food produced is safe.

At present in the UK, biosolids are not accepted for use in organic farming. There seems to be no data to support this other than the perception and concern of the industry.

Other people working with Alec are:
Alison Austin, Senior Manager, Alison.Austin@sainsbury.co.uk, +44 20 7695 7585
Brian.Chambers@ADAS.co.uk has also completed much work on this recently (ref-Alison)

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**Participant's Comments**

Long distance haulage makes land disposal less attractive for metropolitan water companies. We do however, need similar systems and land disposal methodologies adopted in Australia.

Three issues: - Incineration, *Yes*, if a license could be obtained
- Anaerobic digestion is already used
- Advanced treatment – *this i*s the energy of the future

To incinerate, environmental issues need to be overcome. Cake and liquid – increasing range of issues; regulations, food crops used on, perception and social values – all will need to be addressed.

They are spending much more on R&D than we are. Their record keeping systems on biosolids applications are more extensive than ours – although Thames Water are wholly managing and approving the process – unlike the system in South Australia. The risk assessment on biosolids reuse would be useful to see. Seems like their concerns are much more with pathogen control, unlike SA where it seems to be much more directed towards heavy metal loadings.

Everything that I experience today was of genuine interest. Consultation with advisors with regard to safe sludge applications and regulatory 'direction' could be modified to meet lowest scale requirements

We are still obviously learning about the management of biosolids processes. I found the discussion stimulating and certainly opened our minds for further discussions with the SA and Victorian regulators.

This session was the most informative to date

The future looks to be highly controlled by European regulators. A high number of organics will be regulated and this may make biosolids reuse in agriculture unattractive.

Australia is still putting policies in place for biosolids reuse and QA procedures. Therefore all of the information collected today will be used.

# England.

## *Beckton Sewage Incineration Plant*

Mark Edges and Grant Lewis.

### Background

The driver for incineration at Becton was that carting the biosolids out to agricultural reuse would cause too much of a 'stink' (odour problem) and they are in a very populated area in London. By incineration they decrease the volume of sludge to 20% of that originally going into the plant. They can then truck this to land fill without odour or pathogen concerns from the public.

**Figure 17. Becton Sewage Incineration Plant, London.**

Although incineration is used for the generation power, the process is still costing large sums of money and only producing about one-third the energy requirements for the whole STW.

The sludge from the sewage treatment works is transferred into reception tanks at the start of the process. The process can be split into 4 or 5 main sections. There is a dewatering section, where sludge is dewatered to the correct dry solids content so it can be burnt. Then there is the incineration section, followed by the heat exchange process, where water is converted to steam for power generation. The rest of the plant is pre-gas cleaning.

### The process

Inputs into the plant are:

- Natural gas for warming up the streams;
- Various chemicals for pre-gas cleanup and boilers treatment; and
- Sludge.

Outputs from the plant are:

- Electricity;
- Anything that goes into the atmosphere;
- Emissions to land which are the ash produced by maintenance from the plant and the residual from the incineration process (i.e. flyash); and
- Emissions to water are all the filtrates, not only from the dewatering process but also the scrubbers later in the process. These are all sent back to the STW. There are limits set regarding the level of contaminants they can discharge into the river. Fortunately they do not have to be concerned about these limits in the incineration process, as all water is sent back to the STW, where by dilution any contaminant problems from the filtrates are minor compared to STW inflow.

### Dewatering

Sludge coming into the incineration process is about 4% dry solids, a polyelectrolyte solution is added to sludge before being fed into the press and the 'cake' produced by the plate filter press is 30 – 32% dry solids.

There is an incinerator at Crossness (south of the Thames) that takes approximately 3,500 $m^3$/day. Crossness has a PE of ~1.5 million and Becton the north side of the Thames, has a PE of ~ 6.7 million. They can take 10,000 $m^3$/day of biosolids at Becton.

**Figure 18. Plate filter press for dewatering biosolids prior to incineration.**

Crossness has centrifuges for dewatering and Becton has plate presses (Figure 18). They are currently comparing the efficiencies of the two dewatering systems. Initial data suggests the centrifuges are proving more cost effective and efficient (1 or 2 % above the plate presses). The consistency and physical properties of the biosolids from the centrifuges also appear to be above that of the presses.

## Incineration

The incineration process has one common biosolids dewatering process and then divides into three identical process streams. Each stream has air travel through the entire system. This is accomplished by 2 fans, one at the beginning and one at the end of the process. These fans push and such through all vessels, respectively. Therefore throughout the entire process there was a slight vacuum. Not only does this supply the oxygen for combustion, but also the air to fluidise the sand bed of the incinerators.

When the fluidised bed of the incinerator settles there is about 2m of sand. The fluidising air, once preheated, is injected via the bottom of the incinerator. It comes up through a small mushroom cap into the base of the incinerator, fluidising the bed of sand. The fluidised bed of sand is very turbulent and breaks up the sludge cakes, making the incineration process much more efficient and keeps emissions low.

The sludge cake is fed into the side of the vessel, about 5.5 m up from the base. There are also natural gas burners which preheat parts of the process and supplementary fuel is available if required. Various methods are used to maximize the inlet air temperature before it is injected into the bottom of the incinerator. It can be heated up to 400ºC by using pre-heaters such as:

- Waste stream from the turbines
- Heat from the boilers

The air temperature as it leaves the incinerator was ~920$^{o}$C.

Potable water is demineralised for use in the boilers to prevent scale build up, which is difficult to clean and has the potential to destroy turbine blades. Boilers are decommissioned once a year in each process stream to allow a thorough testing of all the tubes and fittings to be conducted. To date no degradation has been shown at all in the tubes. It is anticipated that a plant such as the one viewed will last ~25 years. The Becton plant has been operating for 5 years.

Because the plant is burning a sludge rather than industry waste, with plastics in it, deposits in the burners are minimal. When the annual shut down occurs, they find the inside of the incinerator tubes are essentially like new.

The rate-limiting step for the process is the dewatering of sludge.

Although it seems difficult to give comparison of energy efficiencies, at Crossness they export about half of the electricity produced (i.e. ~4.5 MW was produced and about 2.5 Mw was exported). The capacity of the Becton Turbine is about 11.4Mw and it produces about 6Mw with a 50% parasitic load.

A lot of gas is used for the start-up and also the shut-down phase, this is essential when a high heat process is initiated or stopped. The rate at which the incinerator heats up and cools down must be well controlled to help protect the brickwork from cracking, etc.

### Why incinerate?

Incineration is the best option in this area due to the need to reduce the number of trucks carrying sludge through the streets of London; which has proven very unpopular in the past. The reduction in volume and the odour is the key consideration in this situation. Now, only one truck per day leaves Becton instead of five.

### Pre-gas cleaning

Two thirds of the incineration stream is pre-gas cleaning. All of the ash from this is flyash. The bulk of it is taken out by a cyclone and all ash from the process is stored in silos at the end of the building, before being removed and utilised as landfill. There have been attempts to develop contracts where flyash can be used in aggregates or brick manufacture, however, because of the relatively low amounts, no one has been interested thus far.

Part of the gas cleaning process uses a circulated fluidised bed, to remove heavy metals and any dioxins that might be produced as part of the incineration process. Dioxins are the key area of concern at present. Their public profile was raised recently when they were burning the cattle killed due to the foot and mouth crisis, the burning released dioxins. However, at the incinerators, organics alone are being burnt at very high temperatures, without any plastics and it is unlikely that any dioxins will be released in the incineration process.

The next phase of the pre-gas cleaning is a long (5m) sock filter where the deposits are collected on the outside of the sock and the clean air escapes through the centre section. Every now and again there is a big blast of air that knocks the particles to the bottom filter and they are carried away with the ash. Socks last about 5 years.

## *Chertsey Sewage Treatment Works: CAMBI Thermal Hydrolysis*

### Background

Sludge hydrolysis processes can be effective with difficult to digest sludges (e.g. Dairy waste which is high in fats). Biosolids are dewatered with polymer addition and the sludge feed into the CAMBI process (Figure 19). Scrubbing of volatiles is the most difficult part of the process, the hydrolysed sludge is sent to a digester for methane

production. At other sites methane is used to generate electricity. This is not done here, but usually enough power can be generated to power the whole STW.

## CAMBI Thermal Hydrolysis

**Figure 19. CAMBI thermal hydrolysis plant, Chertsey.**

The CAMBI process uses heat and pressure to destroy the cellular and intracellular structures in waste activated sludges.

Key benefits of the CAMBI process:
- Increases the hydraulic loading rate to the anaerobic digester from 2-4% to 10-12%;
- Destroys pathogenic organisms to produce Grade A stabilised solids;
- Increases C.O.D. destruction in the anaerobic digester from 45-50% to 60%;
- Increases digester capacity;
- Reduces sludge volume by 50%;
- Increases gas yields for renewable energy generation if required;
- Increases cake solids from 12-14% to 30-35% using existing equipment;
- Positive energy balance; and
- Eliminates foaming.

Processes:
- Solids are dewatered to 10-15%;
- Solids are mixed with the return steam from the reactor and flash tank;
- Solids are heated by direct steam addition to 170ºc and 120 psi for 20 minutes;
- Class A time v. temp;
- Organic compounds are solubilised;
- Pressure reactor reduced to 60 psi;
- Steam returned to pulper;
- Reactor pressure rapidly released, flashing solids to the flash tank;
- Flashing causes cells to rupture;
- Steam returned to pulper; and
- Hydrolysed solids have reduced viscosity.

**Figure 20. Sludge delivery to CAMBI process STW**

## *Dinner Speaker*

## *DEFRA (Department of Environment, Food and Rural Affairs)*

## *Judith Harris*

### Background

Approximately 1.1 million tonnes dry solids of sewage sludge are produced in the UK annually:

- 0.6 million tonnes 55% recycled to agriculture
- 0.17 million tonnes15% to land fill and land reclamation
- 0.23 million tonnes 20% incinerated

Sewage sludge use was a small portion of organic waste reuse in the UK (Figure 21).

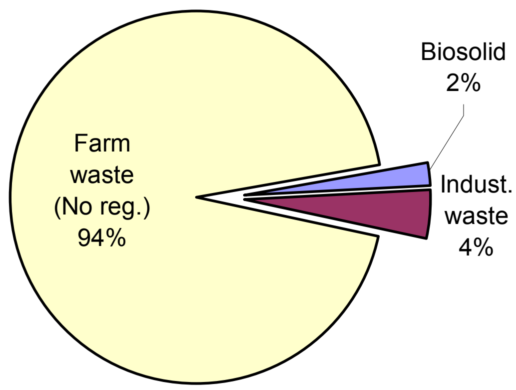


**Figure 21. Summary of organic waste spread on UK agricultural land.**

#### Alternative to agricultural reuse

Alternatives to recycling to agriculture are:

- Incineration, which is not popular with the public or politicians and is relatively expensive.
- Landfill, which is a cheaper option at present, but is not sustainable as defined by the landfill directive.

It is the Government's view that recycling to agricultural land is the best practical environmental option in most circumstances. They are supporting this view with £700,000 for research in next 3 years. Research projects are focusing on:

- Risk assessment of pathogens
- Scope for reducing contaminant levels in sewage sludge
- Pathways of heavy metals in sewage sludge and their effects

They also aim to ensure appropriate controls are in place to protect the environment and human and animal health.

### Controls for biosolids reuse

Current controls are the EU Directive 86/278/EEC on the protection of the environment, in particular soil, when sewage sludge is used on agriculture. There is also a code of practice for sewage sludge (Use in Agriculture) and Regulations from 1989 and 1991. With these regulations there are:

- Mandatory limits for heavy metals;
- Restrictions on the post application use of soil (to protect against transfer of pathogens)
- Sampling, testing and record keeping requirements

Recent developments (1998) include; a government commissioned independent review of scientific evidence, recommendations on sewage treatment and disposal from the House of Commons Select Committee on the Environment and the "Safe Sludge Matrix" developed by water companies and retailers. The Government undertook to reflect these

new voluntary standards in revised regulations and code of practice. The SSM was initially a question of perception and regulation and now they are moving towards statutory status.

## The Safe Sludge Matrix

The Safe Sludge Matrix (SSM) put new controls on sludge reuse in agriculture with the aim of reducing the potential for pathogen transfer in sewage sludge used on agricultural land to produce. This was an organic document where the steering committees looked at paddock→ harvest→ plate risks. The SSM was driven by perceptions and not science, so it was a very conservative precautionary approach. There has been no evidence of a link between application of sewage sludge and occurrence of disease through food or water contamination.

The Safe Sludge Matrix required:

- A ban on surface application of treated sludge to grazed grassland - end 1998
- A ban on the use of untreated sludge on land used to grow food crops - end 1999
- More stringent harvesting and cropping requirements
- Two levels of sludge treatment (Table 9)
- Use of in-system monitoring and end product standards
- Continued need to demonstrate the safeguards applied are proportionate to the potential risk to human and animal health.

## Future steps for regulation of biosolids reuse.

- Consultation on draft regulations.
- Revision of Code of Practice
- Extra costs to water companies allowed for in price determinations for 2000 – 2005
- Proposals to revise Directive 86/278/EEC
- Updating of Directive and commitment to recycling to agricultural land

The main concerns are:

- Soil metal limits are over stringent
- Which organic should be included in contaminant in guidelines
- Use of a prescriptive list of treatment processes as they will not cover new processes that evolve, which will require assessment of the end product.

## Summary

The UK Government supported sludge application to agriculture as the best practice environmental option. They also recognised the importance of up-to-date controls for maintaining confidence in this route. The government was not the only player and the existence of the "Safe Sludge Matrix" was evidence of the importance of a joint approach.

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## *Environment Agency*

### Paul Bryson

Paul is the Sewage Sludge Policy advisor for the Environment Agency (comparable to EPA equivalent). The sludge regulation process is closely linked to national policy development and is governed by sludge use in agriculture regulations from EU Sludge Directive and waste management license regulations. Sewage sludge only becomes waste management if not used for agriculture as supported by the codes of practices.

The current role of the agency is to:

- Audit Agricultural sludge
- Water company record
- Spot check register
- Random inspection of spreading

This role is critical for providing independent assurance.

The National Environment Program (NEP) determines what goes into environmental improvement. Recently, the EU Urban Waste Water Treatment Directive has resulted in more sludge (from better treatment and more people) and fewer disposal routes. These pressures are an ongoing cost to the treatment of sewage.

Future Role of Agency:

- Continue to ensure compliances
- Audit annual reporting
- Implementation of reuse regulations by end of 2002

New Pressures

- New nitrate directives. NVZ (nitrate vulnerable zones)
- Increased controls on the use of organic and inorganic fertilizers
- Inorganic N – sources
- GIS based approach to coordinating
- 6 log kill by enhanced treated sludge
- Lime stabilisation
- Composting
- E.coli/Salmonella difficult to ascertain as little to start with.

### Contact details

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**Participant's Comments**

I'm not aware of similar facilities in Australia, although we heard a strong rumour that the CAMBI process was being considered by Melbourne Water.

Incineration or power from sludge has a high cost associated and appears to be only applicable for large cities with space limitations and where agricultural/landscaping reuse was not practicable. The process produces large volumes of fly ash which currently has no market and was being buried in local landfills.

The most likely biosolids reuse application for CHW will involve the development of a mixture of reuse pathways including landscaping, landfill remediation, forestry and possibly agricultural use.

CAMBI or other pretreatment technologies are very valuable in reducing sludge quantities and increasing gas production. Incineration technology is now old but still very useful to understand the process and discharge limits.

This (the CAMBI process) is at the high-end of sludge treatment technologies – most Australian processes are at the lower end. The EPA has input into the European regulations that are now very stringent. This will make agricultural reuse more onerous.

The CAMBI process was good technology and should be relatively low cost. It is still however, too big for Yarra Valley Water, but was still the best treatment technology we have seen.

I was concerned about the 20% fly ash produced with incineration that still has to be placed (disposed). CAMBI has potential but depends on OPEX and CAPEX processes that are unclear, but obviously expensive.

The CAMBI process is new technology that must be considered with ATHOS, thermal drying and oxidation sludge technologies.

Again, this technology is not used in Australia at the moment, but the CAMBI process has a place in sludge management – however operational/capital costs could be a determining factor.

The EPA's view of impending regulations paints a grim future for biosolids use in agriculture. Landfill/Land rehabilitation is a safe bet at this stage. It is quite obvious that the market/EPA view was perception driven.

The CAMBI process is not in Australia currently, but it should be considered for future projects along with ATHOS and Biostyre processes.

## Little Marlow STW's composting process

Figure 22. Composting facility, Little Marlow.

Richard Hammonds runs the technical side of the composting systems.

The composting operation (figure 22) is in a shed 127m long 42m wide (biggest clear roof span possible with conventional roofing truss). This is a result of unsolvable conflict with residents and the requirement to build a large enough operation. The composting shed has an enormous extraction system and biofilters that work well, except extraction was poor initially, due to the designer's underestimation of passive emissions that are always fogging the shed. Recently, they have finished retro fitting static composting bays (13 bays hold $200m^3$ and the mixing composting process takes up about 2/3 of building). The remaining space is used for maneuvering, mixing and screening.

Biosolids entering the process are dewatered on a belt press to 28-32% solid. They are then mixed with a bulking carbon source (woodchips, Figure 23); 2 parts wood chip (1/3 $ton/m^3$), 1 part biosolids cake (1 $ton/m^3$) by volume. There was a scheme to take untreated biosolids products into industrial cropping utilising the product for compost however, the British Retail Consortium opposed that application. This led to combining hemp dust with biosolids for composting, but the N content was too high. The bulking agent used for the composting process has now changed from wheat straw to wood chips because of the deeper piles and the structural/aeration benefits obtained. However, woodchips have less available carbon and research, into (waste) chips from landscaping, has been undertaken to assess other possible alternatives. They are also trialing two types of wood chips, sawmill waste and shredded green-waste to find a bulking agent that is low (preferable no) cost.

Figure 23. Mixing of biosolids and woodchips.

Design of the composting process was constrained by the existing shed and use of precast units, based on the floor slab. Each composting bay has an aerated floor of upturned steel channels (the length of each bay) in sections with 10 mm perforations, which allow air to be drawn down through the composting process (Figure 24). They draw moisture and heat down into the compost instead of blow it up. This dries the compost at floor level makes it difficult to keep this part of the compost moist.

Managing moisture is the biggest problem faced. To produce the ideal compost, the 28 day retention time should not be exceeded. This ensures that odours are reduced and pathogens killed, producing a safe, 'pleasant' and marketable product.

A single temperature probe set through the back wall of each bay gives a good representation of the compost bay's temperature.

Aerating starts on day 3 (after mixing), at which stage the temp is 70º C (good for pathogen kill). The temperature is maintained at $60^{o}$C for 5-6 days however, they suspect that $45^{o}$C is best for decomposition. Irrigation systems supply extra moisture when required.

Figure 24. **Compost bay with insert of steel floor channeling with air holes.**

The biggest problem with consistency in the composting pile is loss of moisture. After composting, the coarser woodchips are screened through a 10 mm mesh and put back into the composting process. There is about 50% woodchip and 50% compost product in the final compost pile.

Composting is considered slightly cheaper than anaerobic digestion. Compost is left on-site for 5-6 months after processing for maturing and is then considered ready for retail. The maturing time used to be longer (1-1.5 yrs) however, they had problems with weed growth in the compost.

## Marketing

The company originally intended to supply the agricultural market however, they chose to target retail (garden and landscaping) due to the current move away from peat-based composts in the UK.

The base compost is sold as bagged soil improver with a final 10mm screen. They also add coir (coconut husk) as it is inert and dilutes nutrients to prevent seedling scorch. Vermiculite (white) is added to the final, high quality, multi purpose product to camouflage any white plastics that may be in the compost.

Phrases are used on the product bags to manage customer perceptions (e.g. multipurpose compost, healthy plants, food, etc). There is also an endorsement from the Royal Society for the Protection of Birds (RSPB) stating how the peat used in other compost was destroying bird habitats.


**Figure 25. Three bagged compost products containing biosolids**

These types of endorsements help with sales. They have been retailing for 7 years and in the last year they had a 300% increase in demand on the previous 12 months. Metals are not a concern as only 10% of the final compost was biosolids.

They are about to undertake application onto horticultural crops and Safeway wants to be peat free in years to come.  There has also been extensive marketing to the end consumer through garden publications, advertisements, growing trials, and garden centre pushes. Sales increased when the price of peat free compost dropped to the same as peat based.

## Standards

The UK has simple standards which are based on composted green-waste and not composted other materials.  These other materials are currently categorised as materials of higher risk.  It will be 1-1.5 years until standards are established for acceptable metal levels.  Little Marlow has lower local metal outputs and only 10% of the final product is biosolids.


**Figure 26.** **Marketing information on back of compost bags.**

# Liquid injection of sludge

## What is Terra Liquid?

Terra liquid is a quality organic soil conditioner and fertilizer (liquid biosolids), which is ideal for a range of combinable crops and grassland. The advertising boasts that terra liquid gives:

- Great savings on traditional mineral fertilizers
- Valuable organic fertilizer and soil conditioner
- Full ground injection and consultancy as part of the service

Terra Eco's experienced contractors offer the full application package as part of their service and ensure the application is accurate and within set guidelines. After biosolids application they also supply the grower with a detailed report outlining application rate, nutrient and trace element additions. Typical nutrient concentrations supplied by TERRA liquid are outlined in Table 10.

**Table 10. A comparison of typical first year mineral fertilizer replacement values by using TERRA liquid.**

| Nutrient | Kg/ha | Units/ac |
|---|---|---|
| Nitrogen-N | 110 | 88 |
| Phosphate – $P_2O_5$ | 100 | 80 |
| Potassium- $K_2O$ | 30 | 24 |
| Magnesium - MgO | 100 | 80 |
| Sulfur – $SO_3$ | 55 | 44 |

Performance and benefits of TERRA liquid:

- Savings of at least £40/ha against traditional fertilizers
- Valuable organic fertilizer and soil conditioner
- Supplies major and minor nutrients and valuable trace elements
- Nutrients released gradually to promote crop health
- Full delivery and injection service
- Injection loosens the soil acting as a valuable cultivation benefit

TERRA Lime Cake:

- Is an alternative to conventional lime
- Gives savings against traditional lime and mineral fertilizers
- Supplied and applied with Terra Eco. Systems
- Makes friable soil with good spreading characteristics

Terra Lime Cake is produced by blending sludge cake with quick lime (CaO). Water in the cake reacts with the quicklime, producing heat, together with the high pH this stabilises the sludge and kills pathogens. The dry product combined the beneficial nutrients from the cake with a significant neutralising value from the quicklime.

Similar to their other products, TERRA Lime Cake boasted slow sustained release of nutrients through the growing season. However, the lower application rate and impact of the lime, resulted in lower nutrient availability than conventional TERRA cake.

**Table 11. Lime and fertilizer value of Terra lime cake.**

| Nutrient | Kg/ha | Units/ac |
|---|---|---|
| Lime equivalent* | 5t | 2.0t |
| Nitrogen - N | 18 | 14 |
| Phosphate – $P_2O_5$ | 58 | 48 |
| Potassium – $K_2O$ | 15 | 12 |
| Magnesium – MgO | 30 | 23 |
| Sulfur – $SO_3$ | 75 | 62 |

*First Year Mineral Fertiliser Replacement value (based on November application) Neutralising value of 10 and 25 tonnes/ha.*
** Ground Limestone assumed NV 50.*

Benefits:

- Effective correction of soil acidity
- Rich in nutrients and trace elements
- Worth in excess of £30-40/ha

As with all organic manure, TERRA lime cake needs to be ploughed in as soon as possible to comply with the Code of Good Agricultural Practice for the Protection of Air. This minimises the risk of losing valuable nitrogen to the air as ammonia.

## Farm spreading

Biosolids are ~5-6% solid when injected into the soil. Crops grown using raw sludge are industrial crops, like oil canola (glossy magazine production, glad wrap). They usually apply around 200m$^3$/ha or 260 m$^3$/ha on newly treated soil with an 18 months interval of application before growing food crops (e.g. oilseed rape this year and wheat the next season).

As application is all year round (when not too wet) they use tractors with tracks and do not cart a heavy tank liquid sludge on the injection equipment. The tractor has a hose connected to the injector and a tank on the edge of the property that the trucks transport to (Figure 27). The pump on the stationary tank is radio controlled from the tractor cabin. This allows sludge flow to be stopped when empty or turning, etc.

**Figure 27. Liquid sludge injection.**

The current application will be sown in late August, after it has dried out. Some farmers do one pass that incorporates the sludge while sowing. The amount of N in the sludge restricts the amount of sludge applied. Total N must not exceed 250 kg/ha in organic matter additions (Table 7).

## Volumes of biosolids applied at the costs

At present, they apply 350,000m$^3$ raw liquid and 300,000 m$^3$ digested liquid to land. Approximately 5-600,000 m$^3$ is taken from smaller to larger processors for cake production. Application generally halved the farmer's N input and there is no need for P & K application. There was no cost to farmers for the liquid. Cake had a small charge - £1/tonne (AUD$2.65/tonne), however, there is a 25p discount for stockpiling and a premium for spring application of 25p.

Thames Water spread approximately 4,000 ha of raw, digested sludge yearly at 6% solid. This is 1,500 ha raw and 2,500 ha digested sludge. The cost of injection is ~£15/m$^3$ and £2 running cost/m$^3$, (relative to hauling costs). The value to the farmer is ~£30-40/ha. Initially, farmers were cold-called to convince them to use it, now there is no problem and supply cannot keep up with demand.

# *Dinner Speakers.*

## Dennis Brokenshire and Steven Vaughan

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**Participant's Comments**

Composting is an excellent way to go if you have access to wood chips or green waste. You could blend the 2 wastes together to give a valuable product. The major lesson is to produce a product that the community *wants* and have a good marketing strategy.

Composting in a closed system is good technology and could be utilised in areas where transporting is an issue. The retailing of class A compost is an excellent means of improving perception in the market place.

This level of composting has not been carried out in Australia – definitely has an application.

Enclosed composting to reduce buffer distance and minimise public amenity impacts can only be a good thing. It is an advanced process to produce the highest value retail product of bagged compost.

Liquid injection of sludge is unlikely to be acceptable to the public or EPA though. It would be a mistake to assume that a composted product would be automatically marketable.

Composting for Bolivar? – although we currently have a good market for the lagoon dried biosolids.

The Barwon Water Paper put composting and land application into perspective.
- composting has a place subject to a range of issues
- the same applies to land application

The history of land application is important but, there are significant risks. Commencing land application and composting from a green-field view point is the challenge – and what about the regulator?

The use of light presses and fans in producing a quality product that is dedicated to biosolids management is useful.

The process was higher technology in terms of process management and air quality control. A very defined process and only particular feed-stocks used, development of a high quality product for the retail market. The final product is a highly-treated compost to justify an agricultural market.

Regulation of compost is separate from biosolids and there are no constraints from metals. A change of regulations may limit the market – Australian regulations need to ensure 'appropriate compost' products are not impacted by controls such as metal limits.

# Rothamsted Research Station.

## *Rothamsted*

Rothamsted has 5 Divisions: Crops; Pathogens and Plants; Invertebrate Pests; Biological Chemistry; and Agriculture and Environment. Steve is in the Agriculture and Environment Division, which has about 100 staff. In this Division they do everything from biomathematics (modern biostatistics was invented at Rothamsted) to soil and water pollution, crop growth and nutrition and the protection of the environment. There is a £30M development for 200 scientists to be located on site.

### Long-term experiments in England and EU (back ground to current research)

Research is being conducted on sludge because it contains metals and metalloids. Zinc and copper are important in regards to ecological effects. Food regulations are based on Cd and Pb contents and also Hg. These metals form a guide that the producer must be under to be accepted in the market place. As a source of water contamination (surface and groundwater) the only metal of concern is arsenic.

Woburn Market Garden Experiment started in 1942, due to war rations, when they were trying to turn a light sandy soil into a market garden soil. To increase usefulness and water holding capacity, they decided to trial a number of bulking organic fertilizers. Inorganic fertilizer, farm manure, biosolids and composts were included in the trials. Fortuitously the biosolids from London and some of the composts contained high metal loadings, and they were unable to get the soils up to market garden standards in 3 years. Thus, they continued applying organic fertilizers until 1961, at which time someone found a lot of heavy metals in the soils.

It was a nice experiment as the farmer maintained the soil pH at around 6.5, by adding lime to overcome the acidification effects from mineralisation of organic matter, so pH was not a confounding factor. Some of the research showed a linear relationship between total soil Cd and metal content (grain, red beet (less in root than shoot), carrots (bit more Cd in root)). When there is more than 5 or 6 ppm total Cd in the soils you are likely to exceed the 0.1 MPC Cd in Barley grain. For wheat the MPC is 0.2 and you can also determine when you are likely to exceed the MPC by measuring total soil Cd for this soil.

There is a fantastic archive of all sludges added and soils sampled that can be drawn on for new analysis, etc. The amount of metals removed by crops is very small and it would take thousands of years to remove the metals applied by application of sludges high in metals.

From an ecological (soil health) perspective, plots with biosolids applied had half the soil microbial biomass (a measure of all microbes in soil i.e. Ungi, algae, protozoa, bacteria, actinomycetes and cyanophyceae) of control plots in biosolids treated soils, 25 years after the last sludge edition.

After this finding, some sludge experiments in Glebthorp were also tested. These experiments started in 1980 and there were only two sludge applications in the 80s. Then in 1994 they looked at N symbioses and found that with a gradient of Zn and other metals, there was a decrease in yield due to the deceased activity of N fixation. Similar findings in Germany showed that Rhizobium activity in soils tailed off to nothing at

around 300 mg Zn/kg soil. At Woburn they were looking at nitrogen fixation and found it tailed off as you moved from the control to biosolids treated soils.

Woburn research found:

- Metals remain in the top soil, with little leaching or removal in plant material
- Chemical extractability of metals in soils has remained high
- There is a persistent bioavailability of metals

Interpretation of this data has been difficult, due to the combination of a number of metals in the sludge, a limited number of soils and confounding effects in some of the experiments with pH and changes in organic matter applied.

## Current research program

In 1993 a research review recommended that further research was required and this provided the basis for the current research program. The review also decided on a code of practice for biosolids application to land in 1996, which is currently enforced in the UK - taking into account the soils data summarized above and the review. The code of practice has pathogen controls and metals loadings however, organics are not included.

Previous experience resulted in a national experiment being proposed with the aim looking at the impact on soil. This means soil ecotoxicity, ecosystem health, nutrient cycling and plants regarding heavy metal in sludge. It should also allow assessment of new contaminants of concern in the future.

**Figure 28. Woborn field experiments.**

The new research program involves Rothamsted, ADAS (Agricultural, Development and Advisory Service), McCauley and SAC (Scotts Agricultural College) and WRC (contractors) with 9 sites across UK. The initial research highlighted there was not robust science underpinning application of biosolids to soils across the UK. So, the primary aim of the new research program is to provide the science for a robust environmentally and agriculturally sustainable system.

Funding is from the UK WER (UK Water Industry Research limited), which collects money from all water bodies, DEFRA (Dept of Environment Food and Rural Affairs), National Assembly of Wales (dissolved), Scottish Executive (Parliament) and the Environment Agency of England and Wales. Thus, this is a very large project with many

research sites. The project's main aim is to develop the EU direct (1989) and the code of practice (developed in 1996) which lowered Zn guidelines on a precautionary basis, to meet the new EU directive (Table 12). How the new directives relate to several other countries has been summarized in Table 13.

The objectives are to focus on soil microbial activity, crop yield and crop metal uptake. Investigating:

- Microbial biomass, respiration and rhizobium and degradation of organic matter (mineralisation of carbon);
- Chemical measures are speciation and bioavailability and the long-term changes and equilibriums.

Experiments started in 1994 and they intend them to continue for a long time. These experiments are testing sludge cake and liquid sludges manufactured with a side experiment comparing metal salts. There are 9 sites, 2 in Scotland, 1 in Wales and 6 in England. Spreading the field sites around the country, on a range of soils (light to heavy texture, range of organic matter, and one soils with a lot of chalk or calcium carbonate in it) ensures they characterise the major soils and environmental conditions where sludges were applied to agricultural land. The same experiments have been laid out at each site using the same sludges.

**Table 12. Maximum permissible and advisable concentrations of potentially toxic elements in soil after application of sewage sludge to agricultural land and maximum annual rates of addition (MAFF_and_WOAD 1998).**

| | Maximum permissible concentration of potentially toxic element (PTE) pH | | | | Max. permissible average of a 10 year period (kg/ha) |
|---|---|---|---|---|---|
| | 5.0-5.5 | 5.5-6.0 | 6.0-7.0 | >7.0 | |
| Zinc | 200 | 200 | 200 | 300 | 15 |
| Copper | 80 | 100 | 135 | 200 | 7.5 |
| Nickel | 50 | 60 | 75 | 110 | 3 |
| | For pH 5 and above | | | | |
| Cadmium | 3 | | | | 0.15 |
| Lead | 300 | | | | 15 |
| Mercury | 1 | | | | 0.1 |
| Chromium | 400 | | | | 15 |
| Molybdenum | 4 | | | | 0.2 |
| Selenium | 3 | | | | 0.15 |
| Arsenic | 50 | | | | 0.7 |
| Fluoride | 500 | | | | 20 |

Levels of Zn, Cu or high Cd sludges have been applied to span actual and advisory limits. For example, the Zn advisory limit was 200 mg Zn/kg soil and the EU directive is 300 mg Zn/kg soil. The rates are set, below and above this on the dose response curve so they can record what happens either side of these limits. For Cd, the current directive was 3 mg Cd/kg soil, so they have treatments above and below this level. Lower levels are tried as they may be in the region that could be proposed in the future (e.g. 1mg Cd/kg; Table 13).

The biosolids cake experiments are a big part of the experimentation work. In each case, there are untreated control plots. They have a high Zn sludge (6000 ppm), a high Cu sludge and a high Cd sludge (high Cd:Zn ratio sludge), but all have some other metals in them. In each case, spiked sludges have been included so there is only one metal. They

have also digested and undigested sludges high in spiked metals and the relevant controls.

From 1994 to 1998 (Phase 1) the sites have been set up and sludges applied (4 applications to get the metals concentrations required). Sludge was applied to the site and mixed with a spader (like a rotary hoe). Each site was tilled separately within the plot to reduce dilution in mixing the plot with control soils around it. Control and low-metal-sludges spiked were single metals only and implemented at only three sites, to allow comparisons with biosolids cake (as supplied) which have mixed metals.

Properties measured regularly are:

- Chemical: total and available metals and nutrients, carbon
- Physical: Water holding capacity, bulk density

**Table 13. Maximum Permissible Heavy Metal Concentrations in Soil (mg/kg dry wt.) for Selected Countries (after Matthews and Lindner, 1996 cited by WEAO 2001 )**

| Country | | Pb | Cd | Cr | Cu | Ni | Hg | Zn | As |
|---|---|---|---|---|---|---|---|---|---|
| Australia(4) | Contaminate cumulative load | 260 | 2 | | 140 | 85 | 2 | 300 | 20 |
| Austria | Upper | 100 | 11 | 100 | 100 | 60 | 1 | 300 | |
| Belgium | Flanders sand | 50 | 1 | 100 | 50 | 30 | 1 | 150 | |
| | Flanders silt | 300 | 3 | 150 | 140 | 75 | 1.5 | 300 | |
| Denmark | | 40 | 0.5 | 30 | 40 | 15 | 0.5 | 100 | |
| | | | | | | | | | |
| EU (present)(2) | pH 6-7 | 50-300 | 1-3 | | 50-140 | 30-75 | 1-1.5 | 150-300 | |
| EU (proposed)(3) | pH 5-6 | | 0.5 | | 20 | 15 | 0.1 | 60 | |
| | pH 6-7 | | 1 | | 50 | 50 | 0.5 | 150 | |
| | pH >7 | | 1.5 | | 100 | 70 | 1 | 200 | |
| Finland | | 60 | 0.5 | 200 | 100 | 60 | 0.2 | 150 | |
| France | pH>6 | 100 | 2 | 150 | 100 | 52 | 1 | 300 | |
| Germany | pH 5-6 | 100 | 1 | 100 | 60 | 50 | 11 | 150 | |
| | pH >6 | 100 | 1.5 | 100 | 60 | 50 | 11 | 200 | |
| Ireland | | 50 | 1 | | 50 | 30 | 1 | 150 | |
| Italy | | 100 | 1.5 | | 100 | 75 | 1 | 300 | |
| | | | | | | | | | |
| | | | | | | | | | |
| Netherlands | | 85 | 0.6 | 100 | 36 | 35 | 0.3 | 140 | 29 |
| Norway | | 50 | 1 | 100 | 50 | 30 | 1 | 150 | |
| Spain | pH<7 | 50 | 1 | 100 | 50 | 30 | 1 | 150 | |
| | pH >7 | 300 | 3 | 150 | 210 | 112 | 1 | 450 | |
| Sweden | | 40 | 0.4 | 30 | 40 | 30 | 0.3 | 75 | |
| Switzerland | | 50 | 0.8 | 75 | 50 | 50 | 0.8 | 200 | |
| UK | | | | | | | | | |
| pH | 5-5.5 | 300 | 3 | 400 | 80 | 50 | 1 | 200 | 50 |
| pH | 5.5-6 | 300 | 3 | 400 | 100 | 60 | 1 | 200 | 50 |
| pH | 6-7 | 300 | 3 | 400 | 135 | 750 | 1 | 200 | 50 |
| pH | >7 | 300 | 3 | 400 | 200 | 110 | 1 | 300 | 50 |
| Ontario, Canada | pH>6 | 60 | 1.6 | 120 | 100 | 32 | 0.5 | 220 | 14 |
| 1. The USA has not defined maximum permissible heavy metal concentrations in soil | | | | | | | | | |
| 2. EC Council Directive (1986) | | | | | | | | | |
| 3. Draft EC Council Directive (2000) | | | | | | | | | |
| 4. ANZECC *et al.* 2000 | | | | | | | | | |

1998 –2002 (Phase 2) had not been completed so could not be discussed until the final report is approved by the funding group. Consequently, a large slug of data will be published in 2002-2003 when the final report is approved. However, for Phase 1, extractable Zn (ammonium nitrate) increases as pH decreases, except where there is free calcium carbonate. Similar responses for Cd were found, except pH, OC and clay content explains half the variation with extractable Cd, for Cu, Fe oxide helps explain 64 % of the variation of extractable Cu. If OC and clay are included it improves the prediction of extractable Cu to accounting for 73% of the variation. Copper availability seems to be less sensitive to soil pH.

Some of the early microbial data from the biosolids cake plots suggests the undigested sludge (raw with an increased level of degradable organic matter) gives a boost to the soil microbial biomass. However, there is no significant difference across the treatments at this early stage. Microbial respiration and rhizobium numbers also show no variation across the plots.

It is important to look at biomass, relative to respiration, as it increases respiration. It is also important to remember stress can increase respiration but does not have a corresponding increase in biomass.

For the metal amended liquids extractable metals are much more available in the early days, probably because they are amended/spiked sludges. Anaerobic conditions, during spiking, probably transform metals into sulfides during the 6 month spiking period which are then captured as sulfates in soils at time of analysis. This could change dramatically in the future. Copper is the exception and Steve's groups is unsure why this happened.

The crop rotation is wheat and grass, year by year, except for Scotland where it is grass, grass.

## Biosolids applied to land: Advancing standards and practices.

Steve has been involved for 18 month in a study in the US for the National Academy of Science on biosolids which is just about to be released by the National Academy of Science Press. http://www.nap.edu/books/0309084865/html . Biosolids applied to land: Advancing standards and practices (NAS 2002). The study focused, very much, on human health effects and there is nothing on crops, animals or soil ecosystems.
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SEE Symposia 41 and 42 at: http://www.17wcss.ku.ac.th/Symposia/symposia.htm#SubG

# Thames Water - Terra Eco Systems Farm Systems and Environment Ltd

## Liston Noble - Bollington Hall Farm

Liston explained some practical application methods for using EM38 and GIS/GPS methods to assess soils and then manage the farm paddock based on GIS/GPS yield monitoring maps, linked to fertilizer and/or biosolids application. This system can get really detailed information but, it is very expensive and traditional soil mapping techniques and analytical methods are generally used. The use of thermal imagery, etc. is one way around this expense, once it is calibrated for your area and crop. See CD for presentation and further information.

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# Holcim Cement Works

## *Extra visit by Dr. Daryl Stevens*

### Background

**Figure 29. Siggnethal Cement works, Switzerland**

The Holcim Cement works at Siggnethal, is one of several based in Switzerland that uses biosolids as a part of their fuel source. Traditionally, the sources of fuel for the kiln are oil and coal. However, the use of this more traditional source has decreased as other wastes have been utilized. The ratio of energy sources for the kiln energy requirements are now approximately oil 35%, coal 35%, biosolids 10%, animal meal 5%, car tyres 5%, organic solvent waste, etc. 10%. Some cement works use 100% alternative fuels (e.g. not oil or coal). The average alternate fuel use related to the coal equivalents are shown in Figure 31.

### The cement making process

The biosolids arrive at the cement works in big wool bales already dried and granulated. This product is then finely ground before being injected into the kiln as a fuel. Currently, 10% of the fuel for the kiln (which makes a klinker) at Siggnethal is provided from biosolids. There are a number of difficulties in using biosolids in the kilning process, but the biosolids calorific value and silica content are very useful in the process. The cement works actually pays for the biosolids, which were evenly distributed to the three major cement making companies in Switzerland (Jura Cement, Vigier and Holcim). Biosolids are paid for due to the competitiveness between cement manufacturers for access. I could not get an answer on how much they paid for the biosolids. It was mentioned that, fuel for kilns is one of the major costs of the process and the use of biosolids considerably reduces operating costs, even at 10% fuel replacement. Some plants use a lot more biosolids and there is a considerable amount of research being done at present to develop the best methods to inject it into the kilning process for a fuel. As agricultural use is being stopped in Switzerland there will be an even greater supply of biosolids for cement kilning, which seems to be the preferred option in Switzerland at present.

The klinker making process uses a kiln that fluidizes the clay etc., added to the process at a maximum temperature of 1500$^{o}$C, forming klinkers. The combustion gas from the kiln process was used to preheat energy sources entering the kiln, before being scrubbed through an electro filter for dust removal, followed by activated carbon scrubbers. The expelled air is apparently as good as when it entered the process. Any solids removed from the exhaust gas are feed back into the klinker making process.

The kiln itself is approximately 64m long, 4m in diameter and slowly rotates on a 4-degree slope, allowing the clay etc. to slowly move along the kiln. The temperature gets hotter and hotter as it moves down the kiln toward the burners. Retention time for the clay and contaminated soil (it is also used to dispose of some polluted soils) which enters the kiln is approximately half an hour. The klinker falls out the burner end of the kiln ready to be ground to a powder in a metal ball grinder to make the cement.

**Figure 30. Burner end of cement (klinker) kiln**

Four main cements are produced which are a function of the fineness of the powder ground from the klinkers. Some specialty cements are also made (e.g. Rapid set).

Interestingly, Radu's last comment was that the flue dust from incinerators was also great to use for making cement, but was very difficult to handle. They are much better getting the biosolids product, as it also has the added benefit of reducing the fuel costs and was relatively easier to handle.

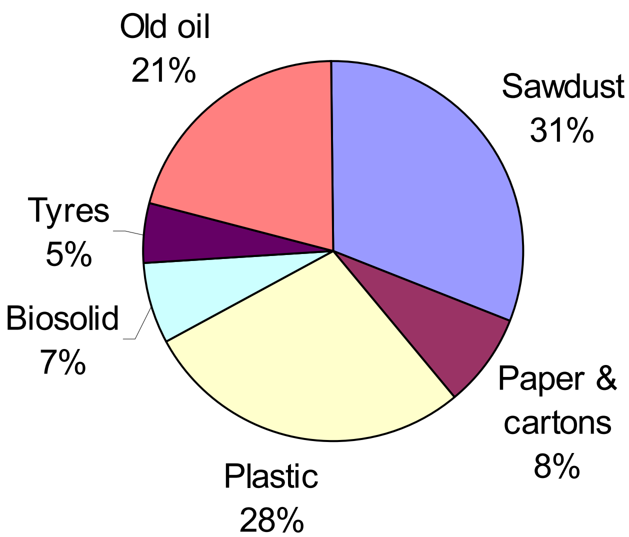


**Figure 31. Alternative energy sources used in cement works in Switzerland (2000). Combined these sources release the same calorific value of 380,000 ton of coal.**

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