TWENTY YEARS OF PROGRESS IN THE TREATMENT AND DISPOSAL OF BIOSOLIDS

Lowe, P.[1], Hudson, J.[2], Whipps, A.[3]

[1]Founder European Biosolids and Organic Residuals Conference, [2]Retired Consultant, [3]Pell Frischmann.

Introduction

The treatment and disposal of sewage sludge has been for many years the Cinderella of the sewage treatment process. The emphasis was placed on achieving effluent quality standards with the aim of cleaning up the rivers and water courses into which the effluent was discharged. However, the simple fact was that meeting improvements in effluent quality standards meant an increase in sludge production and in many cases a growing problem for those responsible for the treatment process. For some the solution was to dump the “untreated” sludge into large lagoons in the hope that the problem would go away, thankfully others took the problem more seriously with investment in anaerobic digestion and disposal to agricultural land. In Europe the latter was brought into sharp focus with the publication and enforcement by national governments of the EC Directive 86/278/EEC (June 1986) on “the protection of the environment, and in particular of the soil, when sludge is used in agriculture”. Thus the emphasis began to move towards developing sustainable solutions for the treatment and disposal of sewage sludge.

The US was also aware of the growing problem of acceptability of sewage sludge as a valued resource. In order to overcome this issue they introduced a changed emphasis by introducing the term “BIOSOLIDS”. The US Environment Protection Agency (EPA) was required under the Clean Water Act Amendments of 1987, to “develop a new regulation to protect public health and the environment from any reasonably anticipated adverse effects of certain pollutants that might be present in sewage sludge.” This led to the publication of the EPA Guide to Part 503 Rule (September 1994) introducing a two tier quality class definition of biosolids: Class A and Class B.

The European Biosolids and Organic Residuals Conference

The US Water and Environmental Federation (WEF) realised there was potential to set up an annual conference devoted to the advancement of science and technology of biosolids. Following a visit to this conference Paul Lowe realised there had to be potential for such a conference serving the European Community and as a result founded the European Biosolids and Organic Resources Conference in 1995. The aim of the conference was to enable the presentation and publication of technical papers with time after each presentation for questions and comments by delegates.

The first conference was to set the scene for the next twenty years and included papers on composting, lime treatment, thermal drying, pelletisation, gasification, ultrasound treatment, marketing, recycling and disposal. Over the next nineteen years over 1500 papers would be presented marking the trends in regulations, sustainability, research and process technology developments.

This paper looks at the trends in treatment and disposal over the past 20 years as seen through the eyes of the papers presented at the European Biosolids and Organic Residuals Conference.

Understanding the Nature and Composition of Sewage Sludge.

It is not surprising when one considers the origin of sewage that sewage sludge is best described as highly complex suspensions, being mixtures of proteins, fats, carbohydrates, polysaccharides, micro-organisms, trace metals, natural and man-made organic compounds, fibres, hair, food particles, inorganic materials such as sand and grit etc., and of course water. Clearly the nature and composition of sludge is influenced by the demographic makeup of the population served, the industrial discharges to the sewerage system, together with the degree of regulation applied to those discharges.

It is also influenced by the degree of treatment and type of treatment processes afforded at the sewage works. In the early days sludge arising at coastal works where the degree of secondary treatment was either non-existent or limited the sludge characteristics were dominated by the primary treatment processes deployed. In the past 20 years secondary treatment has become a statutory requirement and indeed at some locations tertiary treatment has been introduced. As a result the past 20 years has seen a change in the blend between primary, secondary and tertiary sludge and this in turn has influence on the process technology deployed.

It is worth nothing that 20 years ago the official definitions for sewage sludge were those of the EC Directive 86/278/EEC (June 1986) on "the protection of the environment, and in particular of the soil, when sludge is used in agriculture".

In April 2000, 15 years ago, The European Commission published a Working Document on Sludge (April 2000) in which it set out possible revised definitions for sludge. Two concepts then emerges which gave sewage sludge the status of Conventional Treatment or Advanced Treatment in a similar way to the US EPA 503 model.

Untreated sludge means sludge or septic tank sludge, which is neither enhanced treated sludge nor conventionally treated sludge.

Conventionally treated: must be treated so as to ensure that 99% (a 2-log reduction) of the indicator pathogen E. coli has been destroyed with a maximum allowable concentration (MAC) of E. coli of 10^5 per gram (dry solids).

Enhanced treated: must be treated so as to ensure Salmonella spp. is absent and be treated so as to ensure that 99.9999% (a 6-log reduction) of the indicator pathogen E. coli has been destroyed with a maximum allowable concentration (MAC) of E. coli of 10^3 per gram (dry solids).

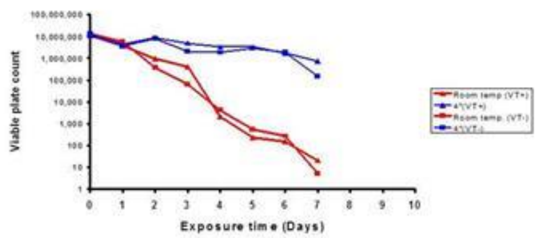


Figure 1. Survival of E.coli 0157 Strains in Stored sludge at 4degC and Ambient Temperature (around 22 degC) {Horan et al 2000}

The latter was to dominate many of the papers presented to the conference for the next 15 years. Work carried out for the UKWIR Horan, et al [2000] describe their investigation into the behaviour of veritoxigenic and non-toxigenic *E.coli* in sewage sludge. They were able to show that that *E. coli* 0157 behaves in a similar manor to indigenous *E. coli*.

Although the European Commission did not implement any findings of the Working Document on Sludge (April 2000), the Biosolids Conference has witnessed a drive to achieve a 6-log reduction in pathogenic organism.

Screening and Dewatering

Figure 2 - Sludge Screens

The past 20 years has witnessed an ongoing debate about the value of screening and dewatering. Sludge arising at a sewage works should be from sewage which has been effectively screened at the works inlet. However, the need for sludge screens does not appear to have been removed. Modern sewage sludge screens allow for much finer and effective screens to be installed. Indeed, fine screens have become an important necessity where the final sludge product is recycled to agricultural land where unsightly debris and plastics are unwelcome. Nevertheless, the processes deployed in the sewage treatment facilities can lead to the balling of fibres, rags and grease, downstream of the sewage inlet screens creating problems in the sludge treatment facilities.

Another trend over the past 20 years has been the practice to concentrate sludge treatment at sludge treatment centres. This means that the sludge treatment plant is not only handling sludge from the indigenous works but the process plant is also required to handle sludge imported from other works and septage collection activities. With this in mind there emerged a need for sludge reception facilities to incorporate their own screening facilities to protect the downstream processes.

Storage

In the ideal world sludge should be processed as soon as it arises so that odour nuisance can be significantly reduced. The reality of the modern world with it's demands on process efficiencies, centralisation of facilities to promote capital investment efficiencies and reduced labour costs means that many sites require sludge storage facilities upstream of the process train and often within the process train.

Figure 3 - Tank Farm

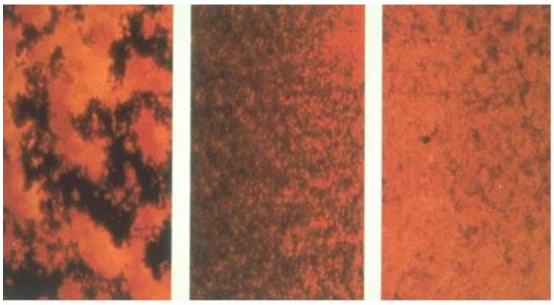
In the past well-constructed earth bank lagoons provided a cost effective solution. However, odour nuisance and public awareness has featured in many papers presented to the Biosolids Conference highlighting the move towards covered facilities and the well-designed tank farm. It has also been observed that storage of dewatered, composted and dried cake presents different operational problems. Nevertheless, investment solutions continued to be driven by the need to minimise odour nuisance and prevention of rewetting.

Sludge Consolidation

A long standing problem for the sewage sludge process engineers and scientists has been how to remove the water from the sludge. The benefits of doing this are both seen in process optimisation and in improving the cost effectiveness of downstream processes. While gravity thickening is probably the simplest process to adopt over the last 20 years this has been superseded by a variety of process techniques. Separating the primary and secondary sludge streams led to a concentration of secondary sludge. As a result we have seen gravity belt thickening widely used for activated sludge with centrifugal thickening less widely used, while flotation and rotary drum thickeners have been used for primary and activated sludge,

However, an observation of the proceedings of the Biosolids Conferences clearly shows how other techniques have taken their place in the process engineers' armoury. These have included reed beds, magnetic separation, freeze/thaw systems, evaporation, electro-dialysis, electro-flotation, crossflow microfiltration and thermal conditioning.

Polymers for Flocculation



Ideal Floc Under dosed Over dosed

Figure 4 - Floc Formation

Much of the progress towards achieving higher dry solids has come from the development of polymers and polymer dosing systems for the conditioning of sewage sludge prior to dewatering. These are now the accepted means of conditioning sludge prior to thickening and dewatering. The vast majority of polymers used in wastewater sludge conditioning processes are high molecular weight organic flocculants.

Automating the polymer dosing process was featured strongly in the first decade of the Biosolids Conference consistent performance and avoiding under-dosing and over-dosing were the drivers leading to an effective automation system.

Interest in polymers has not diminished over the past 20 years and still generates research and development for the optimum dosing technology solutions. The Biosolids Conference has received a number of papers/presentations identifying the advantages of feed forward control and multiple in-line dosing systems.

Dewatering

At the heart of the process to remove water from sludge has been the dewatering technology. Over the past 20 years a wide range of techniques have been identified aiming to break through the 30%ds barrier; indeed achieving this with the economic benefits to the downstream processes and transport have been well documented.

The first 12 years of the Biosolids conference was dominated by the pros and cons between the belt press, the centrifuge and the filter plate press. Fashions moved between them as to which was the ideal solution for a particular site. However, this competition did lead to many improvements in the technology. Multiple rollers were incorporated into the belt press and even two stage integrated dewatering belts were considered a viable option. Improvements in the design of the centrifuge scroll and bowl emerged to squeeze more water from the sludge and improve competitiveness.

The rubber membrane plate and chamber system became an essential part of the filter press design with sizes increasing to 2mx2m filtration chambers. For a period there was a clear distinction in the use with the relatively easier dewaterable sludges being suited for the belt press while the more difficult the sludge saw the choice moved from centrifuge to belt press. Fashion also played a part in the trend as problems with the various systems were identified. Delegates visiting the exhibition today will be aware that competition between these systems is still a live and active topic.

External to mechanical dewatering systems the industry has seen the advancement of hydrolysis and other high temperature and/or pressure systems that, as a by-product of cell lysis, have enabled the release of previously entrapped water molecules. These processes often result in a sludge structure that is more amenable to dewatering, albeit at a major capital cost impact.

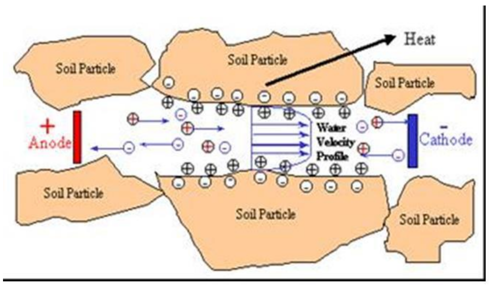


Figure 5 - Electro-osmotic Flow Induced By Voltage Gradient [McLoughlin Nov 2005]

Examining the Biosolids Conference papers some innovations which initially appeared promising had a relatively short life. One example was the idea that electro-osmosis offered improved belt press performance as well as an aid to lagoon dewatering achieving cakes of 40%+ dry solids content.

In contrast, the decanter centrifuge has proved to be a flexible process tool. Many variants are available and all are capable of offering consistent performance with the very minimum of maintenance. Over the past 20 years centrifuge technology has moved forward giving enhanced dewatering performance. Control technology has also helped in controlling and monitoring the performance of the machines.

Much has changed in the filter plate press technology over the past 20 years. The drivers have been to automate batch processes to improve the cycle time and deliver a high solids cake. Large 2mx2m press plates with rubber membranes were at the heart of this development. While this achieved the high dry solids target, cake release still required manual intervention. The response was to develop plate shaking equipment and this was introduced with mixed success. Maintaining a clean cloth in the past required the filter cloths to be manually washed so automatic cloth washing was developed for the filter-press units. In the last few years the Biosolids Conference has heard little of the fortunes of the filter plate press.

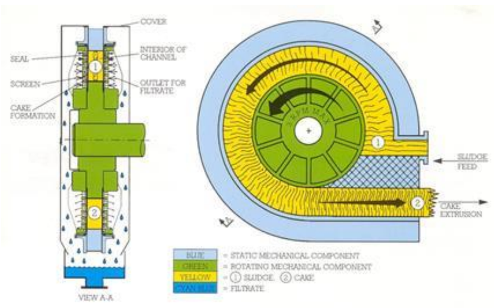


Figure 6 The Rotary Press

While the filter plate press, the belt press and the centrifuge have dominated the sewage sludge market for many years from time to time other dewatering systems have entered the market place to challenge this domination. One such device is known as the Rotary Press which was developed and patented by the Centre de Recherche Industrielle du Quebec (CRIQ). The system was promoted in the UK in the 1990’s, however, a more recent installation at Hampton N.H. USA was been described by Birkel et al [2003] however little has been heard of it since.

Another device known as the screw press also has potential for dewatering of sewage sludge. Trent Bohman [2004] has described a system incorporating the screw press installed at the City of Forks STW’s Washington. Here the sludge is first treated with lime followed by retention to meet the EPA 503 vector attraction rule after which it is transferred via a flocculating tank. En route polymer is added to aid flocculation. The flocculated sludge is then passed to the screw press dewatering plant. During the dewatering phase steam is injected into the screw press to raise the temperature and hence achieve pasteurisation. The cake produced by the lime/flocculation/steam/press system is said to be in the range 25-30% dry solids. The system described is essential one which seeks to achieve an EPA Class A sludge however, the use of the screw press as a dewatering tool is to be noted.

In the last five years the Biosolids Conference has featured the Bucher Press. Claims for the system suggest that cakes of contents of up to 43.5% dry solids could be achieved. Dewatering trials with raw sludge from two different WWTP’s resulted in sludge cake content of 35% and 41% dry solids.

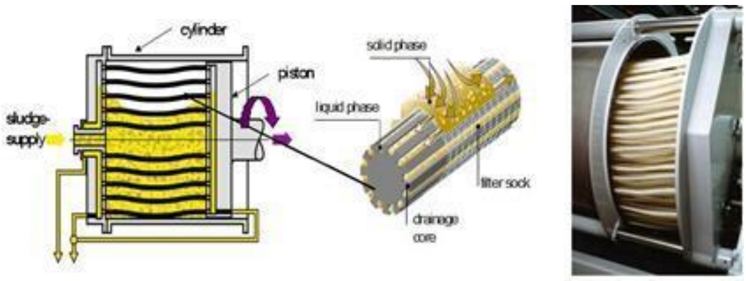


Figure 7 - Hydraulic Press System And Functional Principle Of Drainage Elements, On The Right Side A Opened Cylinder With Drainage Elements. [Boehler et al 2003].

In the experience of the Authors dewatering systems have a habit of falling out of favour only to return to favour some years later having been suitably enhanced/developed to meet current needs. Indeed the researcher may find that solutions to dewatering problems have been found only to be set aside waiting a more favourable time to re-emerge.

Anaerobic Digestion

Anaerobic digestion is probably one of the oldest and sustainable process for the treatment of sewage sludge. This natural decomposition process was harnessed for treating sewage sludge many decades ago. The process has grown from cold digestion lagoons through to large volumetric reactors with 30 to 40 days retention to the more sophisticated present day reactors with 10 to 15 days retention.

Before the start of the Biosolids Conference renewed interest in the digestion process was stimulated by Noone and Brade introduction of digestion for small works using glass-lined steel tanks and innovative heating and mixing systems. A heating technique based on submerged combustion was developed by WRc at Colburn WWTW, North Yorkshire with some renewed interest in submerged combustion technology appearing in the early Biosolids Conferences [Cochrane and Holt 1999].

So in the early days of the Biosolids Conference digestion was ticking along but with little recognition of the value of the process as the optimal work horse for sludge treatment. To some extent it was pushed into the background as a result of renewed interest in thermal drying and incineration of raw sludge.

A paper presented by Panter and Solhiem was to be the catalyst for a step change in the value of this process. They described work at HIAS, Norway on the performance of anaerobic digestion plants receiving a mixture of primary, secondary and tertiary sludge following pre-treatment in a thermal hydrolysis plant at 170°C for 30 minutes. The sludge was fed to the digesters with a dry solids content ranging from 8% to 12% dry solids. What has become known as the “Cambi process” gradually dominated the proceedings of the Biosolids Conference over the past 15 years.

Thermal hydrolysis was not a new process to the sewage treatment world. It had been known for many years that thermal treatment of the sludge prior to dewatering was by far the most effective method for conditioning sludge resulting in high dry solids cakes. The two main processes adopted in the UK during the late 1960’s early 1970’s were the Farrar heat treatment process and the Porteus heat treatment process. The former was a continuous pipe reactor whilst the latter was a batch process. Both were pressurised systems raising the temperature to 180 °C . Three factors were to be the downfall of these technologies;

1. Odour;
2. Overloading of the wastewater treatment processes as a result of returning the dewatered liquors back to the head of the sewage works. In particular the treatability of the liquors because of their hard-core COD content;
3. The excessive wear to the pipe reactors as a consequence of poor grit removal systems.

What made the Cambi process different was that the discharge from the high pressure reactors after cooling was sent straight to the anaerobic digesters. This resulted in a substantial increase in the gas yield and the percent O&V destruction and a neat way of reducing the odour impact of the process. Also, the anaerobic treatment was able to deal with the hard COD problems which had dogged the earlier systems.

Figure 8 - The Cambi Chertsey Plant

The proceedings of the Biosolids Conference offer a unique comprehensive history of the development of the Cambi process from its first UK installation by Thames Water at Chertsey to its worldwide acceptance as a major sludge treatment process stage of the 21st century.

Of course it would wrong to assume that other techniques have not been promoted to secure improved digestion performance in terms of O&V destruction. Techniques such as Enzymic Hydrolysis, The Monsal Hybrid reactor, The Biotherm Reactor, The BIOPASTEUR™ pasteurisation process and reduction by chemical treatment all have a place in the Biosolids Conference proceedings.

Techniques to improve gas production have been described including the use of ultra sound which had a brief appearance. Mechanical Disintegration is also included in the available techniques.

The *MicroSludge*™ process developed by Paradigm Environmental Technologies Inc, Canada utilizes alkaline pre-treatment to weaken cell membranes, mechanical shear to reduce particle size, a SWECO self-cleaning screen to remove oversize debris, and an industrial scale homogenizer to provide an enormous and sudden pressure change to burst or “lyse” the cells.

According to Stephen et al [2003] the heart of the process is an industrial scale homogenizer that provides a large and abrupt pressure drop. At 12,000 psig (82,700 kPag), WAS in the cell disruption homogenizing valve is accelerated up to 1,000 feet per second (305 metres per second, nominally the speed of sound) in about 2 microseconds. This high velocity flow then impinges on an impact ring, disrupting the cell membranes and producing a liquefied WAS homogenate.

A comprehensive review of the ultra sound technique has been given by Barber [2003]. It was identified that for ultrasonic instruments to alter sludge characteristics in a positive way, they must create cavitation bubbles. These bubbles come into contact with the sludge and (partially) destroy the cells increasing biological activity and available substrate to other organisms. Therefore, in order for an ultrasound probe to work efficiently, it must enhance cavitation production.

It was proposed that the technique can be used to treat all the sludge entering the anaerobic reactor or it can be used on secondary sludge entering the anaerobic sludge feed line. The latter appears to be the favoured application. The reality is that ultrasound systems disappeared off the radar and little has been heard of it in the past 5 years.

Of interest the combination of aerobic digestion with anaerobic digestion and thermophilic digestion with mesophilic digestion has led to some interesting process trains over the past 20years. Some typical process trains have included:

- **AGM-M** Acid gas mesophilic reactor followed by mesophilic methanogen reactor digesters in series.
- **AGM-T** Acid gas mesophilic reactor followed by a thermophilic methanogen digester.
- **AGT-M** Acid gas thermophilic reactor followed by a mesophilic methanogen digester.

Composting

Composting featured in the early days of the Biosolids Conference. Its attraction was the green image the public associated with the process. In practice applying the composting process to sewage sludge has been unable to compete with the anaerobic processes. The papers that appeared during the first eight years of the Biosolids Conference pointed towards co-composting with green waste as the way forward. Also from time to time in the last 10 years papers have been presented which combined sewage sludge with green waste. No doubt the process will be revisited in the next decade.

Lime Treatment

The treatment of sewage sludge using lime has been practiced for many generations. Both a lime suspension dry lime and alkaline additives have been used in the process. The requirement to meet the US EPA 503 Rule has resulted in better application of the underlying science and engineering principles. Today, the process takes on many forms including the application of external heat sources to achieve the time temperature regimes as well as the pH stability. The lime process has come of age, however it must be remembered that the biosolids product is not suitable for all soil conditions but will have significant advantages for acidic soils.

Sludge Drying

Sludge thermal drying technology was to launch the first European Biosolids Conference and was to appear as a viable technique over the next 20 years.

The thermal drying of sewage sludge has established itself as a major processing technique.. The technique was deployed as far back as the 1920’s [Hirst 1993] and possibly the best-known sewage sludge-derived product brand name “Milorganite®” also dates back to the 1920’s [Crawford 2005]. The process offers the opportunity to safely pasteurise the sludge for subsequent recycling achieving a log-6 reduction (99.9999%) of enteritic bacteria.

The technique has the ability to produce a product having the attractions of relatively low volume, handleability and spreadability while still retaining the fertiliser nutrient value of the sludge source. In addition, it can provide a product that capitalises on the inherent calorific value of the sludge making it a suitable "green" fuel substitute for fossil fuels having particular value for use in cement kilns, co-incineration plants and fossil fuel power stations.

The technique requires a heat source and the resulting product emerges from the drying unit at high temperature. Unless this temperature is dramatically reduced in the downstream process units there is a potential for smouldering and subsequently combustion. Product cooling is therefore essential.

Unlike other sewage sludge processing techniques the drying process can be engineered to produce a product within a given size range and shape. This is achieved either by the inherent granulation process followed by classification using screens or by a product formation process such as pelletisation where the size and shape is determined by the dies used and where necessary followed by the classification stage to remove fines and oversize material.

However thermal drying processes can result in the production of a fine dust, which in admixture with air, can become an explosion hazard. In addition escaping dust can make the working environment unacceptable. It is therefore important to adequately engineer solutions to any dust problem that may arise both in the vapour stream and in the void spaces of the process units. Following the process developments to thermal drying plant through the Biosolids Conference proceedings shows how the engineering solutions to suppress potential explosive and fire hazards was to change its fortunes. The cost of process modifications to meet new regulations (DSEAR: 2003) began to cast doubt on the continued application of thermal drying systems. Granulation problems associated with raw sewage sludge high fibre content were also identified. Pelletisation techniques were introduced into some process streams to give a more uniform produce and reduce the dust formation. The largest plant in the UK was built at Bran Sands but in the lifetime of the Biosolids Conference was to be closed down in favour of adopting the Cambi process, in part due to increasing gas and energy prices.

Figure 9 - General View of Bran Sands Plant Northumbrian Water UK [Courtesy Andritz UK]

Incineration

In the United Kingdom, co-combustion of sewage sludge and domestic refuse was practiced as early as 1876, to raise steam to power pumps and other machinery. (CIWEM 1999) An eight cell refuse destructor burning refuse and sludge from a filter pressing plant operated at Bolton between 1902 and 1929 (Stanbridge 1977). However, incineration of sewage sludge was established in the UK between 1969 and 1978 when 13 incinerators were built. Seven of the thirteen incinerators were multiple hearth furnaces, three were fluidised bed furnaces and the remaining three were rotary hearth furnaces. With the exception of the two largest multiple hearth incinerators at Sheffield and Coleshill and the fluidised bed furnace at Peel Common, Gosport, the others had very limited life, indeed some were commissioned and then mothballed.

In 1985 Yorkshire Water became increasingly concerned about sludge disposal in the West Yorkshire conurbation. A computer WYSDOM model developed in conjunction with WRc was able to demonstrate the limiting constraints on existing and possible future disposal routes. This led to a re-evaluation of the incineration process as a viable economic disposal option. This model formed the basis for more user friendly models for the strategic evaluations of disposal options.

The new era for incineration gained public acceptability as a result of adopting new emission standards based on the German TA Luft 86 standards. This gave way to revised German air quality standards, BimSchV90(1990) leading eventually to the Incineration Directive: 2000/76/EC. During the lifetime of the Biosolids Conference the proceedings identified the establishment of the fluidised bed as the acceptable process Technology. Plants at Bradford, Sheffield, Huddersfield, Leeds, Birmingham, Shell Green, Beckton and Crossness were built. Upgrading some of these plants to meet public concerns associated with dioxin emissions adversely affected the basic autothermic design resulting in the use of additional fuel to raise the after burner temperature from 850ºC to 1200ºC so increasing the operating costs. Arguments for the incineration of raw sludge v digested sludge are also identified in the Biosolids Conference proceedings.

During the construction phase of the incineration program in Yorkshire, the planning process changed to include the need to produce an Environmental Impact Assessment. These often aided the planning process since it demonstrated that the impact of the incineration process on the environment had been considered in some detail.

One of the major concerns nearly always raised when plans are proposed for the construction of a sludge incinerator in Britain is the presence of dioxins in the flue gas emissions. Dioxins and Furans are destroyed by incineration at temperatures above 850ºC. However the concern is that they will be reformed by "de Novo" synthesis as the gases are cooled in the boiler. The reaction takes place as the gases are cooled slowly through the temperature range 450 to 200ºC catalysed by the copper present in the ash. (Hagenmaier 1988). The reaction also requires the presence of carbon, hydrogen, chlorine and an excess of oxygen. A well designed gas cooling system will ensure that gas cools as quickly as possible through this temperature range, that there are no pockets where the gas velocity will be reduced locally or that fly ash will collect.

The term dioxin is used to denote a family of compounds known chemically as polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). There are 75 PCDDs and 135 PCDFs. Each individual PCDD and PCDF is termed a congener while groups of congeners with the same number of chlorine atoms are called homologues.

Very few of the modern incinerators if any, discharge dioxins at levels near the permitted discharge limit. Housley (1994) gave data for the three Yorkshire incinerators at Bradford, Huddersfield and Sheffield, designed to meet the old TA Luft Standard, indicating levels of dioxins in stack emissions at a level below 0.04 ng/Nm^3 which indicates the level of dioxin destruction to be 98.5%.. Where plume suppression is not required or gas cleaning is by "dry" techniques the volume of the stack emissions will be lower and hence the calculated mass of dioxins discharged to atmosphere will be lower with consequential greater percentage destruction.

A number of the modern incinerators are coming to the end of their asset lives and refurbishment or replacement options were considered based on technological and financial considerations. The Esholt incinerator in Yorkshire for example has been replaced by a Biothelys Thermal Hydrolysis and digestion plant, with cake and liquid import facilities; the Blackburn Meadows incinerator being replaced by a Mesophilic Anaerobic Digestion Plant configured to enable thermal hydrolysis to be added if needed in the future. Other Incinerators are being refurbished to extend their useful life.

Gasification and Oil from Sludge

Processes that offered so much potential but failed to make it into the repertoire of the sewage sludge process engineer are gasification and pyrolysis. Papers by Whipps, A., and Whiting, K. (1999) and Howson, J. H, (2001) appeared in the 4th and 6th Biosolids Conferences and presented information on the pilot plant evaluations. Papers on the Oil- from-Sludge process also appeared in the 5th, 6th and 7th Biosolids Conferences but then dropped off the radar. Gasification could well re-appear as a future acceptable process but sadly oil-from-sludge may have had its day.

Odour

There has not been a year gone by without papers on odour being presented to the Biosolids Conference. Often these papers have had little attention from delegates which makes the subject the Cinderella of the technologies. Yet as far as the public is concerned, it is the odour nuisance that tops the list of sewage related complaints. Reviewing the papers the Biosolids conference has highlighted the problems associated with the measurement of odour. Electronic noses have been described. Odour abatement technology has taken various forms in order to abate the nuisance. Covered tanks are now a common feature at sewage treatment plants with exhaust systems leading to odour reduction units. It is doubtful if this topic will ever go away as the next generation struggle to satisfy the demands of a more informed and discriminating public.

Liquor Treatment

Liquor treatment is still an important subject covered by the Biosolids Conference and will remain so for many years to come. Until a few years ago the treatment of sludge liquors in the UK involved recycling the flows back to the head of the works for treatment with the incoming sewage. Almost every works had its own method of treating and disposing of its own sludge. Sewage works design loads were usually calculated to include liquors from the local sludge treatment plant.

More recently the requirement for higher standards of treatment for sludge to be used on agricultural land, and a requirement for the construction of the more centralised advanced treatment and disposal facilities where advantage could be taken of the economies of scale. Sometimes the existing sewage works have become overloaded leading to a need to increase the size of the receiving treatment plant to deal with the additional sludge liquors; in some cases the nature of the liquors and the economics of enlarging the existing works compared with separate liquor treatment plant has resulted in the latter option being the preferred way forward.

The treatment of sludge liquors and particularly the reduction of ammonia levels by chemical methods have been practiced in the USA and Scandinavia for a number of years; however in the UK the use of purpose designed activated sludge systems appear to be the favoured approach.

More recently the requirement for higher standards of treatment for sludge to be used on land, and a requirement for the construction of the more advanced treatment and disposal facilities such as drying and incineration have led to sludge treatment being concentrated at sludge disposal centres where advantage could be taken of the economies of scale.

Based on the results from a Yorkshire Water pilot plant study, a full-scale plant was designed and built at Knostrop, Leeds, incorporating a jet aeration system to provide oxygen and mixing in the aeration basin was built in 1988.

Millar, Gordon and McCluskey described the use of a CASS™ pilot plant to treat centrate liquors. CASS™ is a development of the basic sequence batch reactor process which featured a combination of biological selector and variable volume reactor technology and accomplishes both biological treatment and solids-liquid separation within a single reactor basin. The first reported use of CASS technology to treat sludge liquors at a commercial level was at Goddards Green in Southern Water, UK. Brown and Sale (1999) outlined the Southern Water strategy for treating sludge liquors.

Another proprietary activated sludge process used for treating sludge liquors is the Amtreat™ process. Two papers (McAteer 2000, Barnes 2000) discuss the development of Cliff Quay Waste Water Treatment Plant in Anglian Water, UK. An Amtreat™ plant, a completely mixed, high rate nitrifying activated sludge plant was constructed and the above papers describe the construction and commissioning of the liquor treatment plant. The plant has been shown to be capable of reducing ammonia levels of 1,200-1,400 mg/l to less than 5 mg/l.

Other treatment technologies have been used to treat sludge liquors. A paper by Davies (2000) outlined the experience of commissioning the first Kaldnes™ sludge liquor treatment plant at Shoreham Waste Water Treatment Plant in Sussex, UK. The process is based on a moving bed biofilm reactor or moving bed reactor (MBR).

Mene and Tattersall described pilot work supported by 6 British Water Companies. The trials demonstrated that a three stage Pegazur plant with a 15% Biocube fill ratio would remove between 70% and 95% of the influent ammonia with a corresponding loading rate of 0.8 kg Amm-N/m^3 reactor/day. High BOD and SS levels in the influent were found not to effect ammonia removal. The experience and data have been used to develop package plant for the UK market.

Membrane technology has been used to treat sludge liquors at two works at least in the UK (Brindle et.al 2003). Brindle, Kennedy and Churchouse reported on the treatment of sludge liquors at Daldowie, in Scotland, UK, using the Kubota Membrane Bioreactor Process (MBR).

More recently (Hegarty 18th Conf.) a study was carried out by Welsh Water to examine the potential of ammonia removal from thermally hydrolysed waste activated sludge and digestate on a laboratory scale in order to establish the conditions for optimum recovery of ammonia. The authors concluded that between 80 and 90% removal from digestate was possible depending on stripping conditions.

With thermally hydrolysed waste activated sludge pH adjustment to between 10 and 10.5 was required to support optimum stripping conditions.

Recycling and Sustainability

From the very first conference until the 20th conference the subject of recycling and sustainability has been addressed. We have seen fashions change from liquid to thermally dried products and to cake. Spreading techniques and application rates have been brought into line with modern farming practices. The papers are too numerous to describe here but readers would do well to study the conference papers as part of the process of reviewing their strategic plans.

However, because sludge treatment and recycling are very much tied up with regulations and legislative developments we review those changes below.

Legislative Trends and Other drivers

The treatment and disposal of sewage sludge has been governed by a range of legislative measures that have seen significant change over the past 25 years, commencing with the EC Directive 86/278/EEC of 12 June 1986. This legislation, transposed into UK legislation by the Sludge (Use in Agriculture) Regulations introduced key quality parameters for sludge applications to agriculture in terms of "heavy metals" and the protection of the environment. These regulations saw the phasing-out of raw sludge operations that were still common practice in a number of areas and the introduction of recording soil and sludge quality parameters.

The advent of the Urban Waste Water Treatment Directive (91/271/EEC) introduced the legal obligation to terminate sea disposal of sewage sludge. This legislation linked to an earlier obligation set by the Oslo North Sea Convention (1972) and the compliance date was subsequently set as 31st December 1998. The UWWTD posed significant challenge to the water industry as it legislated the requirement for a major change in sea disposal practices for a number of large conurbations (e.g. London, Bristol, Liverpool, Manchester, Newcastle, Belfast) and for other coastal catchments introduced secondary waste water treatment requirements. As a consequence an increase in sludge generation was being phased in at the same time as large conurbations were seeking alternative disposal to sea. A range of alternative solutions were promoted involving significant investment in sludge processes including sludge incineration, thermal drying with recycling to agriculture and expansion of conventional anaerobic digestion.

A key driver to treatment standards came as a result of the challenge posed by the British Retail Consortium (BRC). Reacting to concerns over agricultural recycling and public perception of sludge in the human food chain the BRC sought to severely restrict applications. As a consequence of concerted efforts of Water UK and ADAS, The Safe Sludge Matrix was developed to secure the future of agricultural recycling via treatment quality parameters. The Safe Sludge Matrix introduced two treatment standards: conventional treatment and enhanced treatment with specific microbiological reduction requirements. For the first time the microbiological quality of sludge had to be determined before it's use in agriculture could be confirmed. To avoid continuous microbiological monitoring and inherent delays to applications to agriculture the water industry adopted the HACCP principle of quality assurance following a program of specific process and microbiological monitoring.

Despite creating a paradigm shift in sludge operations, The Safe Sludge Matrix did not become a statutory requirement under any revision of the Sludge (Use in Agriculture) Regulations. The Safe Sludge Matrix remains a "voluntary obligation" to this day.
The EU Landfill Directive (1999/31/EC) has had a significant impact on the recycling of sludge to agriculture with the removal of organic waste (i.e. sewage sludge) from normal landfill operations. As a consequence "poor quality" sludge no longer has a fall-back position of the landfill disposal route and the treatment and storage of sludge under the auspices of The Safe Sludge Matrix becomes more significant. The spectre of the Foot and Mouth disease that hit UK agriculture in 2001 prompted a derogation of landfill restrictions for sewage sludge to be deposited in designated landfill sites for a specific period; however this is not considered a future fall-back position except in extreme environmental circumstances.

The EU Nitrate Directive (91/676/EEC) has also had significant influence on the recycling of sludge to agriculture defining Nitrate Vulnerable Zones and the restriction of sludge application rates based upon the soil index, agricultural practice of ammonium nitrate fertiliser applications and of course the nitrogen content of sludge. This has required a closer working relationship with farmers to better understand agricultural practice, both in terms of crop requirements/uptake of nutrients, fertiliser strategy and sludge quality. As a consequence a number of water companies faced a reduction in sludge application rates and in the extreme the loss of certain land bank areas.

The introduction of Renewable Obligation Certificates (ROC) has had a beneficial effect in stimulating the investment in the expansion of anaerobic digestion systems at a time when gas and energy prices worked against the extensive investment portfolio of thermal drying plants. Faced with challenges of the Water Industry's Asset Management Plan, the ROC incentives also supported new investment in enhanced digestion systems, or Advanced Anaerobic Digestion (AAD). Typically AAD systems utilising thermal hydrolysis processes are able to treat a higher sludge throughput than conventional mesophilic digestion with resulting improved thermal and energy balances.

The phasing-out of ROC incentives in 2017 has caused a number of water companies to re-evaluate the use of biogas which, under the replacement mechanism of Contracts for Difference and Feed In Tariff, is looking less favourable and unlikely to provide such positive support for new investment post 2017. However, under the Renewable Heat Incentive, alternative commercial benefits for the direct injection of biogas to the natural gas grid have been investigated and form an important part of their strategic provisions.

Similarly the implications and benefits of the Renewable Transport Fuel Obligation (RTFO) for the use of biogas in vehicles continues to be investigated for future implementation.

Future Outlook

The generation of sewage sludge, or biosolids, is not set to decline with the current forecast demographic growth of the UK. Such growth will require the on-going development of sustainable sludge treatment and recycling options.

It is considered agricultural recycling will continue to form the mainstay of sustainable recycling options however the current move towards phosphorous limitations above defined soil quality indices will have a similar impact on sludge application rates as experienced with nitrate sensitive areas. As a consequence sludge application are likely to involve higher operational costs associated with greater travelling distances, lighter application rates and the need to develop greater land-bank areas.

Sustainable treatment systems will be expected to deliver greater operational efficiencies in terms of thermal and energy balances. This will remain the key challenge for the industry.

As part of the UK regulatory price setting exercise (PR 14) Ofwat's discussion documents on the future of water "Towards Water 2020" has stimulated strategies and options for promoting markets. In particular Ofwat will be publishing a sludge market consultation document later this year (2015). It is envisaged topics for consultation will focus on current environmental regulations relating to sludge and potential changes and experiences with the development of informal sludge markets.

Finally this conference has a great future and the importance of sharing information and data through the presentation of papers remains its founding principle and should be encourages by leaders of this industry.

References

This paper draws extensively from The Proceedings of the European Biosolids and Organic Residuals Conference 1995 to 2014. Edited by Lowe and Horan.