Case Study

Water Management

WM Case 15 EU: Sludge to power – Converting Human Waste to Energy

Background.

Disposal to landfill is wasteful of a potentially useful resource and as well as using up limited space in the landfill site, causes multiple management problems at the site related to stability, leachate generation, odour, vermin and landfill gas production. There is a need and opportunity for major expansion in sludge treatment facilities in China. This maybe in the form of separate regional sludge treatment facilities or in combination with municipal solid waste treatment. In Europe sludge treatment tends to be closely coupled with wastewater treatment facilities and the businesses that manage these.

Anaerobic Digestion vessels – the principle means of sludge treatment and energy recovery. Source: Atkins

However, Sludge is not just a problem in need of disposal, it is also a raw material and resource that can be converted to useful products such as energy and fertiliser / soil conditioner. This is something in common with the wet components of municipal solid waste, food processing waste and some agricultural waste. These materials can be combined and biologically digested to yield gas; dried and combusted to yield heat; or part dried and then put through gasification or pyrolysis to produce both gas and heat.

Examples from Europe.

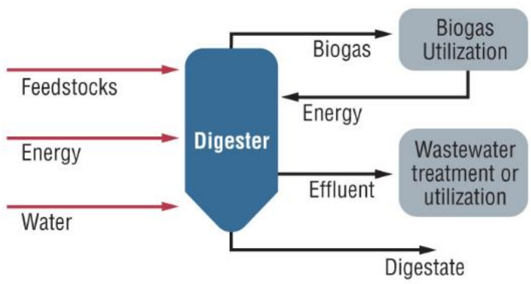
Starting parts of integrated urban waste management solutions. They combine the water, waste, wastewater and treatment cycles with energy, industry and transport networks to build means of recovering and reusing energy to achieve dramatic improvements in resource efficiency. As the technologies and financing and regulatory environments develop so the ability to implement ever more effective integrated solutions increases, working towards a circular economy.

Baltic Biogas Bus[1]

The biogas methane from sludge digestion is often burnt in a gas engine and used to produce electricity, but the value of that methane used as a transport fuel is much higher. The exhaust emissions of Compressed Natural Gas (CNG) powered busses are much less polluting than those from Diesel busses. In Stockholm, Sweden most of the Bus fleet has now been converted to run on either CNG derived from Biogas produced by sewage sludge digestion or on ethanol produced from wood processing waste and some imported sugar cane waste. Anaerobic digestion processes are at the heart of turning waste materials into valuable fuels. The scheme includes the Kappala plant in Stockholm producing Biogas by sewage sludge digestion and the Hendriksdal plant which also takes the organic portion of household waste and sewage sludge for co digestion in an AD plant. The Biogas produced from these and other plants around Stockholm are put through purifiers and scrubbers and then compressed to make suitable for use as vehicle fuels. As the system has expanded over the last decade so more sources of Biogas have come on line including landfill gas and anaerobic digestion of farm wastes. The bio gas is used not just for vehicle fuels but also for industrial and domestic heating. Demand exceeds supply and it has been necessary to plan connection of different sources and distribution points. Biogas has a different composition from Natural Gas and so it is necessary to either construct a separate Biogas Grid or to process the gas more highly to put into the natural gas network. New processing facilities employing a Pressure Swing Adsorption (PSA) process were installed at Sofielund plant early 2015 and a second process was under construction at Hendriksdal plant as of late 2015 capable of treating 3000 m3/h of Biogas[2]. The crude cost of using Biogas as a fuel for the bus fleet is about 8% higher than diesel (2012 prices)[3] but the environmental benefits of Biogas mean it can be considered a net zero carbon fuel. When able to interconnect with the Natural gas grid so the value and utilisation of the resources becomes higher.

Similar schemes have been initiated around Sweden and now 60% of public buses nationally use fuel from biogas, bioethanol or biodiesel.[4]. In the UK pilot biogas to public vehicle fuel pilots have been put in place in the cities of Bristol and Bath

Example of a Bio-Bus in Bath – fuelled with methane recovered from sewage sludge . Source: Atkins



Anaerobic Digestion – the principle means of sludge treatment and energy recovery Source:Atkins

Advanced Sludge processing. Sewage sludge is a difficult material to handle and to treat. It is a complex living mass of highly variable composition potentially containing chemical contaminants such as heavy metals and a wide range of pathogens. Before re-use the dangers in the sludge must be reduced. For chemical contamination such as heavy metals it is generally impossible / very uneconomic to separate them out and so if detected measures must be taken in the sewer catchment to prevent discharges in the first place. For the Pathogenic organisms these will always be present and before sludge can be used in any context where it would be in contact with the environment, such as spread on land, it must be processed to kill pathogens by a chemical or thermal process. Anaerobic Digestion is the main means of treating sludge to stabilise it and to release energy as methane (Biogas), however, this is not a very efficient process. In order to achieve greater integrated use of sludge, a favoured solution is thermal hydrolysis of sludge followed by anaerobic digestion.

Thermal hydrolysis (THP) is a two-stage process combining high-pressure boiling of waste or sludge followed by a rapid decompression. This combined action sterilizes the sludge and makes it more biodegradable, which improves digestion performance. The process also improves the physical structure of the sludge making it easier to dewater and so increase loading rates to digesters. Sterilization destroys pathogens in the sludge so that the residue can meet stringent requirements for application to agricultural land. The main processes in use are the CambiTHP™ process[5] and Veolia's Exelys™ process[6]. An example of the application of this process in the UK is the Esholt treatment works in Yorkshire[7]. Thermal Hydrolysis plants are getting established in China with CAMBI plants under construction at 5 plants in Beijing operated by Beijing Drainage Group[8]. The final residue from digesters where sludge has been pre-treated with THP can be dewatered to 35 to 40% dry solids by physical methods (such as centrifuges, belt or filter presses) and forms a high quality organic agricultural fertiliser and soil conditioner.

Anaerobic Digestion can also be applied to other waste streams such as household, food processing or agricultural waste in isolation or mixed with sewage sludge. In all cases thermal pre-treatment can be considered.

Thermal Pyrolysis

Another route for the treatment and energy recovery from sludge and organic solid waste is thermal Pyrolysis. Pyrolysis is the high temperature decomposition of carbon based material in the absence of oxygen, whereby the outputs are syngas (a highly combustible gas largely comprising carbon monoxide, hydrogen and methane) along with bio-char (a charcoal-like material that is a potential fuel source in its own right). It has significant potential commercial and environmental benefits over other combustion technologies that may be applied to sludge[9].

Pyrolysis may be used on raw sewage sludge or on various municipal, food or agricultural waste components. It can also be applied to the dewatered sludge following THP and anaerobic digestion. Despite great potential for the release of energy in the waste cycle, pyrolysis as a process is still in the development phase with plants processing solid and industrial wastes in operation but as yet no full scale plants in operation processing sewage sludge or mixes. Further strategic investment could bring this technology to commercial scale.

Co-Incineration

Wastewater sludge, generally as dried pellets, can be co-combusted in coal-fired power stations and cement kilns. In power stations, sludge can contribute <5% by weight of the fuel input with minimal impact on operation. Dried sludge has a calorific value similar to a low-grade brown coal. Sludge cake is "dried" prior to firing using the spare water evaporation capacity of the power station required to dry the coal. Very little infrastructure is required in the power station compared with building similar thermal treatment technologies in dedicated sludge plants. The main challenges are in transporting the sludge to the Power Station and regulation regarding combustion of sludge being classed as a waste disposal process unlike burning coal, which can lead to unnecessary administrative complications.

Low Grade Heat and sludge drying. There are major physiochemical and thermodynamic barriers to overcome to separate the water from the sludge. Without separation of the water the energy from combustion, gasification or pyrolysis of the organic material in the sludge will be entirely consumed in the evaporation of the water in it. There are various sludge dryer solutions available that require the input of energy in the form of natural gas to supply the heat for drying[10]. They are also difficult and unreliable to operate. Therefore either low energy separation techniques are needed or a very low cost source of energy can be used to dry the sludge. Where there is access to a thermal pyrolysis of combustion process to release energy from the organic components of the sludge the removal of the water represents an opportunity to utilise low grade heat to concentrate energy into a recoverable form.

Power Plants and many industrial processes produce vast amounts of hot exhaust gasses or hot water from cooling processes. It is difficult to extract such energy for useful purposes. However the evaporation of the water from sludge can represent a means of effectively concentrating that energy in a manner that can make it accessible. Increasing the Dry solids content of a typical Sludge from 25% to 75% dry solids will increase the energy yield from its combustion more than 6 fold, from around 1500 to 9750 kJ per kg. There are various technologies available for using waste heat, concentrated with heat pumps to evaporate the water in sludge and so achieve 75 to 80% dry solids cakes which are then a concentrated energy source[11]. Solar energy can also be used for this purpose, though large areas would be required, this can be better as a combination of drying beds heated by recovered hot water inside greenhouses to gather solar energy as well. (An example of such can be seen in China at Ningjin treatment works in Shandong.)

Greenhouse with floor heated by hot water from heat pumps taking energy from the warmth of sewage treatment works effluent. Sludge Drying system Ningjin, China,[12]

Conclusions

In Europe there is a progression to increasingly integrated sludge management strategies. For example in the Thames water region it is anticipated that in the 10 years from 2008 there would be an increase in the proportion of sludge treated by energy recovery processes from about 40% to about 60% of the total sludge, with a corresponding proportional reduction in sludge sent to land. Thermal hydrolysis is applied to increase the energy recovery yields and produce smaller volumes of higher quality products to send to land. Solutions integrated with solid waste management and the implementation of pyrolysis, gasification and co-incineration will become more developed and widespread[13].. As illustrated in Sweden by integrating the sludge digestion and the transport fuels systems higher value can be derived from the biogas products produced. In China, there has been a massive investment in wastewater treatment capacity over the last 5 to 10 years. Most major towns and cities now have sewerage leading to treatment plants. In recent years the standards for treatment have been raised to full secondary treatment and increasingly to tertiary treatment with nutrient removal.

Credentials:

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Sources and Further Reading

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