Application of Enzymic Hydrolysis technology for VFA production and agricultural recycling of sludge

M.S. Le[1], and D. Harrison[2]
[1]United Utilities North West, Lingley Mere Business Park, Warrington, WA5 3LP, United Kingdom. Tel. 01925 537269. Fax 01925 537511. Email MS.Lee@uuplc.co.uk
[2]Monsal, Oak House, Ransom Wood Park, Southwell Road West, Mansfield, NG21 0HJ, United Kingdom.

Abstract The key principle of the UK Government's vision for sustainable waste management is based on recognising that waste has value and can be moved up the adopted Waste Hierarchy. Enzymic Hydrolysis technology is the application a natural microbial cycle. It harnesses the actions of a series of soil bacteria to accelerate the mineralization process of complex organic matter to return nutrients to the land, destroying harmful pathogens at the same time. The present paper provides an initial report on the use of this novel technology in a sludge digestion process to produce enhanced treated biosolids for agricultural recycling. It also highlights the potential of the technology for the production of Volatile Fatty Acids, which have important applications in wastewater treatment.

Keywords Agriculture; Enzyme; Fermentation; Hydrolysis; Pathogen; Recycling; Sludge; VFA

Introduction

The treatment and disposal of sewage sludge has historically presented a major challenge to society and to the water industry. Rising sludge production coupled with more demanding environmental standards has placed new pressures on the water industry's existing treatment assets. In addition, there has been a big change in waste regulation fuelled largely by the recognition that incineration and landfill are not sustainable options. There is therefore an opportunity to develop processes that deliver products, which meet defined quality standards, and which have value to markets such as agriculture.

United Utilities is one of the 10 privatised water companies in the UK and Blackburn is one of its major sludge centres for the Northern region. Every year the centre processes 13,500 tonnes sludge for 0.5M people from the Blackburn and South Lancashire area and safely recycles it to agriculture as a valuable fertiliser for farmers. The introduction of the Safe Sludge Matrix(1) at the end of 1998 provided new guideline for the treatment of pathogens in sludge. As most of the accessible land bank within 25 miles of the works is grassland, this called for the highest standard of treatment. Since 2003 lime had been added to sludge after digestion for enhanced pathogen destruction to provide a greater safety margin. However, long-term use of lime in sludge treatment was not sustainable because of its high cost, its tendency to increase product odour and soil pH as well as the greater volume at the end of treatment. Ideally, any additional treatment should have none of these drawbacks and should complement or even enhance the existing sludge treatment process.

This paper provides an initial report of the successful completion of the first phase of the Blackburn demonstration programme for the application of Enzymic Hydrolysis technology in sludge agricultural recycling. It also highlights the potential of the technology for the production of Volatile Fatty Acids (VFA), which are essential for successful biological nutrient removal applications.

Enzymic Hydrolysis Technology

Enzymic Hydrolysis technology is the application a natural microbial cycle that occurs during anaerobic digestion. The process is a complex chain of biochemical reactions effected by several types of microorganisms that require little or no oxygen. It is commonly described as a series of four distinct steps:

1. Hydrolysis – the solubilisation of solids by enzymes
2. Fermentation – the biological synthesis of fatty acids
3. Acetogenesis - the conversion of fatty acids to vinegar
4. Methanogenesis – the conversion of volatile fatty acids (VFA) to biogas.

Enhanced Enzymic Hydrolysis is a revolutionary new technique based on Enzymic Hydrolysis technology developed by United Utilities in partnership with Monsal Limited [2,3]. It utilises a novel plug-flow reactor that provides the ideal condition for maximum production of digestive enzymes that are responsible for pathogen destruction and VFA production. This enables a kill rate of 99.9999 per cent, which is over 1000 times more effective than conventional digestion systems. With six tanks in series there is little chance of flow bypass and this also facilitates the natural selection of microorganisms (Figure 1). Sludge is held in the first three reactor tanks at 42°C for 24 hours to encourage the bacteria to grow rapidly and to release their enzymes. The last three reactor tanks are kept at 55°C for maximum pathogen destruction, whilst allowing some of the enzymes to continue working. Hot water from the Combined Heat and Power (CHP) system is used twice, first in the hot stage (HE2) then the warm stage (HE1) for maximum energy efficiency.

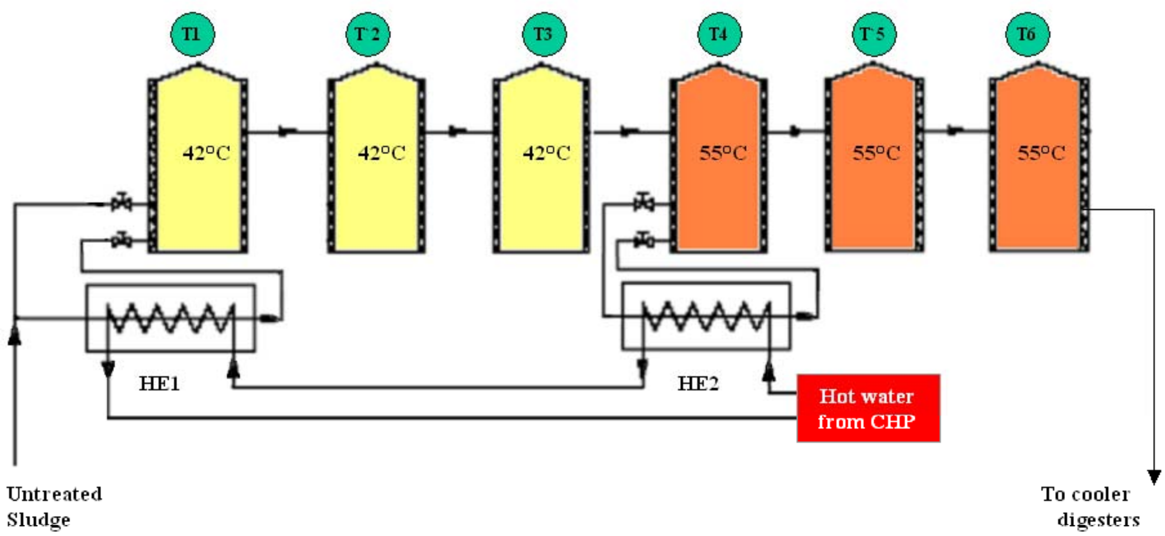

Figure 1 Enhanced Enzymic Hydrolysis Process Schematic Diagram

This breakthrough produces a rich, benign soil nutrient, which meets strict EU specifications and means sludge can be returned safely to the environment. Additionally, a high percentage of the organic content of processed sludge is converted into renewable electricity. This contributes to the government's renewable energy targets and also has commercial value through Renewable Obligation Certificates.

The Blackburn Sludge Treatment Scheme

The Blackburn Sludge Treatment Scheme is the first full-scale demonstration of Enhanced Enzymic Hydrolysis for the production of enhanced treated standard biosolids for agricultural recycling in Europe. The technology is particularly appealing because of its low operating temperature enabling it to work successfully with just waste heat from the CHP scheme. The Safe Sludge Matrix defines two standards of treatment as follows:

- 'Conventionally treated' means that sludge has undergone treatment to reduce its *E. coli* content by at least 99% and the final product has less than 100,000 *E. coli* count per g dry solid. This standard is applicable to arable applications.
- 'Enhanced treated' means that sludge has undergone treatment to reduce its *E. coli* content by at least 99.9999% and the final product has less than 1000 *E. coli* count per g dry solid. The product must also be free of *Salmonella (*not detectable in 2 g dry solid). This standard is essential for grassland as this requires surface application.

The scheme comprises a single Enzymic Hydrolysis process train (Figure 1) and a cooler that feeds four pre-existing mesophillic anaerobic digesters. Each of the digesters has a working volume of 2,000 m^3. The plant can operate in the "Conventional" mode or the "Enhanced" mode. In the Conventional mode all reactor tanks are kept at 42°C, which obviates the need to operate the cooler and reduces energy consumption. This flexibility allows the plant to serve the limited arable land bank during sowing seasons.

Commission of the plant began in December 2005. The following summarises the early performance results of the plant, which has been operating in the Conventional mode.

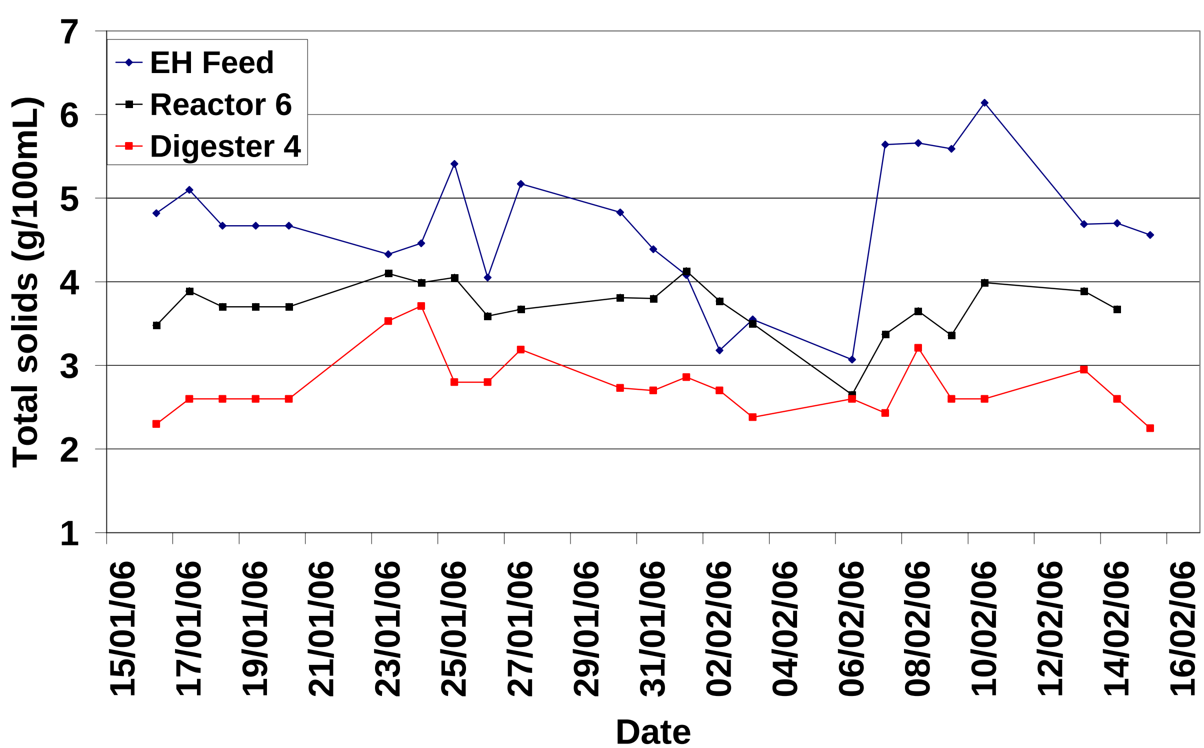

Figure 2 Reduction of total solid in pre-treatment and digestion steps.

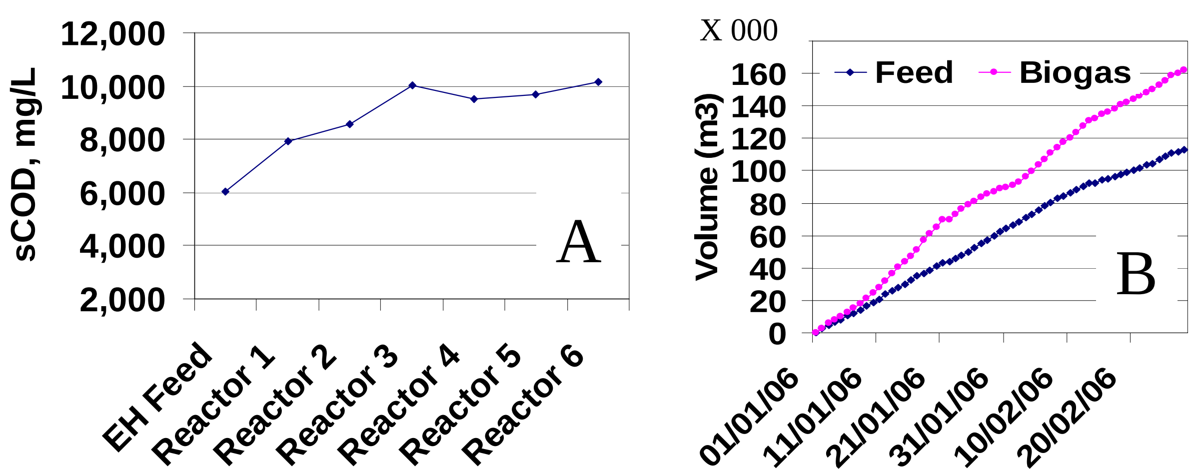

Figure 3 (A) Changes in the soluble COD in the reactor tanks (B) Cumulative sludge volume fed to digester 4 and corresponding biogas volume from same.

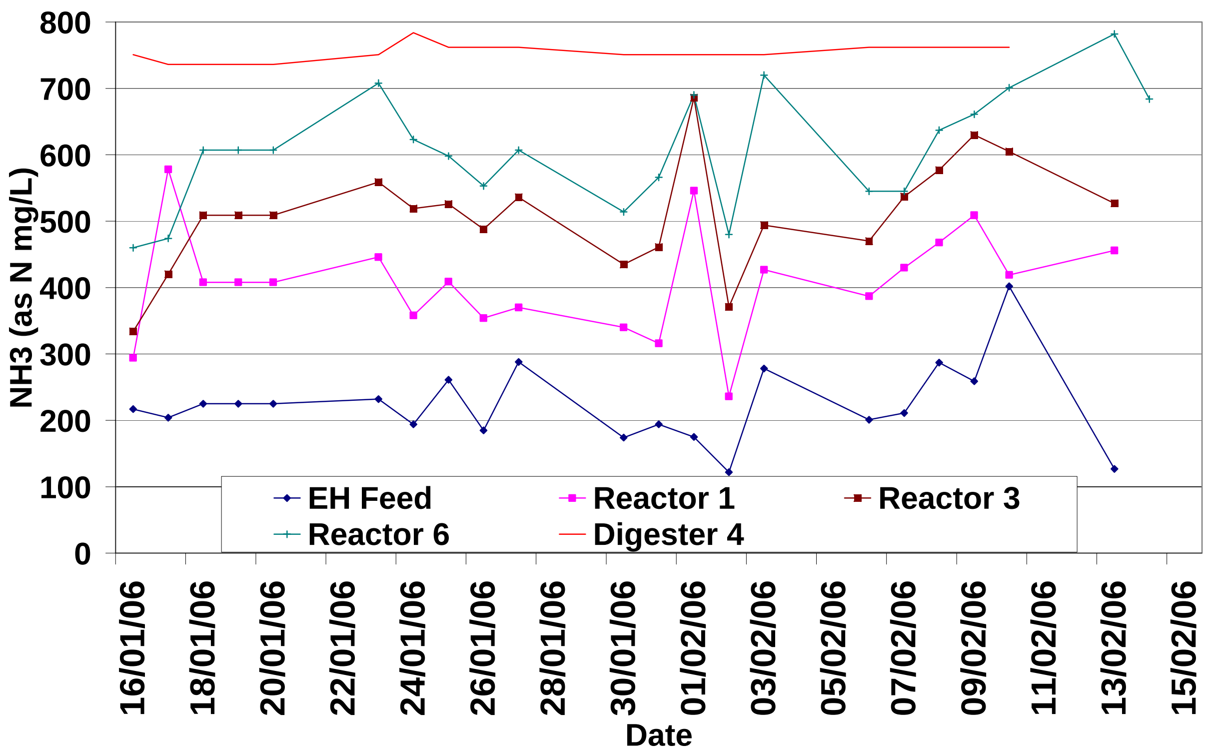

Figure 4 Changes in ammonia level in different reactor tanks.

The early plant performance data showed that there was good overall total solid reduction (41% compared to 35% for traditional digestion). This was probably due to the additional solid destruction in the reactor tanks (Figure 2). The effectiveness of Enzymic Hydrolysis is evident from the substantial increase in soluble COD and ammonia in the reactors (Figures 3 and 4). Figure 3 also shows that the production of biogas was proportional to the sludge feed rate.

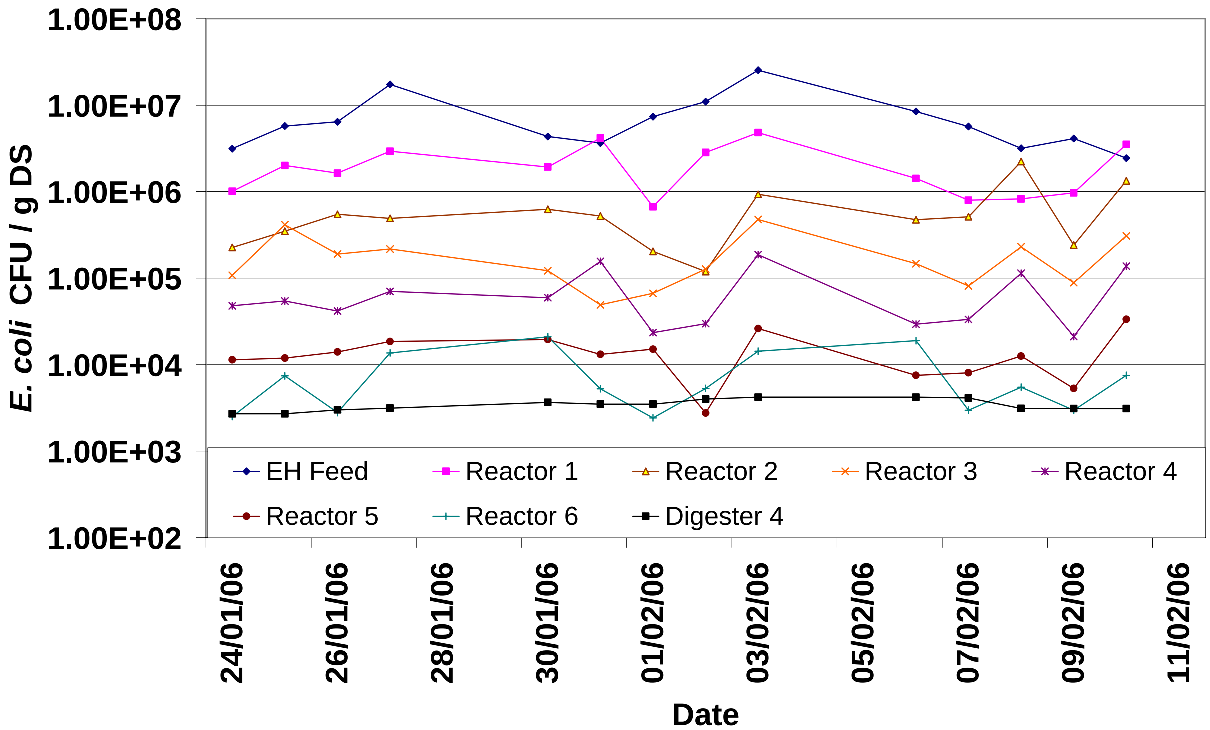

Figure 5 Changes in *E.coli* level in different reactor tanks.

As can be seen from Figure 5, there was a steady reduction *E. coli* as the sludge was passed through the reactor train. Overall, the pre-treatment by itself achieved 3-log reduction in *E. coli* number. The digesters showed very little additional *E. coli* reduction.

VFA Fermentation

Enzymic Hydrolysis technology is currently being considered for the production of VFA from sludge. This novel application is of huge environmental and economic significance. In VFA production the process proceeds through hydrolysis and fermentation to acetogenesis taking up to 6 days from start to finish. The dewatered biosolids is a fermented cake that is virtually pathogen free (meets the UK Enhanced Treated Standard) and suitable for agricultural recycling.

Early results from the large-scale fermentation trial (80 m^3 batch runs) have been very encouraging (Table 1). The liquor contains high level of VFA (up to 6,370 mg/L as C after 6 days fermentation for an un-thickened sludge). No *E. coli* or *Salmonella* were detected in the cake product. The cake stacked well, and was of low odour. Initial test results indicated that the cake met the Enhanced Treated Standard for agricultural recycling. The trial has demonstrated the ability to produce cake of low odour / good stackability in just 4-6 days using Enzymic Hydrolysis technology and centrifuge compared to 30 days by conventional digestion. Since the use of a conventional digester has been avoided, this process would offer huge savings in capital investments as well as the cost of supplying the carbon source where biological nutrient removal is practised.

Table 1 Summary of the VFA fermentation process trial.

Sludge feed	DS %	VS %	pH	total COD	
Average of 7 runs	4.52	72.15	5.72	51,450	
Fermented sludge	SS%	tVFA	pH	total COD	sCOD
Average of 7 runs	2.34	5,580	5.18	41,600	9,392
Fermented liquor	HRT, d	pH	Amm N	COD	tVFA
Batch 4	4	5.2	538	9,360	4,150
Batch 8	6	4.9	450	11,200	6,370
Fermented cake	pH	DS%	*E. coli*	*Salmonella*	
	5.54	27.0	Not Detected	Not Detected	

VS destruction = 67% (Van Kleeck)
TS destruction = 48%
COD destruction = 9850 mg/L (20% of total)

Conclusion

This paper provides an initial report of the successful completion of the first phase of the Blackburn demonstration programme for the application of Enzymic Hydrolysis technology in sludge agricultural recycling. There was good overall total solid reduction (41%). The pre-treatment by itself achieved 3-log reduction in *E. coli* number, exceeding the requirement of the Conventionally treated sludge standard by a good margin. The paper also reports encouraging results that highlight the potential of the technology for the production of VFA, which are essential for successful biological nutrient removal applications.

Acknowledgment

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