OPERATION OF AN UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR (UASB)

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68th Annual Water Industry Engineers and Operators' Conference
Schweppes Centre - Bendigo
7 and 8 September, 2005

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ABSTRACT.

This paper discusses the operation and principles of a UASB in a domestic wastewater treatment plant.

This paper will outline why the UASB was chosen for the Echuca Reclamation scheme, the fundamental concept, process description and optimisation that the process engineers and operations staff encountered during commissioning.

KEY WORDS.

Build, Own, Operate and Transfer. (BOOT), Flow Equalisation tank (FET), Upflow Anaerobic Sludge Blanket (UASB), Chemical Oxygen Demand (COD), Volatile Fatty Acids (VFA,s), Micro-organisms (Acidogenic, Acetogenic, Methanogenic).

1.0 INTRODUCTION.

In a partnership with Coliban Water, Earthtech will operate the Echuca Water Reclamation Scheme under a BOOT contract for the next 25 years.

The use of a UASB process in a domestic wastewater plant is unusual and has come about due to the very high organic loads discharged by industry to the Echuca wastewater system.

This process is complex but highly efficient in the removal of organic content of the wastewater.

1.1 Echuca Reclamation Scheme Layout.

The Reclamation scheme consists of:

- the Inlet works (contrashear mircoscreen rotating drums (2 no), washpactor, grit classifier, and COD, pH, conductivity online measuring instrumentation.
- Flow Equalisation Tank (FET)(1 no) and UASB bypass pump.
- Upflow Anaerobic Sludge Blanket Reactor. (UASB)(2 no) This also includes heat exchangers, boiler and biogas system.
- Intermittent Decanted Extended Aeration reactors. (IDEA's) (3 no cells).
- Filtration. Sand filters (3no).
- Disinfection. Chlorine gas.
- Storage facilities, (Emergency and Effluent storages).
- Solids handling. (ASD, Drying beds)
- Pump stations and associated distribution system.
- Outstations for reuse scheme. Effluent is shandied with Goulburn Murray Water (GMW) irrigation water at 3:1 to 9 no primary producers.

Effluent is treated to class B standard.

Over the next 5 years, the planned upgrades will allow flow from the township of Rochester to be treated at the plant.

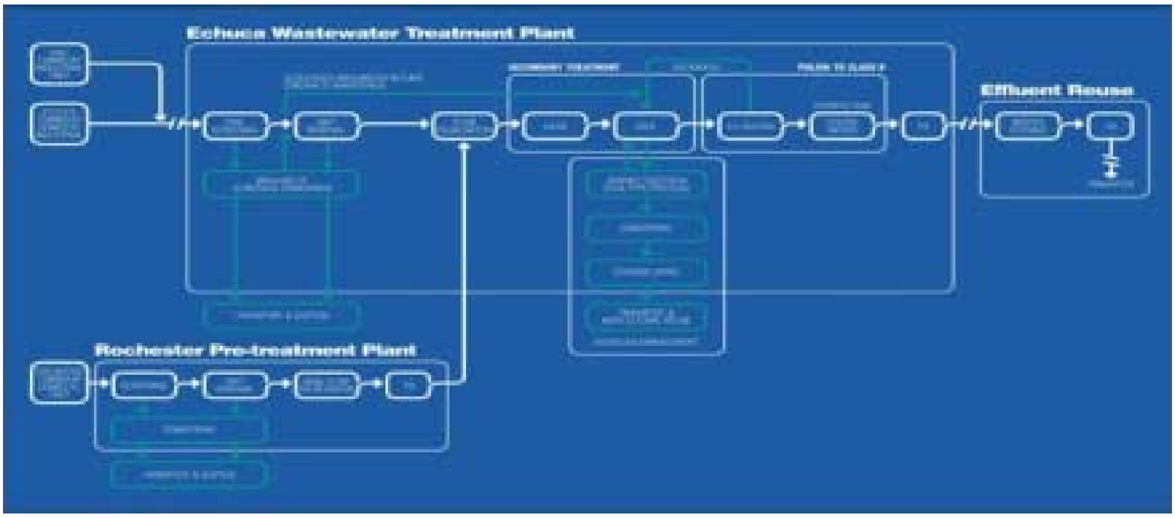

Figure 1: *Echuca Wastewater Treatment Plant Schematic*

Figure 2: *Echuca Wastewater Treatment Plant*

2.0 ECHUCA RECLAMATION PLANT

2.1 Flow Equalisation Tank.

The wastewater from Echuca is pumped approx 7 kilometres from Coliban Water's Terricks Road Pump Station through the inlet works and then flows into the FET. The FET is a 35 metre diameter by 4.15 metre deep concrete (post tensioned) storage that has a upside down roof, (the super structure frame is on the outside of the tank due to the harsh environment inside the tank).

There are 3 agitators located inside the FET that gently mix the influent to allow it to homogenise and prevents settling of suspended solids. The tank also allows for attenuation of the influent flow peak and troughs and pH balancing. Due to the storing of the influent, a reduction in pH occurs with tissue through acidogenic fermentation.

Acidogenesis is where dissolved compounds are converted into simple compounds, (volatile fatty-acids, alcohols, lactic acid, CO_2, H_2, NH_3, H_2S) and new cell-matter.

It was found that a detention time of approx 6 hrs (or 70% of tank capacity) was required to achieve the desired pre-acidification. Pre-acidification is determined by measuring the VFA's to COD ratio.

Figure 3: ***Flow Equalisation Tank***

2.2 UASB feed pumps and Bypass pump.

The wastewater flow from the FET can either be:

- pumped to the UASB,
- bypassed to the IDEA cells, or
- as operation staff have found, partly bypassed around the UASB with a small amount of flow going straight to the IDEA cells
- as the COD removal through the UASB was too efficient and the IDEA process was not receiving sufficient supply of organic material.

2.3 pH Dosing

The pH in the FET effluent line to the UASB is measured with inline pH monitoring instrumentation, caustic soda is dosed to adjust the pH up to the setpoint. A pH of 7.5 has been found to be the optimal level with the level at the distribution loops then lowering slightly to a pH of 7.0 feeding into the reactor. This also minimises the consumption of caustic soda and provides safe operation at level for the methane reactor.

2.4 Recycled flow and Warm Water Recovery Heat Exchanger

FET effluent is shandied with flow from the UASB effluent. The FET recycled effluent then flows through the warm water recovery heat exchanger. It has been found that there is 3 to 4^{o}C transfer of heat at the main heat exchanger.

The warm water heat recovery exchanger recovers the heat from the UASB effluent.

2.5 Heat Exchanger

The main exchanger is a water bath transfer type, connected to the boiler. The boiler is a dual fuel 'Loos' boiler, operated on either LPG, biogas or a mix of both gases.

This second Heat Exchanger further heats the pre-heated influent by approx 2 to 3^{o}C.

2.6 UASB Reactors

The UASB reactors are an enclosed chamber system approximately 6 metres deep and heated influent is passed through a complex distribution system placed evenly across the bottom of the USAB reactor. There are 16 feed loops with 20mm feed holes spaced at even distances to achieve an even up-flow in the reactor, the flow in the loops is rotated daily, thereby reducing blockages.

The rise rate through the reactor is controlled by the feed rate from the FET and the recycle rate. The optimal rise rate in the reactor chamber has been determined to be 0.3m/sec. Recycle effluent is necessary to have sufficient mixing and upflow velocity through the granulated sludge.

As the influent flows through the loops and enters the reactor chamber, a hydrolysis reaction occurs. Hydrolysis is where enzymes excreted by fermentative bacteria convert complex, heavy, un-dissolved materials (proteins, carbohydrates, fats) into less complex, lighter, materials (amino acids, sugars, alcohols).

As the flow rises through the granulated sludge the Hydrolysis reaction is consumed and converted into an Acetogensis form.

Acetogenesis is where digestion products are converted into acetate, H_2, CO_2 and new cell-matter.

As the rise continues the Acetogenesis is consumed and enters the Methanogensis phase. Methanogenesis is where acetate, hydrogen plus carbonate, formate or methanol are converted into CH_4, CO_2 and new cell-matter.

COD removal of up to 80% has been achieved from the influent.

There are 6 sampling points at various heights (located around the UASB to monitor the cells SP1 0.3m, SP2 0.6m, SP3 0.9m, SP4 1.2m SP5 2.0m and SP6 4.0m). These sampling points aid in the monitoring and operation of the UASB by allowing the operators to determine the sludge depth and to take samples for various tests.

2.7 Separators and Biogas system

A 3-phase separator device at the top of the chamber effects the separation of the clarified wastewater, biogas and sludge.

Figure 5: ***View of Separators***

Methane is stored in the top 500mm of the chamber. A biogas compressor extracts the low pressure biogas and compresses it to high pressure which is then used to operate the boiler. If gas production is greater than what the boiler can burn, a flare is used to burn off the excess biogas.
2.8 Sludge.

Excess sludge is withdrawn from the bottom of the reactor. As this is a small amount, it is undertaken twice yearly. The sludge is quite thick (5-10% DS), is stable and can be pumped to the drying beds with the aerobic sludge.

The methods for determination of excess sludge from the IDEA cells is by measuring the amount of sludge carryover in the UASB effluent exceeding 100ml/L of settled volume after 60 mins. The settled volume after 60 minutes from the 6 no sampling points exceeding 1000ml/L on the SP 1,2 and 3 which are spaced 300mm apart, is also another method for calculation of the excess sludge.

2.9 Start up issues

One of the difficulties encountered at the start up of the process was obtaining the initial granulated seed sludge; this was sourced in Melbourne and Brisbane, the sludge had been laying dormant for sometime.

Other problems encountered were:

- At start up and as a result of the low activity of the granulated seed sludge the measured pH was >11. To lower the pH, the UASB cells were dosed with hydrochloric acid.

- The recycle rate was higher than the feed rate and washout of sludge was happening. To keep the velocity in the reactor at 0.3m/sec, it was then necessary to readjust the recycle rate.
- The temperature in the reactors at start up had to be bought up to 36oC to get the bacteria to become active. As UASB cells had not started to produce sufficient biogas to fuel the boiler, it was expensive to operate the boiler on LPG for this period of time.
- Programme changes to the operating system were alos required, so that feed and recycle pumps setpoints can be better controlled.

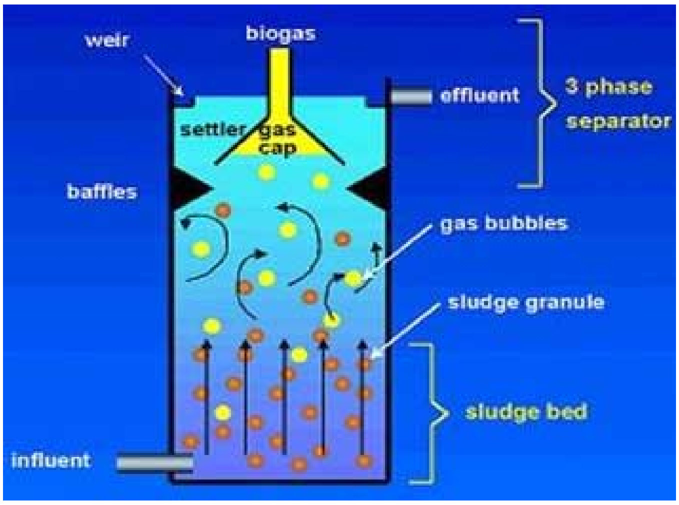

Figure 6: *Diagram of Flow Through a UASB Reactor*

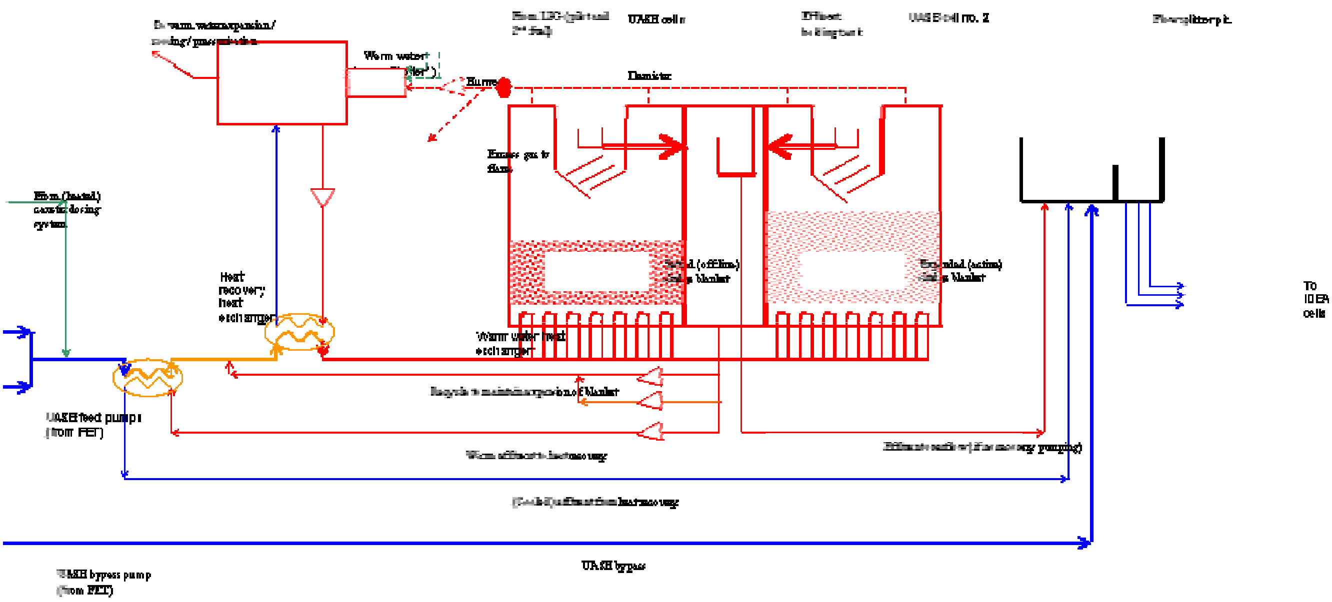

Figure 7: *UASB Reactor*

UASB (simplified)

Note:

Separation of inflow to each UASB cell, ventilation, sampling and excess sludge systems not shown, for clarity. Also note that liquid level inside level will be below overflow weir by a height = gas pressure (~ 0.2 - 0.3m)

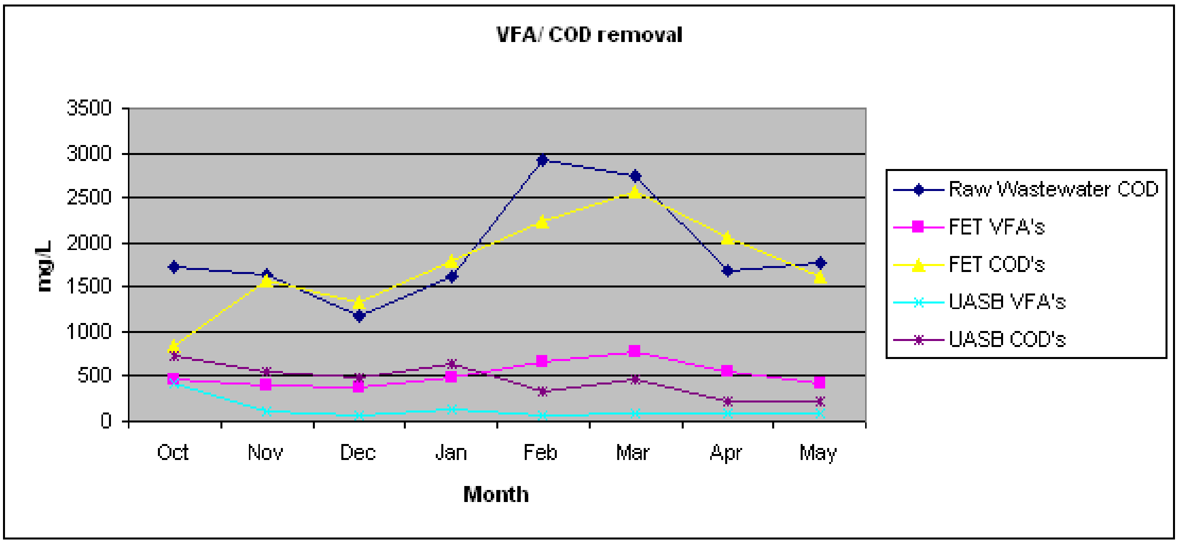

Figure 8: ***Treatment Performance***

3.0 CONCLUSION.

This is the first year of operation of the treatment plant and the operation staff are still learning of ways to operate and optimise the UASB process. From this limited period of operation, it has proven that the selection of the UASB in this particular application has been the correct one. I look forward to being able to further optimise and improve the performance of the plant and particularly the challenges the UASB provides.

4.0 REFERENCES

Earthtech O&M manual (Kay White)
Enviro-Asia Manual (Dennis Cablin)