Nitrogen reduction trials of advanced on-site effluent treatment systems

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The combined effort and cooperation of many parties have contributed to this project:

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Executive Summary

Regional Plans from Environment Bay of Plenty and Environment Waikato have recognised the contribution of significant amounts of nutrients (primarily nitrogen) to sensitive receiving environments from communities, served by on-site effluent treatment systems. Nutrient contributions help to cause the eutrophication of water bodies, especially lakes.

Wastewater treatment technology has progressed in the past few decades. Advanced on-site effluent treatment (OSET) systems are now capable of achieving greater treatment of wastewaters, which in turn results in reduced impacts on the environment. In recognition of this, regional authorities are implementing policies that will utilise commercially available nitrogen reducing on-site wastewater treatment technology, to avoid adverse effects of nutrient discharges to land degrading waterways.

A trial of five commercially available advanced on-site effluent treatment (OSET) systems, has been undertaken to evaluate their potential, particularly with respect to nitrogen reduction. One system, from Devan Blue, was a test system (not commercially available) and this was replaced part way through the trial with a second system. Untreated sewage from Rotorua City's Eastside sewer was fed to the advanced OSET systems over 11 months, with the feed rate simulating typical domestic use.

Once the systems had stabilised (14 to 16 weeks) all showed the capability to reach Environment Bay of Plenty's On-Site Effluent Treatment Regional Plan 2006 Rule 11 and 13 limit of 15 g/m^3 total nitrogen (TN). Only Innoflow's Orenco AdvanTex® AX20 system could remain under the 15 g/m^3 TN for a consistent period as well as complying with Environment Waikato's Proposed Waikato Regional Plan Variation 5 (Lake Taupo Catchment) permitted activity discharge limit of 25 g/m^3 TN. The Orenco AdvanTex® AX20 system achieved an 82% TN removal from the influent. Other systems removed on average 63 to 73% of TN.

Table 1 Statistics for Total Nitrogen in effluent and influent for weeks 16 to 55

Advanced OSET System	Median (g/m^3)	Minimum (g/m^3)	Maximum (g/m^3)
MicroFAST 0.5	23	14	42
Hynds Lifestyle	20	10	27
Oasis 2000	25	10	45
Orenco AdvanTex® AX20	13	7	23
Devan Blue Test System	33	10	53
Devan Blue *DB9000 NRS*	-	14	38
Influent	*71*	*31*	*135*

Note: Devan Blue Test system data is for weeks 16 to 34, and the DB9000 NRS is from week 50 to 55. No median result is presented for the DB9000 NRS as the system was not trialled for a sufficient time to accurately assess its nitrogen reduction performance.

Monitoring results showed that all systems were able to achieve the biochemical oxygen demand (BOD_5) and suspended solids (SS) discharge limits, set in both Environment Bay of Plenty's and Environment Waikato's regional plans. Systems were shown to remove 27-30% of total phosphorus, 92-99% of $CBOD_5$, 96-99% SS, and all systems achieved a better than 10^2 order faecal coliform reduction (Oasis 2000 > 10^5 order).

Installation problems and mechanical failure were some of the reasons attributed to low nitrogen reduction of influent in some systems. External environmental factors were explored as potentially impacting some systems. It was concluded that the as at least two systems achieved excellent TN reduction of the influent that environmental factors had not greatly influenced the trial and were the same for all systems. The functioning of the systems aeration, solids retention times and other system functions are not discussed as these parameters were not measured.

Contents

Chapter 1: Introduction

The contribution of nutrients from on-site effluent treatment (OSET) systems has been implicated as a contributing factor to the eutrophication of New Zealand lakes (NIWA, 2000). Due to the location and density of some lake-side communities served by on-site effluent treatment systems, contributions of up to 25% of the total nitrogen (TN) input to the lake may be coming from OSET systems (NIWA, 2000). To address the continued flow of nutrients into the environment, particularly TN, Environment Bay of Plenty has put in place policies, methods and rules under its On-site Effluent Treatment Regional Plan 2006 (Plan) to limit TN discharges from septic tanks. One method to meet reduction targets set in the Plan, is to replace or modify conventional on-site wastewater treatment systems with advanced OSET systems capable of greatly improved TN reduction.

Nitrogen in influent is primarily composed of organic matter and ammonium-nitrogen, with effluent from conventional OSET systems having greater than 85% ammonium-nitrogen (Bioresearches, 2003). As such, conventional OSET systems have offered little nitrogen treatment. Advanced OSET systems seek to more effectively reduce suspended solids and organic loads, as well as reduce nitrogen. Knowledge of the quantity of nitrogen reduction by advanced OSET systems has for the most part, relied on information supplied by the manufacturers or suppliers of advanced OSET systems. Bioresearches (2003) documented many of the systems available in New Zealand, finding that the TN concentration in the effluent ranged from 0.5 - 45 grams per cubic metre (g/m^3) (i.e. 50 - 80% TN removal)). However, as most of these advanced OSET systems are biological treatment systems employing nitrification-denitrification biological reactions, they are sensitive to a variety of parameters that can affect nitrogen removal efficiencies. For rules for TN discharge limits to be effective, reliable information on the nitrogen reduction from commercially available systems is required.

To gain improved knowledge of the potential for advanced OSET systems, to remove nitrogen from domestic influent, Rotorua District Council, Environment Bay of Plenty and Environment Waikato commissioned a trial of commercially available advanced OSET systems. A number of manufactures and/or suppliers of OSET systems were approached and as a result, five systems were installed for trial (one system, Devan Blue, was changed part way through the trial). All systems were installed without any irrigation treatment connected.

This report details the results of the 55 week trial. The primary objective of the trial is to see if TN output from the advanced OSET systems of 15 g/m^3 is achievable and to discuss factors inhibiting nitrogen reduction. An opportunity is also provided in the trial to observe how well the advanced OSET systems meet suspended solids (SS) and biochemical oxygen demand (BOD_5) levels, as set in the On-Site Effluent Treatment Regional Plan 2006.

Chapter 2: Trial regime

Five advanced OSET systems (Table 2) were trialled to determine outputs over the period of eleven months (May 2005 to April 2006), with the exception of two systems: Oasis supplied system was monitored for nine months and the original Devan Blue test system was replaced after seven months by the DN9000 NRS (the Devan Blue test system initially installed will not be available on the commercial market).

Untreated wastewater from Rotorua City's Eastside sewer is screened, before passing into a header tank from which influent is delivered to the systems in equal quantities. Influent was pumped to each system twice daily by positive displacement pumps operating from a single variable drive. Loading regime was 1.0 m^3/day/system with 66.7% of the load delivered between 6 am and 11 am every morning and the balance between 6 pm and 9 pm at night. This pumping regime is designed to simulate average household usage. Harrison Grierson Consultants and AWT New Zealand Limited provided technical assistance for the trial setup.

Table 2 System specifications from supplier

Supplier	System	Treatment		Process	Effluent Quality		
		Flow (L/day)	Tank Capacity (L)		BOD_5 (g/m^3)	SS (g/m^3)	TN (g/m^3)
Innoflow Technologies Limited	Orenco AdvanTex® (AX20)	1,900	7200	Recirculating textile packed bed filter.	≤ 15	≤ 15	<25#
Hynds Environmental Systems Limited	Hynds Lifestyle	1,800	8,500 (1,850)^	Submerged Aeration Filtration (SAF) technology.	≤ 20	≤ 20	≤ 25-30
Oasis Clearwater Environmental Systems Limited	Oasis 2000 (TEXASS)	2,500	9,400	Submerged membrane reactor, aerated waste water system.	≤ 30	≤45	≤10
Smith & Loveless new Zealand Limited (FAST)	MicroFAST 0.5	1,800	5,400	Fixed activated sludge treatment, aerated with suspended growth media (with SFR Biomicrobics).	≤ 10	≤ 10	≤ 10*
Devan Blue∆	DB 9000 NRS	1,500	6,400	Advanced multi stage fixed growth aerated system.	≤ 20	≤ 30	-

*Based on total kjeldahl nitrogen (TKN) figures supplied (TKN + Nitrate ≤10).
^ Emergency storage capacity.
# Based on results from Orenco AdvanTex® (AX100) systems (or larger).
∆ Systems specification for new installed system (First system will not be commercially available).

Photo 1 Advanced OSET trial site, Rotorua

Effluent from each system was collected in a 200 litre drum from which grab samples were taken between 7 am and 11 am. Sampling occurred every six days, ensuring sampling occurred on a different day of the week. Over the fifty-five weeks of sampling, samples were also taken every day for five to six days, every seven to ten weeks. The effluent distribution and sampling programme is based on information from Ewert, Couper and Maginness (2005).

Samples were analysed for pH, alkalinity (Alk), total nitrogen (TN), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), total phosphorus (TP), dissolved reactive phosphorus (DRP). Additional analyses of carbonaceous oxygen demand ($CBOD_5$), total suspended solids (SS) and faecal coliforms (FC) were done on the consecutive daily sampling events. Analysis was performed by the Rotorua District Council Environmental Laboratory (IANZ accredited) in accordance with “Standard Methods for the Examination of Waste Water”, APHA, AWWA, WPCF. Temperature of effluent was measured in the outflow collection drums. The drums are filled intermittently depending upon the individual system characteristics. As 1,000 litre of influent is introduced to each system over the course of a day, the 200 litre effluent drums are periodically flushed as influent is introduced.

Chapter 3: Results

The results of analysis are presented in two forms. The first is based on grab samples taken daily over six to seven days, which occurred at six to ten week intervals (see Table 3 and Figure 1). The second is based on grab sample data taken every week, where six days equals one week (see Figure 1, Figure 2, and Table 4).

Effluent characteristics of the five systems are variable for most parameters partly due to problems experienced by some systems, changes in influent quality and environmental factors. All systems do achieve high percentage reductions in SS, $CBOD_5$, FC and TN, once the systems stabilised. After the initial stabilisation period (16 weeks) all systems averaged a better than 90% reduction in $CBOD_5$, SS and FC (Table 4). Reduction in TN varied from 63% to 82% and all systems achieved a very similar reduction in TP, varying from 27% to 30% (Table 3).

The systems generally maintained a pH of greater than pH 7, with the average influent pH at around pH 8. All systems were net users of alkalinity using on average 43% to 81% of alkalinity.

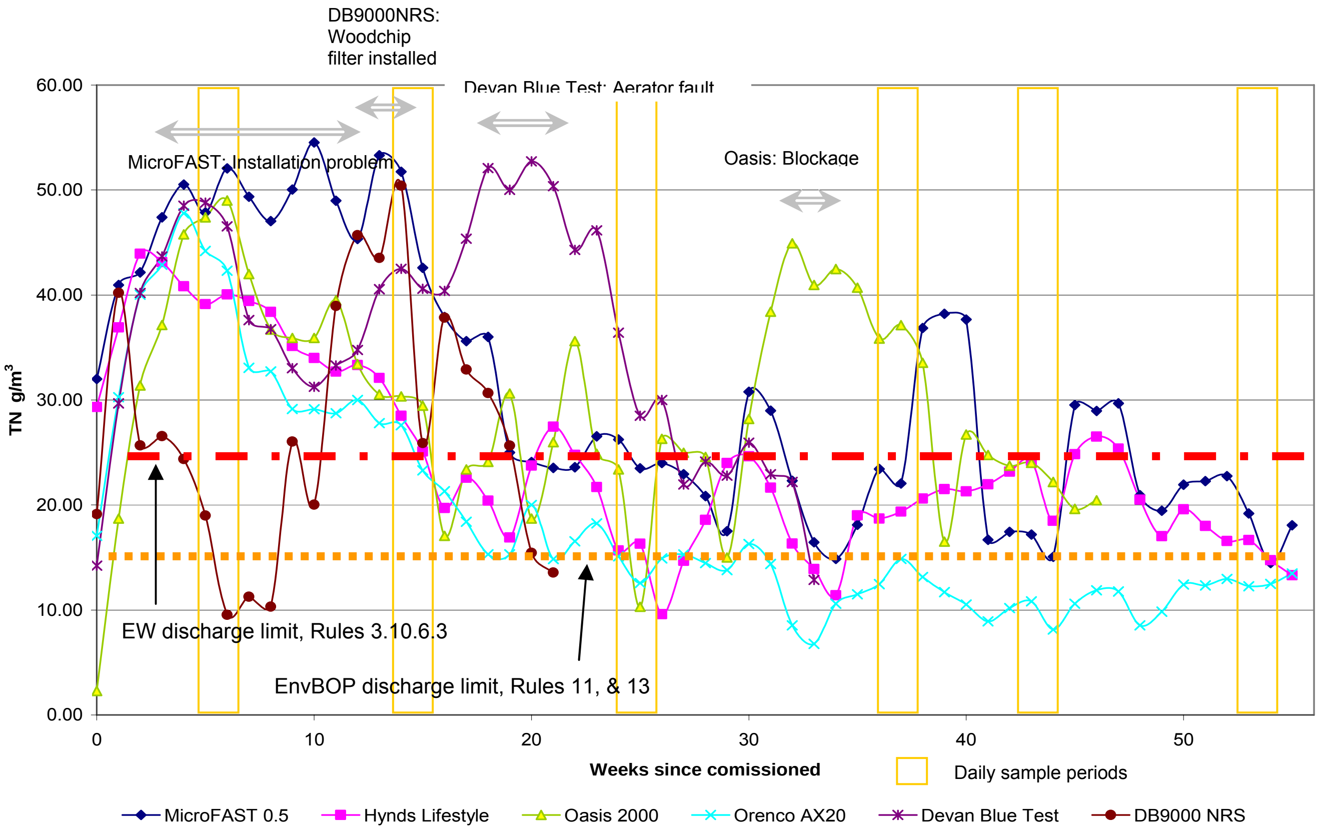


Figure 1 Total Nitrogen for five advanced on-site effluent treatment systems. (Note: the Oasis 2000 was installed 10 weeks after other systems, and the DB9000NRS 35 weeks after).

Table 3 Average characteristics of influent and effluent over time

Influent	Alk (g/m^3)	pH	$CBOD_5$ (g/m^3)	FC cfu/100mls	SS (g/m^3)	Temp °C	NH_4-N (g/m^3)	TKN (g/m^3)	TO_XN (g/m^3)	TN (g/m^3)	TP (g/m^3)
Wk 6/7	273.6	8.4	245	10914286	275	15.8	51.8	72.8	0.2	73.0	12.0
Wk 15/16	224.9	7.7	217	4300000	497	14.7	36.1	53.4	0.0	53.4	9.0
Wk 25/26	210.7	7.7	138	4557143	152	17.9	35.2	50.7	0.0	50.7	7.9
Wk 37/38	279.9	8.2	165	10200000	193	19.5	50.8	67.8	0.3	68.1	10.4
Wk 44/45	322.2	8.3	310	14757143	399	19.8	62.6	91.5	0.0	91.5	13.8
Wk 54/55	286.6	8.3	236	8248333	269	17.8	56.4	75.8	0.0	75.8	11.6
FAST – MicroFAST 0.5											
Wk 6/7	243.1	7.4	52	1765714	27	13.2	42.3	52.4	0.0	52.5	7.8
Wk 15/16	203.9	7.9	7	26617	6	14.5	32.1	35.7	2.0	37.7	8.7
Wk 25/26	161.4	7.6	12	85714	15	18.0	17.8	22.2	2.8	24.9	9.1
Wk 37/38	161.0	7.7	7	70833	6	20.8	19.1	23.8	2.2	26.0	9.0
Wk 44/45	176.0	7.8	9	134000	9	19.0	22.7	26.9	1.9	28.8	8.9
Wk 54/55	91.0	7.3	5	57083	6	16.2	5.9	8.4	5.9	14.2	8.0
Hynds Lifestyle											
Wk 6/7	14.4	6.4	7	279143	13	12.5	1.2	4.7	35.9	40.6	6.9
Wk 15/16	51.3	7.2	2	20367	3	12.8	0.2	2.5	19.2	21.7	8.2
Wk 25/26	69.0	7.2	5	42429	5	17.2	0.2	3.2	12.5	15.7	8.7
Wk 37/38	52.6	7.2	4	26000	7	19.9	0.5	3.5	17.8	21.3	8.7
Wk 44/45	32.0	7.0	4	9461	9	18.3	0.3	2.6	22.2	24.8	8.2
Wk 54/55	62.1	7.4	1	15683	2	16.3	0.1	1.6	9.9	11.5	8.1
Oasis – Oasis 2000											
Wk 6/7	-	-	-	-	-	-	-	-	-	-	-
Wk 15/16	78.1	7.4	8	83133	6	13.1	10.9	15.4	29.1	44.4	7.5
Wk 25/26	33.3	7.2	1	7	1	18.1	0.1	1.4	24.0	25.4	8.2
Wk 37/38	67.7	7.3	5	148	10	20.0	0.6	2.6	18.2	20.9	9.1
Wk 44/45	294.1	8.3	2	12	3	16.7	32.6	34.7	0.6	35.3	5.7
Wk 54/55	59.6	7.4	1	3	0	15.9	0.0	0.4	14.8	15.2	7.3
Innoflow - Orenco AX20®											
Wk 6/7	152.6	7.2	5	12729	8	11.8	21.5	23.8	11.0	34.8	7.3
Wk 15/16	61.1	6.6	3	53967	5	12.4	0.4	3.2	19.4	22.6	7.8
Wk 25/26	71.3	6.9	2	37314	2	17.1	0.1	1.9	12.5	14.4	8.6
Wk 37/38	70.5	6.7	1	44286	2	19.6	0.2	1.5	13.3	14.8	8.3
Wk 44/45	82.8	7.1	1	51857	2	17.6	0.2	1.4	9.3	10.8	8.1
Wk 54/55	72.0	6.8	1	24467	1	15.7	0.1	0.8	9.7	10.5	7.5
Devan Blue – DB9000 Test System											
Wk 6/7	184.8	7.7	20	1228000	16	12.9	31.2	35.1	2.6	37.7	7.7
Wk 15/16	206.4	7.6	10	62167	8	14.6	33.7	37.7	1.7	39.5	8.5
Wk 25/26	120.7	7.4	6	16629	5	18.3	16.2	18.9	6.9	25.8	8.6
Devan Blue – DB9000 NRS											
Wk 37/38	49.9	7.1	8	16229	10	19.7	6.4	10.4	17.1	27.5	8.7
Wk 44/45	206.9	7.2	84	422857	11	17.6	32.0	38.1	0.0	38.1	8.4
Wk 54/55	89.9	7.3	5	20167	6	16.3	9.6	8.6	3.5	12.1	8.3

Temperatures increased with the warmer summer months then began to cool again, with the trial ending in autumn. Under normal installation conditions, these systems would be inserted in the ground and thus moderated by the insulating effect of the ground. As the systems are above ground, it is possible that temperature variations have affected trial results. In winter, it is likely that the advanced OSET systems would go through a greater temperature change over the course of a 24 hour day. The effect of temperature on the systems is further discussed below.

Table 4 Percentage removal of influent constituents by OSET systems

System	TN	TP	$CBOD_5$	SS
MicroFAST 0.5	67%	30%	96%	96%
Hynds Lifestyle	73%	31%	98%	98%
Oasis 2000	63%	27%	99%	98%
Orenco AX20®	82%	30%	99%	99%
Devan Blue DB9000 NRS	67%	30%	89%*	97%

*BOD reduction was negatively influenced by installation of a bark filter. It is likely to be similar to the other systems trialled.

Figure 1 shows a plot of TN over the 55 week trial. In Figure 1 and Figure 2, it can be seen that Orenco AdvanTex® (AX20) and Hynds Lifestyle systems have achieved the best nitrogen reduction, followed by the MicroFAST 0.5. The range of TN found in the effluent and influent as well as medium and inter-quartile data is displayed in Figure 2. Data used to derive Table 4 and Figure 2 is from week 16 onwards, after which time the systems had stabilised and good TN removal rates were occurring for most systems.

Table 5 Statistics for Total Nitrogen for weeks 16 to 55

System	n	Mean (g/m^3)	Median (g/m^3)	Minimum (g/m^3)	Maximum (g/m^3)	Std.Dev. (g/m^3)
MicroFAST 0.5	41	25	23	14	42	7
Hynds Lifestyle	41	20	20	10	27	4
Oasis 2000	32	27	25	10	45	9
Orenco AX20®	41	13	13	7	23	4
Devan Blue Test*	20	34	33	13	53	13
Devan Blue DB9000 NRS*	6	-	-	14	38	-
Influent	*41*	*72*	*71*	*31*	*135*	*28*

* Statistics representing the new Devan Blue test are from week 16 to 34, DB9000 NRS from week 50 to 55.

All systems did achieve less than 15 g/m^3 TN in effluent at some stage in the trial. However, only one system did this with any consistency. Other systems dipped below the 15 g/m^3 TN target for only a short period.

Systems have taken around 14 to 16 weeks to settle in as nitrifying bacteria numbers build up and the nitrification-denitrification process starts to function effectively (Figure 1). After this time all systems (apart from the MicroFAST 0.5 system) start markedly reducing the total nitrogen in their outflow. The Devan Blue supplied test system seems to be on par with the Innoflow and Hynds supplied systems until week 10 when the TN content of the raw sewage increased. After this point, the Devan Blue supplied test system has an increased TN concentration in its output and shows some recovery when the TN concentration of the raw sewage drops.

An incorrect installation has been found to be the reason for the MicroFAST 0.5 systems lack of performance in nitrogen reduction over the first 14 weeks of the trial. This problem was rectified on 22 July (week 14) and adjustments made through to 29 July.

A blockage and consequent overflow from the Oasis 2000 system has also affected nitrogen renovation over weeks 30 to 34. It would also appear that further problems have occurred with the MicroFAST 0.5 and Devan Blue systems at various times from week 34 onwards (Figure 1).

A new Devan Blue system was replaced the test system at week 35. The DB9000 NRS system stabilised relatively quickly under summer conditions, compared to the other systems installed in winter, achieving less than 15 g N/m^3 TN within five weeks. However, it would seem installation of a wood chip filter detrimentally impacted on the system impeding nitrification. Unfortunately, this phase of the trial ended without accurate determination of the systems nitrogen reducing capability. However, from week 53 onwards, with removal of the filter, the system was achieving excellent TN reduction.

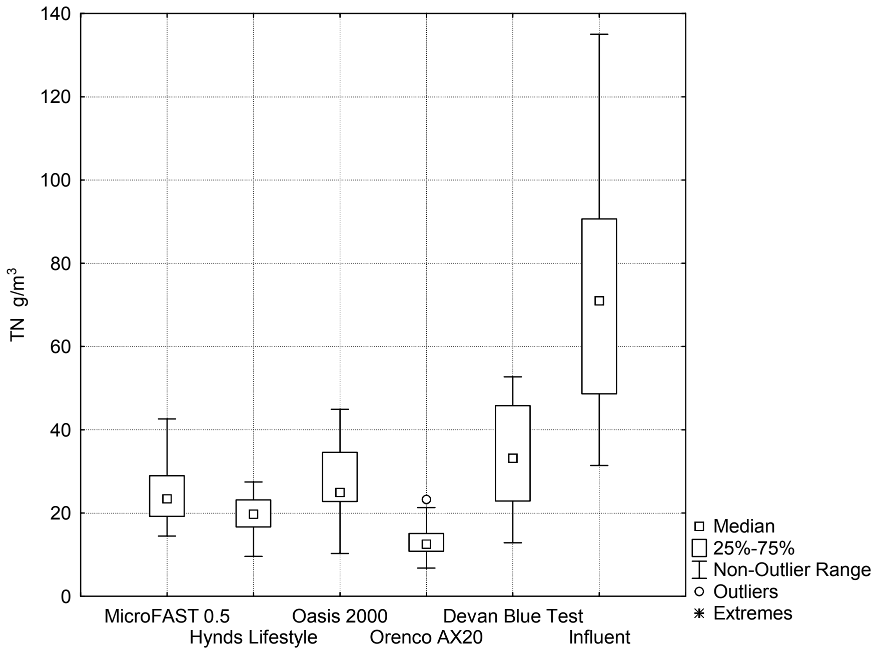


Figure 2 Total nitrogen box-whisker plots for advanced on-site effluent treatment system (effluent and influent), from week 16 (Oasis 2000 from week 26).

Faecal coliform levels were generally reduced by an order of greater than 10^2 (Figure 3). The Oasis 2000's membrane filtration system achieved the best faecal coliform reduction being greater on average than 10^5 reduced.

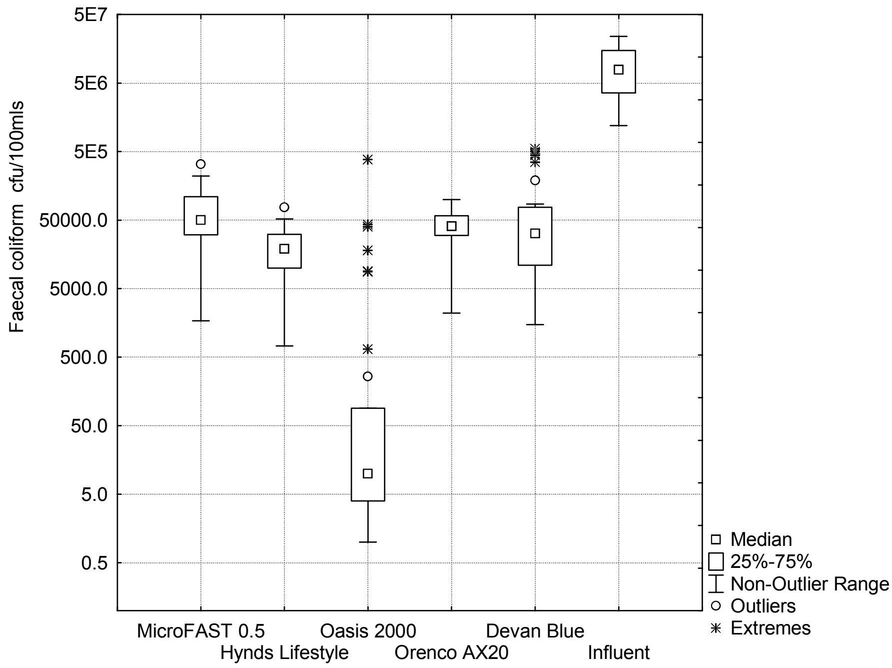


Figure 3 Faecal coliform box-whisker plots for advanced on-site effluent treatment system effluent and influent, from week 15

Chapter 4: Discussion

The Innoflow supplied system (Orenco AdvanTex® AX20) achieved a median TN of 13 g/m^3 for the period week 16 to 55, with TN removal efficiency better than 88% at its peak performance (Figure 4). This was the only system to consistently remain under the 15 g N/m^3 target. Next best was the Hynds system, with a median of 20 g/m^3 TN and a peak removal of over 84% TN. Median values for MicroFAST 0.5 and Oasis 2000 systems were 23 and 25 g N/m^3 respectively. The Devan Blue test systems median TN value over the 16 to 34 week period was 33 g N/m^3, however with replacement of the test system with the DB9000 NRS system this figure looks to have the potential to improve.

Once systems had established nitrifying-denitrifying bacteria, only the Orenco AdvanTex® AX20 systems managed to meet Environment Waikato's permitted activity rule discharge limit of 25 g N/m^3 in the effluent.

Both the Innoflow and Hynds supplied systems have been effective in nitrification and nitrate dissimilation. The other systems have at time had problems with nitrification. This can be partly explained by mechanical faults and installation problems, but there are other factors that have been raised as potential reasons for less than ideal total nitrogen reduction.

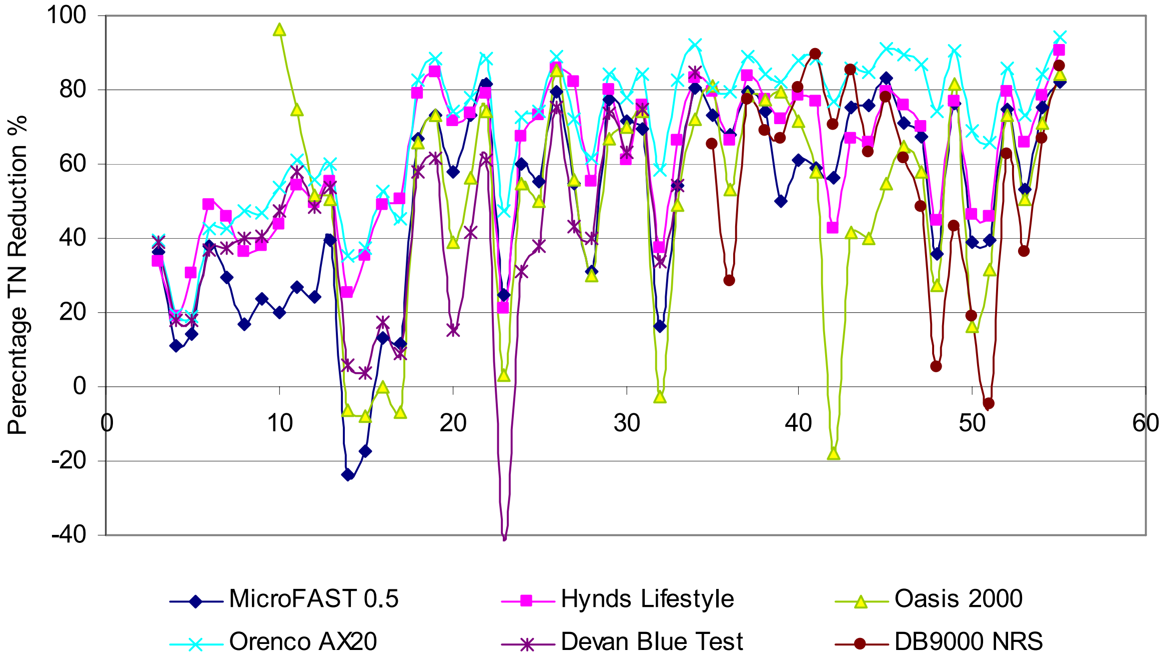


Figure 4 Percentage TN removal or influent by advanced on-site effluent treatment systems, based on weekly data

Reduction of TN through nitrification-denitrification and nitrate dissimilation in septic systems can be affected by a variety of factors. These include:

- Features of the systems (e.g. capacity, surface area, circulation, etc.)
- Dissolved oxygen content
- Organic loading rate and solids retention time
- Inhibiting substances
- Alkalinity and pH
- Available carbonaceous material
- Temperature

4.1 System features and function

Each system has different features and this analysis will not dwell on any specific system feature(s) or function(s), accept to report electricity consumption (measured during the trial).

Two systems had consistent electricity consumption over the trial period (Figure 5), Orenco AdvanTex® AX20 and Hynds Lifestyle. Other systems had variable consumption due to a variety of factors: mechanical failure; incorrect installation; and blockages.

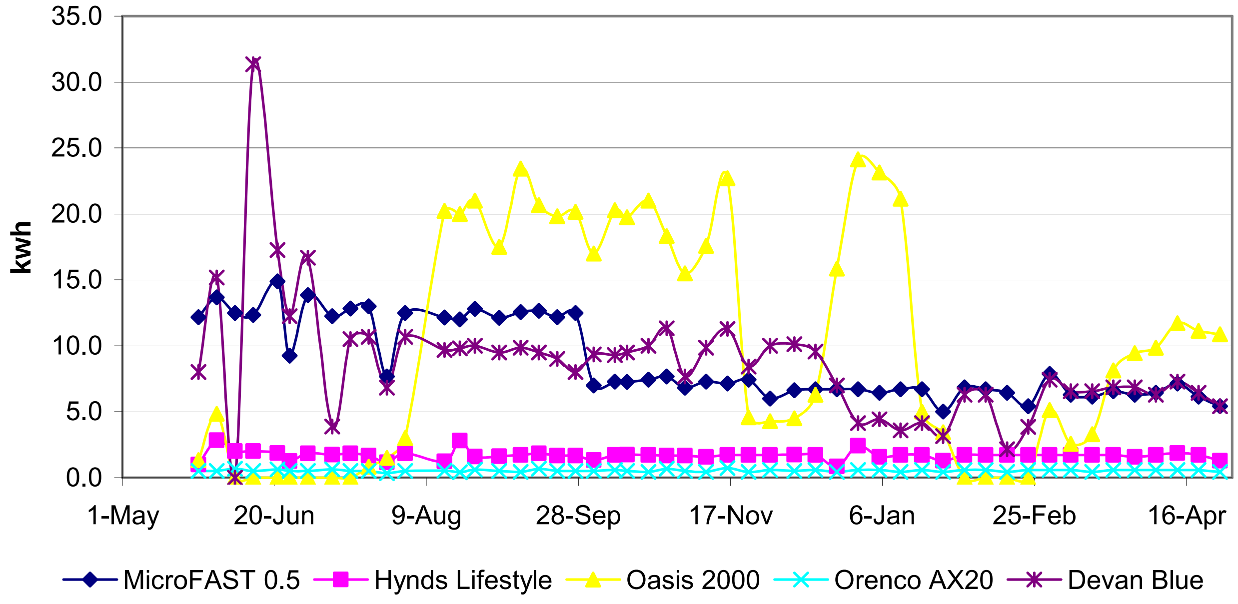


Figure 5 Electricity consumption by advanced OSET systems over trial

4.2 Dissolved oxygen

Specific system aeration characteristic and dissolved oxygen (DO) content are not being measured in this study and so cannot be considered in this analysis. It is just worth mentioning that decreased DO can become a growth limiting factor in the nitrification process and this is likely to have played a part in the increase in TN in the Devan Blue test system when the aerator malfunctioned.

4.3 Organic loading rate and solids retention times

Organic loading rate and solids retention times can affect both nitrification and denitrification. The loading rate (influent) is fixed for all systems and is designed to be representative of the loading rate for an average household, within the design specification of the systems. However, depending upon how an effluent treatment system is designed, the ratio of BOD_5 to total kjeldahl nitrogen (TKN) can affect the nitrification process.

Figure 6 shows the correlation between $CBOD_5$ and TKN in the influent over the trial. This correlation plot shows that over the trial the ratio between $CBOD_5$ and TKN has been reasonably consistent. Using a conversion factor for changing $CBOD_5$ to BOD_5 of 0.68 the median ratio of BOD_5:TKN is 2.0 (sd = 0.7). Such a ratio suits systems with a separate stage nitrification chamber (Water Pollution Control Federation, 1983). Most systems have such a chamber and this helps increase the BOD_5:TKN for nitrification in the next stage. Thus the organic content of the influent should be suitable for most advanced on-site effluent treatment systems trialled, with the influent being delivered at a fairly consistent BOD_5:TKN ratio.

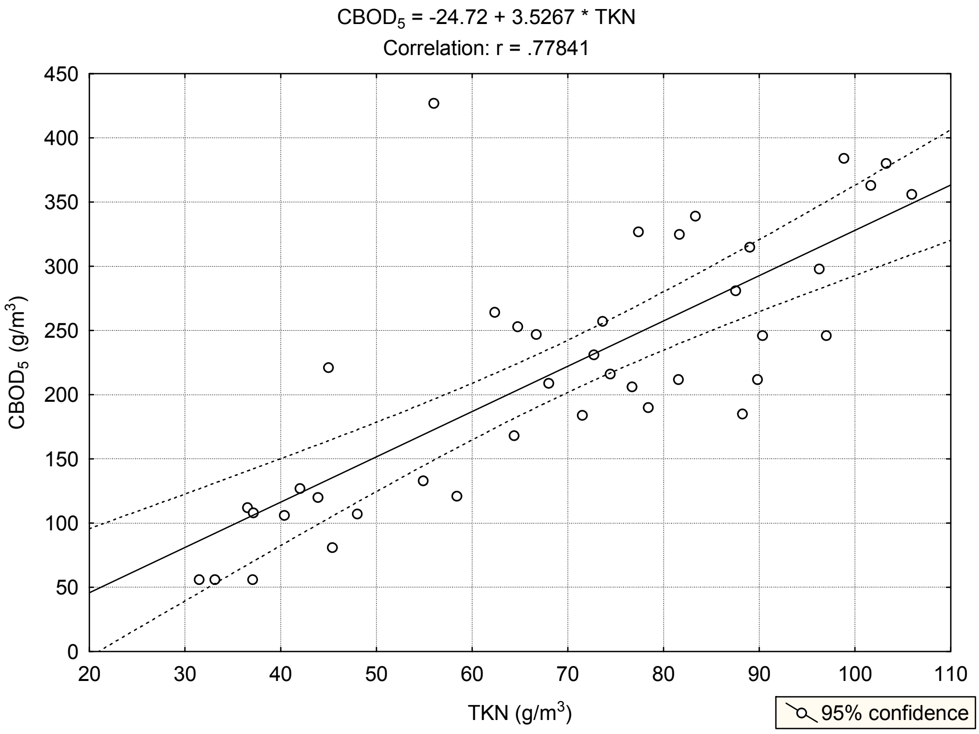


Figure 6 Correlation of $CBOD_5$ and TKN in influent

4.4 Inhibiting substances

The influent comes from a predominantly urban source, with minimal contributions from industrial and commercial premises. It is likely that a variety of substances could be present in the sewage that may affect the growth of bacterial species and enzymes in the advanced OSET systems. However, inhibition of nitrification does not seem to have occurred in the Orenco AdvanTex® and Hynds Lifestyle systems, with both systems achieving high ammonium-nitrogen conversion to nitrate and nitrite. Thus it is likely that the influent has not contained inhibiting substances in high enough concentrations to greatly impact on the nitrification process in the advanced OSET systems.

4.5 Alkalinity and pH

A low pH will inhibit nitrification/denitrification and this is controlled by the available alkalinity. The pH in all systems remains fairly stable (Table 2). Generally an alkalinity of greater than 50 g/m^3 is recommended to deal with fluctuations in influent ammonium-nitrogen concentrations. For pH, the recommended optimum level for nitrification is a pH of 7.5 to 8.6, while maintaining a pH of greater than 7.2 and between 7 and 8 for denitrification (Water Pollution Control Federation, 1983).

Alkalinity and pH are not measured within the systems, so no assessment of their controlling influence is made here. One observation worth noting is that the Orenco AdvanTex® AX20 outflow pH reaches as low as 6.2 (Alk < 50 g/m^3). However, a low pH in the outflow does seem to have affected nitrogen reduction with excellent results still being achieved.

4.6 Carbon content

Removal of available carbon in the advanced on-site effluent treatment systems occurs in settling, nitrification and dissimilation of nitrate. An excess of available carbon in the nitrification process can limit nitrifying bacterial growth. The microorganisms responsible for completing the dissimilation of nitrate are facultative heterotrophic aerobes contained in the wastewater that are also responsible for $CBOD_5$ oxidation. Again, carbon is not measured within the systems so no assessment of carbon limiting nitrification-denitrification reactions is made here.

4.7 Temperature

Temperature affects the biochemical reactions within the advanced on-site effluent treatment system. Changes in the influent can also be brought about by seasonal temperature differences. Temperature changes (diurnal or otherwise) within the systems are difficult to establish without 24 hour monitoring, but is likely to vary within in each chamber. Figure 7 shows that the effluent temperatures have their greatest difference between readings in winter, lying somewhere between influent and ambient air temperatures. Effluent temperatures reach just under 10ºC in winter and over 20ºC in summer.

Comparison of ambient air temperatures (measured at Pererika, Rotorua) with effluent temperatures indicate that effluent temperature in the systems drops with air temperature changes. It is unlikely that the extent of diurnal temperature variation that occurs in ambient air is repeated in the systems, as the lowest temperature recorded in the 200 litre drums was 8.5ºC compared to an 8 am low of 4.0ºC. This would suggest that heat loss occurs, but may not be significant in the systems over a 24 hour period.

As temperature effects nitrification it also has a direct relationship with the growth of microorganisms. The rate of ammonium-nitrogen oxidation is directly proportional to growth of nitrifying organisms and it can be seen that in both the Innoflow and Hynds systems ammonium- nitrogen oxidation has been achieved, almost completely regardless of temperature variation. Effluent from the Orenco AdvanTex® AX20 has recorded the lowest temperatures (Figure 7) and yet has one of the best nitrification rates, also suggesting temperature has not had much of an impact on the TN reduction.

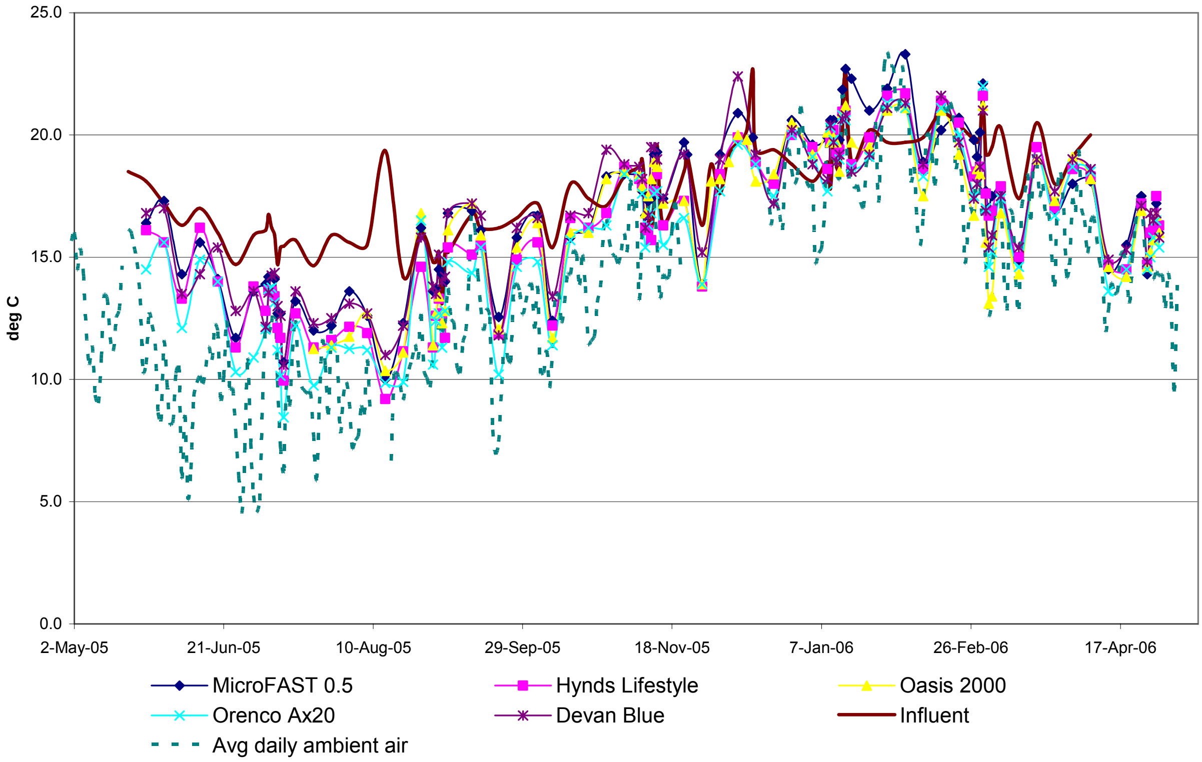
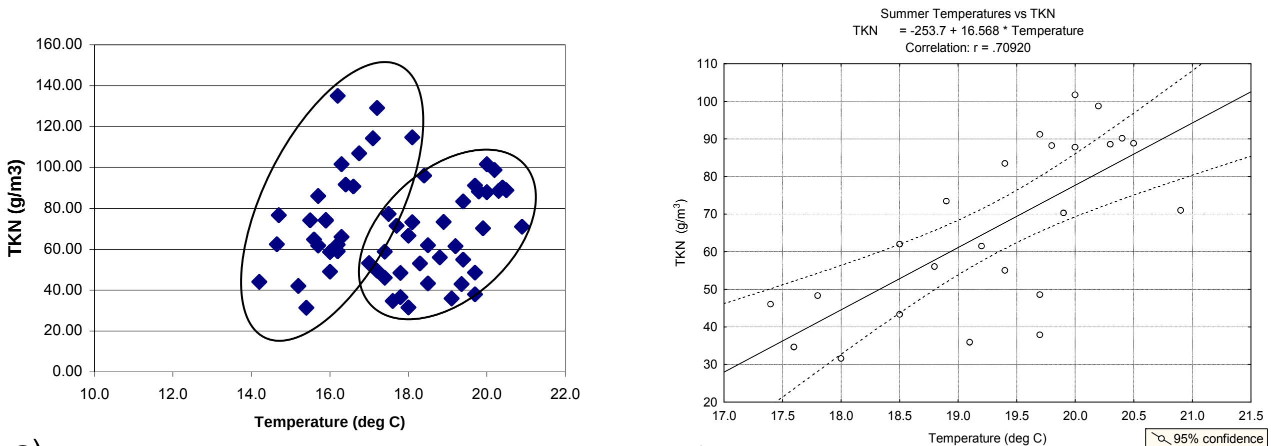


Figure 7 Ambient air, influent and effluent temperatures

Given the current data set, it is difficult to tell if temperature is a major limiting factor in the dissimilation process. However, denitrification has been reported to occur as low as 0ºC (Water Pollution Control Federation, 1983).



a) b)

Figure 8 Influent temperature versus TKN for a) over the trial period and b) summer.

The TKN concentration is important as it dictates available carbon in the system to the quality of NH_4-N to be converted. It is possible for hydrolysis/acidogenisis of the influent to be influenced by temperature. Analysis of influent data indicates that the influent make-up has changed with a change in temperature (Figure 8). In Figure 8 (a) when influent temperature is plotted against influent TKN, two distinct groups of data are apparent. Inspection of the groups (minus outliers) shows that there was a distinct summer grouping (late November to mid April) and a winter grouping. Correlation of the summer grouping indicates that TKN is temperature related, however no correlation is found for the winter grouping. This would suggest that influent organic loading is more variable over the winter months, potentially impacting on the nitrification process.

Chapter 5: Conclusion

A trial of five different advanced on-site effluent treatment systems has successfully provided information on the ability of these systems to reduce nitrogen, BOD and SS in domestic sewage. The focus of the trial was on the reduction of total nitrogen to meet the limits as stated in Environment Bay of Plenty and Environment Waikato regional plans.

The limit of 15 g/m^3 from rules 11 and 13 of Environment Bay of Plenty's On-Site Effluent Treatment Regional Plan 2006 was achieved by all systems in this trial (after settling). However only one system, Innoflow's Orenco AdvanTex® AX20, could sustain this target. It was also the only system to meet the Environment Waikato regional plan maximum permitted discharge limit of 25 g N/m^3.

Several systems had problems over the trial period. The MicroFAST 0.5 had an initial installation problem, Devan Blue's installation of a woodchip based filter in their DB9000 NRS system resulted in elevated $CBOD_5$ and TN concentrations. Likewise the Oasis 2000 systems results were affected by a blockage during the trial.

All systems successfully achieved the limits for BOD_5 and SS as set by Environment Bay of Plenty's and Environment Waikato's regional plans.

Systems took around 16 weeks for nitrogen reduction to stabilise to around target levels. When this wasn't achieved it became apparent that incorrect installation or system malfunctions had caused nitrogen reduction to fluctuate.

Environmental factors influencing the trial with the potential to compromise the efficiency of the advanced OSET systems to reduce nitrogen were explored. These potential problems included micro-organism inhibition due to toxicants in the influent, temperature extremes, variation in alkalinity and influent concentrations and loading. It is concluded that environmental factors did not have much bearing on trial results as they were the same for all systems and some systems achieved excellent nitrogen reduction.

Influent quality does not seem to have been a factor affecting the nitrification-denitrification process. However, influent is more variable over the winter months than summer. This difference is temperature driven and may affect the functioning of some systems. While temperature may affect nitrification/denitrification, the major limiting factors are alkalinity, pH and possibly the carbon content of the influent.

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Appendices

Appendix I Log book – record of visits to and work done on systems

Appendix I – Log book – record of visits to and work done on systems

OSET log book					
Ref No.	**Date**	**Time**	**Person/Company**	**Nature of Visit**	**Comment**
1	20/05/05	7:00	Andy B	Vf drive tripped	Reset drive and PLC. Pump unblocked system back on line by 10:00am
2	23/05/05	9:30	Jack LeComte	Unblock pump 5	Blocked with rags
3	26/05/05	9:00	Jack LeComte	Unblock pump 4	Line from pump blocked, cut line fit mac union.
4	31/05/05	11:00	Devan Blue	System 5 had no power	Bplug in shed not in properly.
5	10/06/05	8:30	Mark Mohi	Vf drive fault	Fitted extension to system 5 pipe. Leak in last joint (KJ/SB informed Devan Blue. System 4 Kwh meter to be checked. (Townley Elect.
6	13/05/05	10:15	Devan Blue	Installed plate clarifier	Installed plate clarifier into irrigation pump sump. Installed pressure gauge to irrigation filter.
7	13/06/05	12:10	Devan Blue	Noted nitrate still lowish & Amm. High	Change setting X 2 Aeration.
8	21/06/05	10:30	Hynds Environmental	Check aeration and filters	Zabel blocked so cleaned and replaced
9	23/06/05	8:45	Innoflow	System check	Checked levels;POD growth. Temp monitoring to be set up by AB
10	28/06/05	3:00	Devan Blue	Check out system	Added sep-tech 500ml to aeration tank all well.
11	1/07/05	10:15	Devan Blue	Site visit with Lix Milne for sampling	Ecogent Karl & Bill visit lab for latest results.
12	6/07/05	16:00	Jack LeComte	System 5 not using Kwh	Found main switch on unit "OFF" turned on.
13	11/07/05	15:30	Andy B	Increase pump rates	Increased min speed P1 - 18 to 25: P2 - 17 to 25: Done to increase daily flow up from 930 litres per day.
14	19/07/05	14:30	Oasis	Commissioning System 3	
15	20/07/05	8:45	Tony Hamon	All pumps tripped	Reset system
16	21/07/05	15:00	Smith & Loveless	Checked system found Aeration fault.	Put up sign
17	22/07/05	10:00	Smith & Loveless	Fixing system problem	Adjusted aeration pipe by raising 100mm. Need to return later to do electrical mod.
18	22/07/05		Niki J & John B	?? Hynds	Checked aeration; changed valve for clarifier (ball to gate). Cleared zabel & irrigation filter. Zabel filter blocked.
19	23/07/05		Smith & Loveless	Checked system after pump pipe changed	
20	28/07/05		Smith & Loveless	Pump pip[e unit cut shorter	
21	29/07/05	7:00	Andy B	No flow	Fault on level probe no flow till 10:00
22	29/07/05	10:00	Andy B		Increased min speed P1 - 25 to 30: P2 - 25 to 30: max speed P1 - 79 to 85: P2 - 63 to 70.Done to increase daily flow up from 930 litres per day.
23	29/07/05	11:00	Smith & Loveless	Process Check	Checking unit after alteration made yesterday
24	29/07/05		Hynds Environmental	Visitors escorted to plant by JD.	Complaint received 1/8/05 re visit and S&L working on their unit.
25	15/08/05	9:30	Andy B	Pumps tripped	Reset back on line 9:30am

26	15/09/05		Devan Blue	Clean service system	
27	28/09/05		S&L	System tripped - entire system removed pump connection	
28	29/09/05		S&L	All working again	
29	5/10/05		Hynds Environmental	General check	All good
30	5/10/05		Townley Elect	Change date for daylight saving	
31	11/10/05		Devan Blue	Service	Clean filters
32	28/10/05		Oasis	Check System	
33	7/11/05		Devan Blue	General check	
34	16/11/05		Hynds Environmental	6 monthly service	Beauty
35	17/11/05		Oasis	F/T sludge return and clean	All good
36	22/11/05		Townley Elect	Connect up Super treat	
37	23/11/05		S&L	Sampling influent & Effluent	
38	15/12/05		S&L	General check	Grab sampling
39	21/12/05		Devan Blue	Install new replacement system	
40	23/01/06		Biolytix	System Commissioning	
41	26/01/06		Devan Blue	General check adjust recycle time	cool
42	9/02/06		Oasis	Unit overflowing	
43	16/02/06		Devan Blue	Install clarifier unit to pump out stage	even more cool
44	20/02/06		Biolytix	Paint lid white	
45	23/02/06		Devan Blue	Check clarifier seal cable junction	
46	27/02/06		Devan Blue	Sample taken	
47	1/03/06		Hynds Environmental	Service reset sludge return	
48	7/03/06		Devan Blue	Sampling influent & Effluent	
49	??		Devan Blue	Remove polishing filter	
50	5/05/06		Hynds Environmental	General check	
51	1/06/06		Devan Blue	Relocate flow meter	