PERFORMANCE RANKING of ON-SITE DOMESTIC WASTEWATER TREATMENT PLANTS

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Background

The Bay of Plenty Regional Council (BOPRC), Waikato Regional Council (WRC) and Rotorua District Council (RDC) began testing ex-factory on-site domestic wastewater treatment units in 2005 to assess their total nitrogen reduction performance. The objective was to certify treatment performance capabilities for systems to be installed in the Rotorua Lakes (15g/m^3 Tot-N) and Lake Taupo (25g/m^3 Tot-N) catchments. Manufacturers were making unproven claims as to Tot-N reduction performance and with over 30 plus systems on the market the councils needed to be certain that treatment units installed in developments around the lakes would achieve their effluent quality requirements.

Early Testing Trials under BOPRC Management

The first two testing trials [Trials 1 and 2 (2005 to 2007)] were carried out at an unsecured testing facility set up at Rotorua Wastewater Treatment Plant (Figure 1). However, problems with the dosing system and the lack of site security initiated a re-design of the testing facility at the end of Trial 2. Following a major upgrade carried out by RDC in 2007 (Figure 2) a new on-site effluent treatment testing facility (OSET TestFac) was commissioned for Trial 3 (2007/2008).

The OSET NTP

During 2008 SWANS-SIG (the Small Wastewater and Natural Systems Special Interest Group of Water NZ) negotiated with BOPRC and RDC to utilise the new TestFac for an On-site Effluent Treatment National Testing Programme (OSET NTP). Funding grants from the Ministry for the Environment and the Water Managers Group of Water NZ facilitated the development and publication of testing procedures. An approach was then made to all local government authorities throughout New Zealand for funding grant support during which some 13 Regional and Territorial Councils were recruited as Funding Partners. OSET NTP operations then commenced with Trial 4 (2008/2009).

Manufacturers/suppliers pay a testing fee, and funding grants cover management and audit costs. The oversight and management structure is shown in Figure 3. SWANS-MAG is the specialist Management and Audit Group appointed by SWANS-SIG which provides oversight of the operations team and audits and reports on all testing results.

Systems Tested

Twenty companies and one council agency (BOPRC) have participated in Trials 1 to 8 from 2005 through to 2013. Some 35 OSET systems have been tested (Figure 4)

- 18 during Trials 1 to 3 under BOPRC oversight and
- 17 during Trials 4 to 8 under OSET NTP oversight.

BOPRC Trial 3 testing results were used to prove the OSET NTP auditing and reporting methods. The OSET NTP has audited and reported on test results for 21 systems over Trials 3 to 8 (see Table 1 below).

Testing Procedures

Trial 4 testing procedures (the first under OSET NTP oversight) involved:

- 2 month settling in period (biological media development);
- 3 month pre-benchmarking period (nitrification and denitrification development period);
- 3 month benchmarking period; and
- 1 month high flow test period (with a doubling of flow over one week followed by three weeks recovery).

[1] On-Site NewZ is an Information Service for the NZ On-site Domestic Wastewater Industry
www.onsitenewz.wordpress.com

Samples are taken on a six day cycle so as to cover all days of the week. Dose loading is a 1,000L/day controlled discharge to represent daily flow increments from a typical household.

Table 1: OSET Units Tested Trials 3 to 8 (2007 to 2013)

Company	OSET Unit	Treatment Process	Abbreviation
Trial 3 (2007/2008)			
Biocycle Holdings, Napier	Biocycle 6300 [development model not available commercially]	SAF	**Biocycle**
Innoflow Technologies Ltd, Auckland	AdvanTex AX-20 Mode 3	rPBR-T	**AdvanTex**
Oasis Clearwater Systems, Christchurch	Oasis Clearwater S 2000	SAF	**Oasis**
Waipapa Tanks, Kerikeri	Waipapa Tanks Maxi-Treat MV-C 3000 (superseded by Econo-Treat)	SAF	**Maxi-Treat**
Trial 4 (2008/2009)			
Humes Pipeline Systems, Auckland	Humes FR1 [model not currently available commercially]	SAF	**Humes**
Hynds Environmental, Auckland	Hynds Advanced Lifestyle	SAF	**Hynds**
WaterGurus (NZ) Ltd, Christchurch	WaterGurus NovaClear	MBR	**NovaClear**
Waipapa Tanks, Kerikeri	Waipapa Tanks Econo-Treat VBB C-2200 2	SAF	**Econo-Treat**
Trial 5 (2009/2010)			
Devan Group, Tauranga	Devan Green [model not available commercially]	SAF	**Devan**
RX Plastics Ltd, Ashburton	Airtech 7000	SAF	**Airtech**
Innoflow Technologies Ltd, Auckland	AdvanTex AX-20 Mode 3	rPBR-T	**AdvanTex**
Trial 6 (2010/2011)			
Bay of Plenty Regional Council, Whakatane	BOPRC AWTS NI [Council evaluation of bark-bed denitrification system]	AWTS-NI	**AWTS-NI**
Quantum Waste Water Systems, Levin	Quantum Eco System	SAF	**Quantum**
Trial 7 (2011/2012)			
Allflow Equipment Ltd, Nelson	Allflow Klaro 9000 10PE	SBR	**Klaro**
Trial 8 (2012/2013)			
Aqua Nova NZ Ltd Auckland	Aqua-nova	SAF	**Aqua-nova**
Aqua Nova NZ Ltd Auckland	Aqua-nova NR	SAF-NR	**Aqua-nova NR**
TechTreat Ltd Kerikert	TechTreat SS10	SAF	**TechTreat**
Ecological Technologies Auckland	BIOROCK-S	Passive Media	**BIOROCK**
Findlater Construction Ltd nelson	Findlater PA 5x5	SAF	**Findlater**
Super-Treat Systems NZ Ltd, Kerikeri	Super-Treat NZ12	SAF	**Super-Treat**
EcoSewerage, Coromandel	Eco Sewerage	Worm-Wetland	**EcoSewerage**

Treatment Process Key:

SAF	Submerged aerated filter	AWTS-NI	Submerged aerated filter & bark bed denitrification
SAF-NR	Submerged aerated filter & nitrogen reduction	Passive media	Gravity dosed patented media layers
MBR	Membrane aerated bioreactor		
SBR	Sequencing batch reactor	Worm-Wetland	Worm based primary treatment & wetland cells secondary treatment
rPBR-T	Textile recirculating packed bed reactor		

Performance Evaluation
There are two phases to performance evaluation. First, BOD and TSS results are assessed against AS/NZS 1547 secondary effluent quality requirements [90% samples <20/30g/m^3 BOD/TSS]

Second is benchmarking involving 16 test results from 3 months operation for six effluent quality parameters plus power consumption. Benchmark letter grade ratings are based on median values for effluent quality as per Table 2 below:

Table 2: Benchmark Rating Indicators

Rated indicators for median value	Rating letters and corresponding effluent quality				
	A+	A	B	C	D
BOD (g/m^3)	<5	<10	<20	<30	≥30
TSS (g/m^3)	<5	<10	<20	<30	≥30
Total nitrogen (g/m^3)	<5	<15	<25	<35	≥35
Ammonia nitrogen (g/m^3)	<1	<5	<10	<20	≥20
Total phosphorus (g/m^3)	<1	<2	<5	<7	≥7
Faecal coliforms (cfu/100ml)	<10	<200	<10,000	<100,000	≥100,000
Energy (kWh/d)	0	<1	<2	<5	≥5

Test Results
Of the 21 systems Trials 3 to 8 which the OSET NTP has audited and reported on, three have been withdrawn from the market, one has been superseded by a new model and a fifth is a non-commercial system (BOPRC bark filter unit). Reports are provided to individual manufacturers and Funding Partner Councils and one page "performance certificates" are posted on the OSET NTP web-pages on the SWANS-SIG website for use by members of the public.

Meeting AS/NZS 1547 Requirements
Of the 17 commercially available systems audited and reported on during Trials 3 to 8, only 47% met 100% of the BOD_5 and TSS requirements (that is 8 treatment units out of 17) with the other 53% (9 treatment units) meeting only the 90% requirements. This demonstrates that treatment systems at the scale required to handle daily household wastewater flows can exhibit variable performance, even under controlled conditions as at the testing facility.

Two of the 4 commercially withdrawn systems did not meet the AS/NZS requirements and one system did not submit for AS/NZS review

Performance Ratings under Benchmark Testing
The following Charts are derived from the rating tables within the performance certificates available from the website.

Aggregated benchmark rating
The aggregated benchmark rating overall comparison (Chart 1) is based on scoring A+ at 5, A at 4, B at 3, C at 2 and D at 1. For example the sample rating table below (Table 3) has a score of 24.

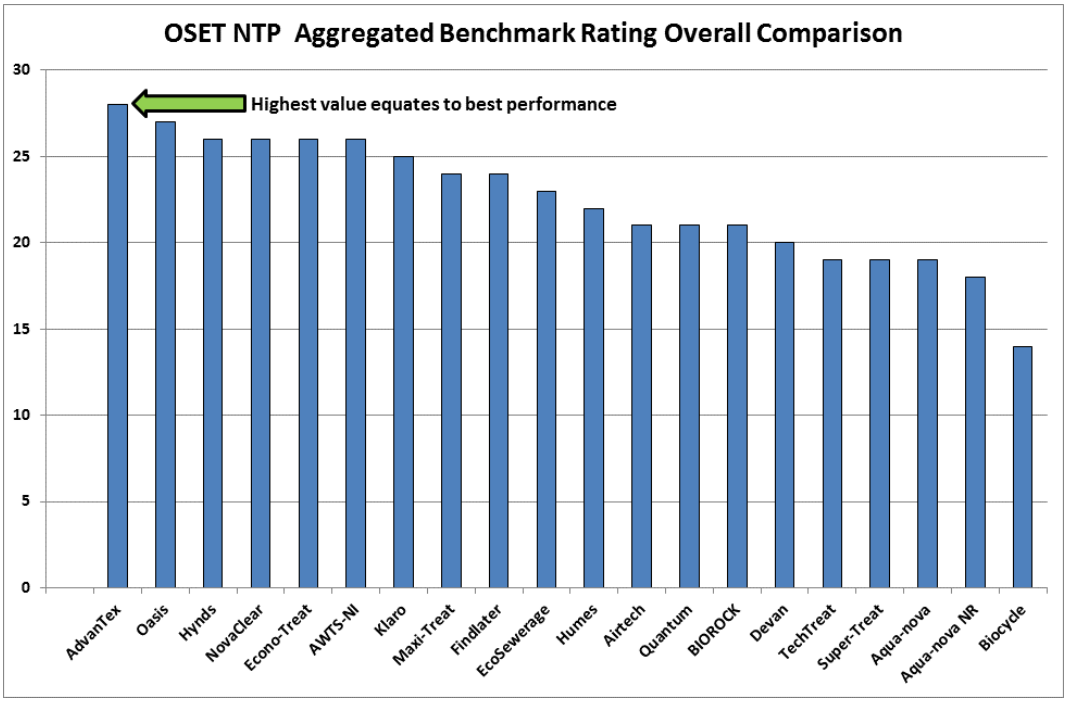
This aggregated benchmark rating can also be converted to a "Performance Star Rating" as set out in Chart 2.

Chart 2 shows that the AdvanTex recirculating packed bed reactor textile filter and the Oasis submerged aerated filter are the top performing treatment units at a Five Star Plus rating.

Table 3: Sample Rating Table

Indicator Parameters	Median	Std Dev	Rating	Rating System				
				A+	A	B	C	D
BOD (g/m^3)	**7.2**	4.7	**A**	<5	<10	<20	<30	≥30
TSS (g/m^3)	**4.5**	7.2	**A+**	<5	<10	<20	<30	≥30
Total nitrogen (g/m^3)	**18.4**	2.5	**B**	<5	<15	<25	<30	≥30
NH_4- Nitrogen (g/m^3)	**2.91**	1.14	**A**	<1	<5	<10	<20	≥20
Total phosphorus (g/m^3)	**4.23**	0.55	**B**	<1	<2	<5	<7	≥7
Faecal Coliforms (cfu/100mL)	**75,500**	29 x 10^3	**C**	<10	<200	<10,000	<100,000	≥100,000
Energy (kWh/d) (mean)	**1.55**	--	**B**	0	<1	<2	<5	≥5

Chart 1:



Treatment performance stability

The median values of benchmarked parameters have been used in Chart 1 to rank the aggregated performance. However it is the standard deviation which indicates the variability of results. The higher the standard deviation the less stable the treatment performance related to an individual parameter. If the standard deviation values are summed for each of the five chemical parameters then a comparison between the summed values can be made. This comparison is set out in Chart 3.

Chart 2:

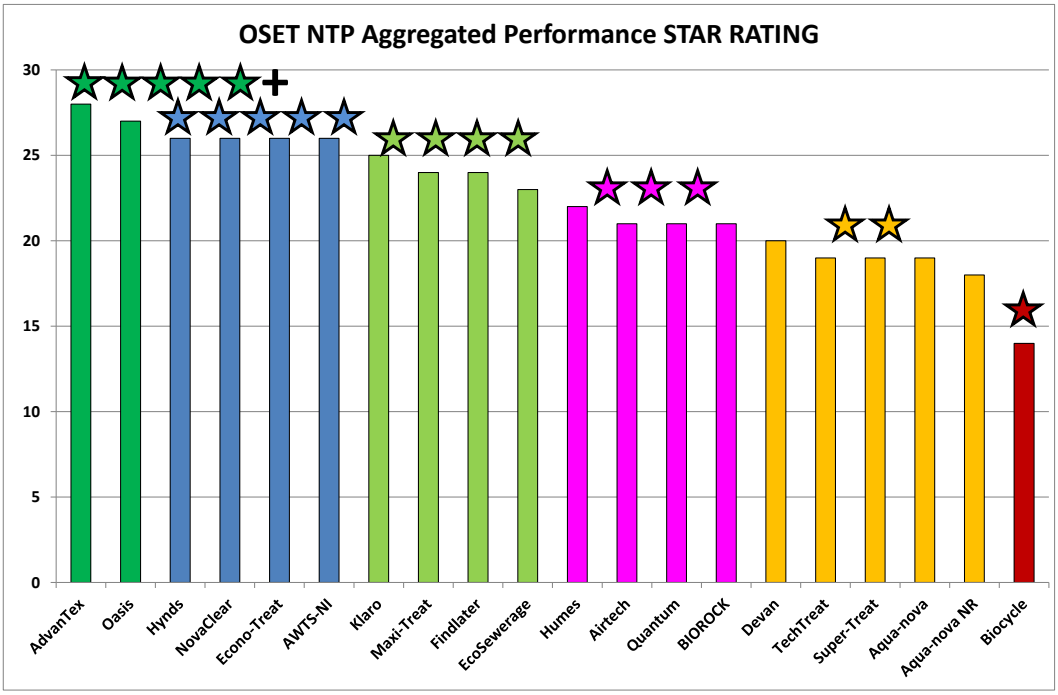
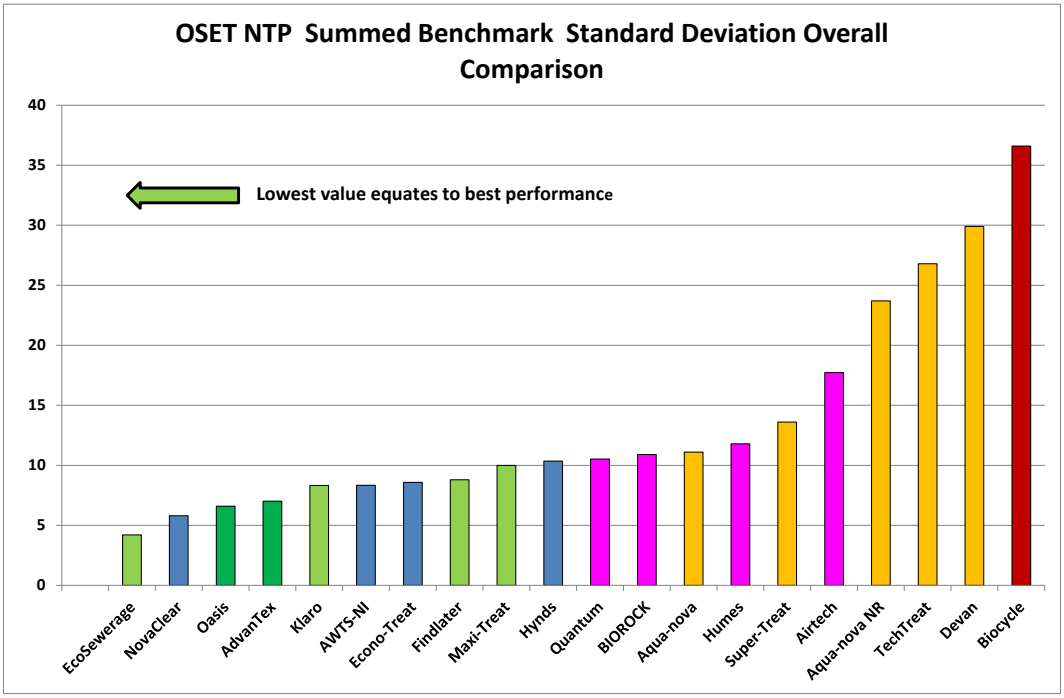


Chart 3:



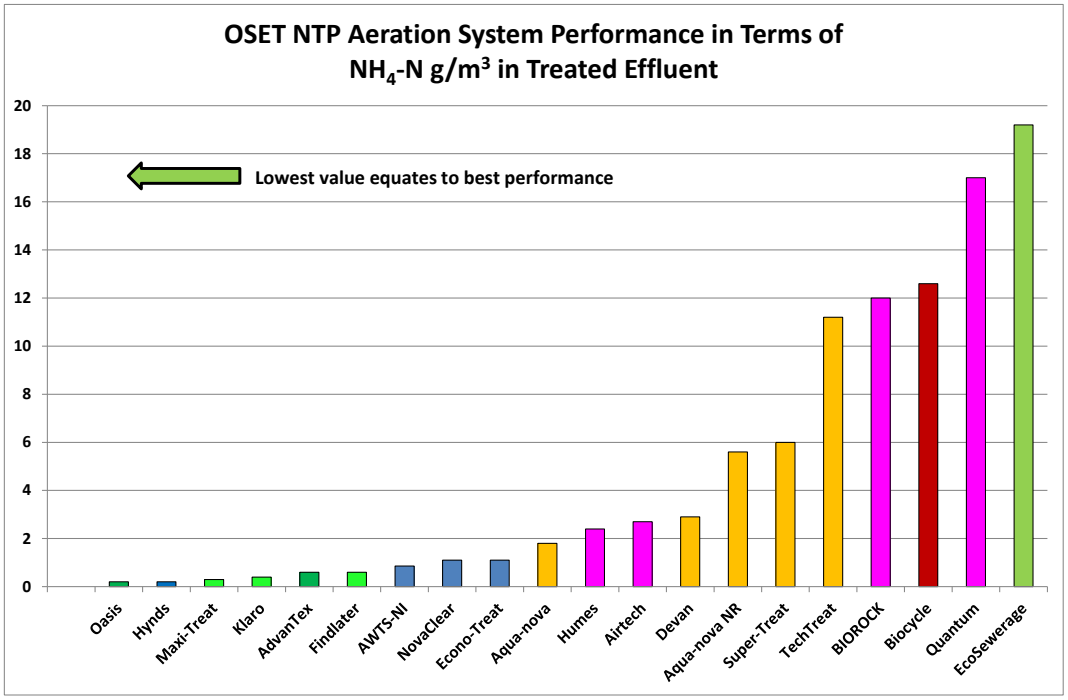
The EcoSewerage worm-wetland and the NovaClear membrane bioreactor are the most stable ahead of the two Five Star Plus treatment units.

Aeration performance

The effectiveness of aerobic treatment (as supported by the aeration system) is best assessed via the ammonia oxidation (nitrification) performance of a treatment unit. This is indicated by the treated effluent ammonia concentration, with low NH_4-N values indicating high aeration performance. Chart 4 compares the benchmark effluent NH_4-N values for each treatment unit.

The six best aeration performance systems in terms of ammonia reduction involve four submerged aeration filter units (Oasis; Hynds; Maxi-Treat; Findlater), a sequencing batch reactor (Klaro) and a textile recirculating packed bed reactor (AdvanTex).

Chart 4:

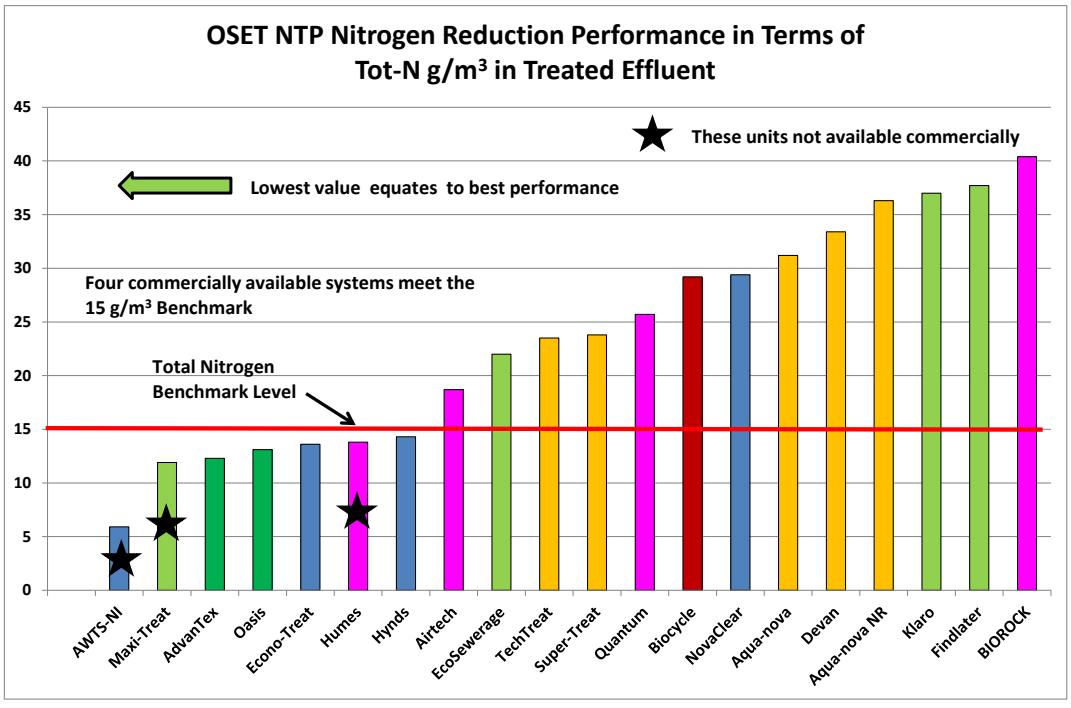


Those treatment units with very high aeration performance need to be checked out as to their energy use as they may in practice be "over-treating".

Nitrogen reduction performance

The nitrogen reduction performance is important for some councils in implementing nutrient management practices for rural residential development. For example only those treatment units with a total nitrogen rating of A or A+ meet the BOPRC 15g/m^3 TN limit for installation of OSET units in the Rotorua Lakes areas. Currently only four commercially available systems achieve this treatment level (as shown in Chart 5 for Advantex, Oasis, Econo-Treat and Hynds).

Chart 5:



Energy use

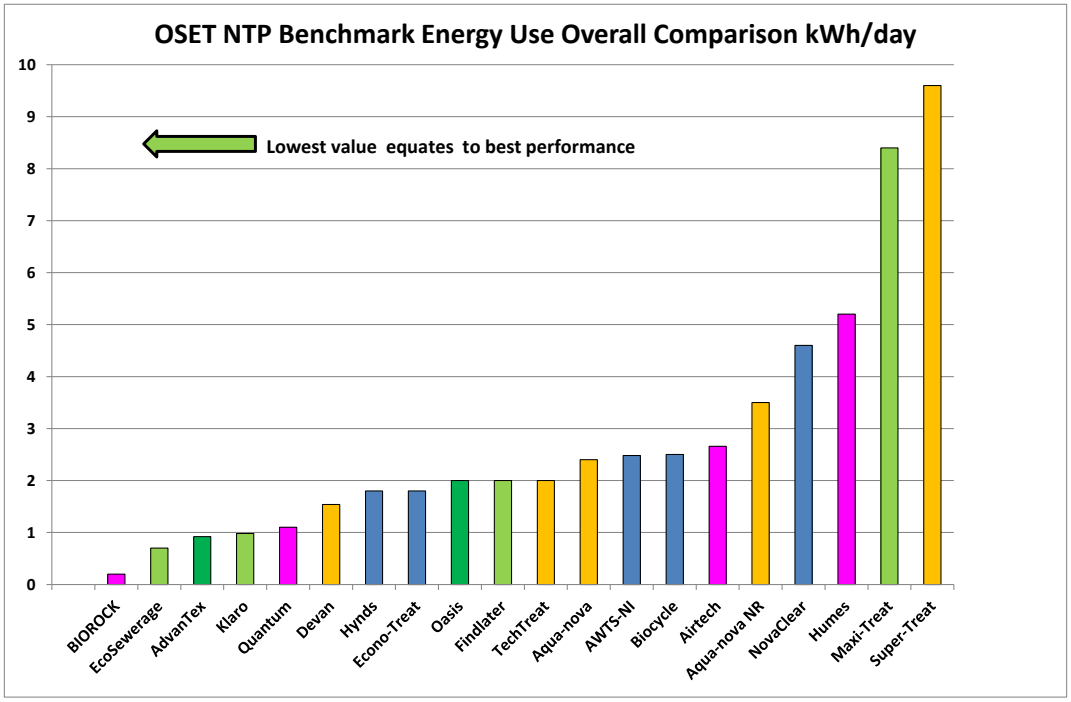
In selecting an OSET system for their property a key element in homeowner evaluation of alternative treatment systems will be capital cost, along with running cost. The OSET NTP testing results assist in evaluating running costs via the average daily energy benchmark value. It is important to recognise that the kWh/day benchmark values do not indicate likely field performance. The overall energy rating of a treatment unit reflects conditions at the test facility – power consumption for effluent pumping under field conditions will be specific to the irrigation distribution system as installed.

Chart 6 compares the benchmark kWh/day average daily energy use for each system. The five lowest energy use units include two with passive ventilation systems (BIOROCK and EcoSewerage) a textile recirculating packed bed reactor (AdvanTex), a sequencing batch reactor (Klaro) and a submerged aerated filter (Quantum).

Overall energy consumption needs to be compared to aeration performance since over-aeration will result in high consumption without necessarily achieving the most appropriate effluent quality level. Chart 6 shows that of the two Five Star Plus units, Oasis (the SAF system) uses twice as much energy as the AdvantTex (textile filter). The Five Star AWTS-NI has high energy use due to the aeration system over-treating to achieve high nitrification (ammonia reduction) prior to nitrogen stripping in the bark filter. The other Five Star high energy use system is the NovaClear MBR unit.

The lowest energy use systems are the BIOROCK passive media system and the EcoSewerage worm-wetland which use gravity flow through media to achieve treatment. Their energy use relates mainly to the irrigation pump for treated effluent.

Chart 6:

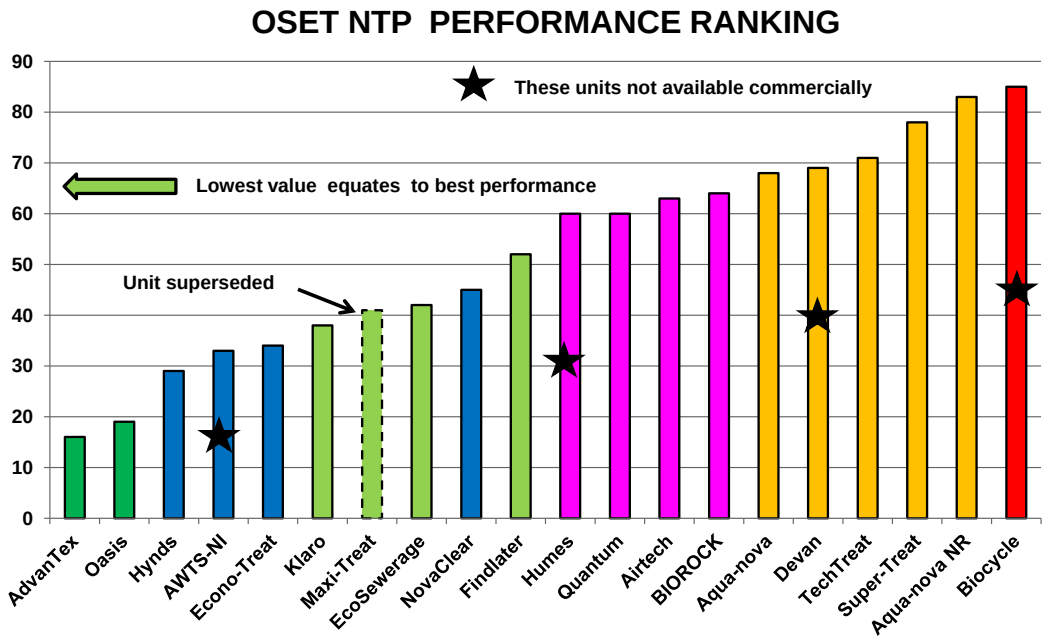


Overall Performance Ranking

It is not feasible to say which of the tested units is the “best” as many factors will influence overall selection for a specific application. Cost is important to homeowners who want to ensure a durable system which provides consistent treatment performance throughout the life of the unit. Lifecycle cost including for capital, operating and maintenance expenditure is important, but it must be recognised that the overall performance of the on-site wastewater system includes not only the treatment unit but the land application system into which the treated effluent is distributed.

However, an overall performance ranking can be derived based on scoring the individual units for each of the parameters in Charts 2 to 6 (aggregated benchmark rating; treatment stability; aeration performance; nitrogen reduction; energy use) by taking the place in each chart and scoring a 1 for first place down to 20 for last place, and summing the place scores for each unit. The result is an OSET NTP Performance Ranking as in Chart 7 below.

Chart 7:



The Five Star Plus units confirm AdvanTex as highest performance ranking over Oasis due to the Oasis higher energy use. The Five Star NovaClear has moved to a much lower ranking due to the high energy use inherent in this MBR process.

Conclusion

The operational procedures and benchmark auditing processes of the OSET NTP are proving most valuable in evaluating the performance of ex-factory and custom built on-site domestic wastewater treatment units available in New Zealand.

The current success of the NTP is due to the voluntary input of the SWANS-SIG members participating in the operations team and the management and auditing group. The whole OSET NTP programme is a “bottom-up” process driven by members of SWANS-SIG with no funding base other than the testing fees paid by manufacturers and the voluntary contributions from council Funding Partners.

The key to the future success of the testing programme lies in recruitment of more Regional and District Council funding partners. The information coming out of the testing programme as made available to funding partners is invaluable to council consenting officers in assisting their evaluation of treatment units for which consent is required, and assessing what monitoring and maintenance conditions need to be set on specific units relevant to their OSET NTP performance outcomes.

Ideally if all councils throughout NZ with significant numbers of on-site domestic wastewater systems join up as Funding Partners adequate funds would be available to move the OSET NTP operations to a secure professional basis and enable development of additional programmes including field testing, holiday load testing and product integrity testing.

Figure 1: Trials 1 and 2 Testing Platforms (2005 to 2007)

Figure 2: New Testing Facility from Trial 3 (2007/2008)

Figure 3: OSET NTP Management Structure

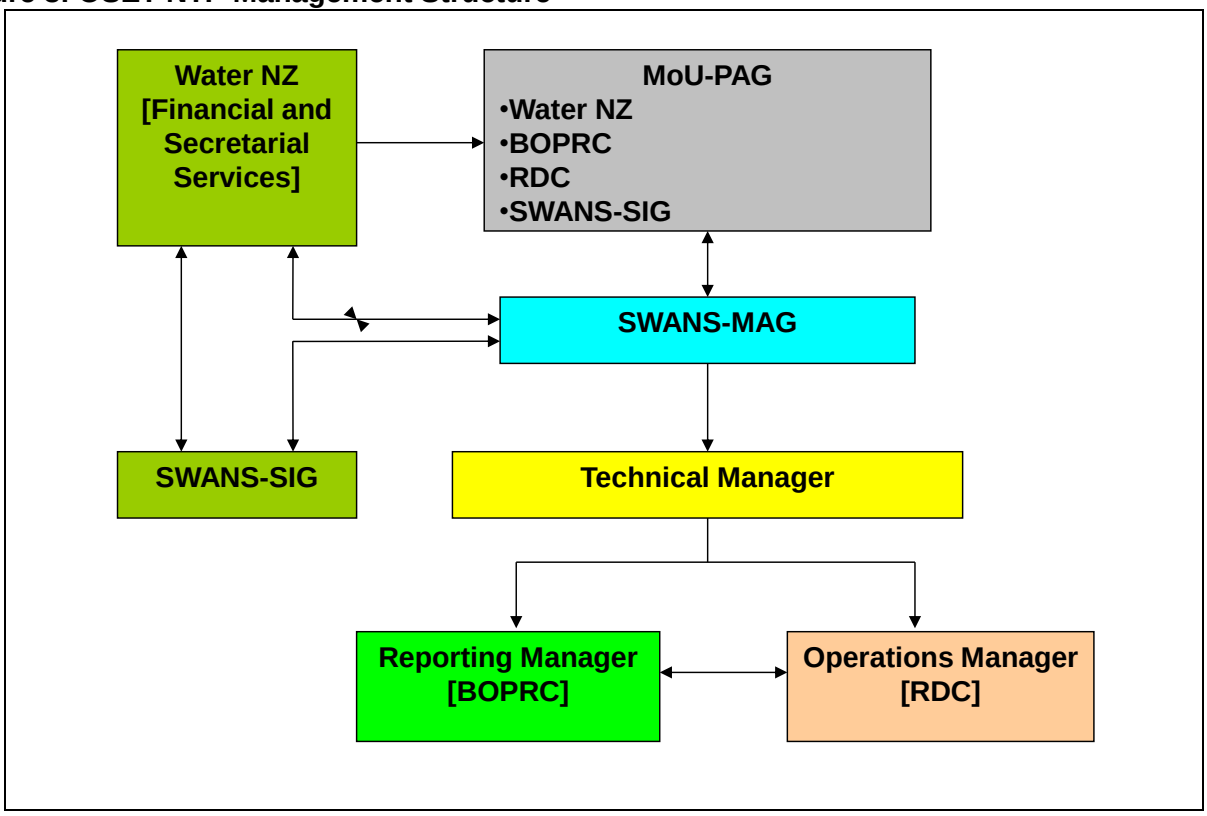


Figure 4: Systems Tested Trials 1 to 8, 2005 to 2013

Company [and number of units tested]	BOPRC Management			OSET NTP Management				
	Trial 1 2005/06	Trial 2 2006/07	Trial 3 2007/08	Trial 4 2008/09	Trial 5 2009/10	Trial 6 2010/11	Trial 7 2011/12	Trial 8 2012/13
Allflow Equipment [1]							1	
Aqua Nova [2]								2
Biocycle Systems [1]			1					
Biolytix [1]	1							
Bio-Microbics – Smith & Loveless [2]	1	1						
BIOROCK – Ecotechnologies [1]								1
Devan Plastics [3]	1	1			1			
Eco Sewerage [1]								1
Findlater Construction [1]								1
Humes Pipeline Systems [1]				1				
Hynds Environmental [3]	1	1		1				
Innoflow Technologies [3]	1		1		1			
Oasis Clearwater Environmental [2]	1		1					
Quantum Waste Water Systems [1]						1		
Reflection Treatment Systems [1]		1						
RX Plastics [3]		2			1			
Super-Treat Systems NZ Ltd [1]								1
Tech Treat Ltd [1]								1
Waipapa Tanks & Waste Treatment [4]	1	1	1	1				
Water Gurus NZ Ltd [1]				1				
BOPRC [1]**						1**		
Total [35]	**7**	**7**	**4**	**4**	**3**	**2**	**1**	**7**
** BOPRC is not included as a "Manufacturer/Supplier" in the NZ Directory of commercial systems.								