SEPTIC SYSTEM PERFORMANCE: A STUDY AT DUNOON, NORTHERN NSW

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Abstract

Twenty septic tank / absorption trench systems in Dunoon NSW were studied to assess their current performance and the effect on performance of three low cost measures, namely: water efficiency upgrades, low phosphorus detergents and septic tank pumpouts. Nineteen of the 20 trenches showed no sign of surface ponding, despite being loaded at rates considerably in excess of recommended guidelines. Analysis of effluent from recently pumped septic tanks indicated annual per capita nutrient generation rates of 4.0 kg of total nitrogen (TN) and 0.5 kg of total phosphorus (TP).

Water efficiency upgrades resulted in significant reductions of water consumption of approximately 45 litres per person per day (Lpd). Analysis of pollutant loads at the septic tank outlet for the four households that received all three management options showed a significant decrease of 0.5 g/p/d in TP loads. Total suspended solids (TSS) loads were high and varied but showed a trend toward reducing for sites that received a pumpout. Decreases in TSS loads were also observed in households that had water efficiency upgrades, indicating that the solids carry-over from tank to trench can be, to some extent, reduced through water efficiency upgrades.

Keywords

hydraulic loading, nutrient loading, pumpout, septic systems, water efficiency upgrades

1 Introduction

A recent study of on-site system practice in NSW by Schwizer and Davison (2001) indicated that 81% of existing on-site systems were septic tank / absorption trench type, and that, despite the recent development of alternative approaches, some 50% of new home-owners continue to adopt this traditional technology. Despite the popularity of this approach, Geary and Gardner (1996) report that studies indicate widespread failure as a result of inappropriate siting, overloading, lack of maintenance and insufficient local authority advice. However, there is evidence that reducing hydraulic loads, nutrient inputs and sludge carry-over can reduce the incidence of some common failures of septic systems such as absorption trench surcharge, inadequate nutrient removal and absorption field clogging (Carew *et al.* 1999; Patterson 1999).

This study was conducted on 20 septic tank/absorption trench systems in and adjacent to the village of Dunoon in northern NSW. The aims were to measure the hydraulic and pollutant loadings (in particular the nutrients nitrogen and phosphorus) generated by households and to assess the impact of low cost options on wastewater treatment within the septic tank. The options examined in this study were indoor water efficiency upgrades, the use of low phosphorus detergents and septic tank pumpouts.

2 Method

A total of 43 participants volunteered for the study following a mail-out to each household in the area and through an article in the local paper. These volunteers were surveyed by telephone as the first phase of screening out unsuitable participants. Volunteers were deemed unsuitable if: permission from tenants and landlords was not obtained for rental properties; the premises were not residential; or it was found that a split septic system was in place or greywater reuse or diversion was occurring. The telephone survey was followed by a site inspection to determine the suitability of the remaining households and to measure flow rates of water using equipment. Water meters were installed on the supply main and all garden devices so that indoor water use, and hence wastewater loading, could be determined by subtraction. A 50mm PVC standpipe was installed in each absorption trench for the purpose of measuring ponding depth in the trench and obtaining water samples. Trench areas were estimated on the basis of visual evidence and, where this was impossible it was assumed that the common practice at the time of construction was followed.

Two sampling periods were conducted a fortnight apart on 24th October and 6th November 2000 to obtain baseline data (Period 1). The following measures were installed from 8th to 17th November: one group of four houses received water efficient appliances (WE); a second group of four houses received low phosphorus laundry detergents to use for the study period (Det); a third group received septic tank pumpouts (PO); a fourth group received all three of the above treatments (All); and the remaining four households, receiving no treatment, acted as the control group (Ctrl). Due to the limited study size, an attempt was made to ensure that water efficient appliances were only installed in households not already equipped with such devices. Similarly, households that had recently (in the past two years) had their septic tank pumped out would not have a pumpout as part of the study. Though more difficult to determine, an attempt was made to introduce low phosphorus detergents only to households not already using them. After a settling period of 16 weeks, three more sampling runs were conducted at fortnightly intervals commencing 26th February 2001 providing post-treatment data (Periods 2 and 3). Of the final group of 20 households, one withdrew after the first three sampling runs (after 26 February) due to dissatisfaction with the sampling process.

At each of the 20 houses, water meters were read, ponding depth in trench was noted, and effluent samples were retrieved from a depth of 500 to 900 mm from the septic tank inspection opening nearest the tank outlet and from the trench standpipe using a 'bailer'. The tank samples were tested for pH, electrical conductivity (EC), TSS, biochemical oxygen demand (BOD), TN and the major cations as a basis for calculating sodium adsorption ratio (SAR). The first set of tank samples was tested for faecal coliforms (FC). All trench samples were analysed for TP and TN. The first set of trench samples was analysed for pH, EC, TSS and SAR. The first two sets of trench samples were analysed for BOD. The final four sets of trench samples were analysed for orthophosphate, ammonia-N (NH_4-N), nitrate-N (NO_x-N), and FC. All laboratory procedures were in accordance with APHA *et al.* (1992).

3 Site and Sample Characteristics

The recruitment process found that a total of 17 (40%) of the households that were contacted divert greywater from their septic system in some way, whether this be through a split septic system or some form of greywater reuse or diversion. The intent was to utilise only those households which did not divert any greywater from their septic system within this study, however, this proved unfeasible given the difficulty in locating suitable households with no greywater reuse or diversion. This resulted in six households which divert some or all of their laundry water being included in the final sample of 20 households. The methods of diverting and/or reusing greywater were not explored in this study.

Average age of the absorption trenches studied is believed to be approximately 15 years with the youngest being at least five years and the oldest more than 30 years. The area experiences a moist subtropical climate with average annual rainfall of 1430 mm. All of the systems studied are on a red krasnozem clay loam. This soil is well structured and highly permeable but has a reputation for clogging after prolonged inundation by wastewater.

4 Results and Discussion

Table 1: Average Values (n=5) for Some Key Parameters of the 20 Systems Studied

Site #	Occu-pants	HLR[a] Lpd	HLR trench mm/d	Pond depth mm	BOD tank mg/L	TN tank mg/L	TN trench mg/L	TP tank mg/L	TP trench mg/L	Treat-ment	years since pumpout
1	4	120*	--	370	289	93	84	23	13	Ctrl	<1
2	2	135	22	187	360	181	79	45	14	All	***
3	1	206	17	212	159	85	57	20	8	Ctrl	***
4	2	112	--	85	225	143	148	18	42	WE	<1
5	2	95	--	187	193	186	146	19	15	WE	<1
6	2	115	17	99	145	94	70	14	15	PO	>20
7	5	61*	--	286	494	263	185	37	27	Det	***
8	2	195*	33	385	221	62	59	11	10	Det	***
9	4	171	50	334	141	83	63	9	8	All	11
10	2	152	25	10	58	74	83	11	12	Det	<1
11	2	**	**	10	359	340	217	49	113	Ctrl	***
12	1	235	26	249	271	68	48	16	11	All	5
13	3	151	--	23	219	50	100	13	81	WE	***
14	3	102	27	210	195	145	129	17	19	PO	***
15	3	115	--	5	154	239	5	28	3	WE	***
16	2	114	26	278	197	152	131	23	20	PO	***
17	1	86	5	118	149	93	42	14	7	Ctrl	***
18	5	85	30	146	407	119	78	19	12	All	***
19	2	**	**	557	132	131	56	18	3	PO	5
20	1	90*	4	133	147	210	13	26	3	Det	***
Mean		**130**	**23**	**194**	**226**	**141**	**90**	**21**	**22**		
Sd		47	12	146	108	76	55	11	28		
Min		61	4	5	58	50	5	9	3		
Max		235	50	557	494	340	217	49	113		

* supply by roof tank **faulty water meter ***information unavailable
-- laundry greywater diverted from septic system [a] hydraulic loading rate

Table 1 provides a summary of some of the key parameters determined for each of the 20 systems tested. The two right hand columns indicate which of the five treatments each house received and, where known, the time since the last tank pumpout. Unfortunately, at sites 11 and 19, faulty water meters rendered flow data unreliable. For the first sampling period (prior to implementation of water conserving measures) mean per capita usage for the four households supplied by roof tank was 108 L compared to 133 L for the 14 households on town water. This difference is not statistically significant (p=0.20).

4.1 Ponding and Nutrient Loading

The depth of water ponding in a trench is an important indicator of system performance. Only one trench (site 19) showed continuing evidence of surcharging, probably as a result of the trench being sited on fill from excavation of the house site. Four of the trenches (sites 10, 11, 13 and 15) contained virtually no water on nearly all inspections despite the fact that they were all subject to above average hydraulic loading rates (HLR). Ponding depth appears to be weakly correlated to both HLR ($r = 0.37$, $n=18$, $p>0.05$) and septic tank BOD concentration ($r=0.35$, $n=18$, $p>0.05$) for the 18 trenches for which adequate data is available.

It was noted that ponding depth was temporarily increased by rainfall, followed by a rapid drop off in trench water level shortly after the event. It is notable that in all but two of the systems the HLR exceeded the design loading rate (DLR) for primary treated effluent on clay loam soils of 10 mm/d as specified in AS/NZS 1547:2000 (Standards Australia and Standards New Zealand 2000). The major finding to come from this part of the study is that, with the exception of one system, all trenches appeared to be performing well from the hydraulic point of view. It is possible that the four empty trenches are not evenly distributing wastewater into the vadose zone and hence minimising the amount of treatment below the trench. This result contrasts with another investigation of on-site system failures conducted in the nearby village of Clunes which found that 27 % of all systems had surcharging trenches (Kohlenberg & Edwards 2000). The Dunoon result could be attributed to the fact that only those residents whose systems were not failing nominated for this study, or that for unknown reasons effluent is not held in the trench as is typical of other sites located on red krasnozem soils.

Overall mean pH of the septic tank water was 7.9 and EC was 1.1 dS/cm. Mean BOD for those trenches with sufficient water to yield a sample was significantly lower (100 mg/L vs 277 mg/L) than for water from the corresponding tanks ($p<0.0001$, $n=33$). A similar result was noted for TN with overall mean concentration dropping from 141 mg/L to 90 mg/L from tank to trench. With few exceptions NO_x-N levels in the trench were < 1 mg/L. The ratio of NH_4-N to TN ranged from as low as 12% to 100% with a mean ratio of 76%. FC concentrations in tanks and trenches ranged from 10^4 to 10^7 cfu/100mL, with mean approximately 10^6 cfu/100mL.

As a number of Councils in NSW base on-site system disposal areas on the basis of nutrient as well as hydraulic loadings, the opportunity was taken to investigate the per capita TN and TP loads generated by individuals within the households under study. Fortnightly loadings per household were normalised to give a per capita annual loading. The sampling method used resulted in a risk that accumulated sediment (additional to recently generated wastewater) might be collected, leading to an over-estimation of the nutrient loading. Therefore, for the purposes of this part of the study, only data from those tanks which had recently been pumped out was used, thereby eliminating the risk of counting nutrient carry-over from accumulated sediment. Systems in which greywater was diverted were also excluded.

Table 2 shows that there is considerable variation in per capita nutrient generation rate between households and also within any given household over time. The mean loadings of 4.0 (range: 2.2 – 5.4) kg/p/yr for TN and 0.5 (range: 0.3-0.7) kg/p/yr for TP are compared with the findings of other studies in Table 3.

Table 2: Annual per Capita Nutrient Loadings to the Tank for Recently Pumped Systems

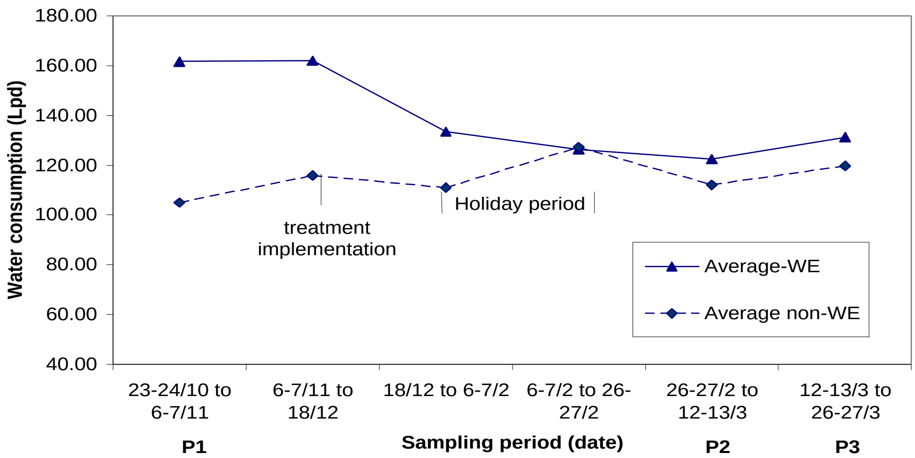
Site #	Occupants	TN load (kg/p/yr)				TP load (kg/p/yr)			
		period 1	period 2	period 3	average	period 1	period 2	period 3	average
6	2		2.9	4.9	3.9		0.4	0.5	0.5
9	4		4.2	4.6	4.4		0.4	0.4	0.4
10	2	4.2			4.2	0.7			0.7
12	1		2.2	2.8	2.5		0.3	0.4	0.3
14	3		4.9	5.4	5.2		0.5	0.5	0.5
18	5		4.2	3.4	3.8		0.6	0.5	0.6
Average		4.2	3.7	4.2	**4.0**	0.7	0.4	0.5	**0.5**

Table 3: Annual per Capita Nutrient Loadings from Various Studies

	This study	Whelan & Titammis (1982)	Witt *et al.* (1974)	Griffiths (1997)
TP (kg/p/yr)	0.5 (0.3 – 0.7)	0.6	1.5	0.9
TN (kg/p/yr)	4.5 (2.2 – 5.4)	3.8	2.2	4.2 to 5.5
Sampling point; Location of study	tank outlet; northern NSW	absorption trench; Western Australia	before septic tank; rural Wisconsin, USA	Several STPs in Australia

4.2 Impact of Water Efficiency Upgrades on Hydraulic Loads

Figure 1: Average Water Consumption for Households that Received Water Efficiency Upgrades and those that did not for each Sampling Period.



The impact of water efficiency upgrades on water use was determined using one period of water use prior to the treatments (Period 1), and two fortnightly periods after the treatment (Periods 2 and 3). While large variations in daily per person water use were noted between households, the variation within any given household was much lower. Due to the high variability in water use between households the *change* in water use from Period 1 (pre) to Periods 2 and 3 (post) within each household was analysed. Figure 1 shows the change in average water consumption over the study period for households receiving water efficiency upgrades and those that did not. Those households without water efficiency upgrades (PO, Det and Ctrl groups) showed an average increase of 7 Lpd from Period 1 to Period 2, and an increase of 14.8 Lpd from Period 1 to Period 3. Water use in households receiving upgrades decreased by 39.0 Lpd and 30.3 Lpd over the same periods. These changes in water use from pre to post treatment are significantly different (P=0.032 and P=0.001) indicating that a decrease in hydraulic load of 45 to 46 Lpd, or approximately a 26%, was achieved by the upgrades.

4.3 Impact of the Management Measures on Pollutant Loads

The changes in pollutant loads at the outlet of the septic tank were used to estimate the impact of the management measures (PO, Det, WE, All) on the effluent flowing out of the tank. Table 4 shows the pollutant loads at the tank outlet prior to and after treatment for each of the pollutant indicators. The pre and post-treatment levels of each indicator pollutant (TN, TP, BOD, TSS, Na, SAR) were analysed using analysis of variance (ANOVA) and Fisher's pairwise comparison with a 10% level of significance to determine whether differences existed between the treatment groups using Minitab 10.5 Xtra Power (Minitab, 1995).

The 10% level of significance was chosen due to the low number of replications and the high level of variation in each group. Analysis was based on per person daily pollutant loads, and those periods in which households had significant periods of absences were not included. The loadings discussed here refer to pollutant loads from the tank to the trench and as such include materials that had accumulated in the tank over time as well as pollutant loads recently generated by the household.

Table 4: Daily Household Nutrient Loads Prior to and After Treatment

Treat-ment	site #	occupants	Avg TN (g/d)		Avg TP (g/d)		Avg TSS (g/d)		Avg BOD (g/d)		Avg Na (g/d)		Avg SAR	
			pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
All	2	2	69	38	25	5	347	36	137	76	25	35	4.0	7.1
	9	4	73	45	10	4	2220	38	149	63	26	24	2.3	3.1
	12	1	34	8	9	1	2750	26	159	19	16	4	2.4	1.3
	18	5	51	49	9	7	67	509	148	135	29	20	3.6	3.3
Average			57	35	13	4	1346	152	148	73	24	21	3.1	3.7
Comparison	1	4	46	45	11	11	145	324	132	145	34	34	4.0	4.2
	3	1	***	23	***	5	***	207	***	54	***	15	***	2.3
	11	2	**	**	**	**	**	**	**	**	**	**	4.0	3.5
	17	1	5	12	1	2	371	488	7	18	2	2	1.5	1.1
Average			25	27	6	6	258	340	69	72	18	17	3.2	2.8
Detergent	7	5	90	76	15	9	865	594	227	104	62	14	9.7	2.3
	8	2	19	27	5	3	244	33	78	88	19	10	3.4	1.7
	10	2	23	*	4	*	24	*	10	*	10	*	1.8	*
	20	1	28	14	3	2	8	328	9	16	8	4	3.3	1.7
Average			40	39	7	5	285	318	81	69	25	9	4.5	1.9
Pumpout	6	2	22	21	4	3	740	29	47	22	7	13	2.3	3.1
	14	3	50	45	7	5	58	24	123	28	17	12	2.5	2.2
	16	2	45	30	7	4	2864	22	69	30	10	8	2.0	1.4
	19	2	**	**	**	**	**	**	**	**	**	**	1.8	1.8
Average			39	32	6	4	1221	25	79	27	11	11	2.1	2.2
Water efficiency	4	2	28	35	4	4	74	110	24	70	8	11	2.2	2.5
	5	2	39	38	5	4	197	38	60	31	14	13	2.8	3.1
	13	3	30	23	8	5	2600	185	143	81	29	16	3.4	3.0
	15	3	91	88	12	9	1665	149	98	38	23	21	2.4	2.7
Average			47	46	7	6	1134	120	81	55	19	15	2.7	2.8

* no sample taken, ** inaccurate water use record due to malfunctioning water meter
*** site unoccupied through duration of sampling period

The high variance in pollutant loads between the sites made analysis of the change in loads from pre to post analysis more useful than an analysis of the average pollutant loads in each treatment group. In general, the Ctrl group showed slight increases in all of the indicators except SAR from the pre to post treatment period, though these were not significant. Fisher's pairwise comparison at 10% level of significance showed that the All group exhibited a reduction in BOD, TP and TN in relation to the Ctrl group. The All group had a significantly greater reduction in TP loads than all other groups (Ctrl, Det, PO, WE) with a reduction of 5.0 g/p/d. The All group also showed the greatest reduction in TN with the reduction of 12.3 g/p/d being significantly different to the changes in the Ctrl and WE groups. The PO group showed a slight reduction of 3.0 g/p/d in TN loads, indicating that sludge removal may contribute to the lower TN levels seen in the All group. However, it is likely that tank pumpout is not the only contributing factor to the significant reduction in TN loads within the All group.

Every treatment group (All, Det, PO, WE) showed a decrease in BOD loads from pre to post treatment. The decrease of 48.8 g/p/d in the All group was significantly different from the slight increase of 7.0 g/p/d exhibited by the Ctrl group. The All, PO and WE groups showed a reduction in TSS from pre to post treatment periods, though this was not significant. This may be due to the very large variance in changes to TSS loads, which ranged from a decrease of 2724 g/p/d to an increase of 320 g/p/d from pre to post treatment. The decrease in TSS loads from the WE group of 342 g/p/d indicates that the reduction in hydraulic loads from installation of water efficient devices in previously non-efficient houses may result in substantial decreases in the load of suspended solids carried from tank to trench.

The Det group showed a decrease of 6.0 g/p/d in Na and 3.5 in SAR, while all the other groups tended to remain stable in Na and SAR over time. However, this decrease is mainly influenced by large decreases in Na loads and SAR from site 7, where it was found that laundry water was diverted from the septic tank after program commencement. Therefore the decreases in Na and SAR noted in the Det group can not be attributed to a change in detergent use in this instance.

5 Conclusions

The results indicate wide variance in hydraulic loads and pollutant loads between the 20 systems under study. The mean loadings of 4.0 (range: 2.2 – 5.4) kg/p/yr for TN and 0.5 (range: 0.3 – 0.7) kg/p/yr for TP are similar to those found by others (Griffiths 1997; Whelan & Titammis 1982; Witt *et al*. 1974). Hydraulic loads for the 20 systems were higher than the 10 mm/d recommended in AS/NZS 1547:2000 (Standards Australia and Standards New Zealand 2000) in all but two instances. Despite this, 19 of the 20 trenches showed no sign of surface ponding. Given the 27% failure rate noted in the nearby region of Clunes by Kohlenberg and Edwards (2000), this result may be due to self-selection of the participant group or unknown factors resulting in effluent not being retained as expected in these soils.

Water efficiency upgrades in households with non-efficient fixtures resulted in decreased hydraulic loads of approximately 45 Lpd, or around 26%. Analysis of pollutant loads at the septic tank outlet for the four households that received all three management options showed a decrease of 5.0 g/p/d in TP loads, which was a significantly greater decrease than all other households. The change in TSS loads was highly varied for the entire group (average decrease of 386 g/p/d ranging from an increase of 320 g/p/d to a decrease of 2724 g/p/d) but showed a trend toward reducing for sites that received a pumpout. Decreases in TSS loads were also observed in households that received water efficiency upgrades, indicating that the solids carry-over from tank to trench can be, to some extent, reduced through water efficiency upgrades.

The recruitment phase of the study found that around 40% of those households volunteering to take part in the program divert greywater from the septic tank in some manner. This indicates there is scope for, and a need to study the implications of greywater diversion and reuse in the area, as well as to determine greywater diversion practices that protect human health and the environment.

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