TEMPORAL VARIABILITY OF SEPTIC TANK EFFLUENT

Robert A Patterson

Lanfax Laboratories, Armidale

Abstract

Research literature, state and local guidelines all provide data on the "typical" quality of septic tank effluent, mostly taken as grab (spot) samples for many operating septic tanks and averaged over the set. There is often no qualification as to the operational status, loading rate, time of day, or water use under which individual systems were operated at the time of sample collection. As water use within the home and the chemicals associated with personal hygiene and household cleaning can add significant levels of particular elements, an understanding of their impact upon water quality is required.

In view of this project, partly funded by the NSW Department of Local Government under the *SepticSafe* programme, a range of rural households had their septic tank effluent discharges monitored over 14 days for pH, electrical conductivity (EC), temperature and redox at 15-minute intervals. Data loggers recorded the readings at each of the 1300 discrete readings. Clean water inputs were monitored by installing a water meter with data logger at the household pressure pump. The water use was also monitored at 15 minute intervals to coincide with the measurements on the septic tank. Inside the house, the occupants recorded the number of persons in residence each day and the start time for each washing machine load and dishwasher load.

There were significant changes to pH, EC, redox and temperature of the septic tank discharge throughout the day, not always in response to activities within the home. The responses to major water use, such as showers and washing machine operations, were not consistent across the sites and the directions of changes varied considerably. Examples are given in the paper to illustrate these findings.

Keywords

chemicals, redox potential, salinity, septic tank effluent, wastewater quality

1 Introduction

The purpose of a septic tank is to provide a receiving vessel for all wastewater generated from a domestic dwelling and to afford limited primary treatment of that wastewater. Primary treatment consists of sedimentation and flotation and a small anaerobic digestion function. The clear water zone within the tank provides a suitable residency period (at least 24 h) to allow lumps to disintegrate, settleable materials to sink, and floatable materials to rise. Older style tanks were typically a single chamber of about 1800-2000 L capacity. Short-circuiting of the wastewater from the inflow to the outflow is a possibility when the tank is unbaffled, particularly when the clear volume is crowded with sludge and scum accumulated over time. Figure 1 shows a typical cross-section of an older-style septic tank with a capacity of 2000 L including sludge and scum. In this project the majority of tanks were of this style.

As wastewater enters the tank, an equal amount of effluent (treated wastewater) is discharged, usually at a slower rate due to the flow-compensating effect of the clear volume within the tank. Mixing occurs within the tank and ideally the contained volume of the tank will buffer the shock of incoming wastewater such that temperature, pH and other wastewater chemistry are "normalised" to an average septic tank quality. The larger the clear volume of the septic tank, the more constant is the discharge quality with respect to total suspended solids (TSS) and, presumably to the other chemical components of the wastewater. It is generally accepted that the quality reflects household behaviour in its wastewater generation rate and the typical wastes disposed of through that system.

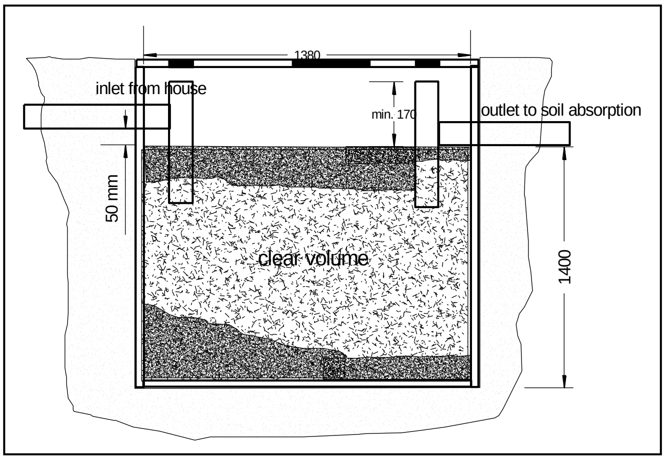

Figure 1: Typical cross-section of older style septic tank

The quality of effluent discharged from a septic tank is usually quantified by taking a grab sample from the discharge. Grab samples are defined by AS/NZS 5667.1:1998 (Standards Australia and Standards New Zealand, 1998) as

> "*discrete samples, usually collected manually ... each sample representative of quality only at the time and place at which it is taken ... recommended when the flow is not uniform, if the values of the analytes of interest are not constant or if the analysis of a composite sample would obscure differences between individual samples*".

It is widely accepted that to quantify the typical septic tank effluent quality, a grab sample is taken from a number of tanks and a statistical analysis performed on those data. It is not usual for the researcher to qualify the sample collection with time of day, day of week, or the household event immediately prior to the sample collection. Is it assumed that the variable of any one septic tank remains the same over a period because of the buffering capacity of clear liquid volume in a septic tank? The author has been guilty of not considering these variables on this assumption. A literature search suggests that other researchers have not accounted for prior household activities, nor standardised the time of day at which samples are taken. Is it that the variability within tanks can be accepted as part of the variability between tanks?

This project was devised to monitor the quality of septic tank effluent with respect to temperature, electrical conductivity (EC), redox potential and pH at a frequency of 96 times per day (@ 15 min. intervals) to determine their temporal change. Such measurements are referred to in AS/NZS 5667.10:1998 (Standards Australia and Standards New Zealand, 1998) as 'continuous measurements' and the method is an alternative to grab sampling and analyses.

2 Methods

Fifteen dwellings on rural residential areas close to Armidale were selected for the study. An initial site inspection determined the effective operation of the septic tank and their suitability for monitoring. Several systems were rejected because septic tanks were overfilled with scum and access to the liquid discharge was restricted. A second requirement was for access to install a water meter into the clean water line between the pump and the house. In several cases, pumps were installed in difficult locations and installation of a meter more complicated than reasonable for the project.

As two sets of monitoring equipment were available, the project progressed at two systems every three weeks – one week to install and refurbish equipment and two for monitoring.

Water Meter. At the start of each monitoring a 20 mm ABB Kent water meter was installed between the water pump and the house. These are typical domestic meters with seven-digit counters and calibrated to measure each 0.5 L of water flow to comply with AS3565.1:1998. The meter is fitted with a facility to output a pulse for each 0.5 L that can be registered by data logging. A Hastings TinyTag *Plus*™ programmable data logger was used to log pulses during the trial. The data logger was programmed to count pulses over each 15 min. period during the 14 day trial. This frequency accounts for 96 pulses each day and a total of at least 1350 periods. Over any 15-minute interval the data logger could register a flow up to 127 L, while flows above this could not be recorded. Data were downloaded to a computer at the end of each monitoring period for analysis.

Chemical properties were monitored on a TPS 90 FLMV Field Lab equipped with sensors for pH, temperature, EC and redox. This equipment can log data and was used to record these parameters at 15-minute intervals. Before each monitoring period, instrument probes were calibrated in the laboratory and batteries recharged. At the end of each period, data were downloaded to a computer for analysis.

During the monitoring period the occupants were asked to record the number of persons resident in the house each day, as well as start times for dishwashing machines and clothes washing machines. While it would have been ideal to record toilet flushes, showers and baths, it was considered such a request was an imposition on the household and less than complete recording would have been a waste of time.

Effluent quality samples were taken from the septic tank at the start and end of the monitoring period for additional laboratory analysis. These results are not reported here.

3 Results

3.1 Equipment malfunctions

The water meters and data loggers functioned effectively for each of the monitoring periods. The data, downloaded using proprietary software, were well presented and easily transferred to a spreadsheet. There were some installation difficulties with the water meters because of owner-installed plumbing, but these were minor. On one occasion the water meter was installed at an incorrect location in the water line on the advice of the home owner, tested at a garden tap and presumed to also measure internal water, however, only the garden tap was monitored and the 14 day monitoring was wasted.

The field data loggers, with the continuous monitoring probes, presented considerable problems including failure to function for the preset 14 day period. The meters were returned to the manufacturers for repairs on two occasions. Unfortunately failure was not evident until the period was completed and in this event data were lost (not logged) and the monitoring period had to be rerun. On several runs, short periods of erroneous recordings were logged, the reason for the aberrations not evident

Solids carry-over in the discharge occasionally lodged on the probes and may have affected readings. A nylon net tied over the probes to prevent this exacerbated the collection of slime and solids. Installation of a septic tank outlet filter and placing the probes inside the filter barrel reduced the problem of fouling.

3.2 Water consumption

The water meter recordings showed the 15-minute flow of water through the internal fixtures. The temporal fluctuations reflect the peak water use periods in the household's activities. Although it was not possible to identify each water use event because only one meter was installed, the recording of the use of the clothes washing machine identified a potential large water-using appliance. Daily water use on a per person basis varied considerably among the homes and within the homes on a daily basis, a sample of which is shown in Table 1.

Table 1 Range of five parameters for four selected systems over 14 days

	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM 4
water use (Lpd) average	84 – 176 (117)	97 – 210 (166)	150 – 374 (216)	65 – 266 (125)
temperature (^{o}C) average	22.4 – 25.9 24.9	20.3 – 24.7 22.0	22.0 – 30.6 24.9	21.6 – 24.2 23.2
pH average	5.9 – 7.9 6.7	6.4 – 7.2 6.7	6.3 – 8.3 7.2	6.6 – 7.7 6.8
EC (uS/cm) average	475 – 1260 715	475 – 1115 810	477 – 1160 655	585 – 1325 * 990 *
Redox (mV) average	-460 to -210 - 390	-460 to –250 -415	-515 to -210 -450	-435 to –166 - 360

* this system used groundwater during this period (EC 830 μS/cm)

Figure 2 shows the daily fluctuations in water use for one household over 28 days, the higher daily events coinciding with use of a washing machine. The household in Figure 2 was mostly occupied by five persons and included some very dirty clothes washing (more washing loads than typical for the household).

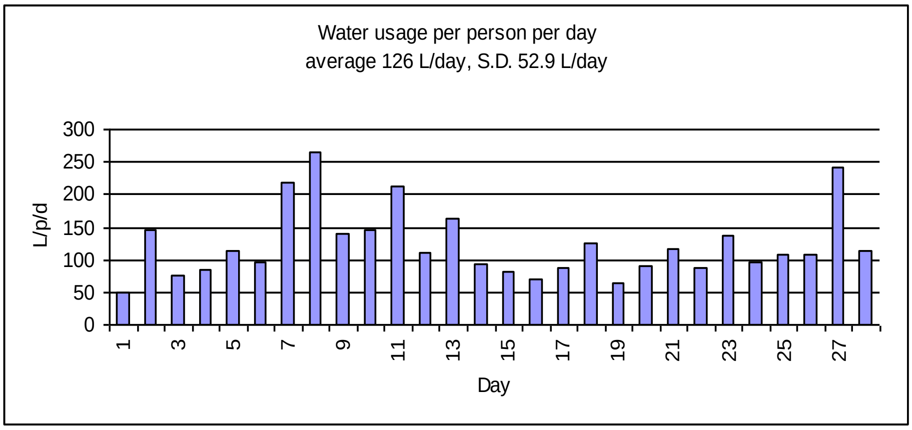

Figure 2 Daily fluctuations in water use, five-person household

Figure 3 shows the 15-minute fluctuations in water use over a weekday where there was no clothes washing during that day. It is clear that around 6.45 - 7.45 am and at 4.15 - 6.30 pm the family was home and the water used was for toilet flushing and bathing.

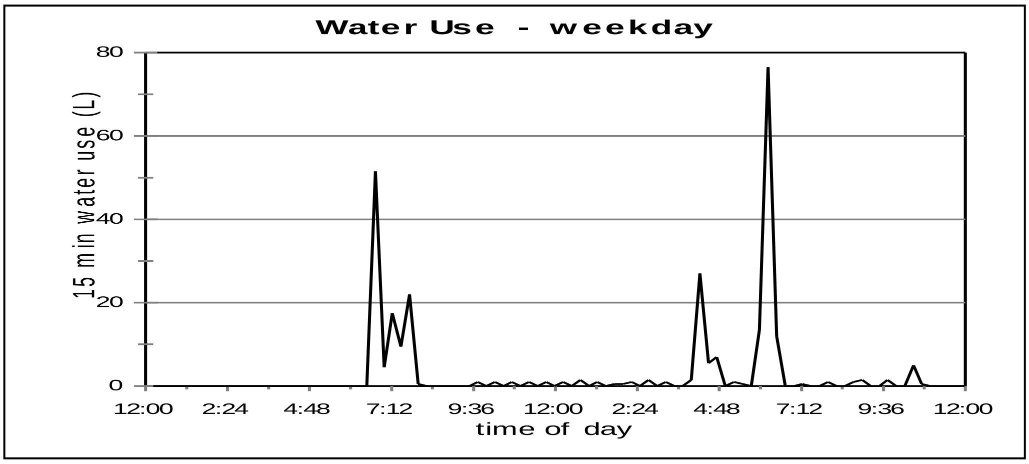

Figure 3: Daily water use on 15-min interval

3.3 Electrical Conductivity

Changes in the total dissolved solids in the effluent are a reflection of the additions of chemicals to the wastewater from activities within the house, of changes to the solubility of inorganic compounds and from the degradation of organic molecules into soluble salts. EC is a measure of all the cations and anions and, unfortunately cannot be used to discriminate between the valuable plant nutrients and the sodium ions which are detrimental to plants and soil structural stability, or other ions that may have a potential for detrimental outcomes.

Figure 4 shows a two-day period during which the washing machine was used on the second day. The first day shows water use between 7.45 and 9.30 am and again around 7pm. The decrease in EC is likely the result of an input of relatively clean water from showers and toilet use with low chemical input. The clean water supply to this house was totally from rainwater.

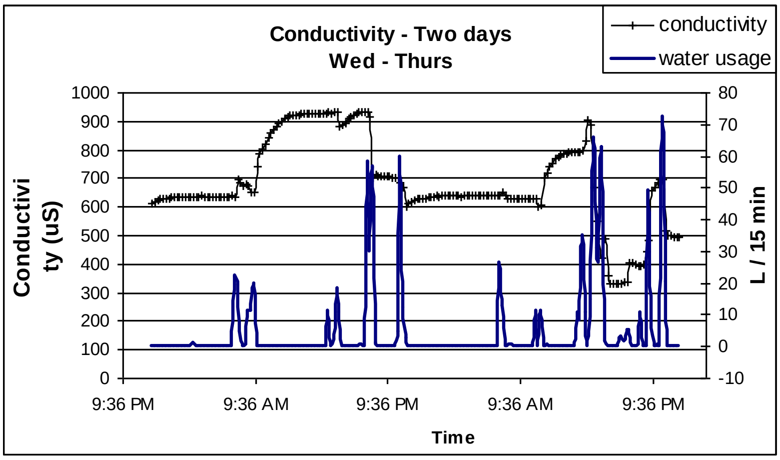

Figure 4: Two day variation of EC compared with water use

On the second day, the same morning routine used about 60 litres of water. At 3.00 pm the occupant recorded one clothes washing load, a dishwashing load at 6.30 pm, while the later events are personal ablutions. During quiescence periods (between peaks) EC increases, and with addition of a predominantly clean water (rain water) the EC decreases. The high increase in the evening of the second day is attributed to the laundry detergents and kitchen activities.

3.4 Effluent pH

The same two days of water use are depicted in Figure 5, plotted with the pH of the effluent.

A similar pattern to that of EC is obvious where the introduction of mostly clean water from showers and toilet lowers the pH with a gradual increase during quiescence.

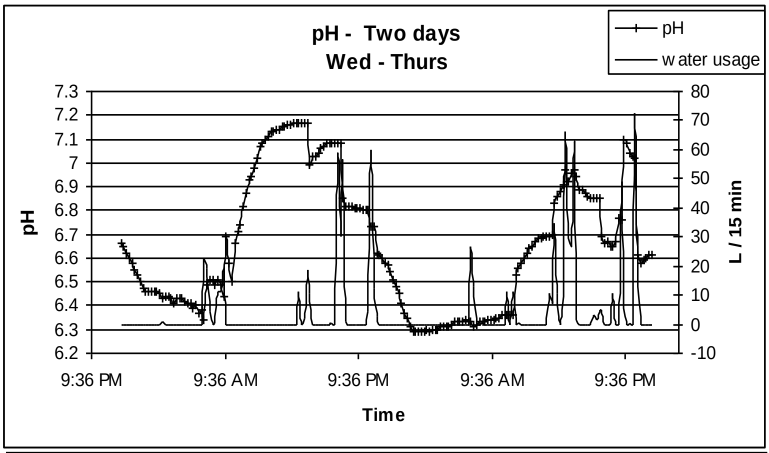

Figure 5: Changes in pH at each 15-min

At each introduction of water the pH decreases except for the 3 pm clothes washing event and the 6.30 pm dishwashing event. Laundry detergents have a high pH in the washing water which is then reduced by the cleaner water from the rinse, deep rinse and spin rinse. Dishwashing-machine detergents have very high pH (>11)

Shower and toilet water later in the evening introduce relatively low pH water (pH around 6.5)

3.5 Redox

Redox is a measure of reduction (negative) and oxidation (positive) potential of the effluent. Anaerobic bacteria require a reducing environment while aerobic bacteria favour oxidising states. As the septic tank is an anaerobic digestion device, its maintenance in a reducing state is imperative. Figure 6 shows redox potential measured each 15-min interval for the same two day period as for EC and pH. The small inputs of relatively clean water have no significant effect upon the highly reducing environment.

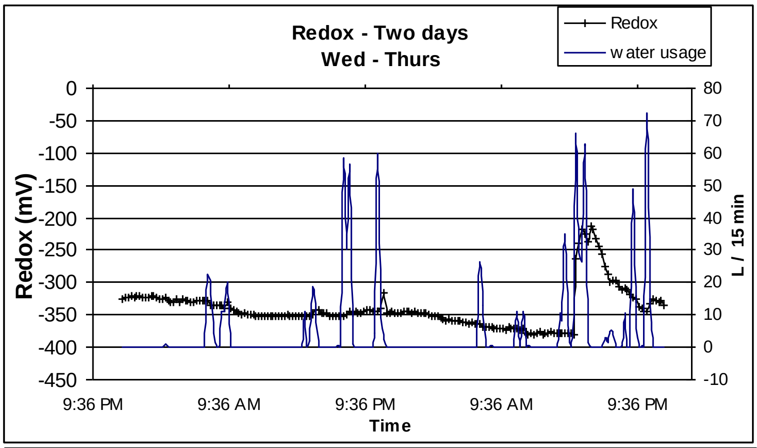

Figure 6: Redox potential with water input

However, the washing machine discharge (3 pm) added salts such as sulphates, phosphates and bicarbonates to the water and increased the oxidation state (reduced negativity), but not sufficiently to change the status from an anaerobic environment. The redox potential showed a rapid return to a highly reducing state. It is this reducing environment that favours denitrification.

3.6 Temperature

As the septic tanks were buried below ground level and had a volume of about 2000 L, fluctuations in temperature were expected to be minor and of short duration, as either hot or cold inputs are small and a return to a constant temperature rapid. Changes from the cold winters of Armidale to the summer temperatures may be significant, but fluctuations within seasons are likely to be low. Hot water sources include showers (about 38^{o}C) and dishwashing (about 60^{o}C). Cold water inputs come from toilet flushing and hand washing.

The effect of clothes washing depends upon whether hot or cold water is used. In hot water washing, only the washing water is hot while the rinse water is cold. In cold wash, all water is at the temperature of the cold water.

Temperature affects the rates of chemical reactions, including the metabolism of micro-organisms – higher temperatures favour faster decomposition. Unfortunately, little can be done to maintain septic tanks at the most efficient operating temperature.

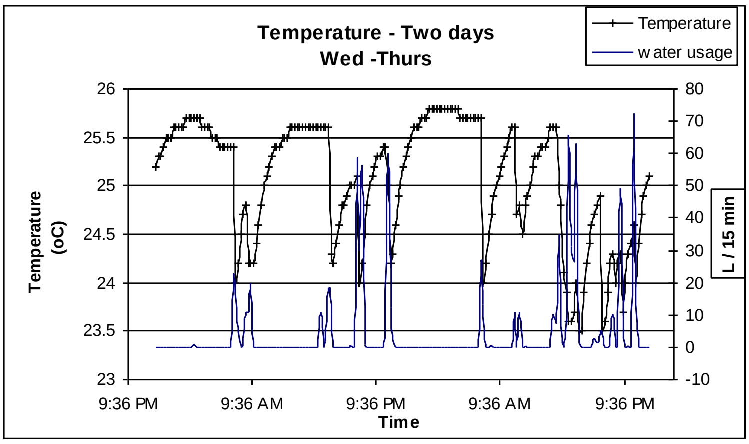

Figure 7: Temperature fluctuation at 15-min interval

In Figure 7 temperature changes are mostly related to cold water changing the summertime tank temperature. Fluctuations over 1.5°C occur with what are probably toilet flushes, and small increases occur with hot water from showers. As cold water is used in this house for clothes washing, the events of the afternoon of the second day tend to keep the effluent temperature below the ambient (25.5°C).

The variations in each of the four parameters for each 15-min. period are considerable. Water use is equally variable throughout the day and from day to day, depending upon the working hours of the occupants. The ranges and averages for four of the monitored systems are shown in Table 1 to show the variation within and between systems.

4 Discussion

4.1 Water consumption

System 1 is a household of three adults where two are at work five days per week and one works three days per week. System 2 is a family of two adults and three children. Both parents work and the children are of school age. System 3 has three adults, two of whom are away at work during the day. During the monitoring period three guests were visiting from the metropolitan area. This household also hosts several discussion groups during the week. System 4 is a family of four adults with two at home each day.

The variations in water use are high, from an average of 216 Lpd to 117 Lpd, while within system fluctuations were considerable. These fluctuations can be related to typical behaviour patterns where washing clothes is not a daily event, but conducted on several occasions during the week, sometimes with up to four loads per day. The high water use for system 3 is likely related to the extra washing loads (eight) during and after three visitors stayed for five days.

The daily fluctuations in water use as shown in Figure 2 indicate that under normal circumstances a septic drainfield is intermittently loaded, although there are often several peaks during the day (morning and night).

4.2 Changes to chemistry during periods of use

Changes in EC, pH, redox and temperature are highly variable throughout the 24 hours and reflect the behaviour of the residents, such as the times they shower, whether they are home during the day, and how many clothes washing events occur during the week. Figures 4 to 7 indicate the highly complex relationships between these events and effluent chemistry. It is evident that the variations during the day and within the week preclude sampling when 'average' conditions apply. Even during periods of quiescence there are significant changes, and immediately following major wastewater inputs the changes can be considerable, some properties increasing while others decrease in their numerical values.

Figures 4 to 7 show considerable effects on effluent chemistry of the laundry in the afternoon of the second day. EC values decrease because of the volume of clean water, but pH increases because of the high pH of the wash water. Temperature reduction reflects the cold water washing used in this household.

Redox potential only reflects major chemical inputs, such as laundry water and dishwashing discharges, but maintains a highly reducing environment.

5 Conclusion

The 15-minute data logging of water use and four effluent quality parameters show high daily variability of flow and effluent chemistry. While water use reflects the behaviour of the house occupants, the effects of wastewater flows on the effluent chemistry from a primary treatment chamber depends upon chemical use. This chemical use includes the source of clean water, rainwater tending to decrease EC and pH. Temperature fluctuations also depend upon whether the clothes are washed in cold or hot water.

The results indicate that a more detailed investigation needs to be conducted on the internal use of water and the effects small increments of wastewater to the septic tank. A similar monitoring of aerated wastewater treatment systems, with a larger tank volume and an aeration zone, may indicate more consistent water chemistry.

From the results reported here and similar project data, it is clear there is no period throughout the day or week when the 'average' effluent chemistry can be taken in a single grab sample. For an accurate reporting of effluent conditions it is necessary to take account of the household events immediately prior to a sampling event and consider the impact of that prior use on the chemistry of the effluent. Such a difficult task is unlikely to be accepted as part of a monitoring program, or even an accreditation program. However, one must accept that a grab sample is no more than an insight to effluent chemistry, an assessment that is within the range of possible values likely to be encountered in a longer term monitoring program.

Acknowledgement

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