

On-Site Wastewater Systems: Investigating Dynamics and Diurnal Patterns Impacting on the Performance of Mound Systems

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Abstract

Many dynamics and diurnal patterns impact upon the performance of effluent disposal areas. The timing of household water use and conveyance to a septic tank impacts on the available volume for application to an effluent disposal area. The timing and method of effluent application will impact on the performance of the effluent disposal area in assimilating nutrients and maintaining adequate infiltration rates. Rainfall patterns will impact on soil saturation at different times during the year; and threshold rainfall events may increase groundwater levels that will impact on the performance of the effluent disposal area. However, the dynamics and diurnal patterns comprising the “whole-of-on-site-wastewater-system” are rarely discussed in the literature. This paper uses data obtained from a study of two allotments in a non-sewered subdivision at Salt Ash (NSW) to highlight these dynamics and diurnal patterns in order to improve the performance evaluation of on-site wastewater systems, in particular Mound systems. Results indicate that under existing septic tank-collection well design criteria the variability in average daily indoor water use and average diurnal water use patterns will impact on the temporal comparative performance of effluent disposal areas (Mound systems) at similar sites.

Keywords: Dynamics; Mound systems; Wastewater systems

Introduction

Mound systems are becoming an attractive alternative to sub-surface absorption trenches particularly in non-sewered coastal areas with high groundwater tables. Mound systems provide additional vertical separation distance between the point of effluent discharge to the Mound and the underlying groundwater, therefore improving the “treatment” of discharged effluent [1,2]. On-site wastewater systems have traditionally been designed based on average daily wastewater loading-rates and land capability considerations such as the land area available for disposal, soil type, long term acceptance rates (LTAR), depth to groundwater and the distance to adjacent water courses [3].

The use of design flow rates as described in septic tank-collection well guidelines [4] indicate that wastewater generated and discharged to the septic tank (per person) is assumed uniform during a given day, which in turn assumes uniform distribution to the secondary collection well (pump chamber) and the Mound. Most wastewater managers know that this is far from reality, as the performance of the Mound will depend on (amongst limiting site factors such as soil type) the effluent load, the rate of distribution to the Mound, and the resistance and hydraulic conductivity of the distribution network within the Mound and the underlying soil. However, the diurnal pattern of effluent discharge to the Mound system is likely to influence the temporal saturation/unsaturation patterns that drive effective treatment within the Mound (aeration), thus the temporal performance of the Mound system.

The diurnal “whole-of-on-site-wastewater-system” patterns are rarely considered in determining the performance of Mound systems because average daily design flows are used as design criteria. This paper reveals the diurnal pattern of each component of on-site wastewater management using Mound Systems, from household water use to the septic tank, and then to the collection well (pump chamber) and the Mound (Figure 1); and reveals the dynamics and diurnal patterns to be considered when evaluating the performance of the Mound and/or modeling these systems.

Background

On-site systems

Septic tanks have been used in unsewered areas for many years as the most suitable form of primary treatment of sewage. The septic tank is a gravity-fed, underground watertight tank generally constructed of concrete, fibreglass or plastic which is usually divided into at least two compartments. The tank receives all sewage and separates the solid waste from the liquid waste. The liquid waste (effluent) passes out of the tank after approximately 24 hours however will also depend on the volume of the septic tank and the hydraulic load. The tank performs three functions; 1) it acts as a settlement chamber for solid materials, 2) it allows some anaerobic bacterial breakdown of waste materials to occur, and 3) it acts as a storage chamber for undigested solid materials (sludge). A common on-site disposal method is the use of absorption trenches, where effluent from the septic tank decants into a long subsurface trench and is absorbed into the surrounding soil.

An alternative to subsurface soil absorption trenches is a Mound system (Figure 2). Mounds are dosed with primary treated septic tank effluent, by pump or siphon, to a distribution network of perforated pipes set in an aggregate distribution bed which sits near the top of an appropriately sized sand-fill media Mound. The wastewater is further treated before entering the native soil beneath, as it passes through the Mound in much the same way as it would if it passed through an

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intermittent sand filter. Mounds have the benefits of increasing the vertical separation distance between the point of application and the soil and groundwater; and they facilitate nitrification and promote increased evaporation and transpiration due to being raised above ground level.

In non-sewered areas the indoor household water use (as wastewater) is typically directed to a septic tank. The size of the septic tank will be designed based on the expected wastewater load from the household. Septic tank-collection well guidelines recommend the size of the septic tank be calculated using a minimum design flow allowance based on a 5-person household and a maximum design flow allowance based on a 10-person household [4]. Therefore the majority of residential homes with ≤ 5 occupants have similar sized septic tanks/collection wells regardless of occupancy.

Initially, the septic tank fills over time until each consecutive discharge of wastewater from the household displaces effluent from the septic tank. The displaced effluent can be directed to a sub-surface absorption trench, to a separate collection well for periodic distribution to a Mound system; or treated further using an aerated wastewater treatment system before discharge by surface irrigation.

Many septic systems utilise a collection well before effluent is discharged by gravity to a sub-surface trench, or pumped to a Mound system or other dispersal field. Assuming the septic tank is full, effluent discharge in a gravity-fed/siphon-fed system will likely reflect the household water use pattern, as wastewater enters the septic tank and the effluent is displaced into the trench or Mound. In contrast, a pump system will utilise a pre-set timing function (pump marks) to activate the pump in the collection well and effluent “dosing” is likely to be less frequent, use discrete volumes, and have a different diurnal pattern to a gravity-fed/siphon-fed system. These are important insights into the likely performance of a Mound system, as the resistance and hydraulic conductivity of the biomat zone [5] and patterns of saturation/unsaturation immediately below the distribution network are likely to vary under different diurnal patterns of effluent discharge to the Mound.

The diurnal saturation patterns of the soil (in the Mound), either by rainfall and/or effluent application, will ultimately determine the rate of treatment. Nitrification will occur under aerobic conditions resulting in nitrate (NO_3^-) formation and plant uptake [6]. De-nitrification transformations will occur differently in soils at variable saturation levels. For example, Figure 3 shows that NO emissions predominantly occur in dry soils and N_2 emissions dominate in saturated soils.

These relationships have implications for the treatment performance of Mound systems. For example, the diurnal effluent application patterns will influence the long-term saturation/non-saturation patterns of the Mound, thus impacting on nitrification/de-nitrification rates within the Mound. An intensification of rainfall has been shown to lead to a decline in NO and the enhancement of N_2O emission and drier soils have been shown to be associated with increased evapotranspiration rates that increase NO emissions [7].

Furthermore, Davies et al. [8] cites research that has identified key factors influencing virus inactivation rates in septic seepage. These factors include temperature, moisture content, pH, soil type, virus type [9], organic matter content, electrolyte concentration [10], and the presence of other biota [11-13]. The diurnal patterns presented in this study warrant further consideration with respect to virus inactivation rates in on-site wastewater systems as most of these factors would be highly dynamic in soil intermittently saturated by effluent application and seasonal rainfall patterns.

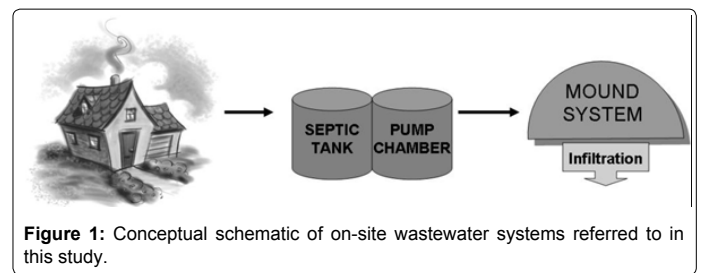


Figure 1: Conceptual schematic of on-site wastewater systems referred to in this study.

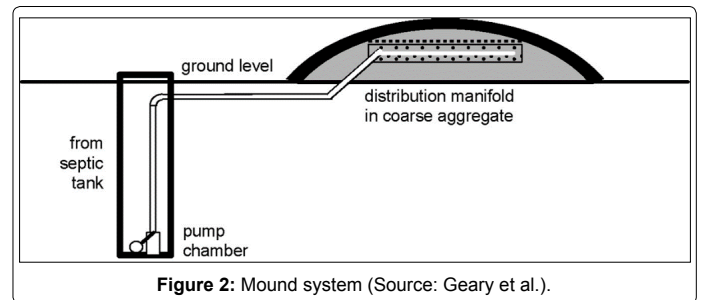


Figure 2: Mound system (Source: Geary et al.).

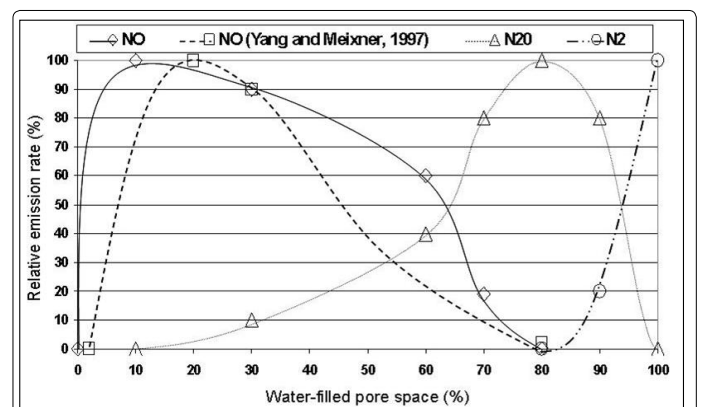


Figure 3: Normalised emissions of NO, N_2O and N_2 from variable-saturated soil (reproduced from D'Odorico et al.).

Household water use and water quality

Monitoring household water use at small time-steps is a relatively recent “tool” for evaluating allotment water supply systems [14], however rarely has it been applied to on-site wastewater management. One exception is Patterson [15] who monitored diurnal water use from a household and water quality in the septic tank (at 15-minute time-steps) and revealed considerable variability in temperature, pH, electrical conductivity and redox potential throughout a two day period. Much of the variability was observed to occur with inputs to the septic tank from indoor water uses and at different times of day. Septic tanks perform under anaerobic conditions and while household water use reflects the behaviour of the occupants, the effect of wastewater flows on effluent chemistry in the primary treatment chamber depended on chemical use (such as laundry products) [15]. Therefore, the diurnal water use pattern in conjunction with the type of indoor use (i.e., laundry, toilet, shower, etc) will impact on water quality, thus the performance of the septic tank.

Catchment and climate

Catchment and climate diurnal patterns will also influence the performance of on-site systems. For example, rising groundwater levels

and intra-daily rain events will reduce the vertical separation distance in areas with high groundwater tables and moderate to fast-draining soils. Monitoring rainfall and depth to groundwater at 6-minute time-steps provides insight into the hydrological connections between the human, catchment and climate processes operating at the allotment-scale.

The significance of diurnal patterns for managing on-site wastewater systems

Research by Lucas et al. [16] highlighted the variability in diurnal water use patterns between households in the Salt Ash area (NSW, Australia); [15] revealed the variability in water quality that can influence the performance of the septic tank; and Beal et al. [5] modelled flow through the biomat and exfiltration zone (in a soil adsorption trench) and found that the resistance and hydraulic conductivity governed variable unsaturated flow-rate. The diurnal patterns of wastewater discharge to the septic tank and collection well and those to the Mound are likely to influence patterns of saturation/un-saturation; thus the temporal performance of the Mound system in treating domestic effluent. This paper qualifies what impact the variations in the observed diurnal patterns are likely to have on overall performance and the modelling of Mound systems.

Methods

The monitoring period presented in this study was from the 1/7/07 to 28/8/07. During this time household indoor water use, rainfall and depth to groundwater were continuously monitored at 6-minute time-steps. The average household diurnal water use pattern was assumed to reflect average wastewater input to the septic tank and also effluent displaced to the collection well. The pattern of discharge from the collection well to the Mound was determined based on the pumping regime at each of the two sites.

Study site

The non-sewered community of Salt Ash is located north of Newcastle (NSW) and is within the Tilligerry Creek catchment. In recent years, declining water quality in the estuary has resulted in the closure of several oyster harvesting zones and, due to the detection of a human virus in sampled oyster tissue, septic tank discharges have been implicated as a potential source.

The study catchment is characterised by high groundwater tables and low lying and flat land comprising soils of fine to coarse sands. These attributes pose limitations on the potential performance of on-site wastewater systems in the area, and thus the potential for contaminant export to the estuary. In the past, most septic systems discharged to a subsurface absorption trench. However, after heavy rainfall many of these systems became inundated with the rising groundwater which confirmed the potential contaminant pathway to the estuary; via large surface drains designed to route stormwater from residential allotments. Failing septic systems or those performing poorly have been incrementally replaced over the past two years with Mound systems (refer Figure 2).

Daily indoor water use, diurnal household water use patterns and water quality

Water use was monitored at the two homes using “smartmeters” [14]. The meters provided water demand from each household at 5 litre increments and at 6-minute timesteps, resulting in diurnal water use patterns for both the monitored homes. Over the study period the

smartmeter dataset for each site was sorted to hours and days then averaged to provide the average diurnal water use pattern (L/hr).

Site F had four occupants (2 × adults, 2 × teenagers) and had an average daily indoor water use of approximately 295 L/day. Site T had five occupants (2 × adults, 3 × teenagers) and had an average daily indoor water use of approximately 425 L/day. Since only indoor demand was sourced from the rainwater tank, it was assumed that after uses in the home, “smartmeter” results reflected actual discharge to the septic systems. Each home produced an individual diurnal water use profile for comparison.

Water quality in the septic tank was monitored every month for pH, electrical conductivity ($\mu\text{S}/\text{cm}$), ammonium (NH_4^+ - mg/L), nitrate (NO_3^- - mg/L), total phosphorus (mg/L), ortho-phosphate (PO_4^{3-} - mg/L), faecal coliforms (cfu/100 mL) and biochemical oxygen demand (BOD_5 - mg/L) using standard methods [17]. Summary tables are provided in results which indicate the variability in septic tank water quality between the two sites.

Collection well discharge patterns to the mound

The effluent pumping regime from the collection well was not measured directly but was estimated based on the knowledge of the homeowner. Both systems used low pressure pumps to distribute effluent to the Mounds.

Rainfall and depth to groundwater (Vertical separation distance)

Rainfall was continuously monitored (6-minute timesteps) using a 0.2 mm tipping bucket rain gauge which was located within 700 m of the sites. Groundwater bores were drilled by qualified contractors to a depth of approximately three metres and a pressure transducer was placed in the bore to record depth to groundwater at 6-minute timesteps.

Results

Daily indoor water use, diurnal household water use patterns and water quality

Figure 4 shows average daily indoor water use for individual days and the average diurnal water use pattern for site F. Daily average indoor water use was highest on the Friday (350 L/day) and Saturday (370 L/day) with a decreasing trend from Sunday (308 L/day) to Thursday (248 L/day). The average diurnal water use pattern displays a distinct morning peak (140 L/hr) and evening peak (160 L/hr), with relatively lower water use during the day.

Figure 5 shows average daily indoor water use for individual days and the average diurnal water use pattern for site T. Daily average indoor water use relatively uniform an was highest on the Monday (455 L/day) and lowest on the Wednesday (390 L/day). The average diurnal water use pattern displays a broad morning peak (approximately 90 L/hr) and a distinct evening peak (185 L/hr). Note that the average hourly water use was determined by averaging the entire dataset and as such cannot be summed to infer daily water use.

Compared to site F, Site T had higher daily water use, a different weekly distribution of water use and a different average diurnal water use pattern. However, the septic system design was similar for both sites and the observed differences are likely to influence the timing and volume entering the collection well and subsequently the timing of the daily pumping regime. These dynamics are often observed but rarely

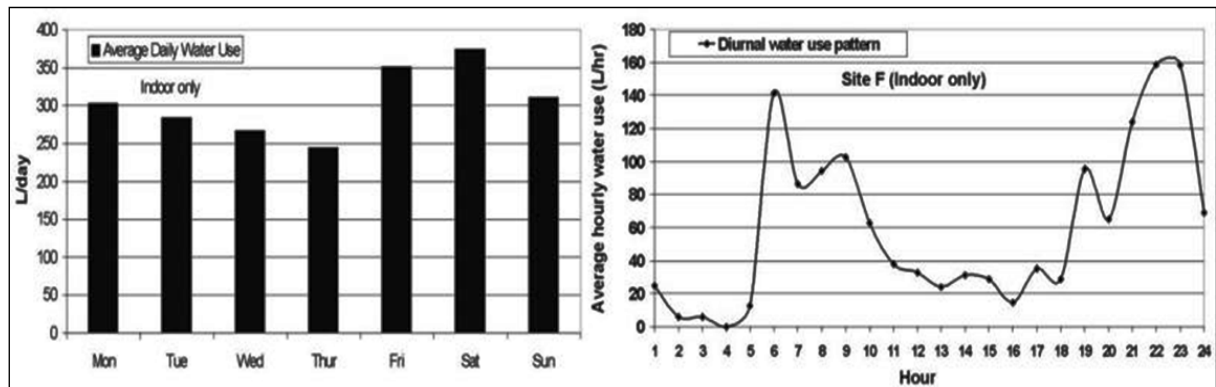


Figure 4: Daily average indoor water use and average indoor diurnal water use pattern (Site F).

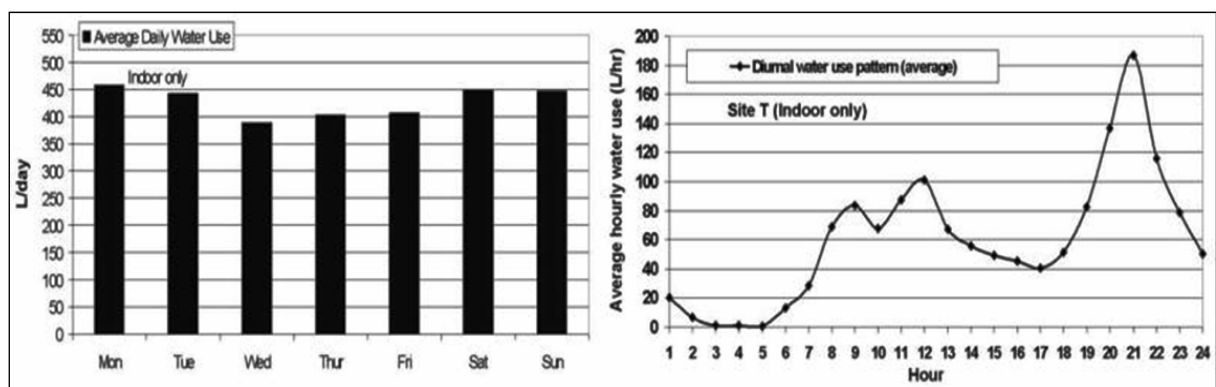


Figure 5: Daily average indoor water use and average indoor diurnal water use pattern (Site T).

applied to evaluating the performance of Mound systems.

Tables 1 and 2 summarise the septic tank water quality for sites F and T respectively and are shown to highlight the variability between septic tank water quality at different sites. Site F had relatively higher average EC, NH_4^+ , total phosphorus, PO_4^{3-} , faecal coliform and BOD results than site T. Furthermore, site F used approximately 50% less water than site T indicating that site F experienced lower diurnal volumes to the septic tank and poorer water quality than site T.

Collection well discharge patterns to the mound

The septic tank and collection well were of the same size at both sites (site F and T) therefore a similar pumping rate was observed. Figure 6 describes a typical daily cycle where a low-pressure pump supplies effluent to the Mound at a rate of 150 L/hr for four hours and twice a day.

However, these rates were not monitored in any way and relied on the knowledge of the homeowner. Water level in the collection well was not monitored, however for the purpose of describing differences between gravity/siphon-fed systems and pump systems, conceptual estimates were applied. A pumping regime is designed to periodically discharge effluent to allow for relatively slow saturation of the substrate immediately below the distribution network of the Mound and the subsequent non-pump time between dosing to allow for infiltration and aeration before the proceeding dose.

Rainfall patterns and depth to groundwater (Vertical separation distance)

Rainfall will inevitably be a major factor in long-term saturation/non-saturation patterns. Figure 7 shows rainfall at 6-minute time-steps and total daily rainfall from the 1/7/08 to the 28/8/09. The 6-minute data indicates similar intensity events for short periods on the 10/7/08 and 21/8/08, however the daily rainfall data indicates that approximately three times the rainfall occurred on the 21/8/08 than on the 10/7/08. Figure 8 shows the change in depth to groundwater superimposed onto the 6-minute rainfall data shown in Figure 7.

All rainfall events (>0.4 mm) decreased the vertical separation distance between the base of the Mound and the underlying groundwater. The total daily rainfall (22 mm/day) recorded on the 10/7/07 decreased the vertical separation distance by approximately 0.10 m and was similar for both sites. The total daily rainfall (70 mm/day) recorded on the 21/8/07 decreased the vertical separation distance by approximately 0.25 m and was similar for both sites. The ratio of decrease in vertical separation distance on the 10/7/08 and the 21/8/07 (0.1 m/0.25 m) was similar to the ratio of total daily rainfall for the same dates (22 mm/70 mm).

The rapid response of groundwater level to rainfall of varying intensity highlights the sensitivity of the area with respect to rainfall and vertical separation distances. Note that the use of a Mound system will undoubtedly provide a minimum vertical separation distance (to

Site	n=9	pH	$\mu\text{S/cm}$ EC	mg/L NO_3^-	mg/L NH_4^+	mg/L Total P	mg/L PO_4^{3-}	$\text{cfu}/100 \text{ mL}$ Faecal Coliforms	mg/L BOD
Septic Tank	Avg	7.2	1944	0.2	232	20	17	1.18E+06	215
	Max.	7.6	2430	0.3	300	24	20	6.00E+06	303
	Min.	5.7	1230	0.1	170	16	14	2.50E+04	102
	SD	0.7	377	0.2	45	3	2	2.13E+06	75

Table 1: Water quality analysis for septic tank samples (Site F).

Site	n=9	pH	$\mu\text{S/cm}$ EC	mg/L NO_3^-	mg/L NH_4^+	mg/L Total P	mg/L PO_4^{3-}	$\text{cfu}/100 \text{ mL}$ Faecal Coliforms	mg/L BOD
Septic Tank	Avg.	7.7	1234	0.4	133	13	10	3.44E+04	187
	Max.	7.8	1420	0.4	165	18	11	6.70E+04	324
	Min.	7.4	1140	0.4	100	10	9	5.46E+03	85
	SD	0.1	90	0	22	3	1	2.15E+04	99

Table 2: Water quality analysis for septic tank samples (Site T).

promote aeration) superior to a sub-surface soil absorption trench periodically inundated by rising groundwater.

Discussion

Monitored diurnal patterns at 6-minute timesteps have been presented for indoor water use, rainfall and depth to groundwater at two sites that use on-site Mound systems. Estimated diurnal patterns for the pump regimes were based on homeowner knowledge and have also been presented. What impact could the variation in the observed dynamics and diurnal patterns have on performance evaluation of Mound systems?

Daily indoor water use, diurnal household water use patterns and water quality

Site F had an average daily indoor water use of approximately 295 L/day and an average diurnal indoor water use pattern with broad and distinct morning and evening peaks. Site T had an average daily indoor water use of approximately 425 L/day and an average diurnal indoor water use pattern with a relatively smaller and broader morning peak, and a distinctly larger and sharper evening peak. Different diurnal water use patterns were observed at each site and are likely to influence the timing of wastewater entering the septic tank, thus the timing of discharge to the collection well. The use of a gravity-fed/siphon-fed or a pump-fed system in distributing effluent to the Mound will impact on the diurnal dynamics of saturation/un-saturation.

The difference in septic tank water quality between sites F and T indicate that the proportion of indoor uses attributed to toilet, laundry, shower and kitchen may be different at each site, however these proportions were unknown. One observation was that site F applied grey-water (laundry only) to the garden and therefore did not enter the septic tank. One expected impact on septic tank water quality from laundry detergents and bleaching agents would be the likely reduction in faecal coliforms. The exclusion of detergent-rich laundry wastewater to the septic tank and/or lack of dilution (of blackwater) by relatively lower household wastewater flows may be possible explanations for increased faecal coliforms at site F than site T.

Figures 8 and 9 conceptually describe diurnal patterns (using Site F data only) for a gravity-fed/siphon-fed Mound system and a pump-fed Mound system respectively and are used for comparison during discussion.

Collection well discharge patterns to the mound

Figure 9 shows the diurnal patterns for a gravity-fed/siphon-fed system discharging to a Mound. Assuming the septic tank and collection well are at capacity, every pulse of wastewater from the home will displace a discrete volume to the collection well. In a gravity-fed system, a corresponding discrete volume would leave the collection well and enter the soil distribution network with a diurnal pattern similar to indoor water use. In a siphon-fed system, effluent is continuously siphoned to the soil distribution network once a maximum “siphon-mark” in the collection well is reached. Discharge to the Mound is likely to occur in larger volumes and less frequently than with a gravity-fed system. However, at different times during the week and particularly if the home is left unoccupied for prolonged periods, a siphon-fed system will likely have a diurnal (and longer-term temporal) discharge pattern similar to a pump-fed system.

Figure 10 shows the diurnal patterns for a pump-fed system discharging to a Mound. Assuming the septic tank and collection well are at capacity, every pulse of wastewater from the home will also displace a discrete volume to the collection well. Upon reaching threshold pump marks in the collection well, the low pressure pump delivers effluent to the Mound in relatively smaller doses and for shorter periods within the day. Compared to gravity-fed/siphon-fed systems, the use of a pump-fed system provides longer periods (within a day) of unsaturated soil that promotes nitrification in the Mound.

Rainfall and depth to groundwater (Vertical separation distance)

Rainfall will inevitably be a major factor in long-term saturation/non-saturation patterns. Depth to groundwater displayed a high sensitivity to rainfall and responded almost immediately after rainfall. The coarse sands in the area allow for rapid infiltration and this was observed in comparison in the 6-minute rainfall and depth to groundwater data. The substrate used in construction of the Mounds was predominantly sand graded to design specifications as stated in Whitehead and Associates [18]. Therefore, any considerable rainfall (>0.4 mm) may likely increase % saturation of the Mound before effluent is applied. However, the physical attributes of the Mound systems serve to increase the vertical separation distance; and this is likely to reduce the significance of the observed changes in vertical separation distances at the study sites (in comparison to a sub-surface absorption trench that may become submerged by high groundwater).

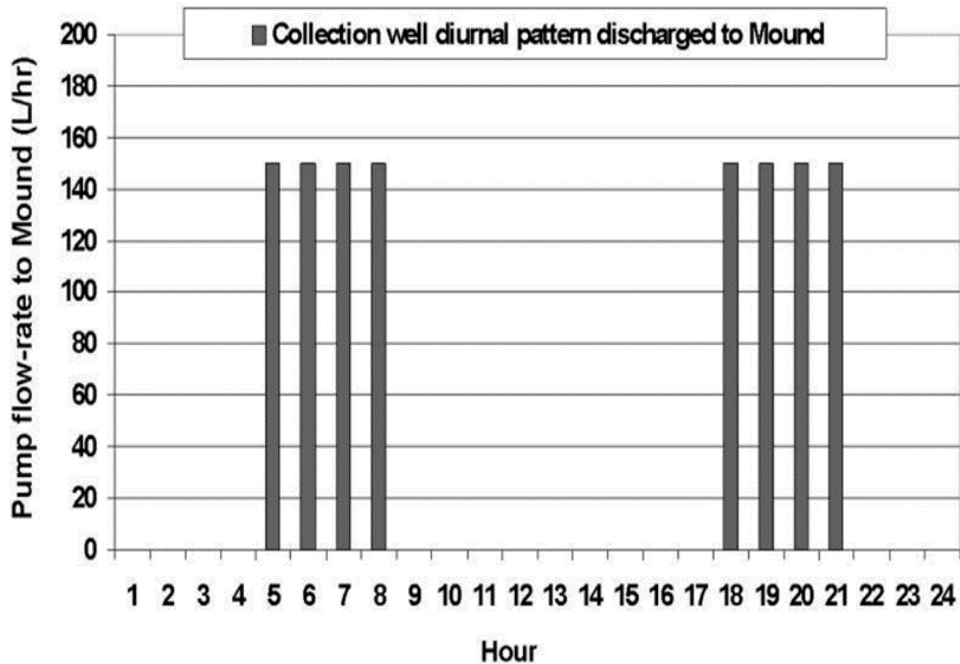


Figure 6: Pre-set pumping regime for sites F and T (from pump marks).

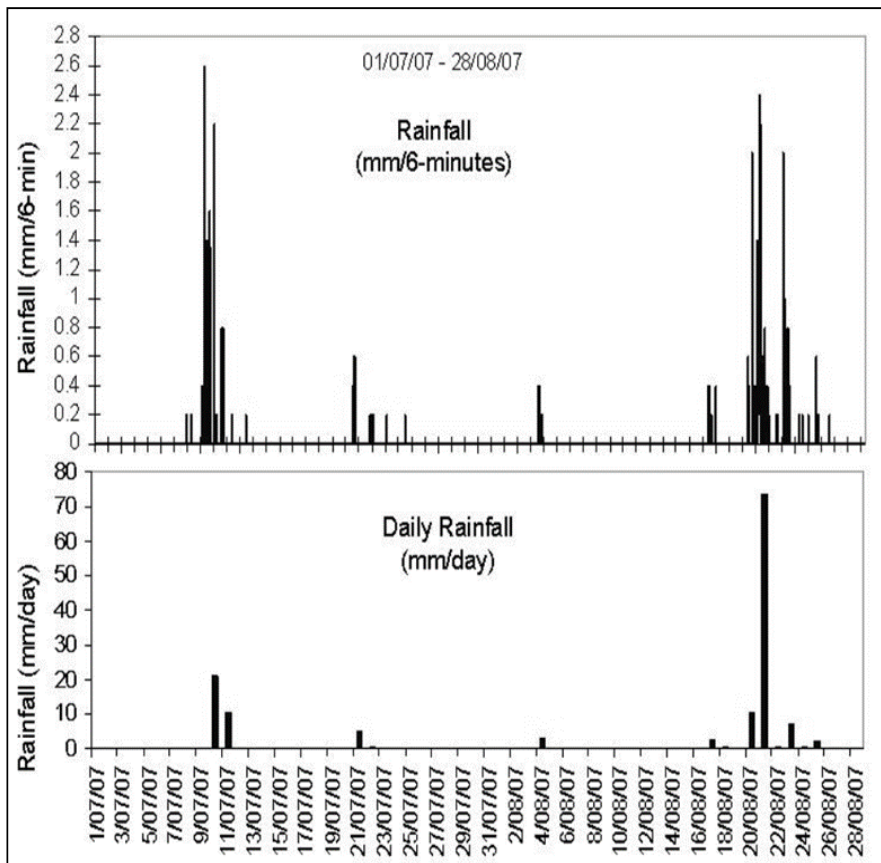


Figure 7: Rainfall monitored at 6-minute time-steps and total daily rainfall.

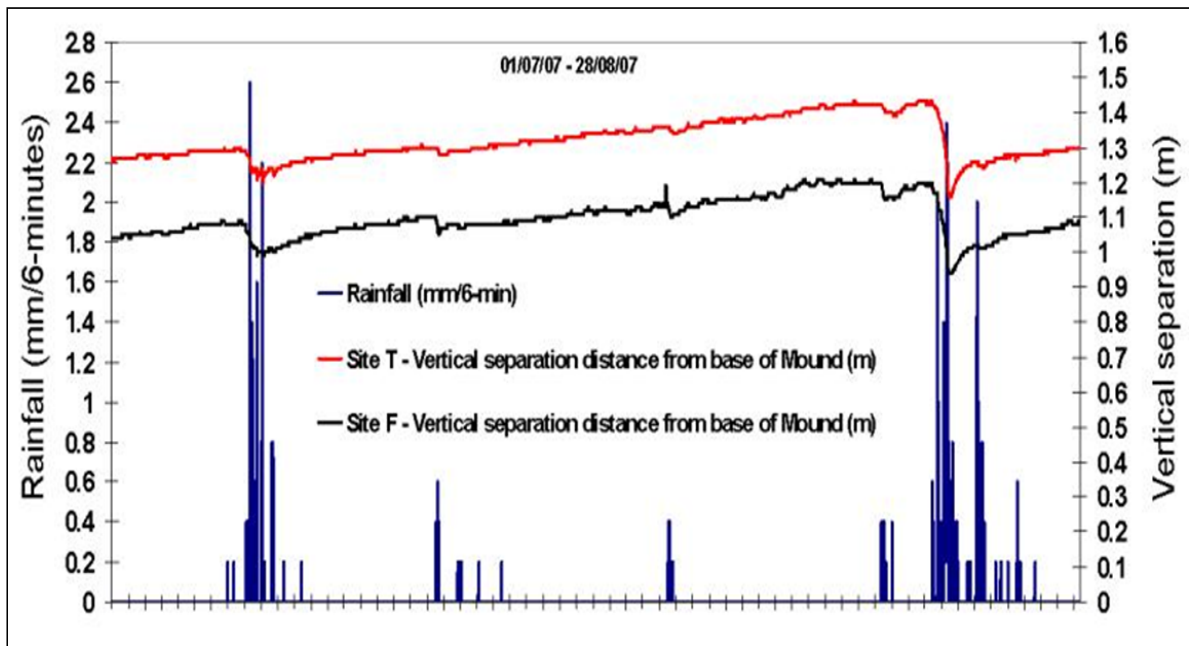


Figure 8: Change in depth to groundwater (vertical separation distance) as a result of rainfall monitored at 6-minute time-steps.

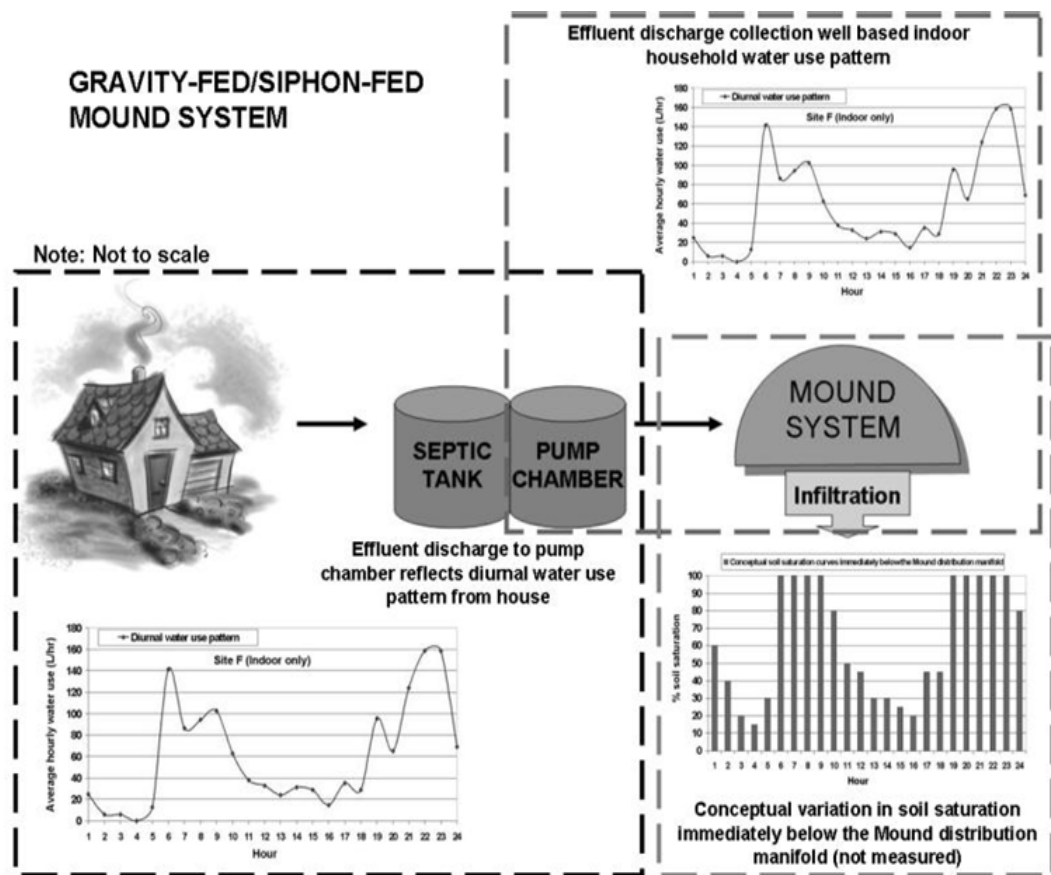
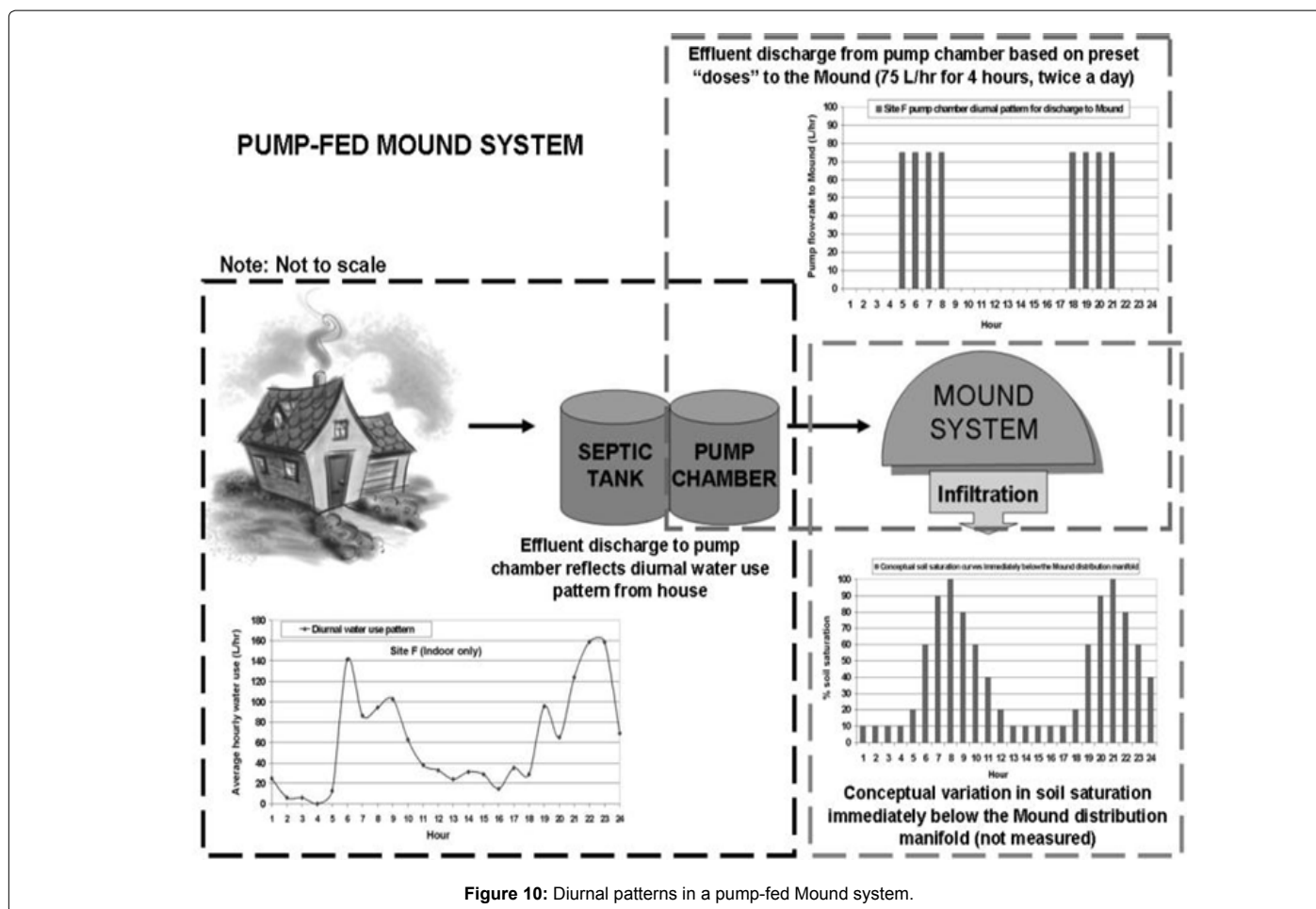


Figure 9: Diurnal patterns in a gravity-fed/siphon-fed Mound system.



The significance of diurnal patterns in on-site wastewater management

Due to the differences in average daily water use, diurnal water use pattern and septic tank water quality between the two sites, effluent entering the Mound will impact differently on Mound systems with similar design attributes fed by similar sized septic tank/secondary collection wells (pump chambers).

The design criteria for septic tanks are traditionally based on a general purpose philosophy, and an over-sized septic tank-collection well is unlikely to provide overflow problems (and additional risk) when compared to an under-size septic tank-collection well. However, this may create an issue for the "timing" of effluent discharge to the Mound and ultimately the temporal performance of the Mound. Using the two study sites as examples, site T daily average water use was approximately 50% greater than site F, and therefore wastewater at site F is likely to reside for longer periods in similarly sized septic tank-collection wells and be pumped to the Mound less frequently. A potential alternative is to "resize" the pump chamber (or alter pump marks) to increase the frequency of effluent application which would maintain a long-term soil moisture pattern suitable for optimising nitrate formation and promotion of de-nitrification.

The size of a Mound system is based on design flow allowances different to those used to design the size of the septic tank-collection

well. Mound design is based on design flows that consider occupancies of ≤ 5 people [1,2] and the septic tank-collection well design criteria is based on design flows for between 5-10 people [4]. This means that input to and output from the septic tank-collection well will vary considerably with relatively lower occupancies and/or average daily indoor water use. This will vary the diurnal "doses" to different Mound systems with similar pump marks and will likely exclude comparison between Mound systems in gauging relative performance.

Smaller volumes of wastewater entering the septic tank will result in longer periods before pump marks are reached and activate effluent-dosing to the Mound. Larger volumes of wastewater entering a similarly sized septic tank will result in relatively shorter periods before pump marks are reached and activate effluent-dosing to the Mound. Longer-term patterns of saturation/un-saturation in the Mound will be governed by the frequency of effluent application and will have implications for the long-term performance of the Mound. For example, infrequent effluent application to a Mound may result in organic material and salts "drying" within the delivery pipe system and/or the Mound distribution manifold; and is likely to impact on infiltration rates [19-24].

Figure 11 conceptualises the likely long-term frequency of effluent application at sites T and F as a function of relative household water use to similarly sized septic tanks/collection wells with similar pump marks. The frequency of effluent application to the Mound is

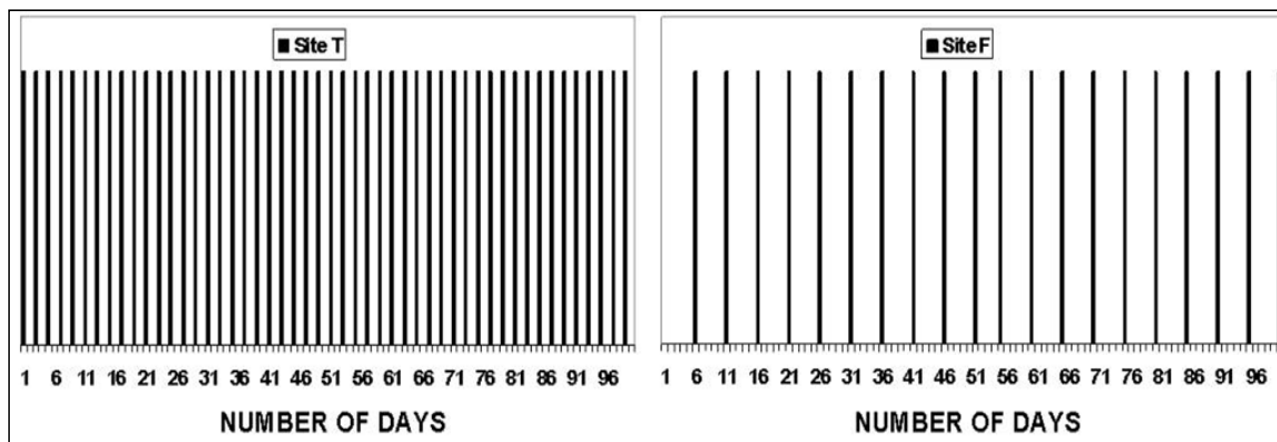


Figure 11: Conceptualised long-term patterns of effluent application at sites T and F as a function of relative household water use feeding similarly sized septic tanks/ collection wells with similar pump marks that activate effluent application to the Mound.

considerably different between sites. One conclusion that may be drawn from Figure 11 is that soil moisture (in the Mound) at site T would likely be relatively higher (for longer periods) although less variable than at site F. Seasonal rainfall patterns will also influence the generic patterns shown in Figure 11 which may negate the significance of such variability, particularly in moderate to high rainfall areas.

Furthermore, the diurnal pattern of saturation/un-saturation will be different for Mounds supplied by gravity-siphon or a pump. Low pressure dose-pumping has been demonstrated to provide improved management of the diurnal saturation/un-saturation dynamics of the Mound, as saturation of the substrate immediately below the distribution network in the Mound will occur less often, thus promoting aeration for longer periods of un-saturated conditions in the Mound.

Conclusion

The diurnal patterns presented in this study indicate that the performance of Mound systems in residential homes will vary with different daily average indoor water use and diurnal indoor water use patterns. The variability in septic tank water quality may also impact on Mound performance by reducing infiltration rates over time with respect to variable effluent application rates. These differences are likely to contribute to the relative performance of Mound systems at similar sites. The timing and volume of effluent delivery to the Mound is likely to play an integral role in the long-term performance of the Mound system and the dynamics and diurnal patterns presented in this paper warrant further consideration in managing on-site wastewater systems, particularly if nitrification/de-nitrification rates and/or virus inactivation rates are to be determined. The concept of using average effluent-loading rates may be misleading for evaluating Mound performance if the dynamics and diurnal patterns of the on-site wastewater system are not appreciated at intra-daily time-steps (i.e., 6-minutes).

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