ENVIRONMENT DESIGN GUIDE

ON-SITE DOMESTIC WASTEWATER TREATMENT AND REUSE

Phillip Geary, David Stafford and Joe Whitehead

SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts

- On-site wastewater management offers cost effective alternatives to conventional sewer systems.
- Well designed, installed and maintained on-site wastewater systems can provide equivalent or better public health and environmental protection than conventional sewer systems and often offer a greater range of options for sustainable reuse of treated effluent.

This note includes:

- Descriptions of a range of systems used for the on-site treatment and disposal or reuse of domestic wastewaters from residential developments in non-sewered areas in Australia
- The major components of these systems
- Greywater treatment and reuse
- Well-known and emerging small-scale options
- Site and soil assessment requirements and land capability considerations for system selection and sizing
- Design, performance and maintenance requirements for each of the systems.

The on-site wastewater treatment train typically comprises a number of the following elements:

- Source
  - All points of wastewater generation within the household
- Collection and primary treatment
  - Septic tank
  - Greywater tank
- Secondary treatment
  - Sand filter
  - Aerated wastewater treatment system
  - Reed bed
- Tertiary treatment (disinfection)
  - Chlorine
  - Ultraviolet light
- Land application, disposal or reuse
  - Soil absorption trenches
  - Evapotranspiration beds
  - Irrigation areas

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Identify the current regulatory guidelines for each Australian state, and the various Australian/New Zealand Standards which deal with the on-site management of domestic wastewaters.
- Seek competent professional advice to complete a land capability or site and soil assessment prior to system selection, location and sizing.
- Minimise load by selection of water saving devices.
- Size according to effluent load and site and soil limitations.

Cutting EDGe Strategies

- Consider the full range of alternative options including low energy and passive alternatives.
- Optimise treatment and reuse potential.
- Consider individual on-site or community and decentralised options for both treatment and reuse.
- Higher level treatment options minimise land application demands and maximise opportunities for reuse.
- Many alternatives are suitable as retrofit options for established dwellings.

Synergies and References

- *BDP Environment Design Guide:* TEC 11

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This note includes descriptions of the different systems used for the on-site treatment and disposal/reuse of domestic wastewaters from residential developments in non-sewered areas in Australia. It also examines greywater treatment and reuse, which may be relevant in sewered areas. A number of well-known and emerging small-scale options are discussed, as well as the site and soil assessment requirements and land capability considerations which are required in the process of selecting and sizing an appropriate system. Aspects of the design, performance, and maintenance requirements of each of the systems are also described in this note.

1.0 INTRODUCTION

Over the last few years there have been significant changes to regulations regarding domestic wastewater management in each Australian state and at the national level. The current legislative requirements for each state are outlined in this note, and the informative joint *Australian/New Zealand Standard 1547:2000* (Standards Australia, 2000) on domestic wastewater management, is introduced. Changes to the various state regulations and the development of national guidelines have been influenced by the need to conserve water and an increasing public awareness regarding the sustainability of our current water and wastewater use practices, particularly pollution of waterways and the potential risk to human health from faecally contaminated waters.

Domestic wastewaters are generally characterised by two major waste streams, although most on-site systems deal with all household wastes combined together. If segregated, the two waste streams are: toilet wastes, commonly referred to as blackwater, and other household wastes, commonly referred to as greywater or sullage. Domestic greywater is household wastewater which has not come into contact with toilet waste. Increasingly people are interested in reusing this stream for applications such as garden watering, and less commonly, for toilet flushing. The reader is referred to *BDP Environment Design Guide* TEC 11 (Booker, 2001) for a definition of domestic wastewater, a breakdown of the typical daily Australian concentrations of contaminants in each domestic wastewater stream, and the daily contaminant loads per capita.

A number of the more commonly used on-site wastewater treatment systems and their various components are described in the following sections of this note. The various components, which may be selected at each stage of the treatment chain, are shown schematically in Figure 1. Following the collection and primary treatment of domestic wastes, effluent may be treated to a higher standard using biological processes and by a number of the devices described. Depending on the level of this secondary treatment and the land application/reuse option chosen, effluent may need to be disinfected. A number of disposal/reuse options are available in unsewered areas. At each site however, an assessment should be made of the hydraulic capacity of the soil and consideration given to any land capability constraints (for example, slope) prior to selecting the most appropriate system for that site. In most cases professional assistance will be required following the site and soil assessment process to determine which system is most cost effective for the site and to ensure that the one selected will work effectively within any of the identified land constraints.

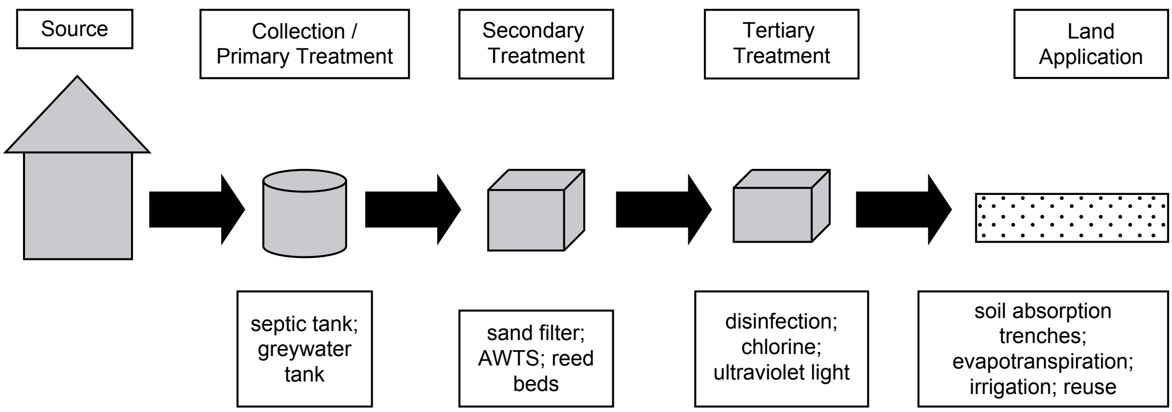

Figure 1. Schematic of on-site wastewater system components (adapted from McCardell et al., in press)

Table 1. Relevant state legislation and design guidelines for domestic wastewater management

State	Component	Regulation / Act	Guideline / Code of Practice
NSW	All On-site Wastewater Management	Local Government Act 1993	*Environment and Health Protection Guidelines for On-site Sewage Management for Single Households* (Department of Local Government, 1998)
	Greywater		*Environment and Health Protection Guidelines for On-site Sewage Management for Single Households* (Department of Local Government, 1998) *Greywater Reuse in Sewered Single Domestic Premises* (NSW Health, 2000)
VIC	All On-site Wastewater Management	Environment Protection Act 1970	*Septic Tanks Code of Practice* (EPA Victoria, 2003a) *Land Capability Assessment for Onsite Domestic Wastewater Management* (EPA Victoria, 2003b)
	Greywater		Information Bulletin No. 812 – *Reuse Options for Household Wastewater* (EPA Victoria, 2001) *Appropriate Reuse of Greywater* (Department of Human Services, 2003)
QLD	All On-site Wastewater Management	Plumbing and Drainage Act 2002	*On-site Sewerage Code* (Department of Natural Resources and Mines, 2002)
	Greywater		*Guidelines for Use and Disposal of Greywater in Unsewered Areas* (Department of Local Government and Planning, 2003)
SA	All On-site Wastewater Management	Public and Environmental Health Act (Waste Control) Regulations 1995	*Standard for the Construction, Installation and Operation of Septic Tank Systems in South Australia* (SA Health Commission, 1995), and Supplements
	Greywater		*Greywater/Sullage Systems* (SA Department of Health, 2003)
WA	All On-site Wastewater Management	Health Act 1911	Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations; Code of Practice for the Design, Manufacture, Installation and Operation of ATUs Serving Single Dwellings
	Greywater		*Draft Guidelines for the Reuse of Greywater in Western Australia* (WA Department of Health, 2002)
TAS	All On-site Wastewater Management	Plumbing Regulations 2004	Tasmanian Plumbing Code 1994 *AS/NZS 1547:2000 – On-site Domestic Wastewater Management* (Standards Australia, 2000)
	Greywater		As above at Local Council discretion
NT	All On-site Wastewater Management	Public Health (General Sanitation) Regulations	Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent
	Greywater		NTDHCS (2004) – Information Bulletin: *Greywater Reuse in Single Domestic Premises*
ACT	All On-site Wastewater Management	Public Health Act 1997	*AS/NZS 1547:2000 – Onsite Domestic Wastewater Management* (Standards Australia, 2000)
	Greywater	Environment Protection Act 1997	Fact Sheet: Greywater Reuse Environment Act (2004)

2.0 THE REGULATORY ENVIRONMENT

In the majority of urban areas in Australia, domestic residences are connected to a reticulated sewerage system where a wastewater utility (which could be a semi-private corporation or local council) manages the transport, treatment and disposal/reuse of all domestic wastewaters. For the remainder of the population, typically in outer-urban, small community and rural areas (approximately 12 per cent), all domestic wastewaters are treated and disposed of on-site, that is, on the individual site or allotment where they are generated. A large number of these wastewater systems are supplied with reticulated mains water, while the remainder rely on rainwater tank collection for domestic in-house use.

It is particularly important where households rely on small-scale on-site wastewater systems that effluent does not contribute to contamination of any waters used for potable supplies or recreation, that public health standards are maintained and that environmental values are protected. There is increasing evidence that the export of nutrients and pathogens in runoff from large numbers of poorly managed systems in small areas do have a measurable detrimental impact on receiving waters (Whitehead and Geary, 2000).

On-site wastewater management in Australia is typically regulated by legislation which is administered by a state government department, although the department responsible and its level of practical involvement in system management varies significantly as shown in Table 1. Within each state there may also be different approaches to on-site wastewater management. Some state guidelines outline design requirements for sizing individual on-site systems and other land capability considerations for siting systems, while others rely on individual councils to interpret and apply the guidelines. As a result there may be different approaches within a state, for example, approaches to the sizing of effluent land application areas vary within NSW. Several states also refer (and some defer) to the guidance provided by the joint Australian/New Zealand Standards for all-purpose on-site domestic wastewater management.

Over the past few years, most Australian states have also developed guidelines (which in some cases are still in draft form) for the treatment and reuse of greywater, although there is still conjecture about its treatment and storage given the public health and environmental issues described in section 7.0. Generally, on-site wastewater management (including greywater) varies between states and within states, particularly as the practical aspects associated with the interpretation and application of the guidelines are managed by the local regulatory authority (the council).

3.0 SITE AND SOIL ASSESSMENT FOR ON-SITE WASTEWATER SYSTEMS

Site and soil assessment is a critical element in on-site wastewater management system selection and design. Site and soil assessment should only be undertaken by suitably qualified and experienced professionals familiar with wastewater management and the description and assessment of the topography, soils and environmental constraints of a site.

Any site and soil constraints will determine the minimum level of wastewater treatment required and hence guide the selection of treatment system. Site constraints and required separation distances from sensitive receptors (waterways, bores, buildings, boundaries etc.) will determine the amount of available land for application of the wastewater and help determine a suitable location for the land application system. The characteristics of the receiving soil will determine an appropriate loading rate for the hydraulic component of the wastewater, and together with the existing or proposed vegetation for the land application area, enable assessment of the minimum area required for the sustainable application of the nutrient (nitrogen and phosphorus) content of the wastewater.

Guidance as to the required level of detail of site and soil assessment and the methodologies to be employed is to be found in *AS/NZS 1547:2000 – Onsite Domestic Wastewater Management* (Standards Australia, 2000) and the various State Government regulations or design guidelines (Table 1). Reference should also be made to each local council's requirements, for example in NSW, where each local regulatory authority has been required to prepare its own 'On-site Sewage Management Strategy' as part of the *SepticSafe* Program reforms (Department of Local Government, 1998; Irvine and Hillier, 1999).

The reason many older on-site wastewater systems perform poorly, or fail, is because insufficient attention was paid to site and soil assessment. However, with careful site and soil assessment, sound system selection is possible with a high measure of assurance that sustainable long-term performance can be achieved. The site and soil assessment should be thought of as a risk management process, one that identifies potential risks associated with on-site wastewater systems and management actions to address those risks. It is important that the assessment be carried out as early as possible in the development process i.e. at the rezoning or subdivision stage. This allows the size and design layout of lots to reflect risks that have been identified via the site and soil assessment.

4.0 ON-SITE WASTEWATER TREATMENT SYSTEMS

4.1 Pretreatment of domestic wastewaters using a septic tank

In unsewered areas within Australia, domestic wastewaters were, until the mid 1980s, almost exclusively pretreated in a septic tank and gravity fed to below ground absorption trenches (as shown in Figure 2), or to an evapotranspiration bed. The traditional domestic on-site system therefore has two components: a septic tank, used to provide partial treatment of the raw waste under anaerobic conditions, and the disposal field (typically designed as lines of trenches or as a single bed to encourage evapotranspiration), where further treatment and final disposal of the liquid discharged from the septic tank takes place. Both system components are generally installed below ground surface. The manufacturing and system requirements for septic tanks are dealt with in *AS/NZS 1546* (Standards Australia, 1998). The passive anaerobic pretreatment of wastewaters in the septic tank results in the removal of approximately 40-60 per cent biochemical oxygen demand (BOD_5), 50-70 per cent total suspended solids (TSS), 10-20 per cent nitrogen (N), 30 per cent phosphorus (P) and a reduction in numbers of microbiological contaminants as described in Gardner et al., (1997). Table 2 provides a general summary of the design, performance, and maintenance requirements of a standard domestic tank.

The further treatment or renovation of the effluent by soil is very important. Effluent percolates through the soil where a variety of physical, chemical and biological transformations occur prior to it reaching surface or groundwaters. An assessment of the site for the tank and the soil's hydraulic capacity is required to determine if the site conditions are suitable generally, and to determine whether it is hydraulically capable of dealing with the design loads. These hydraulic loads are usually based on the size of the proposed household and whether a reticulated mains water supply is available, or whether water supply is from a rainwater tank.

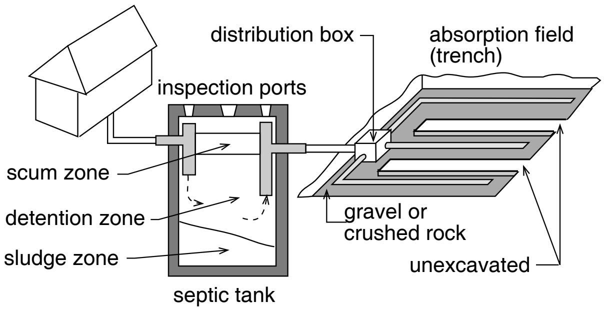

Figure 2. Conventional septic tank/land application system (Gardner et al., 1997)

4.2 Effluent filters

Significant improvement in the performance of disposal fields in soil-based systems can be achieved by the use of outlet filters on septic tanks. Filters prevent gross solids leaving the septic tank thereby reducing the clogging in the effluent disposal area and the likelihood of its failure. Removal of gross solids from the effluent means that small diameter pipework may be used without clogging problems. The filters are simple, inexpensive and low maintenance devices fitted in the outlet T of a septic tank. Typically, they are made of slotted pipe, mesh tubes or stacked discs often within a cassette. Usually the filters are simply placed into the outlet T through the inspection cap. They can be easily retrofitted to most existing tanks to improve system performance.

Periodic cleaning of an effluent filter is required and this is usually by simply hosing the filter down into the septic tank. Although only limited data is available to accurately quantify their performance (Byers et al., 2001), it is clear that they retain gross solids in the tank and modulate outflows thus enhancing the performance of primary treatment within the septic tank. They also dramatically reduce suspended solids and some may also reduce BOD_5 and fats, oils and greases in the wastewater stream. By these means, the life and efficiency of the following treatment and/or disposal systems are considerably enhanced. Their use is becoming widespread internationally due to regulatory pressure; they should be required in all new septic tank installations in Australia.

4.3 Siphons

In situations where a passive wastewater treatment system is sought or where power is not available, automatic dosing siphons provide an option for periodic dosing of wastewater to treatment systems, for example sand filters, or drainfields. Advantages of siphons are that they transform low or variable flows into regular doses, are suitable for pressurising manifolds and drain fields, have no moving parts, require no electrical connection and utilize proven technology. They do however require an understanding of hydraulic principles to ensure appropriate use and operation, and are not suitable for detention or slow release systems (Stafford, 2001).

4.4 Septic tank with packed bed filters

Packed bed filters are biological and physical treatment units with a long history of use in wastewater management. These filters, which use graded media such as sand and gravel in treating small to medium volume wastewater flows, can produce a high quality final effluent. They are aerobic fixed film bioreactors (where biological treatment occurs on the organic film coating the media), and in addition to physical (screening and sedimentation) and chemical (adsorption of dissolved pollutants) processes, they perform as a biological filter. It is particularly important that professional assistance be sought in the design of a packed bed filter as the characteristics of the filter media are particularly important. The grain size must

Table 2. Pretreatment using a septic tank - system description

Description	All wastewater is usually gravity fed to a buried septic tank. Tanks are typically plastic or concrete of about 2,400-4,500 litre (and larger) capacity, ideally fitted with a baffle. Solids settle to the bottom and a scum forms at the surface. Anaerobic digestion of organic solids occurs. Effluent is discharged by gravity for further treatment.
Uses	Septic tanks provide primary treatment. The discharge may then be further treated and disposed of on site or collected for central treatment and disposal.
Performance	If sized for a detention time of 3-4 days, a significant reduction of BOD_5 and TSS will be achieved.
Space requirements	Tanks occupy less than 4 square metres in area. Only the lid is visible at the surface. Space is also required for subsurface dispersal of treated effluent in the land application area.
Maintenance	Septic tanks have no moving parts and require no power. They should be pumped out when sludge build-up or scum thickness reduces the available capacity for wastewater detention (about 2-5 years for combined wastewater and about 15 years for greywater).

be small enough to screen out as much suspended solids as possible, while being large enough to avoid clogging. It must also enable microorganisms to colonise the filter in order to maximise the biological treatment processes. Typical design guidelines are available in most states which deal with sand filter design (including media size selection), construction, and operation and maintenance. Geary et al. (2003) provide a summary of design requirements and an assessment of their performance.

There are two types of packed bed filters (single pass (intermittent) filters or recirculating filters) which are increasingly being used in new installations where a high effluent quality is required for on-site reuse by such means as subsurface drip irrigation. In the majority of cases, the filter material is graded sand. In single pass filters, the wastewater is collected after it has percolated through the sand and is piped to the disposal area. A single pass filter is shown in Figure 3 and the system description is provided in Table 3.

Recirculating filters are able to produce wastewater to advanced levels of treatment. A schematic diagram of the components of a recirculating filter is shown in Figure 4 and a description of the system components in Table 4. Primary treated wastewater from the septic tank is delivered to the recirculation tank where mixing and biochemical treatment take place. Pumps in the recirculation tank deliver wastewater to the filter bed in frequent timer-controlled doses. With each dose, the wastewater percolates through the filter (which could be coarse sand/fine gravel, peat or other media such as crushed glass, polystyrene pellets, fabric, foam, zeolite), and the contaminants are removed and broken down by naturally occurring microorganisms living on the filter media. The highly aerobic flow from the filter bed drains back to the recirculation tank for mixing with incoming wastewater. After a few more passes through the filter bed and recirculation tank, the treated wastewater is ready for land application or reuse.

It is possible to produce a final effluent quality with quite low organic and suspended solids concentrations. One of the other differences with respect to a single pass aerobic filter is that the recirculation process is also able to achieve significant nitrogen reductions through nitrification/denitrification processes. This is as a result of the continued addition of the carbon rich septic effluent into the recirculating tank which is also receiving the nitrified effluent from the filter bed. Single pass intermittent aerobic filters, while also able to achieve low organic and suspended solids concentrations, generally produce a highly nitrified effluent.

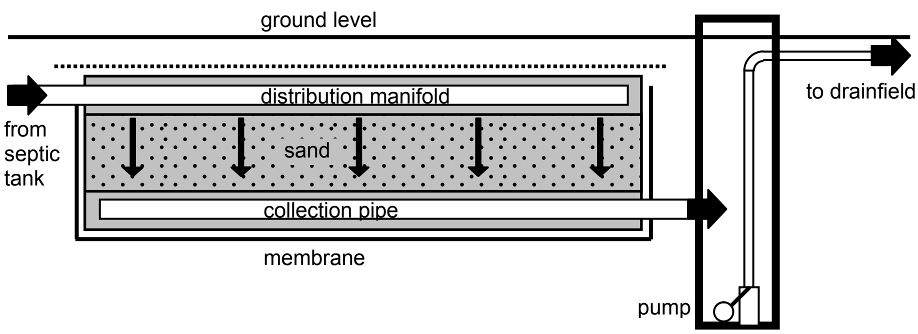

Figure 3. Single pass (intermittent) sand filter

Table 3. Septic tank with intermittent sand filter – system description

Description	Effluent from a septic tank is dosed (by pump or siphon) over a sand filter. The discharge can then be disposed of by subsurface means or surface irrigation if disinfected (ultraviolet light or chlorination).
Uses	These systems provide complete onsite treatment to acceptable standards and are suitable for individual residences, housing clusters and light commercial applications.
Performance	Typically excellent results, well below minimum standards are achieved for BOD_5 and TSS reduction. Pathogen reduction is considerable. As oxygen is available to the system, organic nitrogen compounds and ammonia are converted to nitrate nitrogen through the process of nitrification.
Space requirements	Septic tank 4 square metres; sand filter 20 square metres plus on site disposal area. Typically sand filters are buried so the visual impact is minimal. Space is also required for dispersal of treated effluent in the land application area.
Maintenance	Septic tank – occasional pump-out as above; sand filter – minimal but may need occasional back- ushing of the distribution manifold to ensure efficient operation; odours may occur if the sand filter is not properly designed or aerobic conditions are not maintained. If pumps are used for dosing they will require periodic servicing and in the long term may require replacement.

Much of the recent research and development in the area of packed bed filters has been undertaken overseas. One recent innovation has resulted in an advanced packed bed treatment technology that uses a textile medium. This system consists of a watertight fibreglass basin which is filled with an engineered textile and which actually sits on top of the existing septic tank. As well as having a small footprint, the recirculating textile filter offers an extremely large surface area for biomass attachment and high water holding capacity due to capillary effects within the filter micropores. These systems have been developed following many years of research and can be engineered to produce a high quality effluent.

Peat can also be used as a filter medium in on-site wastewater treatment. Typically peat biofilter modules are located on, or partially buried in, the soil and primary treated wastewater from the septic tank irrigated over the peat bed for treatment prior to infiltration into the soil. Such filters can be adapted in much the same way as a recirculating sand filter to enhance nitrogen reduction where this is required. In Australia, Victorian peat has been successfully utilised in the construction of peat bed filters (Patterson et al., 2001).

4.5 Aerated wastewater treatment systems

Aerated wastewater treatment (AWTS) systems or units (ATU) are small self-contained proprietary biological treatment systems which rely on mechanical devices to provide mixing, aeration and pumping of effluent. AWT systems are based on either two tanks or a single tank where effluent is subjected to accelerated aerobic breakdown (Table 5 and Figure 5) using air blowers or a Venturi system. A final effluent is produced using various combinations of pumps, blowers, filter media for bacterial growth, and settlement and chlorination chambers. With the required management and maintenance (including periodic sludge removal), the final effluent produced should be clear and odourless and should meet quality criteria approved by the regulatory authorities. Effluent from an aerated wastewater treatment system may be land applied either above ground (if permitted by the regulatory authority and disinfected) or below ground. There are a large number of these proprietary systems available in each Australian state.

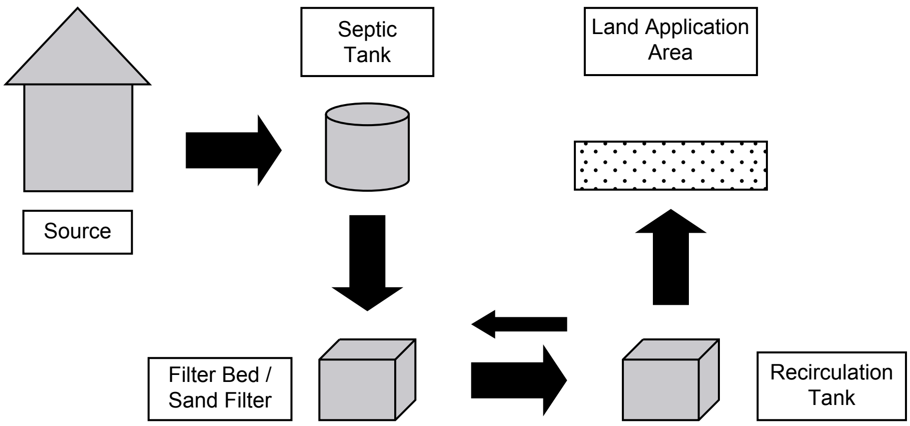

Figure 4. Schematic of recirculating filter (adapted from Geary et al., 2003)

Table 4. Septic tank with recirculating sand filter – system description

Description	Effluent from a septic tank is dosed (by pump or siphon) over a sand filter. The filtered effluent is circulated to a pumping tank for recirculation of discharge (typical ratios 3:1 – 5:1). The discharge can then be disposed of by subsurface means or surface irrigation if desired.
Uses	Similar to septic tank with intermittent sand filter.
Performance	Similar to septic tank with intermittent sand filter. However, both oxidation and reduction of nitrogen occur resulting in reduced total nitrogen concentrations.
Space requirements	Similar to septic tank with intermittent sand filter. Although the recirculating sand filter may be slightly reduced in size, additional pumping tanks are required. Typically, sand filters are buried so the visual impact is minimal although recirculating pump and/or control enclosures may be visible as well as pumping chamber access lids.
Maintenance	Similar to septic tank with intermittent sand filter. Recirculating filters require two pumps or at least one pump plus a siphon so electrical supply and pump maintenance/ replacement are required.

5.0 OTHER TREATMENT SYSTEMS

The treatment systems described below are currently in use where permitted by the relevant state regulation and local authority. There is increasing interest, particularly from the public, in their ability to 'naturally' treat waste and wastewater in domestic situations. In the case of the composting toilet, consideration needs to be given to separate greywater treatment and disposal (section 7.0); in the case of the reed bed, effluent from the treatment system needs to be land applied.

5.1 Composting toilets

Composting or waterless toilets accept toilet wastes (and sometimes garbage wastes) and utilise the natural process of composting to effect decomposition of organic material. Air is introduced through an opening to pass through the composting materials and exit through a vent. Excess liquids need to be allowed to drain for collection or evaporation. As a result of aerobic decomposition processes and predation and natural die-off within the compost pile, the numbers of pathogenic microorganisms are significantly reduced. The biological degradation of the organic wastes converts the sewage into a humus-like material. A number of different proprietary types of composting toilets are commercially available, although owner-built designs are also available (Davison et al., 2001), subject to regulatory requirements in each jurisdiction.

One commonly used composting toilet, where waste is treated continuously, has the point of use separated from the decomposition chamber in a large vault system (Figure 6 and Table 6). Another type of system has the point of use directly attached to the chamber and waste is treated in batches. In these latter systems where adjoining composting chambers or vaults are used alternately, the process of composting in an already full chamber can be allowed to proceed until completed and to produce mature compost for burial in the garden. The empty chamber is then used again. Composting units may contain heater elements to accelerate the composting process and a number incorporate a fan for improved ventilation and to assist with evaporation.

Bulking agents including food waste or sawdust may be periodically required to provide a carbon source and to balance the carbon to nitrogen ratio for optimal composting. Toilet products must be chosen with care to maintain an aerobic microbiology in the compost pile. Composting systems are often used in combination with wetland filters such as reed beds (section 5.2) where separated wastewaters are treated by vegetation grown specifically for this purpose. Composting toilets are particularly suited to sloping sites where they can often be readily accommodated beneath buildings.

In many jurisdictions, there are particular health and environmental requirements for the removal and reuse

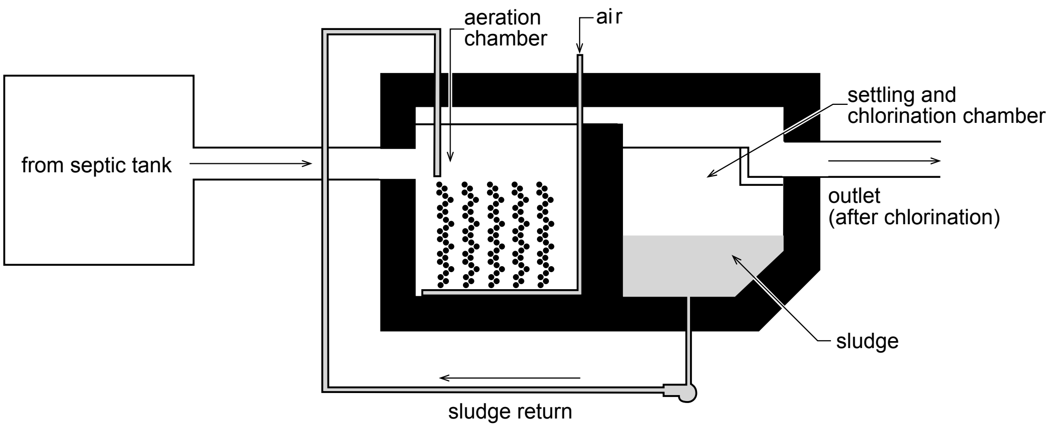

Figure 5. Aerated wastewater treatment system (AWTS) (adapted from Gardner et al., 1997)

Table 5. Aerated wastewater treatment system (AWTS) – system description

Description	Effluent from a septic tank passes into a tank in which it is aerated, usually by electrically powered blowers. Clarification and disinfecting chambers are commonly included in the aeration tank with sludge return to the septic tank.
Uses	Similar to septic tank with intermittent sand filter but particularly in areas where space is limited.
Performance	Similar to septic tank with intermittent sand filter.
Space requirements	Septic and aeration tank up to 10 square metres plus space for surface irrigation or sub-surface soil disposal. Tank lids, air pump and control enclosures are visible at ground level.
Maintenance	Septic tank as above; aerating system requires regular (usually quarterly) maintenance by experts as well as reliable power supply and acceptance of limitations of the system by home owners.

of compost from composting toilets. Composting toilets require a certain amount of user interest and involvement to ensure satisfactory operation, and whilst they can provide a most satisfactory low impact sanitation option for some, in other cases they prove to be a less than satisfactory option as some individuals are not prepared to accept waterless systems. Careful consideration should be given to the maintenance and servicing needs of the system and the need to adequately deal with greywaters.

A number of more sophisticated 'natural' systems, combining features of composting systems, vermiculture, aerated treatment and trickling filters, are emerging in the Australian market. These are generally more complex than composting toilets and also require a degree of owner interest and involvement to ensure satisfactory ongoing performance but are, in some cases, capable of achieving high levels of treatment. Disposal of the treated wastewater is generally subsurface unless disinfected, in which case surface irrigation may be possible.

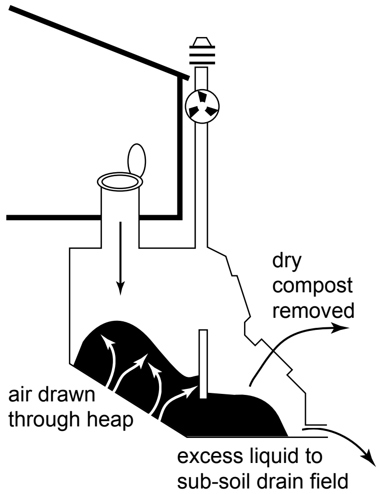

Figure 6. Composting toilet (source: http://www.dlg.nsw.gov.au)

Table 6. Composting toilet – system description

Description	Waste plumbing is divided into two systems. Greywater is collected and fed to a septic tank and on-site disposal; toilet waste is treated by aerobic decomposition to produce compost.
Uses	Composting toilets can provide considerable water savings. The area required for greywater disposal only can therefore be less than that for combined systems. Owner acceptance and involvement required in maintenance.
Performance	Needs to be carefully and regularly monitored and maintained.
Space requirements	Composting chambers vary widely in volume and are best suited to sloping sites where space is available below floor level. Vents, air admission grilles and composting chambers all need to be incorporated in the building design.
Maintenance	Moisture content, temperature, carbon supply, mixing and aerobic conditions must all be monitored and balanced. Compost needs to be periodically removed and disposed of or reused in accordance with State regulations.

5.2 Reed beds

A constructed wetland or reed bed is a wastewater treatment system which uses natural processes to improve water quality. These have been used for successfully treating, and particularly filtering, municipal wastewaters and stormwater runoff where systems receive low hydraulic and constituent loads. Reed beds mimic the water purification properties of natural wetland systems. They use the same plants, soils and microorganisms as natural wetlands to remove contaminants, nutrients and solids from the water. The plants in wetlands provide a place for microbes to attach. While these microbes take nutrients from the water to grow, the processes by which microbes actually transform and remove pollutants is complex. In addition, wetland plants also absorb nutrients, and like the microbes, they convert the nutrients into a form that they use for their growth. As the process of uptake, transformation, and release of nutrients in the wetland repeats itself, some of the nutrients in the system are trapped in the soils or released into the air.

Reed beds for domestic wastewater treatment typically pass wastewaters horizontally or vertically through permeable media (Figure 7 and Table 7). They may be underlain by either an impermeable membrane or clay material and are usually planted with emergent wetland plants. The subsurface flow reed bed, where effluent is confined below the surface of the substrate, is preferable in urban situations as there is little risk of odours and public or animal exposure to pollutants. Insect vectors and mosquito breeding problems are limited because there is no surface water in these systems and the rhizomes and substrate provide a huge surface area for microbial attachment and treatment of the water. This allows the reed bed to have smaller dimensions requiring less space compared with surface flow reed beds.

6.0 ON-SITE LAND APPLICATION SYSTEMS

Depending on the treatment system used, effluent may be land applied in a number of ways. As previously described, effluent from the septic tank is usually land applied below ground because of its poorer quality and because it is not disinfected. Usually a network

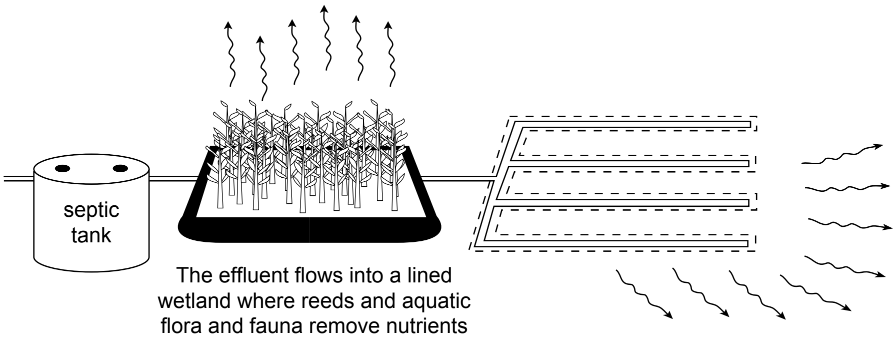

Figure 7. Reed bed system (source: http://www.dlg.nsw.gov.au)

Table 7. Reed beds – system description

Description	Effluent from a septic tank passes into a lined wetland (membrane or clay) through a gravel bed about 600 mm deep planted with selected deep-rooted vegetation providing root contact. The filtered waste is discharged to sub-surface soil disposal.
Uses	Individual and group housing, public and commercial buildings.
Performance	Typically excellent results, well below minimum standards are achieved for BOD_5 and TSS reduction.
Space requirements	Septic tank – 4 square metres; reed bed – typically 4 square metres per person minimum, up to 300-400 square metres (larger in cold climates). Although all components are usually buried, the reeds will be visible (up to 1.8 m high). Space may also be required for the dispersal of treated effluent.
Maintenance	Septic tank as above; wetland may require some replanting during the establishment stage. Seasonal harvesting of wetland plants. Ponding must be monitored and prevented.

of trenches or a bed is constructed (Figures 1 and 2) and effluent is distributed by gravity, or the system pressurised and effluent pumped to the network. If the site and soil assessment has indicated that the soil may be unsatisfactory for further treatment on-site, or if the groundwater table is too close to the surface, an option may be to import suitable fill material and distribute effluent by pumping to an above-ground mound (Section 6.1). If a higher quality of effluent is achieved by the selected wastewater treatment system, effluent irrigation may be possible on-site following disinfection (Section 6.2). In each of these situations, a pump chamber is required following either the septic tank or the wastewater treatment system.

6.1 Mounds

Mounds dose primary treated septic tank effluent, by pump or siphon, to a distribution manifold 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 as it passes through the mound in much the same way as it would be if it passed through an intermittent sand filter, before entering the native soil beneath. Mounds have the benefits of increasing separation distance between the point of application and the soil and groundwater, they facilitate nitrogen reduction and they permit increased evaporation and transpiration due to their being raised above ground level. Amended media designs offer opportunities for phosphorus removal where this is a requirement. Mound design and sizing requires professional input but with appropriate design higher hydraulic loading rates can be applied than to conventional trenches. Mounds can offer an attractive landscape option in situations where soils, high groundwater tables or climate otherwise restrict alternatives. A typical mound design is shown in Figure 8 and further detail in Table 8.

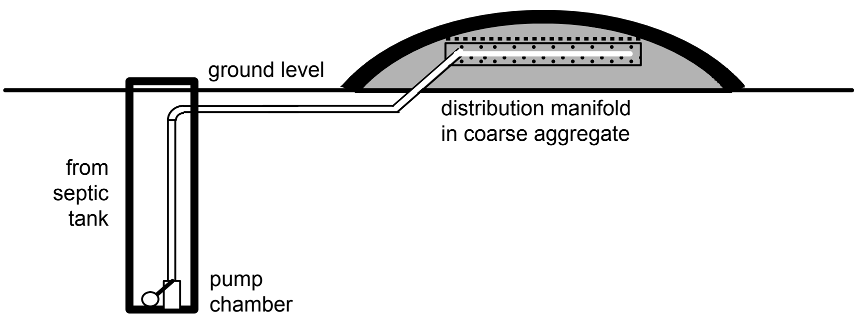

Figure 8. Mound system

Table 8. Mounds – system description

Description	Pretreated effluent is pressure dosed via a manifold in coarse aggregate near the top of a mound of sand through which it permeates. The mound is constructed above grade.
Uses	Mounds are used where soil permeability is low, rock is close to the surface, or if water tables are high. They are suited to most climates.
Performance	Depending upon design, mounds can significantly reduce BOD_5 and TSS. Nitrification can be significant.
Space requirements	Area is determined by analysis of soil tests and is quite variable but can require a large footprint.
Maintenance	The system requires reliable power, and pump and control maintenance or replacement; alternatively, on sloping sites siphons may be used to eliminate the need for power or maintenance. Mound vegetation requires maintenance.

6.2 Drip and spray irrigation

As previously described, effluent of a higher quality obtained from an on-site wastewater treatment system may be land applied using either subsurface or surface drip or spray irrigation. Irrigation of lawns, shrubberies and garden beds is possible. A calculation needs to be undertaken to determine the required area. One important requirement for effluent disposed above ground is that it be disinfected. Typically chlorine or ultra-violet light is used in these small-scale systems prior to above ground applications. Most, though not all, states allow subsurface irrigation without disinfection. This has the advantages of removing the wastewater from human contact and avoids the environmental disadvantages of chlorine disinfection both adversely affecting vegetation and killing off soil microbes which would otherwise assist in further treating the wastewater once in the soil. A number of the system requirements for both drip and spray irrigation are described in Tables 9 and 10.

7.0 GREYWATER TREATMENT AND REUSE

An increasingly important area is the potential which exists for segregating domestic wastewaters into their black and greywater components. This segregation offers a means of enhancing the conventional methods of treatment and disposal, and of facilitating the development of alternative strategies for wastewater management, one of which may be to reuse greywater on-site. The current reuse of greywater in Australia is, however, generally ad-hoc. While greywater reuse may still be illegal in a number of metropolitan areas where sewerage systems exist, most states have prepared greywater reuse guidelines (see Table 1), and at least

Table 9. Drip irrigation – system description

Description	Drip irrigation has three defining characteristics: pressurised lines with regularly and appropriately widely spaced emitters (ensuring even low rate distribution of effluent), dose/ rest cycling and shallow installation within the root zone.
Uses	Particularly suited to landscaped areas, sites with high water tables, irregular sites and on steep sites where siphons can replace pumps to pressurise lines.
Performance	The system combines the benefits of normal soil treatment, evapotranspiration and nitrogen uptake in the root zone. However, careful design and maintenance are required.
Space requirements	Area is determined by interpretation of soil characteristics and may be quite variable. The system is not visible in the landscape.
Maintenance	The system requires pump and control maintenance or replacement; filters, that require periodic back ushing, must be fitted to protect emitters from blockage.

Table 10. Spray irrigation – system description

Description	Only waste that has been through primary and secondary treatment as well as disinfection is suitable for spray irrigation.
Uses	Spray irrigation may be considered where water tables are high or soil conditions are unsuitable for subsoil systems. Water savings can be made by taking advantage of the reuse of treated waste to irrigate landscaped areas. Spray irrigation is not suited to small lots, steep slopes and must not be located near creeks or dams.
Performance	Similar to drip irrigation systems but offers higher evaporation rates.
Space requirements	The surface area required is considerable, up to 2.5-5 times the area required for a subsurface system. Run-off control may also be required.
Maintenance	The system requires reliable power and pump and control maintenance or replacement. Sprinkler heads need periodic cleaning and vegetation requires maintenance.

one state (Victoria) has established a rebate scheme to encourage greywater reuse in metropolitan areas. Booker (2001), in *BDP Environment Design Guide* note TEC 11, provides a detailed discussion on greywater quality and various treatment technologies required for disposal and/or reuse.

In general, there are three main options for greywater: direct diversion, primary treatment and subsoil application, or secondary treatment with disinfection and surface/shallow subsurface irrigation. If greywater is stored for more than 24 hours it must be treated and disposed of in accordance with all-waste on-site wastewater management principles. Direct diversion is considered acceptable with council approval and use of a licensed plumber/drainer for installation. Otherwise, system design must be approved by the relevant state authority.

A variety of proprietary greywater treatment systems exist, many of which rely on coarse filtration using rock, sand or other media in a discrete filter module, or below ground in a trench filled with filter media. A commonly used greywater system involves the collection of greywater and its immediate redistribution to the landscape for sub-surface lawn and garden watering. No storage is allowed, although a surge tank can be incorporated for coping with sudden influxes and for housing a distribution pump. The greatest potential for greywater re-use does appear to exist in the area of garden and lawn watering and this can result in some savings in potable water use. The Alternative Technology Association (2004) has recently reported on trial results from six households where greywater reuse systems have been installed in metropolitan areas. This review discusses some of the available technologies and issues such as legislative responsibilities and potential for litigation risk. The on-going management of greywater systems is particularly important in urban environments and a number of the regulatory bodies view this as an impediment to wide-scale application.

In all situations where domestic greywaters are to be collected, stored and land applied, advice should be sought on the contents of appropriate household products. Patterson (2004), for example, has a discussion on some of the chemical compounds present in kitchen products, cleaning agents and laundry products and the environmental impacts associated with their use. Apart from causing deleterious impacts to the biota within the septic tank, certain household products may contribute to a long-term deterioration in soil structure if land applied. There is a clear need for residents to be aware that on-site wastewater systems are biological systems and that care needs to taken in the selection of products for household use. There is also a concern with greywater because there is a general presumption that because the toilet wastes have not come in contact with it, pathogenic organisms are unlikely to be present. Greywaters may still contain human faecal indicator bacteria in concentrations high enough to indicate a health risk from the potential presence of pathogenic microorganisms. Greywaters must be treated to destroy the microorganisms present and human contact should be prevented. Ensuring that the above requirements are met is perhaps one of the reasons why no consistent approach to greywater reuse has developed within Australia.

REFERENCES

Alternative Technology Association (2004), *The Great Greywater Challenge,* ReNew, Issue 89, October-December, 34-37.

Booker, N. (2001), TEC 11 – *Greywater and Blackwater Treatment Strategies,* BDP Environment Design Guide, November 2001, RAIA.

Byers, M.E., Zoeller, K.E., Fletcher, J.D., (2001), *Septic Tank Effluent Filters: Monitoring and Assessment,* in Mancl, K. (ed.) Proceedings of the Ninth National Symposium on Individual and Small Community Sewage Systems, American Society of Agricultural Engineers, St. Joseph, Michigan.

Davison, L., Schwizer, B. and Kohlenberg, A. (2001), *The Use of Composting Toilets in New South Wales, Australia,* in Proceedings of the Annual Conference of the International Ecological Engineering Society, Lincoln University, Christchurch, NZ, 25-29 November.

Department of Local Government (1998), *Environment and Health Protection Guidelines, On-site Sewage Management for Single Households,* Bankstown, NSW.

Department of Local Government and Planning (2003), *Guidelines for the Use and Disposal of Greywater in Unsewered Areas,* Building Codes Queensland, Brisbane.

Department of Natural Resources and Mines (2002), *On-site Sewerage Code.* Available from http://www.lgp.qld.gov.au/

EPA Victoria (2001), *Domestic Wastewater Management Series, Reuse Options for Household Wastewater,* Publication 812, November 2001.

EPA Victoria (2003a), *Septic Tanks Code of Practice,* Publication 891, March 2003, Melbourne.

EPA Victoria (2003b), *Land Capability Assessment for Onsite Domestic Wastewater Management,* Publication 746.1, Melbourne.

Gardner, E.A., Geary, P.M. and Gordon, I. (1997), *Ecological Sustainability and On-Site Effluent Treatment Systems,* Aust. J. of Env. Management, 4(2), 144-156.

Geary, P.M., Stafford, D.J. and Spinks, A. (2003), *Performance Monitoring of a Low Cost Alternative On-site Effluent Treatment System,* SepticSafe Research Grant R13 Project Report prepared for NSW Department of Local Government.

Irvine, R. and Hillier, H. (1999), *Beyond Wallis Lake: New South Wales On-site Sewage Management Reforms and Application to Coastal Zone Risk Management,* in Proceedings of 9th NSW Annual Coastal Conference, Forster, NSW Coastal Council, 386-393.

McCardell, A., Davison, L. and Edwards, A. (in press), *The effect of nitrogen loading on on-site system design: a model for determining land application area size,* Wat. Sci. Tech.

NSW Health (2000), *Greywater Reuse in Sewered Single Domestic Premises,* NSW Government, April 2000.

Patterson, R.A., Davey, K. and Farnan, N. (2001), *Peat Bed Filters for On-site Treatment of Septic Tank Effluent,* in Patterson, R. and Jones, M. (eds) Proceedings of On-site '01 Conference, Lanfax Laboratories, Armidale, 315-322.

Patterson, R.A. (2004), *A Resident's Role in Minimising Nitrogen, Phosphorus, and Salt in Domestic Wastewater,* in Mankin, K. (ed.) Proceedings of the Tenth National Symposium on Individual and Small Community Sewage Systems, American Society of Agricultural Engineers, St. Joseph, Michigan, 740-749.

SA Health Commission (1995), *Standard for the Construction, Installation and Operation of Septic Tank Systems in South Australia,* Adelaide.

Stafford, D. (2001), *Automatic Dosing Siphon Optimisation and Use: A Non Theoretical Approach,* in Patterson, R. and Jones, M. (eds) Proceedings of On-site '01 Conference, Lanfax Laboratories, Armidale, 347-351.

Standards Australia (1998), *AS/NZS 1546.1:1998 On-site domestic wastewater treatment units Part 1: Septic Tanks,* Standards Australia and Standards New Zealand.

Standards Australia (2000), *AS/NZS 1547:2000 On-site domestic wastewater management,* Standards Australia and Standards New Zealand.

Whitehead, J.H. and Geary, P.M. (2000), *Geotechnical Aspects of Domestic On-site Effluent Management Systems,* Aust. J. Earth Science, 47, 75-82.

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