MAINTENANCE AND APPROVAL OF ON-SITE SEWAGE TREATMENT SYSTEMS

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Abstract

This paper outlines the issues with on-site sewage treatment systems and the causes of failure. Practical solutions are proposed. These involve the reuse of effluent for vegetation growth rather than disposal in soil. Soil based disposal systems and the use of soil for effluent treatment are not sustainable. It is suggested that on-site treatment systems should come down to two types in the future. The first is a large septic tank with raised garden beds designed on evapotranspiration and the effluent is irrigated in imported soil. The second is surface irrigation using proprietary systems where improvements are made to increase the reliability of the process including disinfection. The householders are required to acknowledge their role and responsibilities in the operation of the system and safe irrigation of the effluent in this option. In the long term recirculating fixed media treatment systems will be required to ensure effluent quality can be reliably achieved. The reasons for recommending these systems are that they do not rely on the on-site soil permeability or soil tests. They provide a means of reusing the effluent for vegetation growth, can be used in all locations, and are sustainable compared to soil based disposal systems.

Keywords

aerated wastewater treatment systems, recirculating sand filters, septic tanks

Background

Most acreage allotments have on-site wastewater treatment systems, mainly septic tanks, with trenches for soil absorption of the effluent. Many septic tank systems fail due to the hydraulic overloading of their soil absorption areas with surface contamination, health risks and stormwater runoff into waterways. Hydraulic overloading occurs from a number of factors.

- Clogging of soil from the carryover of oil and grease and solids out of the septic tank;
- Inadequate design of the soil absorption system;
- Non-uniform flows causing localised hydraulic overloading leading to anaerobic ponding conditions and progressive trench failure; and
- Sodium salt buildup reducing the hydraulic capacity of the soil absorption area.

The failure of septic tank systems is being addressed in different ways by state and local governments. Many of the policies and proposals that deal with on-site wastewater treatment have conflicting objectives – such as maximising the reuse of wastewater versus minimising health risks. There are major differences between government authorities and within the local communities on what is an acceptable health risk and particularly on what is an acceptable environmental impact from on-site wastewater treatment systems. There has been a large increase in on-site aerated wastewater treatment systems (AWTS) as a response to the problems with conventional septic tanks. Some authorities advocate the abolition of on-site systems altogether and require sewerage reticulation with centralised treatment facilities. However, due to the high capital costs, transportation costs and the environmental impacts of sewage overflows as well as large effluent flows from centralised sewage treatment facilities, on-site wastewater treatment systems will continue to be necessary in the future.

In the Beaudesert Shire, septic tanks have previously been approved in a split system because of the failure of all purpose septic tanks and septic trenches in the past. In the split system, the greywater is surface irrigated and the blackwater is disposed of in septic trenches. The type of residential development occurring in Beaudesert Shire is small acreage allotments where the cost of sewerage reticulation is prohibitive. In the most recent developments, there has been a requirement for aerated wastewater treatment plants to be installed. These are small self-contained proprietary systems consisting of a combination of pumps, airblowers and contact media for bacterial growth which provides aerobic treatment to the effluent after it has passed through an anaerobic compartment similar to a septic tank. This further treatment, including disinfection, achieves a final effluent which is generally suitable for surface irrigation. Surface irrigation has been carried out on designated areas sized according to AS1547 (Standards Australia, 1994) based on soil percolation tests. Some of the soil percolation tests have required irrigation areas of 800-1000 m^2. These areas, under current practice, are not being irrigated uniformly. These areas are also unsightly because they are generally poorly constructed and maintained.

There is a lot of community dissatisfaction with aerated wastewater treatment systems due to their high operation and maintenance costs. These costs are approximately $700 per annum and come from the quarterly maintenance service costs, Council monitoring and inspection fees, power for the pumps and airblowers, replacement every 2-4 years of the pumps and airblowers due to mechanical failure, chemicals for disinfection and periodic solids removal. These high annual costs and the high initial cost of the aerated wastewater treatment and irrigation area cause community dissatisfaction, especially where failure occurs.

In the areas where split system septic tanks have been installed, there is a high level of acceptance and satisfaction with the surface irrigation of greywater despite the malodours and potential health risks from these systems. The prohibition of surface irrigation with greywater has a major impact on costs. The costs of all-purpose septic tanks are higher together with the much greater cost of irrigation of the septic effluent under garden beds. In the past it has been that even with large areas of septic absorption trenches hydraulic failures have occurred in low permeability soils and treatment and disposal is prohibited in Beaudesert Shire.

There is an urgent need to come up with on-site systems that work in most situations without high maintenance costs. Reuse of water is also becoming necessary and we are already seeing proposals for greywater treatment and reuse in sewered areas. The emphasis in on-site treatment systems should therefore revolve around the reuse of treated wastewater rather than disposal in the soil. This will require much greater attention to on-site vegetation than has been the case in the past. The new AS/NZS 1547:2000 (Standards Australia and Standards New Zealand, 2000) is disappointing in that it emphasises soil based disposal rather than vegetation uptake and reuse. Soil based disposal is not only a waste of a water resource but it is unsustainable. There is no soil that can be a long-term sink for water and nutrients without vegetation uptake. It is in vegetation uptake that sustainable solutions have to be sought.

On-Site Sewage Treatment Issues

2.1 Septic Tank Issues

Septic tanks have treated wastewater for hundreds of years. A household septic system properly designed, installed and maintained on suitable soil can be as effective as a sophisticated sewage treatment plant. The main issue with septic tanks is where their use is proposed in low or high permeability soils. In these soils experience has shown that septic soakage trenches do not work. The soil surrounding the soakage trenches cannot accept continual dosing with water, nutrients and chemicals except where it is so porous the underlying groundwater becomes contaminated.

2.2 Causes of Failure in Septic Tank Systems

The main causes of failure are:

Lack of Maintenance

The solids and scum layer in the septic tank accumulate to such an extent that they flow out of the tank into the absorption trench. The surrounding soil then becomes permanently clogged rendering rectification impossible. An in-tank filter stops this from occurring and is a low cost improvement to septic tank systems. It is considered such filters should be mandatory in all septic tanks.

Insufficient Septic Tank Volume

Oil and grease can not be broken down in the short detention time (2-3 days) available in conventional size septic tanks. Domestic grease traps are completely ineffective for modern dishwashers and their detergents. In addition vegetable oils rather than animal fats now predominate in domestic wastewater. Vegetable oil remains in solution at low temperatures (35^{o}C) which means a large septic tank is needed to enable enough cooling to occur and for the oil to come out of solution. A large tank volume is needed to allow for the oil and grease to come out of solution, to accumulate and to break down over a long period. Vegetable oil, if it is not separated from the effluent, clogs up the soil. The minimum working volume for a septic tank system is considered to be 6,000 litres. This tank volume is not a significant extra cost compared to conventional sized septic tanks and provides many advantages that are explained further in this paper.

Progressive Trench Failure

In gravity systems effluent flows into soakage trenches without being evenly distributed. Many domestic activities such as washing hands, toothbrush cleaning, rinsing dishes etc cause only a small amount of water to flow out of the septic tank into the soakage trench. The initial section of the trench is continually wetted causing anaerobic conditions to occur in the surrounding soil. A fungal mat is created which becomes impervious. The small flows then continue onto the next section of trench creating similar conditions and progressively the whole trench fails. Pumping of effluent is the only was to obtain an even distribution of effluent and provides many other advantages. These are explained further in this paper.

2.3 Aerated Wastewater Treatment Issues

Maintenance Costs

Maintenance costs are high with AWTSs mainly because these systems appear to be market driven to low cost components. The pumps and air compression equipment are often subject to extreme conditions with high temperatures and in Beaudesert Shire many owners experience a high replacement rate on their equipment after the two year warranty period. Most systems are installed by builders who are dollar driven and the cheapest approved AWT system is installed. The new home owner is then contracted into the particular system and their service agents on the basis that any change will void warranty.

The experience in Beaudesert Shire is that there is a big difference in the capabilities between maintenance service agents with allegations by home owners that some service agents only carry out minimal maintenance on their AWT systems and replace chlorine tablets. Most AWT systems have a primary sedimentation tank before the effluent is aerated for further treatment. These tanks fill up with solids at a similar rate to septic tanks and the solids have to be tankered to an approved disposal facility. Many home owners purchase AWTs under the impression that pump out costs, similar to a septic tank, do not apply to AWTs. Some service agents empty tanks on-site where home owners are unable to afford the costs of tankering the waste solids off-site.

The maintenance costs in an AWT include the following:

- Quarterly service agent costs including chlorine tablets $200-$250/annum;
- Power costs for the pump and aeration equipment $120-$150/annum;
- Replacement of pumps and air compressors $800-$1000 every 2-4 years;
- Pump out of solids $300-$400 every 5 years; and
- Council inspection, administration and regulatory costs $50-$100/annum.

The average annual maintenance cost of an AWTS is around $600-$800, without including costs in maintaining the irrigation area and the irrigation pipework. This is a very high cost on top of the capital cost of the system. Many homeowners are unaware of these maintenance costs when they purchase an AWTS or the fact that some initially higher capital cost systems would have lower whole of life costs and more reliable treatment than the cheapest systems.

Failure Rates

The failure rate of AWTS has been investigated in a number of studies and generally is approximately 40% regardless of the type of AWTS installed. In many cases though, failure of the AWTS can be attributed to lack of knowledge and care by the householder in the use of products, medications and large water volumes being discharged into these systems or to a lack of maintenance on the system.

The design of the AWTS is important, as solids are prone to overflow when high wastewater discharges are experienced such as continuous washing loads. Most AWTS designs are based on a hybrid of submerged media and activated floc. None of these systems follow conventional sewage treatment plant design principles. There are no mechanisms to reliably retain activated sludge in the aeration tanks. It is considered many proprietary systems could be improved with fixed media for biomass buildup and retention in the systems.

Even a poorly performing system has an effluent quality that would be superior to untreated greywater. It is considered that subsurface irrigation defeats the purpose of having an AWTS, a high capital and high maintenance cost facility. Many ATWS manufacturers are developing new disinfection technologies and filters for their systems to ensure a much more reliable effluent suitable for surface irrigation. These include the addition of small sand filters, ozonators, ultra violet lamps, additional chlorination tanks.

Lack of Householder Education

The role of the householder is critical to the effective operation of AWTSs. Some householders are unaware that many of their household cleaners and disinfectants destroy the bacteria within their AWTS and result in poor effluent quality with potential health risks. Some householders try to minimise costs by turning off the power or put the system into holiday mode to save on power costs. Others refuse to engage service agents or repair/replace the pumps and aeration equipment in their AWTS when there is mechanical failure. The use of antibiotics also affects the bacteria within these systems. It is considered that some householders should not be allowed to have surface irrigation due to their lack of concern about effluent quality and the operation of these systems.

Beaudesert Shire Council has introduced a form for householders where surface irrigation is approved. This form requires the householders to acknowledge their responsibilities in relation to the proper operation of the AWTS and approved irrigation area. Some of the population are very careful with their systems and often have sufficient technical ability to maintain their AWTSs. It is considered that training should be available to enable householders to carry out routine maintenance with service agents available to carry out mechanical/electrical/system modifications as required. Education of homeowners about on-site systems and their role in the effective operation of them is a critical issue.

Councils need to balance their regulatory role with education and information to all householders with on-site sewage treatment systems.

Irrigation Areas – Approval and Operation

The design of the irrigation area is the most important part of AWTS effectiveness but is generally the most deficient. In low permeability soils, large irrigation areas are required (500-1000 m^2) which are impractical. It is not possible to uniformly irrigate these areas.

The vegetation within the irrigation area is also critical to the environmental impacts from AWTSs. Where there is plant growth on grass or garden beds nutrients will be taken up. Providing some of the vegetation is removed off-site from time to time, a sustainable nutrient balance may be able to be achieved. Some soils can provide long term sinks for phosphorus. It is also important to minimise sodium salts that are used as fillers in some of the cheaper washing powders.

A build up of sodium salts in the soil will gradually reduce the hydraulic capacity of the soil resulting in poor plant growth and effluent runoff problems. The planting of boundary vegetation to filter overland flow from effluent irrigation areas is also an important factor, often overlooked in AWTS design and approval.

Finally, nutrient runoff and nutrient balance for AWTSs need to be placed in the context of overall catchment management. There is little point in developing AWTSs to remove nutrients if fertiliser application and animal matter is uncontrolled particularly as the total amount of nutrients discharged per household is approximately 8 kg of nitrogen and 3 kg of phosphorus per annum. Ensuring environmental flows occur in the waterways is considered more important than nutrient runoff from on-site systems.

What Systems Work

3.1 Septic Tank Option

In my view current septic tank design is inadequate and large tanks with in-tank filters should be mandatory. The minimum working volume of a septic tank or tanks in series should be 6,000 litres. This large capacity gives 6-8 days sedimentation which improves effluent quality, provides a large buffer for toxic discharges and enables a long period (up to 10 years) before any pump-out of accumulated solids is required. The tank system should be designed to avoid short-circuiting with an in-tank filter to ensure no solids are carried over into the effluent disposal or reuse areas.

Pumping of effluent is required for the following reasons, even though it is energy intensive compared to gravity flow. Pumping

- enables a uniform flow to be obtained, critical to obtaining an even distribution of effluent,
- provides flexibility in design, so that the system is suitable for all sites, regardless of topography, and
- enables new areas, or additions to existing beds, to be irrigated if required in the future.

This flexibility is important where, for unforeseen reasons, a new garden bed area or an increase in the design area is required. With a pumped effluent system, changes in irrigation layout can be made with little cost. This flexibility is not available with septic absorption trenches relying on gravity flows. When septic trenches fail, the cost of rectification is so high or impractical, that mostly nothing can be done about the problems. It is here that septic tanks have incurred their poor reputation.

At least two stages of sedimentation are needed to maximise solids and oil/grease retention within the septic tank. A static filter is required just prior to the effluent pump well. This filter is to ensure that solids are retained within the septic tank and are not carried over into the soil treatment and reuse areas. The filter also improves effluent quality by filtering the effluent through the biological slime that builds up on its filtration plates.

Irrigation System

The irrigation design requires separate lines to be installed in at least two mounded garden beds. Even distribution of the effluent is critical in the irrigation system. Pump head and outlet holes in the pressure piping need to be properly designed.

A slotted agricultural drainage pipe 65-80 mm dia. is threaded over the pressure piping so that effluent is distributed uniformly within the slotted agricultural drainage pipe. The agricultural drainage pipe:

- Facilitates even distribution along its length;
- Prevents pump flow blowouts through the soil to the surface;
- Minimises root intrusion through having an air gap between the drainage pipe and the pressure pipe;
- Facilitates future maintenance of the pressure piping, if required.

Garden Bed Design

The total area of garden bed is 400m^2. The layout of the garden beds should be in at least two separate areas. The garden bed design concept is to provide landscaping for the allotment and, in addition, have a controlled soil for the breakdown of pathogens and nutrients. The garden beds are proposed with 200 mm of imported organic garden soil. The clay component within this type of soil provides a filter and absorption medium for phosphorus and pathogens. Fine sand material in this soil enables an even distribution of effluent and maximises evaporation rates. The use of an organic garden soil facilitates plant growth and helps ensure that the effluent is treated adequately in the soil system. Nitrogen is removed by adsorption, fixation, volatilisation, biological uptake and denitrification. The organic matter within the septic tank effluent and the soil provides the carbon source for the denitrifying bacteria. The removal of phosphorus in the garden bed soil occurs from plant uptake, biological immobilisation, and adsorption and precipitation processes. Phosphorus sorption is enhanced with clay and the organic matter in shallow disposal systems. Gypsum is required in the garden mounds to help avoid the build of sodium salts from the effluent.

The use of imported soil in the proposed garden beds enables this system to have minimal reliance on the allotment soil characteristics and no soil testing is required. The careful design of these garden beds ensures that rapid plant growth can be achieved, thereby providing visual landscape benefits for householders using this system. Once the vegetation is established little maintenance is necessary due to the integration of plant species to provide both ground cover and a tree canopy.

Potential Common Effluent Drainage Scheme

This septic tank design provides the core facilities for a common effluent drainage scheme. There is a large capacity septic tank for solids retention, an in-tank filter to ensure there are no solids or screenings for pumping, a pump well and submersible pump and a distribution valve to enable part or all of the effluent to be pumped off-site to a localised sewage treatment plant. The option of being able to pump only part of the effluent off-site has major cost savings in the treatment plant capital and operational costs, and in the environmental impact of the off-site reuse or disposal of the effluent. The assimilative capacity of the on-site garden beds for effluent irrigation can be used to obtain major cost savings. This will also maintain the on-site landscaping and help reduce potable water consumption through reduced garden watering.

In small schemes it would also be possible to collect all the on-site septic effluent, treat it to a very high standard and return the effluent for continued reuse using the irrigation system and garden beds already constructed. Another possibility is for full on-site effluent reuse during plant growth periods and operation of the common effluent drainage (CED) scheme only during low growth periods again with major cost savings.

3.2 Aerated Wastewater Treatment Option

Improvements to proprietary systems are required in this option to ensure the reliability of the process and disinfection of the effluent. These improvements include small sand filters, chlorine contact tanks, ultraviolet and other systems that will increase the reliability of the disinfection process. The best way to improve reliability is to recycle effluent in low flow periods, increase submerged biomass, provide a separate chlorine contact tank to ensure adequate disinfection in surge flows, and provide some form of physical filtration (low maintenance or self cleaning) – preferably before disinfection – to contain activated floc within the system.

Recirculating Fixed Media System

This type of treatment process overcomes all of the problems associated with aerated systems. In the long term this process should be able to be incorporated into all proprietary systems.

The first component is a very large capacity septic tank. This provides a number of advantages:

- The long detention time in the tank ensures that effluent quality from primary sedimentation is maximised for up to 10 years without maintenance;
- The large tank volume and long detention time optimises the separation of fat and oils from the effluent. There is no need for an arrestor prior to the septic tank; and
- Transport costs associated with an eventual pump out of the tank are minimised.

The effluent is then continuously pumped over a sand or other media filter system. The recirculation system allows for nitrification and denitrification. The design also optimises the biological activity within the media filter through constant small doses of organic matter. Dosing of the filter medium in small doses maximises the oxygen transfer in a thin film over the media particles, which enables viruses and pathogen die-off.

The advantage of this system is that the process is highly reliable and effective with minimal maintenance. The reliability comes from two factors. The long primary sedimentation time ensures that the effluent being passed through the sand filter has only small amount of suspended solids in it and the media filter being a physical and biological process ensures that a high quality effluent is achieved at all times. Both of these processes are reliable, there is no way to circumvent the primary sedimentation time or to bypass the physical sand or other media filtration process. There is no possibility for excess solids to bypass the system onto the irrigation area. There are savings in power and replacement costs over AWTSs that require mechanical compressors for aeration.

Overall the recirculating media filter offers many advantages. These are the low maintenance and robust treatment process where there can be a high degree of reliance that the effluent quality for surface irrigation will be constantly achieved. This allows the flexibility to use most of the site area for irrigation and as the nitrogen nutrient is reduced in this process a sustainable nutrient balance is likely. In my view this system and other aerobic sand filtration systems are the answer to on-site sewage treatment and the safe reuse of household wastewater.

4 Conclusion

This paper suggests that on-site treatment systems should come down to two types in the future. The first is a large septic tank with raised garden beds designed on evapotranspiration and the effluent is irrigated into imported soil. The second is surface irrigation using proprietary systems where improvements are made to increase the reliability of the disinfection process and the householders acknowledge their role and responsibilities in the operation of the system and safe irrigation of the effluent.

In the longer term, recirculating fixed media systems will be required rather than specifying polishing units for the current hybrid aerated wastewater treatment systems. This will provide a much more robust and reliable process for surface irrigation of effluent. The reasons for recommending these systems are that they do not rely on the on-site soil permeability and provide a means of reusing effluent for vegetation growth. It is considered the reuse of effluent will become mandatory in time and soil based disposal systems will be prohibited to help conserve scarce water resources.

References

Standards Australia (1994): Australian Standard 1547 on Disposal systems for effluent from domestic premises.

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