Treatment of sewage from isolated dwellings

Small, isolated communities require special considerations in the treatment and disposal of sewage. There are now a variety of options for the treatment, disposal and re-use of sewage. Such systems can produce an efficient equal to or better than a conventional treatment plant.

Isolated dwellings present their own problems of sewage disposal. The septic tank has conventionally been used to treat the sewage. It consists of one or two tanks for settling of solids with the overflow disposed via subsurface surface seepage. Soil percolation depends on the soil's ability to be used efficiently. Groundwater is usually not a major consideration, but have to be emptied on a regular basis. Properly designed, a septic tank may perform satisfactorily in unobtrusively conveying wastewater away from a dwelling, but hazards in rocky or clayey soils result in ponding of untreated sewage. More generally, septic tanks contaminate groundwater with human pathogens, nutrients (nitrogen and phosphorus) and other pollutants disseminated within the soil. The septic tank or soil absorption system should be sited away from vulnerable groundwater sources such as wells, springs, deep seepage, waterways and agricultural or natural resources.

Criteria for selection

During the selection process, each option must be considered in terms of its ability to satisfy the following criteria. But, in addition the extent of treatment necessary, the type of the site and the future needs, the requirements and personal or community attitudes and preferences, should also be considered.

Re-use of resources. Wastewater is often considered a source of public health problems, to be disposed of and not as a resource. The choice of disposal and treatment system is usually governed by the disposal strategy. Reasons for re-use and options of re-use are well documented.

Protect the environment. Protection of public health is one of the reasons for treatment of sewage. Protection of the environment should also be considered. The conventional system of soil absorption of wastewater is the septic tank and soil absorption system. The effluent from a septic tank after soil treatment does not usually meet the criteria of maintenance of groundwater quality and hence needs further treatment.

Nutrient removal may become necessary in many situations where nutrients can cause pollution either directly by, for example, nitrates in the treated wastewater or through eutrophication of the receiving water. Simplicity of operation. A system, sophisticated in its technology and control, may tend to be complicated in operation. Frequent servicing and regular checking may become inevitable in operating an on-site treatment plant. While aiming for the best performance possible, a system that has minimum operational requirements and is relatively easy and simple to maintain should be the preference.

Minimum use of chemicals. Chemicals have been used for phosphorus removal and disinfection. Biological phosphorus removal is beneficial to a chemical removal process. Disinfection by ultraviolet radiation should be considered in place of chlorination. Substrate micro-irrigation, for example, may not demand disinfection to the level it is necessary at present.

Other general aspects of this such as installation costs, maintenance expenses, aesthetic considerations, durability of the equipment and low energy consumption should also be considered in the selection of a system.

Systems designed for low water usage

Domestic sewage generally consists of wastes produced from the kitchen, toilet, kitchen sink, bathtub, and shower, wash basin and laundry. Toilet waste, generally referred to as black water, makes up 25-30 percent of the total flow, while the other wastes, which comprise 75-70 percent of the flow, are collected separately. This indicates the design of low water-use systems attempts to reduce the amount of water, and black water may, for example, be reduced significantly, producing only sludge. The black water contains the major portion of biochemical oxygen demand (BOD), suspended solids (SS), bacteria and nutrients. So, if the black water is treated separately then treatment of grey water alone becomes easier and less complicated.

The potential of pollutants being transported by the water in the black water are not all soil organisms significantly reduced, but because water is generally the conveying medium for the pollutants. VIP toilets and the Ventilated Improved Pit (VIP) toilet is a product of the Centre for Appropriate Technology (CAT), Australia. Even though this is a pit toilet, its special construction ensures minimum odour and the problem of family of five to use the same unit for 10 years. In Australia this has been found to be suitable for camping places in national parks, main roads departments, rest sites and remote communities. Composting toilets. Composting systems do not require any water connection, periodical pumping-out, chemical dosing or on-going treatment. Composting toil converts the waste with the nutrients in it into garden compost. It can be installed as single dwellings or community ablations irrespective of the soil type of the area and should not create any environmental pollution. Three composting toilets approved by the Health Department of Western Australia are described in the following.

Chula Multislim. The Chula Multislim consists of a sloping improved pit compost tank which has been divided into an upper section for the treatment of fresh wastes and a lower section for the treatment of mature compost. The toilet seat is placed on the top of the tank. A vent pipe fitted with a fan to exhaust air from the bottom of the tank providing air flow through the compost. The compost can be extracted using an auger provided at the top of the toilet, in the direction towards one side. The Doximus is partially filled with active compost at the time of installation and inoculated with beneficial soil organisms, in particular tiger and rod composting worms.

Dromex. The toilet seat of the Dromex system is connected to a circular composting chamber of about 4.5m³ which is of sufficient volume for a family of five. A brick ventilated flame pipe with a fan to exhaust air from the bottom of the tank providing air flow through the compost. The compost can be extracted using an auger provided at the top of the toilet in the direction towards one side. The Doximus is partially filled with active compost at the time of installation and inoculated with beneficial soil organisms, in particular tiger and rod composting worms.

Sani-Lo. This toilet is designed for use by six to eight people and hence is small and compact. It consists of four separate composting chambers in India and found to be a novel low water-use toilet for safe processing of human excreta without odour and fly problem. The toilet pan is directly connected to a tank of 1m x 1m x 1m which has a removable cover with ventilation holes. This can serve a family for about three years. BVT is started off by pitting the contents of the pit in the compost.
These systems have a pre-treatment module similar to a septic tank which is for primary sedimentation and anaerobic decomposition. The recommended volume of three days' storage for a septic tank is following by the most of the systems. Domestic on-site systems receive wastewater usually as slow flow rather than a constant flow. So the volume of the septic tank should be large enough to prevent the discharge of settled solids to the next chamber.

The most significant unit is the aerobie chamber where the biological treatment system takes place to provide water quality to the secondary effluent standard. This will remove nitrogen and phosphorous from the effluent.

Bicyclo. Bicyclo is an aerobic treatment system which provides a primary level of treatment to produce an effluent which meets the 0.5 mg/l BOD and 30 mg/l SS effluent quality standard. This is available in two sizes. The domestic model is designed for four people and the commercial model is for offices, restaurants or other public institutions. The Bicyclo treatment system consists of a circular tank which is divided into four compartments: primary settler and anaerobic digestion chamber; 2 aerobic chamber with fixed media and bubble aeration facility; 3 secondary sedimentation chamber with the settled sludge pumped back to the septic chamber and 4 chlorination and storage chambers. Chlorination is by tablet chlorine dosing to the final effluent and is used to correct the effluent when the water volume reaches a preset level. The soil at the irrigation area can be amended with neutralised basaltic residue for phosphorus removal.

Clearwater system: This is an aerobic treatment system which has two separate tanks. The first one is a circular tank of 5.7m diameter and 6.5m high which functions as a sedimentation and septic tank. The second tank is a rectangular tank with three compartments: an aeration tank of 3.6m, a final clarifier of 3m and a chlorination and storage tank of 1.7m. The aeration tank has panels for attached bacterial growth. The irrigation system is very similar to other systems such as Bicyclo. 

Nutrient removal: Nutrient removal varies for aerobic treatment systems at present. There are units available in Austraila which offer some nutrients, with many organisations being involved in further research in this area.

Five treatment systems approved by the Health Department of Western Australia are the representative of the available systems. These systems incorporate state-of-the-art treatment techniques available at present:

- **Envirocyle**: Envirocyle is an aerobic treatment unit designed to treat sewage produced in a household of five people. The system has multiple treatment chambers based on the activity of the sludge process. This is a circular unit with two primary settling chambers, two aerobic chambers, a clarification chamber, a clarifier chamber with a clarifier and storage to provide enough contact time, and a chamber for clarifier and pumping for final disposal. The final effluent after secondary clarification and chlorination is used for spray or trickle irrigation.

- **Bicyclo**: Bicyclo is an aerobic treatment system which provides a secondary level of treatment to produce an effluent which meets the 0.5 mg/l BOD and 30 mg/l SS effluent quality standard. This is available in two sizes. The domestic model is designed for 10 people and the commercial model is for offices, restaurants or other public institutions. The Bicyclo treatment system consists of a circular tank which is divided into four compartments: primary settler and anaerobic digestion chamber; 2 aerobic chamber with fixed media and bubble aeration facility; 3 secondary sedimentation chamber with the settled sludge pumped back to the septic chamber and 4 chlorination and storage chambers. Chlorination is by tablet chlorine dosing to the final effluent and is used to correct the effluent when the water volume reaches a preset level. The soil at the irrigation area can be amended with neutralised basaltic residue for phosphorus removal.

- **Clearwater**: Clearwater 5000 + installation - Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aeration - Tablet chlorination required - Available in concrete and stainless steel in various sizes - Removes nutrients

- **Aquoris**: Aquoris is a fixed chamber primary sedimentation and anaerobic digestion; 2 aerobic chamber for denitrification and chemical phosphorus removal; 3 aerobic biological oxidation including nitrification in subsurface biofilter and denitrification in submerged filter; 4 secondary clarifier and sludge recycle to the anaerobic chamber; 5 chlorination and storage for irrigation. In addition to the required effluent standard, Aquoris claims to achieve nitrogen and phosphorus removal and good odour control.

- **Envirocyle**: Envirocyle is available in a variety of sizes starting from a domestic unit for 10 people to units for industrial use or for small communities of up to 200 people. The system consists of a conventional septic tank and dual leach drain or soakwell modified by the addition of a filter bed of amended soil with a plastic lining. The filter bed contains neutralised basaltic residue which has the capacity to adsorb phosphate, ammonium and heavy metals. The filter bed is also a good bacterial filter. The treated effluent can be disposed of by soil percolation or surface irrigation.

The system is designed to serve four to six people for approximately 20 years, after which, the filter beds need to be replaced. It is possible to increase the capacity of the system to serve more people or for an extended lifespan. This is a passive system with no requirement for power, chemicals or periodic servicing, except for the need for minimal desludging requirements of the septic tank.

**Comparison of systems**

On-site systems as approved by the Health Department of Western Australia are compared. As they all meet the requirements for effluent quality and public health standards, only special features will be discussed. All systems use a septic tank or equivalent and hence desludging will be necessary. A septic tank and leach drain requires desludging, on average, approximately every three years. If the final effluent is used for irrigation no leach drain and its desludging in necessary. Table 2 summarises similarities and differences amongst the systems, including initial costs and maintenance requirements.

**Conclusions**

Municipal authorities are looking towards sewage and treatment systems are generally the most desirable treatment option because of the high degree of control which can be achieved and maintained over the quality and disposal of treated effluent and sludge. However, when the population density is not high, if on-site disposal is possible, it will be cheaper and will allow better effluent options. Many more on-site systems are becoming available which offer similar facilities to the larger municipal treatment systems. On-site treatment systems can provide a higher degree of protection for the aquatic environment due to the use of land disposal techniques which provide an additional level of treatment due to soil percolation before the treated wastewater enters the aquifer. On-site irrigation allows water uses for the evaporation and plant evapotranspiration and should not cause any pollution. For remote and isolated locations, VIP toilets are ideal. Composting toilets provide the ultimate answer for water conservation and complete re-use of toilet waste if maintained properly. The larger capacity of Civus Multum makes this system more suitable for large families or industrial application. Rota-Loo being smaller and with lesser maintenance demand will be more suitable for small families. Dowmens produces a compost containing worm castings with a higher nitrogen content. It is cheap to install and cheap to operate as it does not require electricity.

For most of the treatment units are similar and produce effluent of similar quality. Clearwater system has a separate septic tank and it is claimed that it only needs to be desludged every 10-15 years - against a normal period of 3-4 years. Aquoris produces a lower nutrient effluent but installation cost is higher; chemical use and yearly desludging operation also means higher operating cost. However, this is available in a variety of sizes serving up to 120 people. Ecomax is a passive system which produces a low nutrient effluent but the filter media needs replacing every 15 to 20 years.

Where municipal systems are not available or are costly due to low density of population, on-site systems provide a variety of options. A composting system for black water and an aerobic system

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Initial Cost ($)</th>
<th>Maintenance Requirements</th>
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</thead>
<tbody>
<tr>
<td>Civus Multum</td>
<td>3000 - 5000 plus</td>
<td>Maintenance by the user - Cost of heating in cold areas - Power cost of fan</td>
</tr>
<tr>
<td>Rota-Loo</td>
<td>3000 + cost for</td>
<td>Maintenance by the user - Cost of heating in cold areas - Power cost of fan</td>
</tr>
<tr>
<td>Dowmens</td>
<td>2500 + cost for</td>
<td>Maintenance by the user - Power cost of fan</td>
</tr>
<tr>
<td>Envirocycle</td>
<td>9000 + installation</td>
<td>Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aeration - Tablet chlorination required - Available in concrete and stainless steel in various sizes - Removes nutrients</td>
</tr>
<tr>
<td>Bicycle</td>
<td>5000 + installation</td>
<td>Quarterly inspection - Desludging every 9-15 years - Power cost for pumps and aeration - Tablet chlorination required - Available in concrete</td>
</tr>
<tr>
<td>Clearwater</td>
<td>5000 + installation</td>
<td>Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aeration - Tablet chlorination required - Available in concrete</td>
</tr>
<tr>
<td>Aquoris</td>
<td>5000 + installation</td>
<td>Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aeration - Tablet chlorination required - Available in concrete</td>
</tr>
<tr>
<td>Ecomax</td>
<td>5000 + installation</td>
<td>Desludging every 15-20 years - Replacement of reduced filter every 15-20 years - Removes nutrients</td>
</tr>
</tbody>
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<tr>
<th>Comments</th>
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<tbody>
<tr>
<td>Recycle of toilet waste as compost</td>
</tr>
<tr>
<td>- A space of 2.5 m deep and 15 m wide. 2 m long in 3 m diameter with a depth of 0.3 m is needed below the toilet.</td>
</tr>
<tr>
<td>Saves 30% on water use</td>
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<tr>
<td>Recycle toilet waste as compost</td>
</tr>
<tr>
<td>- A space of 1.5 x 1.5 x 1.5 m³ is needed below the toilet.</td>
</tr>
<tr>
<td>Saves 30% on water use</td>
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<tr>
<td>Recycle waste as compost</td>
</tr>
<tr>
<td>- Weighs approximately 0.75 US$ per cubic metre.</td>
</tr>
<tr>
<td>Cleared water in stainless steel in many sizes</td>
</tr>
<tr>
<td>Removes nutrients</td>
</tr>
</tbody>
</table>

Table 2: Comparison of Systems Approved by the Health Department of Western Australia
for grey water will assure complete re-use, conservation of water, desalinating only infrequently and reduction in potential nutrient pollution.

Dr Ho is director of the Remote Area Developments Group of the Institute for Environmental Science at Murdoch University and has over 20 years' experience in teaching, research and development of wastewater treatment technologies. Dr Mathew is research fellow and manager of the Remote Area Development Group. He has over 20 years' experience in India and Australia in treatment technologies, including provisions of water and sanitation to remote communities.

References
15. Environment Equipment Pty Ltd, 1/32 James Drive, Rosslea, 3155, Australia.