Developing a Testing Protocol for Vermifiltration-based Onsite Wastewater Treatment Systems (VOWTS)

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Abstract

Vermifiltration wastewater treatment can be a low cost and efficient way of treating domestic effluent. These systems have the potential to replace septic tanks and other underperforming wastewater treatment systems and provide higher quality effluents.

It is clear that while there is great potential in these systems there have been problems with some systems such as the Biolytix BF-6. These problems highlight the flaws in the approval process and are the reason the testing protocol was commissioned by the Western Australian Department of Health.

This report focuses on the process of the development of the testing protocol. The literature review gives an overview of vermifiltration, examines the testing requirements in other States and Territories, assesses the environmental conditions required by worms, and highlights key system design features and potential problems.

The case studies and system reviews are used to get a better understanding of how vermifiltration systems function and the differences and similarities between systems.

The testing protocol aims to provide regulators with a clear and efficient means of testing vermifiltration systems. The protocol focuses on how systems should be tested, the parameters of testing and the acceptable ranges for these parameters. These parameters include temperature, moisture, pH and dissolved oxygen.

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Contents

1. Introduction

1.1.What is vermifiltration?

Vermifiltration onsite wastewater treatment systems (VOWTS) are becoming more prevalent in Australia and internationally. Vermifiltration is the process of using worms and aerobic bacteria to treat wastewater.

This process places wastewater in contact with a filter which contains the worms and bacteria. These organisms then consume the organic matter and bacteria, leaving behind effluent with lower suspended solids, lower biochemical oxygen demand and worm castings (British Standards Institution 2006; Sinha, Nair et al. 2008). This process is a low energy, low cost and efficient way to treat wastewater as a system which when it is functioning properly requires very little energy. The wastewater which is produced by these systems can be up to a secondary quality (Suthar 2012).

Vermifiltration onsite wastewater treatment systems promise to provide a low cost and efficient means of treating domestic wastewater to a prescribed standard. However, there are currently no national protocols or Australian Standards specifically for the testing of these types of systems, unlike other onsite wastewater treatment systems which are tested against AS1546: 2008 On-site domestic wastewater treatment units (Standards Australia and Standards New Zealand 2008) and AS1547:2012 (Standards Australia and Standards New Zealand 2012). This lack of nationalised testing protocol means that the responsibility falls to each state to manage, test and approve vermifiltration systems.

1.2.Why is a protocol necessary?

The Department of Health manages the approvals process for onsite wastewater treatment systems in Western Australia.

Onsite wastewater treatment systems are required to be tested and approved before they can be sold and installed to ensure that human and environmental health is not put at risk and treatment performance is satisfactory. For these systems, which include septic tanks, aerated wastewater treatment units, and waterless composting toilets, the Department uses the standards set out in AS/NZS 1546: On-site domestic wastewater treatment units (Standards Australia and Standards New Zealand 2008), AS/NZS 1547: On-site domestic wastewater management (Standards Australia and Standards New Zealand 2012) and the Code of Practice for Product Approval of Onsite Wastewater Systems in Western Australia (Government of New South Wales 2001). However, none of these standards or codes have specific clauses for vermifiltration and only refer to alternate systems in passing. For example, AS/NZS 1547, clause 4.5.7 Non-standard construction and installation states "Construction and installation of non-standard wastewater-treatment units and primary or secondary effluent-treatment systems may be accepted provided they meet the general performance requirements of the Standard" (Government of New South Wales 2001).

The Department of Health has previously approved a VOWTS. The Biolytix BF-6 was approved for use in Western Australia using the standards set out in AS1547. Subsequently, a significant number of these systems have been failing, requiring almost complete rebuilds. Partly as a result of the number of rebuilds, Biolytix Australia went into receivership in January 2011. These factors prompted the

Department to revoke the company's approval in Western Australia. The company has since been taken over; however the Department has refused to grant approval without evidence of changes to the system design which would reduce the number of system failures.

The Department has since had an application from another company wishing to sell its VOWTS in Western Australia. However, after the large number of Biolytix system failures it became clear to the Department that the current standards and codes do not provide adequate testing procedures and quality assurance for vermifiltration systems, and that a specific testing protocol should be developed.

It is anticipated that the implementation of a standard testing protocol for VOWTS will:

- Improve efficiency of approval processes across States
- Decrease the need to grant approvals on "trial" bases by regulatory agencies
- Minimise other testing requirements to obtain regulatory approvals
- Allow systems to be designed with respect to treatment and design standards

It is hoped that the protocol will be adopted by other States and Territories and may become the basis for an Australian Standard.

1.3. Objectives

The objectives of this project were to:

- Improve the knowledge base regarding vermifiltration wastewater treatment systems
- Produce a literature review which assesses the current vermifiltration wastewater treatment industry, system designs, environmental conditions and problems
- Design a testing protocol for vermifiltration onsite wastewater treatment systems
- Provide the DOH and other regulatory bodies with a consistent method for testing the long term effectiveness of vermifiltration systems
- Provide an effective, objective and consistent method of assessment

2. Literature Review

2.1.Introduction

Vermifiltration-based onsite wastewater treatment systems (VOWTS) are becoming more prevalent in Australia and internationally. They promise to provide a low cost and efficient means of treating domestic wastewater to a prescribed standard. However, there are currently no national protocols or Australian Standards specifically for the testing of these types of systems, unlike other onsite wastewater treatment systems which are tested against AS/NZS 1546: On-site domestic wastewater treatment units (Standards Australia and Standards New Zealand 2008), AS/NZS 1547: On-site domestic wastewater management (Standards Australia and Standards New Zealand 2012), and various State Codes of Practice such as the Code of Practice for Product Approval of Onsite Wastewater Systems in Western Australia (Government of Western Australia 2011) and Septic Tank and Collection Well Accreditation Guideline (Government of New South Wales 2001) . This lack of nationalised testing protocol means that the responsibility falls to each state to manage, test and approve vermifiltration systems.

The testing protocol which will be developed through this project will take into account design, environmental conditions and maintenance requirements. This literature review aims to determine the minimum standards of a vermifiltration system which are necessary for consistent and reliable onsite wastewater treatment. The review also evaluates how each Australian state manages, tests and approves vermifiltration systems.

2.2.Scope

This literature review aims to explore the current vermifiltration wastewater treatment industry and to note how other states in Australia and countries around the world approve and manage these types of systems. Along with the approval process, environmental conditions required by composting worms and bacteria for optimal wastewater treatment, system design and the identification of potential problems are the main focuses. Many of these are features which are unique to this type of system and need to be regulated to ensure quality control.

The main issues causing systems to fail prematurely or perform inadequately will be identified and the testing protocol will take into consideration design features which will prevent those issues. The testing protocol will address issues which may cause systems to fail and will require suppliers to demonstrate how their system will overcome issues, manage faults and servicing.

This literature review will not review wastewater effluent quality, as it is fairly well acknowledged that vermifiltration can be successful in achieving primary and secondary treatment standards(Bajsa, Nair et al. 2003; Hait and Tare 2011).

However, effluent quality does vary between systems and it is necessary to differentiate systems as primary or secondary treatment units. The effluent standard determines the potential disposal methods as described in AS 1547:2012. Primary treatment units treat wastewater to a lower standard than secondary treatment units and as such the disposal method has to restrict human contact as well as disposal conditions to a higher degree.

High nutrient levels in effluent water are a concern to some regulators as there is the potential that the nutrient concentration in wastewater may be increased by these treatment systems, especially if food scraps are placed in the system.

The aims of this review are:

- To examine the regulations and practice of different Australia States and organisations around the world who have a role in approving vermicomposting systems for the onsite treatment of wastewater;
- To determine the minimum environmental conditions required by worms to treat the wastewater to the required standards in a reliable and sustainable manner;
- To identify the minimum design standard requirements for vermicomposting systems;
- To identify the minimum maintenance requirements for vermifiltration systems

2.3. Overview of Vermiculture and Vermifiltration

Vermiculture is the idea of using composting worms to treat waste. This waste can range from household wastes to municipal sewage sludge. Composting worms consume organic matter, pathogens, micro-organisms, heavy metals and other toxic chemicals and produce a stabilised "cast". The most common instance of vermiculture is vermicomposting; the process of treating solid wastes with earthworms. This is a process which is odourless, relatively rapid and low cost (Sinha, Nair et al. 2008).

Vermifiltration is the process of treating wastewater within a system containing composting worms. Although this type of system is based upon the presence of worms, it is the combination of worm degradation and aerobic digestion that treats the wastewater. Most vermifiltration systems in the literature have similar functionality to trickle filters. For example, testing done by Griffith University (Sinha, Herat et al. 2010)compares the treatment of sewage water through a vermifiltration kit with and without the presence of composting worms. The vermifiltration kits are comprised of different sized layers of gravel with soil bedding on top. The wastewater is then uniformly distributed onto the filter surface. This set-up is very similar to a conventional trickle filter system and the results of the experiment showed that the system with earthworms present reduced BOD, COD and TSS more than the control. However, the experiment also shows that the combination of worms and aerobic bacteria act to treat the wastewater.

2.4. System Approvals

2.4.1. Victoria

The approval process for onsite wastewater treatment in Victoria is such that the Environmental Protection Agency is responsible for the assessment of testing results and issuing approval for systems to be sold and used in Victoria. Local government are then responsible for issuing permits to install the systems.

Onsite Wastewater Treatement Systems (OWTS) are approved by the Environmental Protection Agency as “Aerobic Biological Filter”, under the section of “wastewater primary treatment systems” (Government of Victoria 2008).

EPA Victoria provides guidance on how to apply for approval of OWTS. In reference to verification of the systems performance and control, it states “systems which use novel treatment processes should be assessed for compliance with the generic performance criteria for onsite systems in Australian Standard AS 1547:2000 On-Site Domestic Wastewater Management” (Government of Victoria 2008). This suggests that, like NSW, there are no formal guidelines for approval of vermifiltration-based systems. There are four systems which have been granted approval in Victoria, as specified by Table 1.

Table 1 VOWTS approved in Victoria

Name	Approval granted	Valid until
WormSmart	July 2011	July 2016
A&A WormFarm	February 2012	January 2013
OnZite	June 2012	February 2014
AquaClarus SuperNatural	April 2010	April 2015

2.4.2. New South Wales

OWTS using vermifiltration are assessed as “Wet Composting Closet Systems” by New South Wales Health. The Accreditation Guidelines for Sewage Management Facilities Advisory Note 2 states that there is no accreditation guideline for this type of system and that vessels are assessed under the Septic Tank and Collection Well Accreditation Guideline (Government of New South Wales 2001).

There are five systems which have been granted approval in New South Wales, as specified by Table 2.

Table 2 VOWTS approved in New South Wales

Name	Approval granted	Valid until
WormSmart	9 September 2011	31 December 2015

A&A WormFarm	29 September 2010	31 December 2015
OnZite	17 December 2008	31 December 2013
AquaClarus SuperNatural	26 October 2011	31 December 2016
Biolytix BF6	24 August 2011	31 December 2015

2.4.3. Western Australia

Onsite wastewater treatment systems in Western Australia are approved by the Department of Health. In assessing vermifiltration based systems, the Department uses AS 1547:2012 , AS1546 and the Code of Practice for Product Approval of Onsite Wastewater Systems in Western Australia (Government of Western Australia 2011).

A number of vermicomposting systems have been submitted to the DOH for approval. One such system, Biolytix BF-6 Aerated model was granted approval for use in Western Australia. However, Biolytix went into receivership and as of 25 January 2011 approval for this system was revoked. Furthermore, the DOH received a number of reports of failing Biolytix systems due to “clogging by solid matter and worm castings of the geo-textile material located at the bottom of the tank” and has not re-approved the system and will not re-approve without changes to the system design.

Another system which has not been approved for use in Western Australia is the WormSmart BioLogical Waste System. This system has not been approved due to insufficient information as the DOH felt that an appropriate assessment of the system was not possible.

2.4.4. South Australia

The South Australian Department of Health is responsible for the approval of onsite wastewater treatment systems. The Department classifies vermifiltration-based systems as “alternative systems” in the Draft Onsite Wastewater Systems Code (Government of South Australia 2006)and uses AS1547:2012 to assess them. There are currently four systems which are approved for installation in South Australia, as specified in Table 3.

Table 3 VOWTS approved in South Australia

Name	Approval granted
Biolytix BF6	August 2011
A&A WormFarm	April 2005
OnZite	January 2003
AquaClarus SuperNatural	September 2011

2.4.5. Northern Territory

The Northern Territory Department of Health is responsible for the approval of onsite wastewater treatment systems. Vermifiltration-based systems are classified as “alternative treatment systems” under the Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent (Northern Territory Government 1996), which states that AS1547 shall be used to assess alternative treatment systems.

There are currently two systems which are approved for installation in Northern Territory, as specified in Table 4.

Table 4 VOWTS approved in the Northern Territory

Name	Approval granted	Valid until
Biolytix BF6	May 2011	21 November 2016
A&A WormFarm	January 2008	14 January 2013

2.4.6. Tasmania

Accreditation of OWTS in Tasmania is guided by the Tasmanian Plumbing Code Authorisation & Accreditation: Plumbing and Drainage Products Authorisation Process & Onsite Waste Water Management Systems Accreditation Process (Government of Tasmania 2010).

There are currently no vermifiltration based onsite wastewater systems approved for use in Tasmania. The Biolytix BF6 was approved between 2/4/2008 and 19/1/2011, however, when the company went into receivership in early 2011 the Department revoked approval.

2.4.7. United States

The United States Environmental Protection Agency delegates the responsibility of testing and approving onsite wastewater systems to states. There exist some reciprocity agreements between groups of states in the approval of OWTSs. An example of such is the New England Interstate Water Pollution Control Commission (NEIWPCC) which is responsible for approving systems in seven states. There are no specific VOWTS protocols.

2.4.8. United Kingdom

The United Kingdom Environment Agency does not have a specific testing protocol for vermifiltration-based wastewater treatment systems. Instead, the British Standards BSEN 12566 (British Standards Institution 2006) and BS 6297 (British Standards Institution 2007) which are used for conventional OWTSs are applied. There are no specific VOWTS protocols.

2.5.Environmental Conditions

Earthworms require certain conditions to survive and optimise their waste processing potential. In a vermifiltration-based wastewater treatment system, these environmental conditions need to be met to ensure that worm populations thrive and wastewater is being treated to a sufficient standard (Ludibeth, Marina et al. 2012). The following are the key environmental factors which affect vermicomposting systems:

2.5.1. pH

The pH of a system that earthworms can survive in can range from 4.5 to 9. However, the optimum pH is 7 (neutral) (Sinha, Nair et al. 2008).

2.5.2. Temperature

Studies have found that the optimal temperature range for earthworm degradation of waste is 15°C to 25°C (Neuhauser, Loehr et al. 1988). However, they are able to tolerate a temperature range of 10°C to 30°C (Sinha, Bharambe et al. 2008) and heat is a much greater problem than cold (Sinha and Valani 2011).

2.5.3. Moisture

Earthworms require a moist environment to survive. It has been suggested that the optimal moisture content of a vermifiltration system is 60-75% of the soil's water holding capacity (Sinha, Herat et al. 2010; Sinha and Valani 2011). However, worms are able to survive in conditions outside of this but will not be as productive (Sinha and Valani 2011).

2.5.4. Carbon – Nitrogen Ratio

It is accepted that for vermicomposting the carbon – nitrogen ratio should be 25:1. Studies have found that when sewage sludge is used as the feed material in vermicomposting systems, the C: N ratio can be low due to the high nitrogen content of the sludge. To mitigate this problem, it is suggested that "carbon rich bulking materials" are used to increase the ratio (Sinha, Nair et al. 2008). These materials can be organic materials such as straw or leaves. However, in vermifiltration systems the wastewater that passes through is 99% water and laboratory studies have not required additional carbon-loading to achieve substantial improvement in effluent quality(Sinha, Herat et al. 2002).

2.5.5. Aerobic Environment

Worms are aerobic organisms which require oxygenated environments to survive and thrive (Sinha, Agarwal et al. 2010). It is crucial that the filter does not have areas which become anaerobic. Worms will die in these areas and aerobic treatment will cease. Aerobic digestion is significantly faster than anaerobic digestion which also creates foul odours. The cessation of aerobic digestion will also lead to a backlog of untreated waste, which may cause the system to overflow and fail. Once this happens, the system will need to be pumped out and rebuilt internally.

2.5.6. Population and Density of Worms

It has been suggested that to be effective treatment systems vermifiltration systems should be started with a large population of earthworms; at least 15 000 to 20 000 per cubic meter (Sinha, Nair et al. 2008). The population of worms should increase after commissioning and fluctuate with the loading of the systems. A significant decline in worm population can indicate that environmental conditions within the treatment system are not ideal. The population of worms should consist of adults, juveniles and cocoons so that the system remains stable.

2.5.7. Loading Rate

The loading rate of a system is characterized as the volumetric flow rate of waste water through the filter media as defined by Equation 1.

Equation 1 Hydraulic loading rate of liquid through a permeable media

$$Hydraulic\ Loading\ Rate\ (m/h)\ = \frac{volumetric\ flow\ rate\ of\ wastewater\ (m\text{^}3)}{area\ (m\text{^}2)\ x\ time\ to\ flow\ through\ profile\ (h)}$$

(Recycled Organics Unit 2007)

The hydraulic loading rate is important to maintain correct temperature, aerobic conditions and moisture levels.

2.5.8. Minimum Hydraulic Retention Time

Hydraulic retention time (HRT) is characterized as the time which the wastewater is in contact with the filter media and is defined by Equation 2.

Equation 2 Hydraulic retention time of liquid through a permeable media

$$Hydraulic\ retention\ time\ (hours)\ = \frac{porosity\ x\ soil\ profile\ volume\ (m\text{^}3)}{flow\ rate\ through\ filter\ (m\text{^}3/h)}$$

(Recycled Organics Unit 2007)

Retention time is important because it is the amount of time that the filter is treating the wastewater. For BOD loads between 200 and 400mg/L, an acceptable HRT for significant reduction is 30-40 minutes (Sinha, Herat et al. 2010). This amount of time will allow earthworms and bacteria to reduce BOD, COD and TDSS and facilitate treatment. However, for domestic wastewater treatment, it has been recommended that the HRT is increased to between 1 to 2 hours. This is due to the need to reduce pathogens, toxic chemicals and heavy metal concentrations found in sewage (Sinha, Herat et al. 2010).

2.6. System Design

By taking aspects of wastewater treatment system design and vermifiltration into account, a number of factors which need to be satisfied become apparent for vermifiltration-based wastewater treatment systems. Many of these are general wastewater treatment factors which have to be modified, to take into account the presence and continuing survival of worms and bacteria. These also take into account wastewater treatment standards as set out in AS1547.

2.6.1. Depth of the system

The depth of the filter refers to the depth in which worms are expected to be found. In conventional vermicomposting systems that most species inhabit the top 100-200mm of the compost material (Edwards and Fletcher 1988) . It has also been suggested that when the depth of the system reaches over 450mm in depth that compaction and anaerobic conditions are present. In vermifiltration systems, the filter has a substrate material which should give the filter a structure which allows for more voided areas. However, if the loading rate of the system is such to facilitate a build up of a layer of biosolids on the surface, then there may be problems with areas becoming anoxic and ultimately anaerobic. It can then be seen that the waste application method and proper sizing of the system are important to the viability of the system (Recycled Organics Unit 2007). The overall depth of a system is dependent on the substrate material, aeration rate and internal temperature of the system.

2.6.2. Wastewater application method

The method in which wastewater is applied to the filter needs to ensure a consistent application over the entire surface. This will reduce ponding in the system, which can also result in anaerobic conditions.

Wastewater application methods are regulated by AS1547:2012 and codes such as the Code of Practice for Product Approval of Onsite Wastewater Systems in Western Australia , such that systems “ensure even distribution of liquid over any filter bed that may form part of the treatment process”. These systems include sprays and drips, however clogging within these may be an issue.

2.6.3. Processing capacity

The processing capacity of an onsite wastewater treatment system must be in line with AS1547, such that:

- The system can hold the normal flow of a maximum of 10 persons;
- Allow for peak flows;
- Allow for unusual waste loads; and
- Maintain a sufficient hydraulic retention time

2.6.4. Extended periods of non-use

Not all onsite wastewater treatment systems are suitable for use in residences which are not occupied at all times. The concern in a vermifiltration system is that if moisture levels drop, worm populations may decline and intermittent flows may not be treated sufficiently. A system would need to demonstrate that there is no decline in waste treatment after extended periods of disuse

2.6.5. Removal of castings

The by-product of worm treatment is castings. In a system it needs to be clear where and how the castings are converted to vermiliquid and subsequent treatment occurs. Questions which need to be answered are:

- Do these castings build up?
- Where do they build up?
- How they can be removed?
- How often they need to be removed?

2.6.6. Prevention of clogging

Clogging within a wastewater system can occur in a number of areas such as geotextile membranes, pipes and filters. The system needs to demonstrate measures that will prevent clogging from occurring in filters and pipes. This can be done in a few ways such as pre-mixing the influent wastewater. It is also necessary to be able to detect where a system is clogged to be able to remediate the problem. A change in pressure in the system can indicate clogging.

2.6.7. Aeration

Aeration is a significant environmental aspect of a vermifiltration system necessary for the continual survival of the worms and bacteria. The system needs to demonstrate that it can provide sufficient aeration and maintain oxygen levels.

2.6.8. Odour

Vermifiltration systems should not produce an unpleasant odour. A system which is producing an odour is most likely not operating properly and has anaerobic pockets present.

2.6.9. Disinfection

The use of disinfection is dependent on the end use of the treated wastewater and if used it is probably only a viable option for post-treatment.

2.6.10. Alarms

A number of alarms could be fitted to a vermifiltration system including temperature, inlet pressure, water level, backflow, power failure, instrument failure. An alarm system should detect a malfunction quickly and alert the user. It is typical to have an audio-visual alarm system on OWTSs. It needs to be clear what conditions will cause the alarm to sound, how long the system can be used until it fails after an alarm sounds and what is the contingency plan if there are failures.

2.6.11. External inflow prevention

The system should only receive input through specific inlets. Stormwater should not be able to flow into the system as it puts more pressure on the system.

2.6.12. Backflow prevention

System should prevent backflow through the inlet and outlet.

2.6.13. Integrity of the system

The system has to be constructed to the appropriate Australian Standard.

2.6.14. Exclude Vermin

Insects and animals should not be able to enter the tank. This is especially important in the case of mosquitoes as the water may provide a breeding ground.

2.6.15. Tank location

Wastewater treatment systems can be above or below ground. However, a below ground tank is not affected by fluctuations in air temperature as much as above ground tanks. Vermifiltration based systems require a relatively constant temperature so below ground tanks are probably best suited to this application.

2.6.16. Servicing

Servicing of the system should be undertaken at regular intervals (i.e. six monthly) by appropriate technicians.

2.6.17. Substrate material

The substrate is the material which worms live and wastewater trickles through. This material should be relatively inert and not degrade significantly or leach after extensive use. This substrate may need to be replaced periodically and if so should be easily removed and re-inserted.

2.6.18. Installation

System should be installed by a qualified technician as specified.

2.6.19. Flow control

Flow control is required to maintain the duration of time which the wastewater is in contact with the filter, which will allow for sufficient treatment. The minimum hydraulic retention time is one hour, however any increase in this time will result in enhanced treatment outcomes.

2.7. Potential Problems

All systems have the potential for problems. These may result from poor design, incorrect installation/use and/or construction faults. Potential faults which are specific to vermifiltration systems have been identified as follows:

2.7.1. Clogging

Clogging can be a problem in systems which treat solids. In a vermifiltration system the ratio of solid to liquid is very low. However, the worms produce a cast material which may cause filters to become clogged. In addition, if solids are allowed to pass through the filter without proper treatment, parts of the filter may become clogged with untreated waste. Clogging puts increased pressure on pumps, causes a backlog of water which may result in overflowing of the system, and may create an anaerobic environment, leading to a reduction in treatment quality.

2.7.2. Anaerobic conditions

Anaerobic conditions are lethal to worms and other aerobic bacteria. When oxygen levels drop in certain areas of the filter worms will no longer consume waste there. This will result in the proliferation of anaerobic bacteria which produce a foul odour and treat waste at a much lower rate. Anaerobic conditions can result from ponding of water, insufficient aeration, and compression of the filter bed.

2.7.3. Temperature increase

Worms are sensitive to temperature changes and are most active when temperatures range from 20-25°C. Temperatures outside the range of 10°C to 30°C can result in worm deaths (Neuhauser, Loehr et al. 1988).

2.7.4. Toxic effect of domestic effluent

Domestic effluent contains all of the substances that go down household drains, including cleaning products, food, oil and grease. These substances, especially many cleaning products, may impact the worm population due to their toxic effects. For example, it has been shown that sodium chloride impacts the life cycle of composting worm *Eisenia fetida* (Hughes, Nair et al. 2009).

The user of the system is responsible for the effluent contents, however the manufacturer needs to inform users on the correct proper user care.

2.8. Conclusion

A vermifiltration wastewater treatment system is a low cost and environmentally beneficial approach to treating domestic wastewater. However, with careful consideration of each aspect of the system it becomes increasingly apparent that this type of system is not as simple as once thought. The inclusion of earthworms to treat waste brings in the complication of providing and maintaining an environment in which they are at their highest efficiency. Factors such as temperature, moisture level, oxygen level and user care are extremely important for the continued survival of the worm population and to ensure that the effluent quality is sufficiently high.

3. Case Studies

3.1.Site Visits

Site visits to two Biolytix BF-6 units were completed in November 2012. The Biolytix system is the only VOWTS which has been installed in Western Australia and although approval has been revoked, the systems are still required to be serviced every 12 months . A group from the Department of Health inspected two systems in Kalamunda which required servicing (as specified by the local government approval), and these have been used as case-studies. At one site the owner was present to answer any questions about the use of their system.

The site visits were conducted by Ian Matheson, the only plumber who is certified to service the Biolytix system. Ian is an extremely knowledgeable person about these systems and explained the problems they've experienced, showed how they service the units and what is involved in a rebuild. He also shared his knowledge about why he thinks the systems fail and what measures could be taken to stop systems from failing so quickly.

The two systems that were visited were both functioning well.

System 1: Peet Road, Kalamunda

This system is five years old, has been serviced regularly and had some slight ponding and build-up of untreated waste on the top. The owner of this system was present and was happy to provide us with information regarding their water use.

The tank has been installed fully underground and is covered in woodchips by the owner over the hot summer months. This helps to maintain cooler conditions within the tank, which is an important feature of vermifiltration systems. When the system was opened worms were visible on the top of the filter which indicates that the keeping the tank underground and well shaded is important for treatment within the whole depth of the filter.

The system is used by a family of four, consisting of two adults and two small children. The owners considered themselves to be low water users, except for the amount of washing they do due to having young children.

The servicing protocol consists of taking measurements of turbidity, pH and dissolved oxygen. In this system the turbidity was 40NTU, pH was 6.5 and the dissolved oxygen was 7mg/L.

System 2: Sampson Close, Kalamunda

System two was 3 years old, had never been serviced but did not show signs of ponding or untreated waste. As the owner was not present it was unclear how much the system is used. When the inspection cover was lifted there were no visible worms on the surface but when the first layer of filter bags was removed the worms were visible. The lack of worms on the surface may have been due to a lack of input material or the temperature at the top of the system, but it is unclear which. In this system the turbidity was 30NTU, pH was 6 and the dissolved oxygen was 7mg/L.

From discussions with Ian Matheson, it has been noted that systems tend to fail when they are overloaded. The domestic systems were approved to handle 2000L per day, however, from his experience they function better when they are loaded at approximately 500L per day. This lowering in input can be achieved by diverting greywater away from the vermifiltration system.

The dissolved oxygen level in the tank is extremely important to the survival of worms. The system was approved for a dissolved oxygen level of greater than 2mg/L. According to Ian Matheson, most systems are approximately 2mg/L. Matheson found that system failures were occuring when biofilms form on the geotextile membrane. A biofilm forms when water ponds above the geotextile membrane due to high water use. The water cannot pass through the membrane and the water level in the tank rises, causing flooding and worm deaths. Once this occurs, the system needs to be pumped out and rebuilt.

3.2.System Reviews

There are currently five vermifiltration onsite wastewater treatment systems on the Australian market which have received approval for use in various States. These are:

- A&A Worm Farm
- AquaClarus SuperNatural
- Biolytix BF-6
- OnZite
- WormSmart

To develop a protocol which will be used to assess these types of systems, it is essential to have an understanding of the way each system operates as well as the differences and similarities in available systems.

3.2.1. A&A Worm Farm

The A&A Worm Farm is a vermifiltraton system which treats wastewater and household compost materials. The system has no mechanical parts and relies on gravity and wind to distribute waste and aerate the system.

The system is sited in an underground concrete tank. At approximately one third of the height of the tank is a filter of plastic and organic media on which the wormpile sits. The tank has two waste entry points; one wastewater pipe from the dwelling and one compost entry at the top of the tank.

Ventilation is achieved by a vent pipe which opens underneath the filter (Government of New South Wales 2012). The treated effluent flows through the filter and is either gravity fed or pumped to irrigation fields.

The design of this system is such that it uses very little energy to treat the waste. However, the concern is that the wind driven ventilation may not be sufficient to maintain the required dissolved oxygen levels. The manufacturer claims that the system can accept a large volume of kitchen and garden waste, which may lead to decreased effluent water quality. Figure 1shows the schematics of the system.

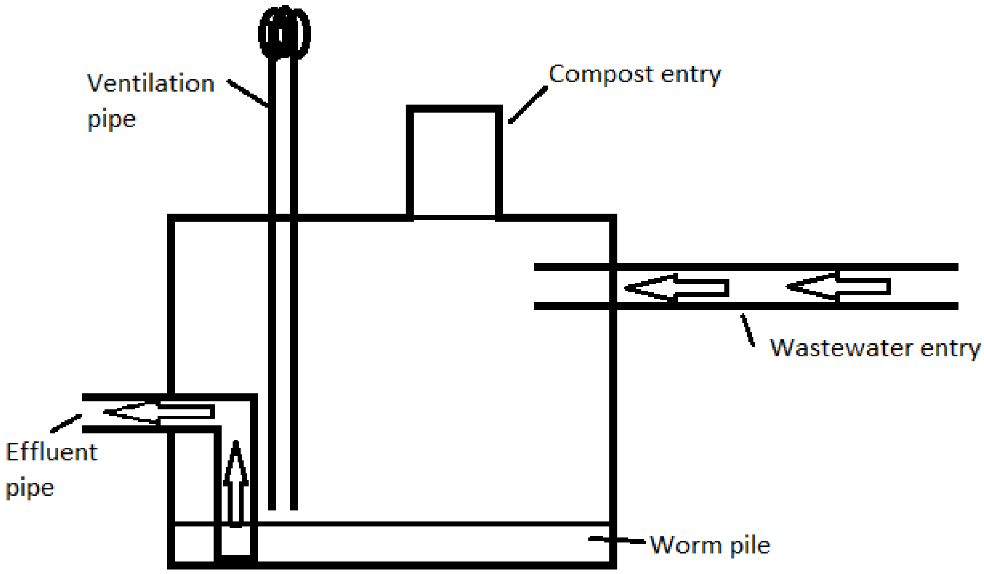

Figure 1 Schematic of A&A Wormfarm system

3.2.2. AquaClarus SuperNatural

The SuperNatural system is a system which treats wastewater by separating solids and liquids and treating them individually within the tank. The solid fraction of the waste is treated by worms and bacteria on a filter bed of organic material, while the liquid fraction is treated by membrane filtration and ultraviolet disinfection. The worm bed receives all of the waste from the house and then the excess liquid is removed (Aqua Clarus 2009). Figure 2 is the schematic of the system.

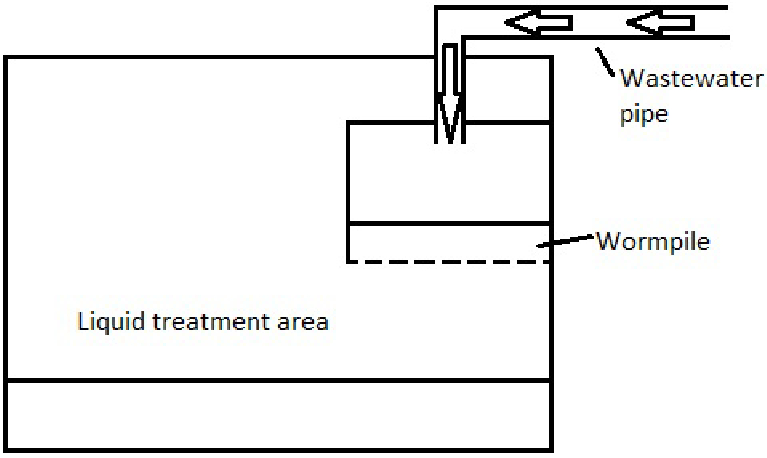

Figure 2 Schematics of the AquaClarus SuperNatural system

3.2.3. Biolytix BF-6

The Biolytix system is the only vermifiltration system which has been installed in Western Australia. However, they are no longer approved for use as the manufacturer went into receivership after many systems began to fail.

The system consists of an underground tank. Within the tank, filter bags filled with plastic filter material are layered with coco peat. This filter bed sits on on a raised platform of geotextile. All of the wastewater is then dispersed via the inlet pipe over these filter bags. Aeration is provided by an air-line which pumps air into the influent wastewater (Queensland Government 2011). Figure 3 is the schematic of this system.

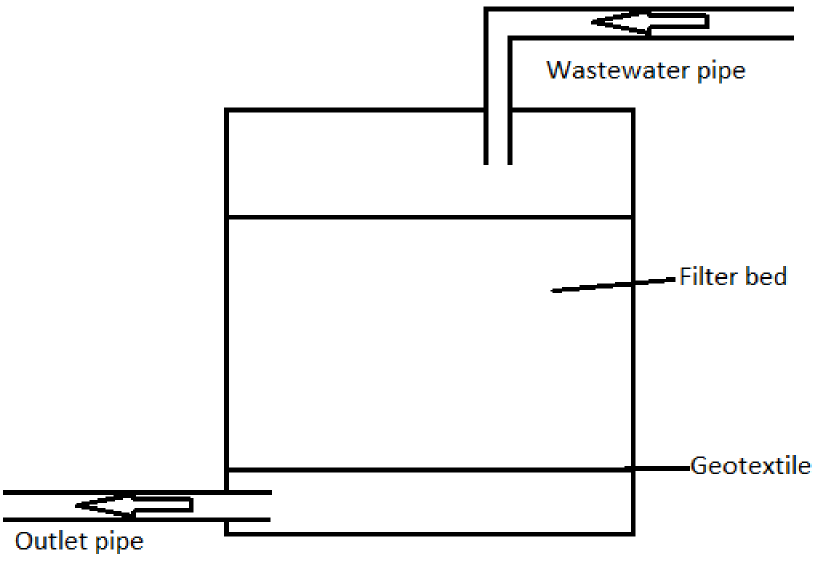

Figure 3 Schematics of the Biolytix BF-6 system

3.2.4. OnZite

The OnZite Wormfarm is situated in a 3200L tank. The tank has two inlets; one pipe for wastewater and one compost bin for organic waste. The filter bed consists of layers of washed river stones, newspaper, and peat mulch on top of a raised platform of geotextile. Worms are added to the filter bed and wastewater is applied via the inlet pipe. The effluent water trickles through the geotextile and is collected at the base of the tank. Aeration is provided by a ventilation pipe to the base of the tank (Government of New South Wales 2012).

This system is approved for use in Victoria, New South Wales and South Australia. Figure 4 is the schematic of the system.

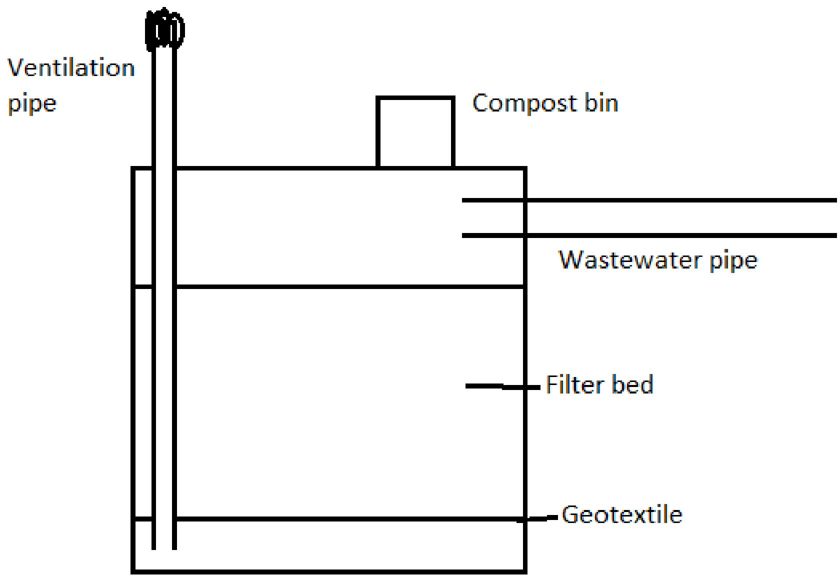

Figure 4 Schematics of the OnZite system

3.2.5. WormSmart

The WormSmart system is situated in a 3000L tank. There are two models of this system; one treats all wastewater simultaneously, the other seperates greywater from kitchen and toilet wastewater. The filter bed consists of layers of plastic mesh and bags of plastic media on top of a raised platform of geotextile. Aeration is provided a 4m ventilation pipe (Environmental Protection Agency Victoria 2011). This system is approved for use in Victoria, New South Wales and Queensland. Figure 5is the schematic of the system.

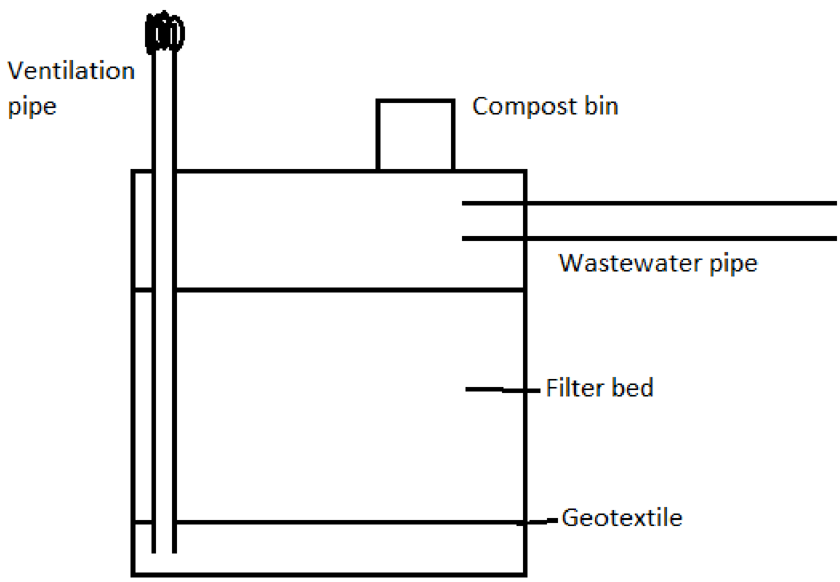

Figure 5 Schematics of the WormSmart system

3.3. Conclusions

It is interesting to note the similarities and differences between these systems and how the protocol may be applied to each. For example, the AquaClarus SuperNatural only uses vermifiltration for a small portion of its waste treatment and the protocol would only be applicable for that part of the system. For other the other parts of the system other testing procedures would be required. However, for other systems such as the A&A Worm Farm and the OnZite systems, the vermifiltration protocol would probably suffice.

4. Development of the protocol

The protocol which has been developed can be split into two parts; the general requirements for vermifiltration onsite wastewater treatment systems and the testing requirements which shall be fulfilled. Sections 1-4 and 6-9 deal with the former, while section 5 is dedicated to the environment conditions inside the treatment system which are required to be tested. The protocol takes into account system design, environmental conditions and maintenance requirements. This chapter justifies the decisions made when developing the protocol.

The protocol provides a consistent, objective and effective method of testing and approving vermifiltration onsite wastewater treatment systems. It includes methods of testing systems, sets minimum standards the systems are required to achieve, maintenance requirements, operational requirements and effluent standards. Not only does the testing protocol address issues which may cause systems to fail, but it asks suppliers to demonstrate how their system will manage faults and servicing.

The protocol takes its structure from the WA code of practice, a document which the Western Australian Department of Health uses to approve other onsite wastewater treatment systems.

The general requirements of the protocol are fairly standard and it refers to other protocols or Australian Standards where it can.

The draft protocol was submitted to the National Onsite Regulators Forum (NORF) for comment.

It is hoped the testing protocol will form the basis of an Australian Standard for onsite vermifiltration systems.

4.1. Environmental Conditions in Treatment Tank

The environmental conditions inside the treatment are extremely important for the survival of worms. The worms and bacteria are central to the treatment process and it is vital that they have environmental conditions which will allow them to thrive. A system which does not provide a suitable environment will have reduced treatment and may fail quickly.

The factors laid out in the protocol have been identified as the most important to worm survival. Table 5 sets out the environmental conditions and the performance requirements which should be met.

Table 5 Requirements for environmental conditions within the treatment tank

Environmental Condition	Performance Requirement
Temperature	90% of samples are between 10 and 25C with no sample above 30C.
Moisture	90% of samples are between 60-75%, with no sample above 90% or below 40%.
pH	All samples shall be between 4.5 and 9.
Dissolved Oxygen	90% of samples above 5mg/L, with no sample below 3mg/L.
Odour	There shall be no offensive odours from the tank.

4.1.1. Temperature

As noted previously, the temperature is a significant factor in the worm survival (Neuhauser, Loehr et al. 1988). Studies have shown that worms can survive temperatures ranging from 10C to 30C, but are most active between 15 and 25C (Sinha, Bharambe et al. 2008).

The protocol states that for temperature "no sample (shall be) above 30C", but does not specify a lower temperature boundary. This lack of lower boundary is due to the increased sensitivity of worms to high temperatures. When temperatures are below 10C, worms are significantly less active but are less likely to die during these times.

As seen in the case studies in chapter 3, worms will not live in parts of the filter which are too warm. In the second case study system, the system was in direct sunlight and when the top was lifted there were no sign of worm activity. The removal of the top layer revealed worms were living further down the filter where temperatures were cooler. This layer of the filter where there were no worms living effectively decreases the depth of the vermifilter which may lead to decreased wastewater treatment.

4.1.2. Moisture

Moisture is also an important factor for worm survival. While worms have been known to survive both high and low moisture levels, the moisture level at which worms are most active is between 60 and 75%.

The upper moisture level which no sample shall be above is 90%. This level was selected because higher moisture levels indicate that water levels are very high. High water levels can indicate that there are problems within the system such as blockages or overloading.

4.1.3. pH

The pH within the vermifilter is expected to change with depth during treatment. Worms are most sensitive to pH's outside of the range of 4.5 to 9. Although worms are most productive at a pH of 7 (neutral), the wastewater that the system will be treating is unlikely to have a neutral pH. To some degree, it is up to the user to maintain the pH of the system by not using chemicals which will significantly alter the pH of the wastewater.

4.1.4. Dissolved oxygen

As aerobic organisms, worms and the other bacteria which break down waste require oxygen. Worms acquire this oxygen through contact with oxygen rich water and oxygen levels need to be sustained to maintain the worm and bacteria population. Wastewater has a high biochemical oxygen demand (Tchobanoglous, Burton et al. 1981) and it is important that areas of the vermifilter do not become anaerobic, as this causes offensive odours and worm deaths.

It has been noted that the dissolved oxygen level should be greater than 5mg/L, with a lower boundary of 3mg/L. It is expected that DO levels will be lower at the bottom of the filter however they shall still be above 5mg/L 90% of the time.

4.1.5. Odour

While odour is not an environmental condition in the treatment tank, it can be a good overall indication of how the system is functioning. Aerobic bacteria do not produce pungent or offensive odours when breaking down wastewater. The presence of an odour may indicate that there is anaerobic digestion taking place within the vermifilter.

These factors will influence the dynamics of the worm population. For the population to remain stable or increase there should be a mix of adults, juveniles and eggs. These populations should be approximately the same for each age group so that the overall population remains steady.

4.2. Environmental Performance Testing

This section specifies the test procedures which shall be undertaken for the parameters mentioned in the previous section.

The three main factors which have influenced the development of the testing procedures are:

- limiting the disturbance of the vermifilter;

- testing at regular intervals and;
- testing at various depths within the vermifilter.

Disturbance of the filter bed during testing may skew results such as dissolved oxygen and moisture by allowing outside air to enter. The tests should be done on a regular basis (i.e. hourly), so minimising the amount of disturbance they cause is vital.

To minimise disturbance, most of these parameters should be measured using probes inserted into the filter. These probes will stay in the filter for the duration of testing and can take measurements at specified intervals.

4.3. Decommission Requirements and Decommission Criteria

This section specifies the requirements and criteria for the decommissioning procedure which shall be undertaken once the performance is completed. Decommissioning testing is done to determine the system's ability to cope with the stresses of wastewater treatment. The worm population will also be sampled at this time.

The decommission evaluation is be done immediately after the 26 week performance evaluation. The purpose of doing an evaluation of the system at this time is to get an understanding of how the system coped under the test conditions. Although the testing period is only a relatively short amount of time compared to a systems expected lifetime, the decommission evaluation is an important part of assessing whether the system may have faults in the future.

The two main parts of the decommission evaluation are the structural, mechanical and electrical integrity of the system and the worm population. The structural integrity of the system is important to assess because it will highlight any design or material faults which will impact the life of the system while the worm population estimation will assess the sustainability of the worm population.

4.3.1. Structural, mechanical and electrical integrity

After the 26 week performance evaluation, the system is decommissioned and all parts inspected for unexpected wear. The test period is short compared with the projected lifetime of the system and should not have large build-ups of untreated waste, clogging or structural faults. This evaluation aims to highlight design faults which may not have been identified earlier.

4.3.2. Estimating earthworm population

The estimation of the worm population is an important feature of the decommission evaluation and may be one of the most important features of the testing protocol as a whole. As worms are the primary means of treatment in these systems it is important that the population remains steady or increases. It is also important that there are juveniles and cocoons; signs that the worms are reproducing and thriving (Meiyan, Li et al. 2010).

The earthworm population is an extremely good indicator of how the system performed during the testing period. It is expected that if the system provided a suitable environment, earthworm numbers would dramatically increase from the initial population. When estimating the population of earthworms it is essential to determine the number of juveniles and eggs which are present as well as the adult worms. This gives an indication of the population dynamics and the sustainability of the population.

Worm population estimation is not commonly done by laboratories and may require training or consultation from someone who is experienced in worm population studies. There are a number of techniques used in the field to estimate worm population; from handsorting soil to using chemical irritants to lure worms to the surface (Chan and Munro 2001). However, with all of these techniques come advantages and disadvantages (Bartlett, Briones et al. 2010). For example handsorting is very time consuming but it is good for estimating population dynamics and chemical irritants are more time efficient but are not as good for estimating cocoon numbers (Jiménez, Lavelle et al. 2006; Čoja, Zehetner et al. 2008). Therefore, the estimation of the worm population shall be done using a combination of handsorting and wet sifting by a sufficiently experienced person.

This method of population estimation was chosen because it will give a better indication of the dynamics of the population. In this evaluation it is important that the number of juveniles and cocoons be estimated as well as the adult population.

The population of worms may vary with depth and it is important to sample at varying depths to get a better reflection of the actual population.

5. Conclusion

It is hoped that the testing protocol will provide regulators with a clear and reliable means of testing and approving vermifiltration onsite wastewater systems.

The protocol provides a consistent method of assessment of vermifiltration systems by looking at the factors which make these systems successes and failures. This report also brings together a lot of knowledge regarding vermifiltraion and the use of worms to treat wastewater

The testing protocol has a large focus on the worm population because of the nature of the system – using worms to treat wastewater means that the system must provide them with an environment in which they can survive and reproduce. Without these conditions worms can die and the treatment process stagnates, causing systems to fail.

The literature review showed that the there was very little information regarding the testing of these systems and that the current methods are not entirely suitable for such a unique type of system. By looking at current system design flaws and environmental conditions required, the minimum standards for systems was developed and the testing protocol came about.

6. References

Aqua Clarus (2009). Super Natural Wastewater Treatment System - Owner's Manual.

Bajsa, O., J. Nair, et al. (2003). "Vermiculture as a tool for domestice wastewater management." Water Science and Technologh **48**(11): 125 - 132.

Bartlett, M. D., M. J. I. Briones, et al. (2010). "A critical review of current methods in earthworm ecology: From individuals to populations." European Journal of Soil Biology **46**(2): 67-73.

British Standards Institution (2006). BS EN 12566-3:2005+A1:2009. Small wastewater treatment systems for up to 50 PT. Packaged and/or site assembled domestic wastewater treatment plants, British Standards Institution.

British Standards Institution (2007). BS 6297:2007+A1:2008. Code of practice for the design and installation of drainage fields for use in wastewater treatment British Standards Institution

Chan, K.-Y. and K. Munro (2001). "Evaluating mustard extracts for earthworm sampling." Pedobiologia **45**(3): 272-278.

Čoja, T., K. Zehetner, et al. (2008). "Efficacy and side effects of five sampling methods for soil earthworms (Annelida, Lumbricidae)." Ecotoxicology and Environmental Safety **71**(2): 552-565.

Edwards, C. A. and K. E. Fletcher (1988). "Interactions between Earthworms and Micro-organisms in Organic-matter Breakdown." Agriculture, Ecosystems and Environment **24**: 235 - 247.

Environmental Protection Agency Victoria (2011). Approval - BioLogical Waste Systems WormSmart.

Government of New South Wales (2001). Septic Tank and Collection Well Accreditation Guideline. Health Department. New South Wales.

Government of New South Wales (2012). Certificate of Accreditation - Wet Composting Closet System - A & A Worm Farm D. o. Health.

Government of New South Wales (2012). Certificate of Accreditation - Wet Composting Closet System - OnZite Worm Farm Wastewater Treatment System. D. o. Health.

Government of South Australia (2006). Draft Onsite Wastewater Systems Code. Department of Health.

Government of Tasmania (2010). Tasmanian Plumbing Code Authorisation & Accreditation: Plumbing and Drainage Products Authorisation Process & Onsite Waste Water Management Systems Accreditation Process. Department of Justice. Tasmania.

Government of Victoria (2008). Code of Practice - Onsite Wastewater Management. EPA Victoria. Victoria.

Government of Western Australia (2011). Code of Practice for Product Approval of Onsite Wastewater Systems in Western Australia. Department of Health. Western Australia.

Hait, S. and V. Tare (2011). "Vermistabilization of primary sewage sludge." Bioresource Technology **102**(3): 2812-2820.

Hughes, R., J. Nair, et al. (2009). "The risk of sodium toxicity from bed accumulation to key species in the vermifiltration wastewater treatment process." Bioresource Technology **100**(16): 3815-3820.

Jiménez, J. J., P. Lavelle, et al. (2006). "The efficiency of soil hand-sorting in assessing the abundance and biomass of earthworm communities. Its usefulness in population dynamics and cohort analysis studies." European Journal of Soil Biology **42, Supplement 1**(0): S225-S230.

Ludibeth, S.-M., I.-E. Marina, et al. (2012). "Vermicomposting of Sewage Sludge: Earthworm Population and Agronomic Advantages." Compost Science & Utilization **20**(1): 11-17.

Meiyan, X., X. Li, et al. (2010). "Treatment performance of small-scales vermifilter for domestiv wastewater and its relationship to earthworm growth, reproduction and enzymatic activity." African Journal of Biotechnology **9**(44): 7513-7520.

Neuhauser, E. F., R. C. Loehr, et al. (1988). The Potential of Earthworms for Managing Sewated Sludge. Earthworms in Waste and Environmental Management. C. A. Edward and E. F. Neuhauser. The Hague, SPB Academic Publishing.

Northern Territory Government (1996). Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent. D. o. H. a. C. Services. Darwin.

Queensland Government (2011). Chief Executive Approval 01/2011.

Recycled Organics Unit (2007) Literature Review of Worms in Waste Management. **1**,

Sinha, K. S., G. Bharambe, et al. (2008). "Sewage treatment by vermifiltration with synchronous treatment of sludge by earthworms: a low-cost sustainable technology over conventional systems with potential for decentralization." The Environmentalist: the international journal for all environmental professionals **28**(4): 409 - 420.

Sinha, K. S., J. Nair, et al. (2008). Vermiculture Revolution: A low cost and sustainable technology for management of municiple and industrial organic wastes (solid and liquid) by earthworms with significantly low greenhouse gas emissions. Progress in Waste Management Research. J. I. Daven and R. N. Klein, Nova Science Publishers.

Sinha, K. S. and D. Valani (2011). Vermiculture Revolution: The technical revival of Charles Darwin's unheralded soldiers of mankind. New York, Nova Science Publishers, Inc.

Sinha, R. K., S. Agarwal, et al. (2010). "Vermiculture Technology: Reviving the Dreams of Sir Charles Darwin for Scientific Use of Earthworms in Sustainable Development Programs." Technology and Investment **1**: 155 - 172.

Sinha, R. K., S. Herat, et al. (2002). "Vermiculture and waste management: study of action of earthworms *Eisinia foetida*, *Eudrilus euginae* and *Perionyx excavatus* on biodegradation of some community wastes in India and Australia." The Environmentalist **22**: 261 - 268.

Sinha, R. K., S. Herat, et al. (2010). "Vermistabilization of sewage sludge (biosolids) by earthworms: converting a potential biohazard into a pathogen-free, nutritive and safe biofertilizer for farms." Waste Management and Research: 872-881.

Standards Australia and Standards New Zealand (2008). "AS/NZS 1546 On-site domestic wastewater treatment units."

Standards Australia and Standards New Zealand (2012). AS/NZS 1547: 2012 On-site domestic wastewater managemement.

Suthar, S. (2012). "Vermistabilization of wastewater sludge from milk processing industry." Ecological Engineering **47**: 115-119.

Tchobanoglous, G., F. L. Burton, et al. (1981). Wastewater Engineering: Treatment and Reuse, Metcalf and Eddy.

7. Appendix 1

Testing Protocol for Vermiculture-based Onsite Wastewater Treatment Systems (VOWTS)

Scope

The Draft Testing Protocol for Vermiculture-based Onsite Wastewater Treatment Systems (VOWTS) sets the minimum requirements for manufacturers to obtain approval of systems.

The Protocol defines the documentation that applicants need to submit as well as the application process to obtain approval for their systems.

The Protocol also set out the requirements for the design, manufacture, installation, operation and maintenance of VOWTS serving individual allotments. The Protocol is performance based and systems will have to demonstrate compliance with the relevant Australian Standards.

Introduction

This protocol relates to the testing, operation and maintenance of vermiculture-based domestic onsite wastewater treatment systems (VOWTS). VOWTS are worm based on-site systems for the treatment of sewage. They are also referred as vermiciulture on-site wastewater treatment systems.

The aim of this protocol is to ensure safe disposal/reuse of treated wastewater by ensuring VOWTS are designed, installed and maintained so when used on a long term basis they;

a) Do not pose a risk to public health

b) Do not pose a risk to the environment

c) Do not cause nuisance

This protocol adopts guidance from Australia/New Zealand Standard 1546 On-site domestic wastewater treatment units and AS/NZS 1547 On-site domestic wastewater management and should be read in conjunction with those standards.

It is anticipated that the implementation of a standard testing protocol for VOWTS will:

a) Improve efficiency of approval processes across States
b) Decrease the need to grant approvals on “trial” bases by regulatory agencies
c) Minimise specific testing requirements to obtain regulatory approvals
d) Allow systems to be designed with respect to treatment and design standards

Purpose

The purpose of this protocol is to:

a) Set out the minimum performance requirements and performance criteria for VOWTS;
b) Set out the minimum test specifications of system design; and
c) Set out the minimum maintenance requirements; and
d) Identify the documentation that applicants need to submit

Product Certification and Quality Assurance

Product Quality Assurance for VOWTS

Prior to obtaining product approval, the manufacturer/designer must obtain certification to an approved product certification program, for each onsite wastewater model. The product certification program must include initial performance testing of the onsite wastewater system, a decommission evaluation, and ongoing surveillance of the manufacturer’s/designer’s quality systems, to meet the requirements of this Protocol.

The testing program must be conducted under the expected operating conditions at full-scale operation of the system. Pre-validation studies from manufactures of parts of the treatment train can be accepted provided the testing operating conditions will remain within the validated range.

The manufacturer shall arrange for the product certification program to be undertaken through an independent product certification agency. See Section 6 for the requirements of the product certification agency and sampling / laboratory testing requirements.

Test Site and Procedure

Where possible, the test site is to be at a specified test facility or at a location acceptable to the testing agency.

a) The raw wastewater must not be pre-treated by chemical addition and should have characteristics within the ranges listed in Table 1.

Table 1: Raw wastewater Characteristics

Parameter	Wastewater characteristics
E.coli or Thermotolerant coliforms	$10^6 – 10^8$ MPN/100 mL
BOD_5	100-500 mg/L
SS	100-500 mg/L
Total Nitrogen	20-100 mg/L
Total Phosphorus	0.04-42 mg/L

b) The test plant shall be installed, commissioned, operated and maintained according to the system builder's instructions. The system builder is responsible for ensuring the system is free of defects and is operable.

c) The product shall be placed under test over a period of twenty-six (26) weeks. During the test period, samples of the final effluent from the product shall be collected and tested weekly in accordance with the procedure set out in AS/NZS

1546.1. The samples for BOD5, total suspended solids and E Coli shall be taken from the outlet.

d) Temperature, moisture, pH, dissolve oxygen and worm population within the system shall be tested in accordance with section 5 of this protocol.

e) All compliance checking, monitoring, testing and sampling is to be performed by a testing agency as defined in section 6.

f) The samples for BOD5, total suspended solids and E Coli and any other parameters shall be directly transported and delivered to a laboratory, registered by NATA to carry out analyses for the parameters specified. Analyses for disinfectant concentration shall be tested onsite immediately after sampling if disinfection is proposed.

g) All testing shall be done at the cost to the applicant.

Structural Performance Requirements

The structural performance requirements for VOWTS are to be in accordance with:

AS/NZS 1547; and
AS 1546:1 On-site domestic wastewater treatment units: Septic Tanks

Effluent Compliance Criteria

Effluent that is to be of secondary quality, in accordance with AS/NZS 1547, shall meet the effluent compliance criteria detailed in AS/NZS 1546.3.

The system shall be designed and installed to prevent cross-connection with the drinking water. Backflow prevention devices are required at locations identified as hazardous for cross-connection. The type of backflow prevention device must be selected according to the degree of risk hazard as provided in the AS/NZS 3500.1:2003 and AS/NZS 2845.1:1998.

Hydraulic Flow Requirements

The testing requirements for hydraulic flows will be in accordance with AS/NZS 1546.3.

Hydraulic Residence Time

The minimum time that wastewater shall be in contact with the treatment filter is one (1) hour.

Nutrient Compliance Criteria

The effluent compliance criteria for accreditation of a system installed in environmentally sensitive areas shall be able to meet the following nutrient criteria:

The total nitrogen (N) shall be less than or equal to 10mg/L in all samples taken; and

The total phosphorus (P) concentration shall be less than or equal to 1mg/L in all samples taken.

The influent used to test this parameter shall also be tested and be significantly higher than the effluent test results in order to demonstrate the significance of the results.

Design Parameters

A product shall be designed to perform on premises under the following loads:

- a minimum daily flow of 150 litres per person;

h) average daily BOD5 of 70 grams per person (raw wastewater);

i) average daily total suspended solids of 70 grams per person (raw wastewater);

j) average daily BOD5 of 50grams (after primary treatment);

k) average daily suspended solids of 50 grams (after primary treatment);

l) average daily total nitrogen of 15 grams per person (where applicable);

m) average daily phosphorus of 2.5 grams per person (where applicable).

Design Considerations

The product shall be designed to:

a) provide adequate capacity for the design wastewater flow, storage of solids and frequency of discharge;

b) avoid the likelihood of cross contamination between internal chambers;

c) ensure even distribution of liquid over any filter bed that may form part of the treatment process;

d) Provide adequate aeration for earthworms and bacteria survival.

e) ensure that the entire structure and its associated inspection and access covers and/or extensions, are integrally sound and the likelihood of damage by penetration of roots, entry of groundwater, or entry of nuisance insects is avoided;

f) provide access for maintenance, desludging and clearing of blockages;

g) avoid access by unauthorized people;

h) provide, where required, a disinfection unit designed in accordance with section 4.1.20

i) avoid foul air and gases accumulating within the system or entering buildings;

j) prevent damage from superimposed loads or normal ground movement;

k) perform with normal maintenance for the specified serviceable life;

l) provide an effluent pump chamber that permits ease of maintenance or replacement of an effluent pump;

m) provide insulation against noise.

Liners

Liners used to prevent the ingress of groundwater and the egress of wastewater shall be of durable material and conform to the relevant Australian Standard.

Tanks and Fittings

A tank or tanks used to contain the treatment process and associated fittings and extensions comprising the product shall be constructed of durable materials. The tank or tanks shall be watertight, capable of withstanding loads imposed on the roof and walls and shall be constructed and installed so that they will not float in areas with a high water-table level or when the tank is emptied.

Design Loads on Tanks

All tanks that comprise all or part of the product shall be designed to withstand loads in accordance with AS/NZS 1546.1 for Septic Tanks.

Construction of Tanks

The manufacture, construction, materials and testing of tanks forming part of a product shall comply with AS/NZS 1546.1 for Septic Tanks.

Emergency Storage Capacity

The VOWTS should have sufficient emergency storage capacity contained within the product, without cross contamination occurring between any chambers.

Note: Where it can be demonstrated that the product does not need as much storage, the emergency storage capacity may be reduced.

Selection of Materials

The materials and products used in the manufacture and/or construction of the VOWTS shall be selected to ensure satisfactory service for the serviceable life of the system. Factors to be taken into consideration include:

a) the type of usage likely to occur and the nature of the wastewater to be treated;

b) the nature of the ground and the possibility of chemical attack there from;

c) the physical and chemical characteristics of the materials and products used;

d) the possibility of abrasion by solids in the flow or chemical attack;

e) the range of temperatures likely to be encountered; and,

f) UV degradation.

Mechanical Equipment

Mechanical equipment shall:

a) be durable, require minimal maintenance and shall be adequately protected from the aggressive environment;

b) be readily accessible for maintenance or replacement;

c) be suitable for continuous and intermittent operation; and

d) be suitable for all imposed loads.

Electrical Equipment

All electrical components for and incidental to the product shall be in accordance with AS/NZS 3000.

Where there is any possibility of an explosive gas mixture developing near a motor, the motor shall be intrinsically safe.

All electrical equipment shall be readily accessible for maintenance or replacement, and shall be suitable for continuous and intermittent operation.

Effluent Pumps

Effluent pumps shall have performance characteristics that match the hydraulic requirements of the irrigation system to be installed in the land application area.

Alarm System

An alarm system shall be provided to indicate an electrical or mechanical malfunction as follows:

alarms shall be provided to indicate failure of mechanical equipment and pumps;

the alarm system shall comprise audible and visible alarms with muting facility for the audible alarm. The muting facility shall reset to audible after 24 hours; and

alarms shall be located in readily visible positions from within the dwelling or as required by the regulatory authority.

Noise

The maximum permissible noise level with all equipment (except the alarm) operating shall be 40 dB(A) measured on fast response at a distance of 1 m from the nearest item of noise emitting equipment, or comply with a relevant current standard.

Disinfection

Methods of disinfection include, but are not limited to chlorination, ozonation and ultraviolet irradiation.

The disinfection chamber and/or apparatus shall have a capacity sufficient for the disinfection process to meet the microbiological criteria as set out in section 6.3.

The disinfection apparatus shall:

- be capable of adjustment to alter the disinfection rate;
- be designed to prevent backflow from the disinfection apparatus;
- be linked to the alarm system to warn of failure, if the disinfection device is electronically controlled; and
- be designed to prevent hydraulic short-circuiting within the chlorine contact chamber.

Requirements for chlorine disinfection are set out in AS/NZS 1546.3.

Performance requirements and performance criteria

Scope

This section specifies the performance requirements and performance criteria that a VOWTS shall achieve.

Performance Objective

A VOWTS shall collect and treat wastewater from a household or non-residential facility in a manner that reduces the risk to public health and the environment.

The performance review aims to determine how well the system performs under specified operating conditions. The review shall:

a) Be conducted at a specified testing facility;

b) Be conducted by a certified independent product certification agency;

c) Be conducted under the expected operating conditions at full-scale operation; and

d) Run for 26 weeks

During the test period, samples of the final effluent shall be collected and tested weekly in accordance with the procedure set out in AS/NZS 1546.1 or 1546.3.

The samples for BOD5, total suspended solids, and E Coli shall be taken from the system outlet. All compliance checking, monitoring, testing and sampling is to be performed by the testing agency as defined in section 6.

All samples shall be shall be directly transported and delivered to a laboratory, registered by NATA to carry out analyses for the parameters specified

Environmental Conditions in Treatment Tank

Scope:

This section sets out the requirements for the (environmental) conditions inside the treatment tank.

Requirements

Table 2 sets out the tests and test requirements.

Table 6 Requirements for environmental conditions within the treatment tank

Environmental Condition	Test	Performance Requirement

Temperature	As specified in section 5.4.6	90% of samples are between 10 and 25C with no sample above 30C.
Moisture	As specified in section 5.4.6	90% of samples are between 60-75%, with no sample above 90% or below 40%.
pH	As specified in section 5.4.6	All samples shall be between 4.5 and 9.
Dissolved Oxygen	As specified in section 5.4.6	90% of samples above 5mg/L, with no sample below 3mg/L.
Odour	Olfactory as specified in section 5.4.6.	There shall be no offensive odours from the tank.

Environmental Performance Testing

Scope

This section sets out the process for the sampling the environmental conditions within the treatment tank, referred to in table 2.

Principles

The evaluation aims to determine if the treatment tank provides the minimum standard of environmental conditions for earthworms and bacteria. Samples shall be taken at different depths within the treatment tank to determine consistency of environmental performance.

Test site

The test site shall be at a specified testing facility.

Installation, operation, maintenance

Installation of the VOWTS shall be in accordance with the manufacturer's instructions. The VOWTS shall be operated during the evaluation as specified by the manufacturer's instructions. Any maintenance required shall be noted in the report.

Analysis of Samples

Sampling and analysis shall be performed by an accredited testing agency

Test Methodology

Test Loading

The VOWTS shall be loaded at the design capacity for the duration of the testing period.

Test Period

The test period shall run for 26 weeks.

Sampling

Sampling of temperature, moisture, pH, and dissolved oxygen within the filter shall commence after the first application of wastewater. Samples will be taken using probes and data loggers inserted into the filter in a manner which minimises the disturbance to the filter and treatment tank. Samples will be taken in a range of depths within the treatment tank.

Samples of odour shall be taken by observing the system and noting any unusual or offensive odours.

Sampling positions

Samples of temperature, moisture, pH, and dissolved oxygen within the filter will be taken at a range of depths within the filter, no greater than 30cm apart. The first sample depth shall be no greater than 10cm from the surface of the filter. There shall be no fewer than four sample depths. At each depth, there shall be no fewer than 2 sample sites.

Samples of odour shall be taken one (1) meter from the system.

Sampling Frequency

Samples of temperature, moisture, pH, and dissolved oxygen within the filter, using probes and data loggers shall be taken hourly.

Samples of odour shall be taken daily, noting the time of sampling.

Meteorological Data

Meteorological data for the test period shall be obtained showing the daily maximums and minimums for the test period.

Reporting

A report for each unit shall include:

a) Manufacturer, model, type and volume of treatment tank;

b) Schematic or design drawings to indicate integral components to be tested;

c) Manufacturer’s design capacity;

d) Manufacturer’s maintenance requirements during test period;

e) Description of the test site;

f) Meteorological data for the period of the test;

g) Observations of any significance (such as undue distortion of the tank or components, or evidence of leakage of liquid);

h) Chronological list of any scheduled or unscheduled maintenance performed during test;

i) Chronological list of pertinent equipment or component failures and actions required for correction;

j) Chronological list of unscheduled visits to test site;

k) Incidents relating to equipment or personnel of the testing agency that affected test conditions, or data acquired during testing;

l) Quantity and type of wastes discharged or removed from the unit or any of its components during test;

m) All test results covering temperature, moisture, dissolved oxygen, pH and odour.

n) Assurance that evaluation has been carried out in accordance with this Standard.

Assessment

Decommission Requirements and Decommission Criteria

Scope

This section outlines the requirements for decommissioning and evaluating a VOWTS subsequent to the performance evaluation.

Decommission Objective

The decommission evaluation shall review how the system coped with the testing procedure.

Decommission Requirements

The decommission procedure shall be such that no damage is done to the system during decommissioning. The procedure shall take place immediately subsequent to the conclusion of performance testing.

Decommission Criteria

Structural Performance

The system shall maintain the structural performance in accordance with section 4.

Solid build up

The system and its associated fittings shall not exhibit a significant build up of solids.

Worm population

The worm population shall not significantly decrease over the test period. Samples of the worm population shall be taken at varying depths within the system, no greater than 30cm apart. The first sample depth shall be no greater than 10cm from the surface of the filter. There shall be no fewer than four sample depths. At each depth, there shall be no fewer than 2 sample sites.

The sampling of worm population causes a high level of disturbance within the filter, so sampling shall only occur after performance testing is completed.

Untreated waste

There shall not be a significant volume of untreated waste within the system.

Reporting

A report for each unit shall include:

a) Manufacturer, model, type and volume of treatment tank;

b) Schematic or design drawings to indicate integral components to be tested;

c) Manufacturer’s design capacity;

d) Manufacturer’s maintenance requirements during test period;

e) Description of the test site;

f) Observations of solid build up;

g) List of damaged or faulty parts;

h) Observations of untreated waste;

i) Observations of any significance (such as undue distortion of the tank or components, or evidence of leakage of liquid);

j) Incidents relating to equipment or personnel of the testing agency that affected test conditions, or data acquired during testing;

k) All test results covering worm population; and

l) Assurance that evaluation has been carried out in accordance with this Standard.

Assessment

Product Certification Agency

Applicants must use an accredited product certification agency to certify their product complies with the design, installation, performance and management criteria in the relevant Australian Standard.

The product certification agency must be accredited by JAS-ANZ (Joint Accreditation System of Australia and New Zealand). Contact JAS-ANZ to find an accredited testing agency which offers product certification on the web at www.jas-anz.com.au.

All laboratories used for offsite effluent / end product quality determinations must be National Association of Testing Authorities (NATA) registered to carry out analyses for the parameters specified. Sampling must be undertaken by a NATA accredited laboratory and directly transported and delivered to a NATA accredited laboratory, to carry out analyses for the parameters specified. Where applicable, residual disinfectant and dissolved oxygen samples must be analysed on site

Applicants should demonstrate that their product has obtained product approval under the Standards Mark Quality Assurance program, has ISO 9000 accreditation, or has gained comparable accreditation under a quality assurance process. If manufacture of the product has not commenced, the applicant must provide evidence that the product has been submitted for accreditation under the type of process described above.

Marking, labeling and signage

The minimum marking requirements for a VOWTS shall be:

a) Manufacturer's name or trademark;

b) Date of construction and installation;

c) Design capacity;

d) Product identification;

e) Top load or any other load limitations

f) Contact details for service

g) Weight of product; and

h) Lifting and transport instructions, where applicable.

All marking shall be permanent, legible and clearly visible.

Warranty and Service Life

By applying for and accepting an approval pursuant to the procedures in this Protocol, the manufacturer of a VOWTS guarantees that the product is:

manufactured and supplied as approved;

built in accordance with an approved product specification; and

fit for use.

The manufacturer shall nominate the guaranteed service life of the system. The service life of a system means the period for which that system is designed and rated to comply with the test criteria reliably, using the components specified.

The service life of components means that period for which they are designed and rated to perform reliably to specification and may vary from the performance life of the system. The guaranteed service life of components shall be as follows:

All metal fittings, fasteners and components of the onsite sewage treatment plant other than the pumps and motors shall be of non-corroding material and shall have a service life of at least 15 years;

All mechanical and electrical parts shall have a minimum service life of 5 years and minimum warranty period of 12 months.

Product Literature

The manufacturer must produce and submit the following drawings and manuals for approval, as indicated in the following subsections.

Drawings

Certified engineering drawings, dimensioned and accompanied by a listing of all components must be submitted. The plans must show the intended layout of the system, including typical siting of tanks, chambers and control panels, pipes, effluent application areas and other relevant details.

The drawings must be scaled engineering drawing(s), preferably A3 size (min. A4), to include both plan-views and cross-sectional drawings of the system as a whole and for each of its components with name, model, size, description, function, material of manufacture and location in the product.

The drawings should also include all dimensions and/or capacities of all components.

If the product receives approval, a public domain ‘certificate of approval’, to inform stakeholders of the approval will be issued. This approval includes a schematic diagram of the approved product so that, for example, a Local Government can confirm that the product specified in a permit application is the one that has been approved. Thus, an application must include a schematic diagram of the product in an electronic format (such as pdf format), suitable for attachment to a certificate of approval.

Owner’s Manual

Each onsite wastewater system must be accompanied by an owner’s manual prepared by the manufacturer. The authorised representative must provide the manual to the owner at the time of system installation or on occupation of the premises. The manual must be written so as to be easily understood by the intended reader and must include, at a minimum:

a) an overview of the product and intended use including a clear statement of examples of the types of wastewater/waste that can be effectively treated by the product

b) a diagram explaining the system and the process

c) warranty and service life

d) servicing requirements

e) troubleshooting guide and signs of failures including the name and telephone number of an appropriate service representative to be contacted in the event that a problem with the product occurs.

f) desludging requirements

g) safety information

h) alarm information and use restriction.

i) A statement confirming that the product meets the requirements of this Protocol;

j) A list of toxic substances / loads to be avoided including a list of household substances that, if discharged to the treatment plant, may adversely affect the integrity of the product, the process, or the environment and the spreading of hydraulic loads

k) Comprehensive operating instructions that clearly delineate proper function of the treatment plant, operating and maintenance responsibilities of the owner and authorised service agent, and service-related obligations of the manufacturer or system builder;

l) A course of action to be taken if the product is to be used intermittently or if extended periods of non-use are anticipated;

m) A list of terms and their definitions

Installation Manual

Manufacturers must provide comprehensive and detailed installation instructions to authorised representatives. The manual must be written so as to be easily understood by the intended reader and must include, as a minimum:

a) A numbered list of product components and an accompanying illustration, photograph, or print in which the components are respectively identified;

b) Design, construction, and material specifications for the components of the product;

c) Wiring schematics for the treatment plant's electrical components;

d) Off-loading and unpacking instructions including safety considerations, identification of fragile components and measures to be taken to avoid damage to the product;

e) A process overview of the function of each component and the expected function of the product when all components are properly assembled and connected;

f) A clear definition of product installation requirements including plumbing and electrical power requirements, ventilation, air intake protection, bedding, hydrostatic displacement protection, water tightness, slope and miscellaneous fittings and appurtenances;

g) Repair or replacement instructions in the event that a product possesses flaws that would inhibit proper functioning and a list of sources where replacement components can be obtained; and

h) A detailed start-up procedure.

Operation and Maintenance Manual

Manufacturers must provide comprehensive and detailed operation and maintenance instructions to authorised service agents. The manual must be written so as to be easily understood by the intended reader and shall include, at a minimum:

a) A maintenance schedule for all components;

b) Requirements and recommended procedures for the periodic removal of residuals from the product;

c) Recommended methods for collecting effluent samples or end products; and

d) The expected effluent produced by the operational system.

e) Service report sheet

f) An evaluation of the irrigation system and the land application characteristics.