ENHANCING NUTRIENT REMOVAL FROM EXISTING ON-SITE SYSTEMS

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Abstract

Thousands of on-site sewage management systems are installed throughout Australia in unsewered urban, rural-residential and rural areas. In almost all instances, these systems do not provide any significant means of nutrient removal prior to release of treated effluent to the local environment and ultimately receiving waters. High nutrient levels contained in domestic effluent treated and disposed of on-site have been a significant concern of the each of the major regulatory authorises such as the NSW Environment Protection Authority, Department of Land and Water Conservation and Department Local Government.

This paper examines what can be done, by way of adjustments or modifications to the treatment and disposal process of existing systems, to reduce ultimate nutrient concentrations contained in domestic effluent managed on-site. Focus is placed on methods of removing nutrients from septic tank and aerated wastewater system (AWTS) effluent. A range of alternative designs and process configurations are reviewed. Recommendations for future on-site system designs are provided. These may provide a simple means of providing for more ecologically sustainable on-site effluent management systems which require smaller effluent application areas and deliver a reduced risk of contaminating our receiving waters.

Keywords

aerobic, anoxic, nitrogen removal, sand filtration

1 Introduction

On-site sewage management systems have been regulated within Australia for some 100 years. However, it has only been in the last 5 – 10 years that a significantly greater emphasis on the design and implementation sustainable on-site effluent treatment and disposal systems has emerged. This has come under the broadly defined banner of ecologically sustainable development (ESD).

Practical ESD requires integration of the environmental and economic considerations relevant to a development. The founding principles of ESD are practically defined as:

- Conservation of biological diversity and ecological processes' integrity and life support systems.
- Social equality including inter-generational equity – the present generation must ensure that development and land-use practices maintain or enhance the health, diversity and productivity of the environment for the benefit of future generations.
- Improving valuation, pricing and incentive mechanisms.
- The precautionary principle- if there are threats of serious or irreversible environmental damage, lack of scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

- Utilising natural resources for individual and community benefit without adversely impacting on natural ecosystems and functions.

With respect to on-site sewage management systems, implementation of ESD principles has meant that nutrient loads contained in land applied sewage need to be considered. This is notably the situation in environmental sensitive areas.

Two alternatives are available to achieve enhanced nutrient removal in on-site sewage management systems: controlling nutrients at their source; and increasing land application areas to sustainable sizes. In many instances where land area is not available, the second alternative is not practical. This paper addresses the first option by providing a description of several simple methods of controlling nutrients at source by improving or enhancing the treatment process.

2 Simple Upgrade Options

2.1 Sand Filtration Systems for Septic Tank Systems

Sand filtration systems provide a relatively inexpensive method of upgrading septic tank installations to provide some nitrogen removal from the waste-stream, together with removal of residual organic matter and suspended solids. They have been widely used in the United States for improving effluent quality from septic tanks, however, despite their general acceptance in Australia, implementation of these systems is significantly more limited.

Intermittent sand filtration systems are used together with a septic tank that provides primary or initial treatment. Following primary sedimentation / treatment, effluent is collected from the septic tank and distributed over the sand filtration unit. Sand filtration systems may be capable of removing up to 50 – 70 % of influent N if properly designed so that both aerobic and anoxic environments are created. To achieve N removal, the following sand filter critical design conditions must be met:

- dosing must be intermittent to enable varying oxygen concentration environments to develop. Intermittent dosing ensures that the sand filter is never fully saturated for an extended period of time, thus enabling a range of microorganisms to coexist.
- an aerobic phase must be the first step in the filtering process.
- this must be followed by an anoxic or near anaerobic phase.

Where power is available, effluent is first collected in a pump-well and then pumped over a sand filtration bed. Filtered effluent is collected via a basal drainage network and fed to a final sump / holding well. Treated effluent can then be disposed of using a variety of methods.

Where power is unavailable, gravity flow must be used in the design to ensure that distribution of septic tank effluent over the sand filtration unit is as uniform as possible. Effluent from the sand filter would then be fed to an absorption trench.

Intermittent sand filtration units are sized such that effluent is required to only pass through the sand filter once (ie. single pass filtration). Typical minimum design specifications are given in Table 1.

2.2 Enhanced Nitrogen Removal in AWTS Systems

The majority of AWTS systems utilise a device such as an air compressor or motorised aspirator to deliver air into the waste stream. Air, which contains about 20% oxygen is subsequently dissolved into the waste-stream to ensure that sufficient oxygen is supplied to micro-organisms undertaking biological degradation of influent organic matter.

Table 1 Typical Design Specifications for Intermittent Sand Filtration Units (Crites & Tchobanoglous, 1998).

PARAMETER	DESIGN VALUE
Hydraulic loading rate	40 – 60 L/m^2/day
Organic loading rate	0.0025 – 0.0100 kg BOD/m^2/d
Dosing frequency	12 – 48 times/day
Dosing tank volume	0.5 – 1.5 time hydraulic load

A common problem with AWTS systems is that the aeration compartment is over aerated, with oxygen levels at or above saturation levels, much higher than the minimum of 2 mg/L required for biological degradation of influent organic matter. This is often the situation in both continuous aeration and intermittent aeration designs and

An example of this situation is provided in Figure 1 which shows dissolved oxygen (DO) levels in the aeration compartment of a continuously aerated AWTS on the NSW north coast after the air compressor had been turned off. The figure indicates that after the air compressor was turned off some 800 minutes, or about 13.3 hours, elapsed before DO levels fell to about 0.5 mg/L, which would be required for denitrification to occur.

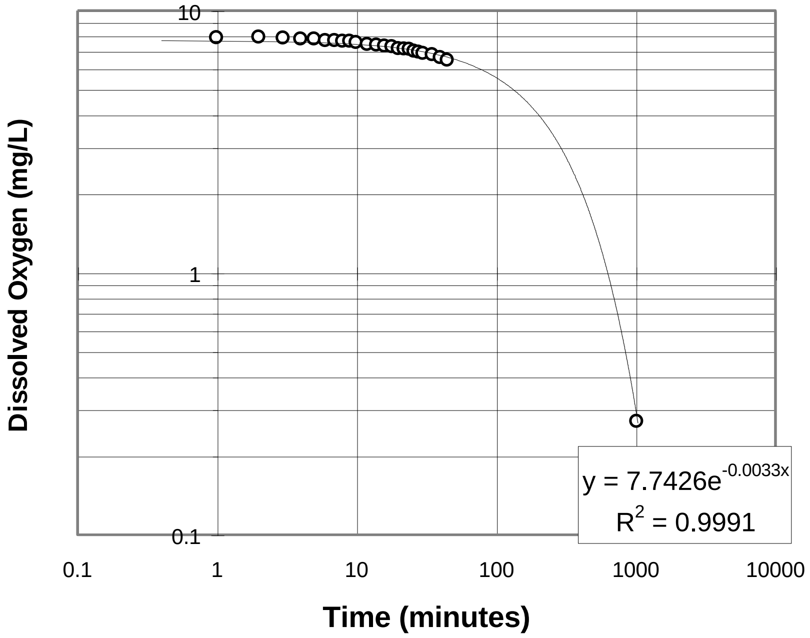

Figure 1 Example of an Over-aerated AWTS System indicating DO levels against time after the air compressor was turned off

The above data illustrate that over-aeration with respect to the influent organic load has the following ramifications:

- Excess air is supplied to the aeration compartment resulting in power wastage
- It is impossible to provide for anoxic conditions to allow for denitrification.

Following on from the above argument, it is possible that the nitrification/ denitrification cycle can be completed in many standard AWTS systems where operating DO conditions are known. The following steps need to be undertaken to enhance N removal from the AWTS.

- DO levels need to be determined. In particular, changes in DO levels after the air supply has been turned off need to be monitored.
- The time taken to reach a DO level of 0.5 mg/L should be determined.

- A simple timer (if not already installed on the AWTS) should be installed to control the air delivery device (e.g. compressor). This should ensure that following a period of aeration, the air delivery device should be turned off for a period determined at step 2 plus 1-3 hours.
- Follow-up DO monitoring should be undertaken to confirm initial measurements and adjustments.

The level of N removal achieved from the above modifications will ultimately depend on site and system specific conditions such as influent organic / N loads and design flow rates.

2.3 Amended Soil Filter Systems for Nitrogen and Phosphorus Removal

Amended soil filter systems combine the advantages of intermittent sand filtration systems with the chemical sorptive properties of a soil medium, providing a simple system capable of removing both N and P from the waste stream. A range of passive reactive filtration systems already exist which provide a medium which both allows for effluent treatment through biophysical means, but also treat effluent by chemical sorption of pollutants onto the filter medium.

The *EcoMax* system, for example, uses a proprietary design and media system and passes primary treated effluent from the septic tank to a large dual evapotranspiration bed area that contains the amended soil media. Media are generally high in iron and aluminium, providing a high surface area to volume ratio and a ready surface for long-term P- sorption. Aerobic and anoxic environments maintained in these filtration beds suggest that significant N removal may also occur within the system.

In terms of practical and inexpensive designs options, simple amended soil systems can be constructed within a sealed bed (eg. Plastic or clay lined), using mixtures of natural soil and coarse sand. An example design of such a system is given in Table 2. Effluent from the amended soil filter can then be disposed of by a range of standard methods and would be of a very high grade with low BOD_5, N and P levels.

Table 2 Example of an inexpensive amended soil design using Krasnozem as the reactive medium.

DESIGN PARAMETER	VALUE	UNITS
Soil medium	Krasnozem	-
P-sorption of Krasnozem	1200	mg P/kg soil
Sand : Krasnozem ratio	2	-
Design life of system	20	years
Hydraulic flow	600	L/day
Influent P	9	mg/L
Design bed depth	0.3	m
Plant P uptake rate	40	kg/ha/year
CALCULATIONS	**VALUE**	**UNITS**
Influent P mass	1.971	kg/year
Plant P uptake	0.42	kg/year
Mass of Krasnozem required	25.9	tons
Volume of Krasnozem required	16	m^3
Volume of sand required	31	m^3
Amended soil bed area	105	m^2
Detention time in bed	52	days

3 Conclusions

The three methods outlined in this paper for enhanced nutrient removal are each relatively simple to implement. Importantly, these methods should not be considered in isolation, but should be thought of as a series of 'tools' which can be used together or individually, depending on the ultimate requirements of the site and sensitivity of the receiving environment where the on-site sewage management system is to be implemented. Summarising the three options:

1. Intermittent sand filtration systems are simple in design, easy to implement, and can considerably improve effluent quality from a septic tank. Where designed properly, such systems are capable of significant N removal.
2. AWTS systems are generally capable of producing secondary quality effluent. However, with simple modifications to the air delivery systems, such devices are often capable of improving the rate of N removal at merely the cost of some limited DO monitoring and a timing switch purchased from a local hardware store.
3. Amended soil systems combine the advantages of intermittent sand filtration systems with the chemical sorptive properties of a natural soil medium. Such systems are capable of providing both substantial N and P removal.

References

Crites, R. and Tchobanoglous, G. (1998) Small and Decentralised Wastewater Management Systems, WCB McGraw Hill