Household Organic Waste Management by Vermiculture

Kuruvilla MATHEW, Martin ANDA and Goen HO

Environmental Technology Centre, Murdoch University, Western Australia, 6150
tel: 61 8 9360 2896 fax: 61 8 9310 4997 email: mathew@essun1.murdoch.edu.au

Abstract
Vermicomposting and vermifiltration are natural waste management processes relying on the use of worms to convert organic wastes to stable soil enriching compounds. Domestic organic waste management can be accommodated through these processes in a sustainable manner. Sustainability can be achieved through the accelerated cycling of nutrients though a closed cycle whereby waste products are put to productive end use. The worms ingest organic matter, fungi, protozoa, algae, nematodes and bacteria, which then passes through the digestive tract. The majority of the bacteria and organic matter pass through undigested (although the organic matter has been ground into smaller particles). This then forms the casting along with metabolite wastes such as ammonium, urea and proteins. The worms also secrete a mucus of polysaccharides, proteins and other nitrogenous compounds from their body. Through the action of ingesting and excreting food, worms create “burrows” in the material that in turn increases the available surface area and allows aeration in conjunction with the aeration already supplied by mixing the biosolids with the chipped green waste. This paper provides an overview of the system characteristics of management systems utilising vermiculture, the associated methods necessary to manage organic waste and the regulatory framework surrounding such activities.

Keywords
vermicomposting, vermifiltration, sludge stabilisation, on-site wastewater reuse, organic waste.

INTRODUCTION

This paper provides the background to the management of domestic liquid and solid organic waste in mainstream Australian society, the regulations that need to be observed in the planning and design of waste management systems, the characteristics of vermiculture, and then 3 case studies of on-site waste management systems that utilise vermiculture: vermicomposting toilets, vermifiltration, and sludge stabilisation.

The paradigm governing wastewater management has focussed on the pollutants in the wastewater and disposal as the solution. It relied on centralised water supply, sewerage and drainage systems with up to 85% of costs incurred in piping and pumping. This paradigm was developed on the Thames River in the last century and its appropriateness for the vast dry continent of Australia has been questioned (Newman & Mouritz, 1996) as has the transfer of these expensive centralised systems to developing countries (Niemczynowicz, 1993) and Australian remote indigenous communities (Race Discrimination Commissioner, 1994). Indeed, the arguments for abandonment of this paradigm in favour of one which cycles nutrients and resources for sustainability are perhaps now as evenly matched against the *status quo* as they were in the last century when the 'water carriage' lobby narrowly defeated the 'dry conservancy' lobby (Beder, 1993). The latter lobby then also sought separation at source with reuse of dry and liquid products for agriculture albeit with much less scientific basis than that available today. Goodland and Rockefeller (1996) proposed three general principles to enable the passage of the new sustainable paradigm: a) cease expansion of sewers and commence decommissioning them; b) promote on-site recycling systems that avoid pollution of water resources; and c) charge the true value of water. In Australia today there is little evidence that (a) is underway in urban centres; however (b) is well underway; and there is certainly discussion of (c) in the prevailing climate of economic rationalism. The focus of this paper is on-site recycling systems.

In assessing the ecological sustainability of nutrient and hydraulic loading rates with on-site effluent treatment systems, Gardner, Geary & Gordon (1996) explained that for septic tank systems allotment sizes of up to 1 hectare maybe required for a single household. However, for transpiration and aerobic treatment systems the area could be considerably less with up to 4,000 square metres being required. Currently, septic tank systems are in use on lot sizes as small as 600 square metres.

Reuse of wastewater occurs most effectively with on-site (localised) or small-scale treatment systems. A major study of Perth's wastewater management (WAWA, 1994) made it clear that it was not possible to reuse all the effluent from centralised treatment plants in the sewered suburban sprawl of Perth - there simply was not enough land for nearby broadacre application. Thus to achieve the goal of total reuse the involvement of a local community in the urban situation would have to be enabled and reuse options in the local context agreed upon. In sewered areas greywater reuse can still be implemented on-site. Greywater or sullage is effluent from the bathroom, washbasin and laundry, and for primary systems should exclude kitchen sink wastewater as it carries oils and high BOD. The more concentrated blackwater (from the toilet) can still go to the sewer along with kitchen effluent. In unsewered areas the blackwater can be treated separately or dry vault composting toilet systems can be utilised. Greywater reuse can result in cost savings (to both the consumer and water utility), reduced sewage flows in sewered areas, and potable water savings of more than 40% when combined with sensible garden design.

BACKGROUND

Current Regulation

The WA State Health Act (Part 7 – Disposal of Effluent and Liquid Wastes) provides regulations for the design and installation of on-site systems including evapotranspiration (ET). However, its requirements are prescriptive and do not allow for site-specific design. For example, the system sizing in Table 1 is provided for on-site effluent disposal.

Table1: For Combined Systems, Other than Flats or Blocks of Units With More Than 4 Bedrooms

Number Of Bedrooms	Soil Classification				
	Sand			Loams or gravel	
	Minimum Infiltrative Area (m^2)	French, leach or evaporation drain (# x length)	Soak wells	Minimum Infiltrative Area (m^2)	French, leach or evaporation drain (# x length)
2 or less	18.8	2 x 6m	3	28.2	2 x 9m
3	25.4	2 x 8m	4	38.1	2 x 12m
4 or more	27.6	2 x 9m	4	41.5	2 x 13m

The Australian Standard for on-site effluent disposal AS1547-1994 (Standards Australia) has recently been upgraded to the superior standard AS/NZS 2001 “On-site Domestic-Wastewater Management. It is more comprehensive in its coverage of on-site systems with a performance-

based approach instead of a prescriptive one. Thus greater diversity and innovation will be possible. The following design criteria is provided:
2.4.1.2 (a) design for 10 person equivalents;
2.4.2.1 (a) daily allowance of 200 L/person for all waste;
2.4.2.1 (b) weekly allowance of 14,000 L for all waste for up to 10 ep;
2.4.2.1 (c) sludge accumulation: all 80 L/person/yr, greywater 40 L/p/yr, blackwater 50 L/p/yr.

The Urban Water Research Association of Australia published “Model Guidelines for Domestic Greywater Reuse for Australia” (Jeppeson, 1996) and this was associated with an increased public and professional interest in greywater recycling in all states of Australia throughout the 1990s.

In February, 1999 a 12-month trial of domestic greywater recycling came to an end in WA. In the shires of Bassendean, Kalamunda and Kalgoorlie/Boulder householders had been permitted, through the use of licensed plumbers, to install approved on-site greywater recycling systems. In the latter shire, where clay soils and low rainfall occur, evapotranspiration-absorption trenches are ideal. No subsidies or other incentives were offered and only 4 systems were installed with a significant opportunity lost to gather information on the performance of new and innovative systems. Nevertheless, the Water and Rivers Commission prepared a policy statement and guidelines for greywater recycling with the support of the Minister who was to table this in Parliament for legislative amendment to the State Health Act. It was widely known that in the order of 20% of householders recycle greywater without permission. This trend will no doubt continue, particularly in rural areas. Experience does need to be gained for local conditions but there is a considerable body of literature for the trial shires to draw from. For example, there are McQuire (1995), Kourik (1995) and Ludwig (1994) for general interest while for contractors and do-it-yourself enthusiasts there are Jeppeson (1996) and Ludwig (1995). Once greywater recycling is approved the next logical step is to conduct trials of dry composting toilets in residential areas with typical lot sizes that one would find in urban areas.

Treated effluent from centralised plants is used on municipal ovals, parks and golf courses in many country towns of WA (Mathew & Ho, 1993). In New South Wales (NSW) treated effluent from centralised plants is allowed in urban areas (NSW Recycled Water Coordination Committee, 1993). National guidelines for the use of reclaimed water via dual reticulation have been prepared (National Health & Medical Research Council, 1996). The level of treatment recommended is secondary plus filtration and pathogen reduction. Alternatives to this include constructed wetlands which may achieve treatment equivalent to open water areas which will allow pathogenic die-off due to UV sterilisation.

The NSW Department of Health (August 1997) published "Waterless Composting Toilets Approval Guideline" in Part 3 of their Local Government (Approvals) Regulation 1993. There are moves afoot for the Health Department of WA to produce a version for Western Australia.

Vermiculture

A means of improving the performance of home compost bins to yield a soil conditioner of greater value is by adding worms. The process is, in fact, no longer composting but vermiculture and a different container can be designed to enhance the productivity. The action of earthworms, vermiculture, enables accelerated decomposition of organic matter. Vermicastings, the product of this action, have both increased available nutrients for soils and marketing value - an increase from some $A20/tonne to possibly $A500/tonne.

It will be necessary to modify conditions in the existing popular bins to produce a conducive environment for worm activity. Composting requires a moisture content of about 50%, carbon:nitrogen ratio of 30:1, aeration to satisfy oxygen demand of microbiological activity resulting in temperatures of up to 70 degrees C. in the thermophylic phase. Earthworms, however, can only survive in the lower temperatures in the range of 12-25 degrees C, enjoy a carbon: nitrogen ratio of around 50:1, a moisture content of around 60% and less aeration is required.

There are three main types of earthworms:

- manure: 6 - 10 cm;
- geophageous (horizontal burrowers): 0 - 30 cm;
- deep burrowers: up to several metres long.

Tiger (*Eisenia fetida*) or Red (*Lumbricus rubella*) worms are the most effective for farming as they are ferocious eaters and fast breeders, as well as African Nightcrawlers (*Endrilus eugeniae*). Blue worms from India (*Periomyx excavatus*) may perform better in warmer parts of Australia than tigers and reds. The provision of a number of species widens the range of foods that will be readily consumed by the worms in your farm. Native worms with a lower metabolic rate are adapted to an environment of lower organic matter but will enhance soil quality if added to deficient gardens.

Satisfactory containers that can be used by a small household, instead of the compost bins, are old refrigerators on their back, polystyrene seafood boxes, and half 44-gallon drums. Good bedding material for worms is provided by cow or horse manures mixed with shredded paper and moistened. Vegetable scraps are added on top (not mixed in so as to avoid high temperature composting) and worms will rise to the surface from the bedding to eat the decaying organic matter. Some 2kg of worms will typically consume 1kg of kitchen scraps a day. Around 1kg of worms can number between 1000-4000 depending on maturity and typically sell at Perth worm farms for $A15-25. Under ideal conditions, 8 tiger worms will increase to 1500 in 6 months whereas red worms are not such rapid breeders. Damp hessian is an effective cover to worm beds as it breathes, can be kept moist, and thus maintains a lower than ambient temperature.

Vermiculture biotechnology can be used for processing domestic refuse after removal of solid, inorganic recyclables. Composting toilets can incorporate vermiculture. Agricultural wastes, manures and food processing wastes can all be processed by worms. Sewage effluent can be treated by means of vermifiltration with agricultural/horticultural reuse of the clean water. Western agriculture can be converted to a sustainable form through the addition of vermicastings from these waste treatment processes, the introduction of worms to the currently sterile soils, and termination of tillage. Worms themselves can be used as bait for recreational fishing, and commercial aquaculture feedstock.

Mechanisms of vermicomposting

More light has been shed on the mechanisms of the vermicomposting process based on the results obtained from trials by the Bathurst City Council (Scarborough, 1999). Scarborough found the entire process appears to be separable into three distinct stages: worm digestion, primary decomposition, secondary decomposition.

1. Worm Digestion

The worms ingest organic matter, fungi, protozoa, algae, nematodes and bacteria, which then passes through the digestive tract. The majority of the bacteria and organic matter pass through undigested (although the organic matter has been ground into smaller particles). This then forms the casting along with metabolite wastes such as ammonium, urea and proteins. The worms also secrete a mucus of polysaccharides, proteins and other nitrogenous compounds from their body. Through the action of ingesting and excreting food, worms create “burrows” in the material that in turn increases the available surface area and allows aeration in conjunction with the aeration already supplied by mixing the biosolids with the chipped green waste.

2. Primary Decomposition

Due to the abundant presence of nitrogen, oxygen and nitrogenous compounds (urea, proteins and ammonia) as part of the vermicast and mucus secreted from the external tissues of the worms, aerobic microbiological growth increases. It is believed that the initial burst of microbiological activity mainly consists of nitrogen fixing bacteria, nitrification bacteria, and to a lesser extent, aerobic bacteria. This is based upon previously established information that burrow walls have a high proportion of the total nitrogen fixing [bacteria] and that casts have higher concentrations of soluble salts and greater nitrifying power. This was reinforced by the results of the trail, finding where there was up to twenty four times more nitrate in the experiment beds when compared to the control. Hydrolysis reactions also occur in the mixture, converting organic nitrogen compounds to ammonia and ammonium.

3. Secondary Decomposition

The hydrolysis of organic nitrogen compounds, nitrogen fixation and aerobic respiration (by aerobic bacteria) consumes organic matter, which further increases the surface area and aeration. This results in a further stimulation of microbiological growth especially the obligate aerobes present in the biosolids (such as *Pseudomonas spp*., *Zoogloea spp*., *Micrococcus spp*. and *Achromobacter spp*.). The explosion in microbiological population then increases the rate of decomposition of the material.

The chipped green waste is vital to the above mechanism. The 100% biosolids, whilst processed very heavily in the upper ten centimetres of the bed, turned anaerobic towards the end of the eight weeks at the depths of the bed, resulting in the objectionable odours typically associated with biosolids.

This mechanism also answers the questions about pathogen reduction / elimination. As the material becomes aerobic, the conditions begin to favour the obligate aerobes (that is microorganisms requiring oxygen to survive, grow and multiply). Pathogens typically are able to process nutrients and reproduce from a range of conditions ranging from aerobic to anaerobic. However, obligate aerobes have evolved to process nutrients and reproduce at the highest level of efficiency in aerobic conditions. Therefore, over time, the pathogens are competitively excluded from water, nutrients and space as the obligate aerobes population continue to increase under their ideal conditions. Virus and parasite reduction is believed to be attributable to a combination of a lack of exposure to host organisms (namely mammals) to reproduce themselves, exposure to a microbiologically active environment and the possibility of the worms utilising viruscidal enzymes as part of the digestion process (Lotzof 1999) or simply by direct digestion.

CASE STUDIES

1. Domestic Vermicomposting Toilets

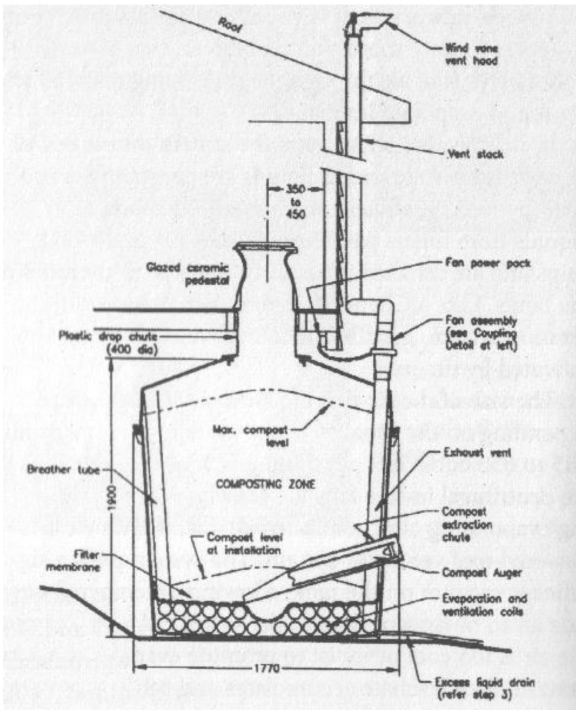

Figure 1: Elevation section view of the Dowmus vermicomposting toilet

The Dowmus vermicomposting toilet is an example of continuous system as opposed to the other main type which is the batch system. Dowmus rely on worms to break down the organic matter put into them. The system is aerobic, completely smell free, and uses no chemicals. Dowmus' dry (non-flush) system requires minimal maintenance. The system consists of a circular composting chamber, which is of a size suitable for a family of five. At the time of installation, compost and soil organisms including red worms and tiger worms are added to the system. The worms are the vital component in this system. Since it only reaches temperatures of 35 degrees, there are no active thermophilic organisms present. Other types of Organic Matter can be put into the system. A family of five can use the Dowmus for a few years before the compost needs to be removed from the chamber.

The ventilation pipe and fan work from the bottom of the tank, dragging air through the compost, keeping it aerated and smell free. The fan requires low energy, and can be solar powered. The non-flush unit consists of a ceramic pedestal with a wooden seat and lid. Food, paper, cardboard, vacuum dust and tampons can all be put into the system, which is not harmed by bleaches and detergents, via the pedestal which sits directly over the chamber. *However*, plastic bags, disposable nappies, plastic coated boxes and garden refuse should not be added.

2. Domestic Vermifiltration Systems

The Dowmus vermicomposting toilet system can be upgraded to receive wastewaters - both blackwater and greywater (Cameron, 1994). In Canberra, ACT about 12 households have had trial systems installed for monitoring by Australian Capital Territory Electricity and Water (ACTEW). Blackwater from the toilet enters a wet composting Dowmus tank and from there effluent goes to a second tank where greywater is also received. In this tank effluents are aerated around submerged volcanic rock media to achieve secondary standard treated effluent. From there the effluent goes to an irrigation storage tank in which chlorination occurs. The final effluent is mixed with rainwater to achieve further dilution and to improve the quality of water. Dowmus has been authorised to install five systems in WA for trial. A unit has been established at Murdoch University in the Environmental Technology Centre's permaculture system. The effluent from the unit is pumped to a series of constructed wetlands for further treatment prior to subsurface irrigation onto an orchard or percolation through the sandy soil back to groundwater.

A new modified design, involving 3 filter layers instead of the older single layer, was developed for an inner-city house in Sydney retrofitted on total sustainability principles (Mobbs, 1998) and is illustrated in Figure 2.

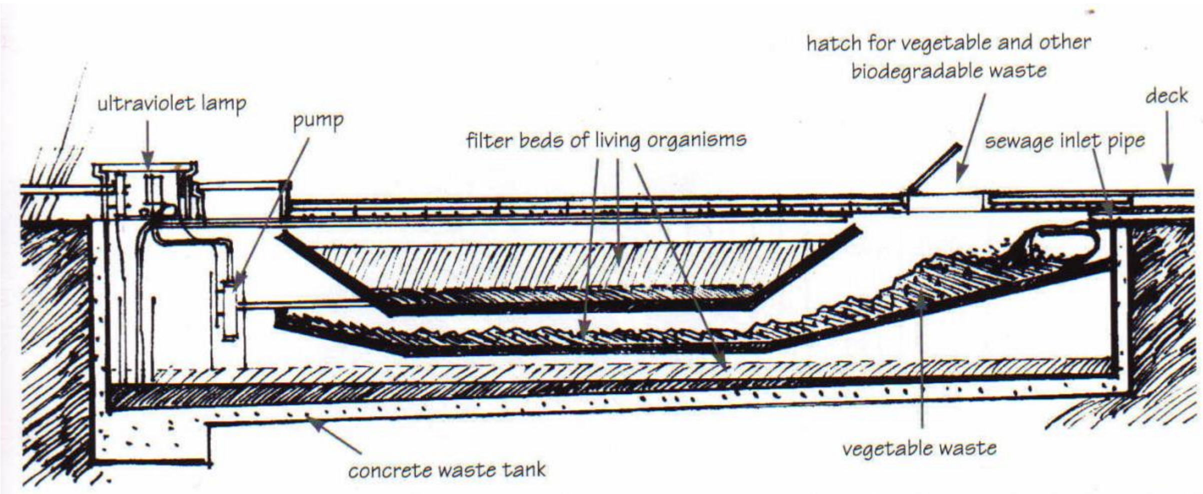

Figure 2: Elevation section view of the improved Dowmus vermifiltration unit.

3. Municipal Vermicomposting sludge treatment

Vermitech (Lotzof, 1999b) has, through the development of proprietary equipment and processes, created a system that can consistently and cost effectively, stabilise a large range of organic wastes including sewage sludge.

The critical elements of very large scale vermiculture are:

- the preparation of the sludge prior to feeding to the worms;
- the controlled application of the feed to the worm beds;
- The raised cage bed structures;
- the environmental control systems for managing moisture, temperature and wind;
- worm biomass management;
- harvesting of the vermicast;
- post processing of the vermicast for sale;
- leachate control;
- sampling and analysis systems for sludge and vermicast;
- information management systems.

Sludge from a broad spectrum of sewage and water treatment plants is being stabilised and the end product sold. Dewatered sludge is taken directly from the treatment plant and fed to the worms without the need for any pre composting or aging. Systems have been installed on a number of sites, the largest being a 400m^3/week capacity facility at Redland in Brisbane Queensland. Testing has established that the vermicast meets the Grade A Stabilisation Standards. Contamination levels while dependent on input contaminants, are managed so that only Grade A or B level vermicast will be marketed. Contamination levels are controlled by analysing incoming sludges and blending in "clean" organic material to the feed mix to reduce the ultimate level. Extensive trials have established a very large market for vermicast. Grower results across a large range of crops, indicates a very large, sustainable market with pricing exceeding $A250/m^3.

The installed system consists of a central worm farm on the Cleveland STP. The collection from each of the five treatment plants is by well proven covered hook lift mounted sludge bins. The worm farm is divided into two areas, the worm bed/waste receival area and the vermicast storage/ post processing area. The worm beds occupy an area of 100m x 80m. The surface is bitumen sealed and drains to a leachate dam with first flush control. The beds are galvanised steel frame with the waste and worm biomass contained within a raised mesh cage. The 14 beds are each 3.6m wide and 70 m long. The beds are modular and can be configured to any length. At Redland, the total available surface area for feeding exceeds 3,000m2 giving a capacity of 400m3/week. The additional 150m3/week capacity was put in place to enable the worm farm to process stockpiled sludge and to take other regional wastes.

The raised cage system is a continuous flow process. Waste is fed to the surface. The worms progressively stabilise the material. The fully stabilised material is harvested from the base. The design maximises the retention of the worm biomass, eliminating the need to separate the worms from the vermicast. It also optimises the environment to promote the development of beneficial bacteria and fungi.

The waste from the five sites is received into a bunded mixing area. Prior to the commencement of operations, sludge was collected from each of the five plants and fed to the worms over a six week period to determine the correct blending to ensure maximum attractiveness of the sludge to the worms. Each waste has its own blend requirement. The objective of blending is to deodorise and aerate the waste and adjust the Carbon/Nitrogen balance, the pH and salinity. A range of mineral, organic and bacterial additives may be mixed depending on the nature of the waste material and the state of the worm beds. The formulae are proprietary. The mixing has made all sludges worm accessible, even some "specially aged" material prepared for an odour/eatability trial. The standard practice of collection, blending and feeding on the same day minimises the potential for any odour build up.

CONCLUSIONS

Domestic dry vermicomposting toilets can be used in National Parks (campsites), isolated roadhouses, farmhouses, and on peri-urban or semi-rural blocks under current legislation in Australia. Their use is ideal in places where disposal of effluent is difficult due to low soil infiltration, lack of availability of land, limited water resources, or in ecologically-sensitive areas. A greywater recycling system may still be needed where wet facilities are required. The mature vermicompost product is free of pathogens, ideal for the garden and results in a cycling of the nutrients. The domestic vermifiltration system can replace septic tank systems. This system avoids the need for periodic pumping of sludge as well as the need for two separate systems. Again vermicompost is produced for the garden and the treated effluent can be recycled on the garden by subsurface irrigation. Any system that requires disposal of effluent from septic tanks can use the vermifiltration method. Both dry and wet systems can receive the domestic organic wastes (food scraps, paper, cardboard, lawn clippings, chopped up garden prunings). The Vermitech sludge stabilisation process uses the same vermicomposting principles and can process successfully sewage sludge from municipal sewerage facilities as well as a range of other organic wastes.

REFERENCES

Beder, S. (1993). Pipelines and Paradigms: The development of sewerage engineering, *Australian Civil Engineering Transactions*, CE35, (1), 79 - 85.

Cameron, D (1994), Compost Filtration: A new approach to on-site resource management, in Mathew K & Ho G (eds), *Workshop on Localised Treatment and Recycling of Domestic Wastewater*, RADG, Murdoch University.

Ted Gardner, Phillip Geary & Ian Gordon (1997), *Ecological Sustainability and On-Site Effluent Treatment Systems*, Aust J Env Management, Vol 4, September, pp144-156.

Goodland R & Rockefeller A (1996), *What is Environmental Sustainability in Sanitation?*, Insight, UNEP-IETC Newsletter, Summer.

Jeppeson, B. (1996). *Model Guidelines for Domestic Greywater Reuse for Australia*, Research Report # 107, Urban Water Research Association of Australia, Melbourne.

Kourik, R. (1995). Graywater for Residential Irrigation, *Landscape Architecture*, 85 (1), 30-33.

Lotzof, M (1999). *Very Large Scale Vermiculture in Sludge Stabilisation. Proceedings from the 13th WWM National Conference on Waste Management*.

Lotzof M (1999b), www.eidn.com.au/technicalpapervermiculture.htm and www.vermitech.com/

Lotzof M (1999c), *The Wonder of Worms for Sludge Stabilisation*, Water, January/February, pp38-42, Australian Water & Wastewater Association, Sydney.

Ludwig A (1994), *Create an Oasis with Greywater*, Oasis Design, Santa Barbara.

Ludwig A (1995), *Building Professional's Greywater Guide*, Oasis Design, Santa Barbara.

Mathew K & Ho G (1993), *Reuse of Wastewater at Jigalong Aboriginal Community*, RADG, Murdoch University.

McGrath D, Ho G & Mathew K (1990), *On-site Wastewater Disposal in Clay Soils - The Use of*

McQuire S (1995), *Not Just Down the Drain: A guide to reusing and treating your household water*, Friends of the Earth, Melbourne.

Mobbs M (1998), *Sustainable House*, Choice Books, Sydney.

National Health & Medical Research Council (1996). *Draft Guidelines for Sewerage Systems - Use of Reclaimed Water*, National Water Quality Management Strategy, Melbourne.

New South Wales Recycled Water Coordination Committee (1993). *New South Wales Guidelines for Urban and Residential Use of Reclaimed Water*, Public Works Department, Sydney.

Newman, P. W. G. and Mouritz, M. (1996). Principles and Planning Opportunities for Community Scale Systems of Water and Waste Management, *Desalination*, 106, 339 - 354.

Niemczynowicz, J. (1993). Water Management and Ecotechnology - towards 2020, *Workshop on Sustainable Urban Water Systems and Ecotechnology*, November 18, ISTP/RADG, Murdoch University, Perth.

Race Discrimination Commissioner (1994), *Water - A report on the provision of water and sanitation in remote Aboriginal & Torres Strait Islander Communities*, HREOC, AGPS, Canberra.

Scarborough J (1999), *Biogreen Castings - Scientifically Assessing the Merits of Vermicomposting Biosolids and Green waste Mixes*, Proceedings of Enviro 2000: Towards Sustainability, Waste Management Association of Australia, 9-13 April 2000, Sydney.

Standards Australia (1994), *Disposal systems for effluent from domestic premises*, AS 1547 - 1994, Standards Australia, Homebush, NSW.

Standards Australia/Standards NZ (2000). *On-site Domestic Wastewater Management*, AS/NZS 1547-2000, Homebush/Well.