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On-site Wastewater Reuse Technology Options in Australia

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ABSTRACT

Domestic wastewater reuse is currently not permitted anywhere in Australia but is widely supported by the community, promoted by researchers, and improvised by up to 20% of householders. Its widespread implementation will make an enormous contribution to the sustainability of water resources. Integrated with other strategies in the outdoor living environment of settlements in arid lands great benefit will be derived. This paper describes six options for wastewater reuse under research by the Remote Area Developments Group (RADG) at Murdoch University and case studies are given where productive use is being made for revegetation and food production strategies at household and community scales. Pollution control techniques, public health precautions and maintenance requirements are described. The special case of remote Aboriginal communities is explained where prototype systems have been installed by RADG to generate windbreaks and orchards. New Australian design standards and draft guidelines for domestic greywater reuse produced by the Western Australian state government agencies for mainstream communities are evaluated. It is recommended that dry composting toilets be coupled with domestic greywater reuse and the various types available in Australia are described. For situations where only the flushing toilet will suffice the unique "wet composting" system can be used and this also is described. A vision for household and community-scale on-site application is presented.

Keywords - wastewater reuse, composting toilets, revegetation, food production, remote communities, dry lands.

INTRODUCTION

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 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 then also sought separation at source with reuse of dry and liquid products for agriculture although with much less scientific basis than what is 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.

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 seweraged 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 seweraged 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 (pit or composting) systems utilised. Greywater reuse can result in cost savings (to both the consumer and state water authority), reduced sewage flows in seweraged areas and potable water savings of more than 40% when combined with sensible garden design.

Significant impact on water and energy use might require greywater reuse to be coincidental with water-sensitive urban design, reduced lawn area, and possibly the growing of food at home and in public open space. There is immense community support for reuse of wastewaters (WAWA, 1994). This paper will review regulatory developments, describe six methods under research by the Remote Area Developments Group (RADG), present options for the three broad soil types in which trials are currently occurring and for remote Aboriginal communities, and explain the broader design approach that needs to be applied with greywater reuse.

CURRENT REGULATION

Domestic greywater reuse, governed by state and local government health acts, is currently not allowed in any of the Australian states although WA state authorities acknowledged that 20% of householders engaged in this practice in Perth (Lugg, 1994; Stone, 1996). In Queensland three options were developed for possible implementation (Department of Primary Industries, 1996). The model guidelines for domestic greywater reuse in Australia (Jeppeson, 1996) covered hand basin toilets, primary greywater systems (direct subsurface application) and secondary greywater systems (mesh, membrane or sand filtration prior to irrigation). For primary systems the guidelines have adopted the California approach requiring the use of a surge tank with a screen to remove lint and hair. Electrical power is therefore required for the automatic pump system and weekly inspection and clearing of the screen. The need for maintenance to these components by the householder resulted in some 80% of Californiasystems being in an unsatisfactory condition. The recommendation of this approach as the solution for Australia is questionable. The updated standard AS1547-1994 guiding domestic effluent management (Standards Aust./NZ, 1996) is significantly more progressive in providing design criteria for a range of treatment systems with reuse and opening the way for further innovation.

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.

In 1996 the WA Government released its Draft Guidelines for Domestic Greywater Reuse (HDWA, 1996) which allow the public to install greywater reuse systems in three shires as a means of conducting trials for 12 months (Fimmel, 1997). The three shires provided different soil types which would no doubt call for different design responses to pollution control and absorption: Bassendean (sands and coarse sandy clay); Kalamunda (shallow soil over rock in hills plus alluvial clay soils lower down on plain); and Kalgoorlie-Boulder (fine silty clay soils). Moreover many dwellings in these areas were unsewered. Funding would not be provided for the trials and the systems proposed would need to gain approval from the WA Health Department prior to installation. With the shire Environmental Health Officers as the public's first point of contact in seeking information and approvals they would need to receive comprehensive training.

The Western Australian State Government agencies, quite rightly, wants to move ahead and respond to the massive public interest in greywater reuse while at the same time exercising caution after the early Californian experience. The three shire trial will provide broad experience if a range of systems are allowed. The monitoring of these will provide invaluable information: Which systems are most appropriate for each of the conditons? How effective are the local government authorities in providing support and direction? How diligent are householders in maintaining these systems? What are the economic benefits? How effectively are greywater systems integrated into the landscape in relation to productivity and nearby recreation? What are the longer term effects on soil and plants? What is the nutrient balance between inputs, plant uptake, and percolation into the soil?

Experience does need to be gained for local conditons 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). The design criteria provided in Standards Australia (1994) reflect the disposal paradigm while its revised version prepared with New Zealand authorities released as a draft only in 1996 allows for significant innovation.

SYSTEM CHARACTERISTICS

A greywater reuse system needs to protect public health, protect the environment, meet community aspirations and be cost-effective. Current on-site treatment systems have generally adopted the technology of the conventional activated sludge plant for large treatment systems. If removal of nutrients is required for installation of on-site units in nutrient-sensitive catchments, phosphorus (P) can be removed by alum dosing and nitrogen (N) by nitrification and denitrification in separate chambers or by intermittent aeration of a modified activated sludge set-up.

If the effluent is used for irrigation of garden plants there is the question as to why N and P should be removed. There may be an imbalance between plant requirement for the nutrients and the seasons, with a higher requirement in the warmer months than the colder months. Rather than removing the nutrients an alternative is to store the nutrients in the soil. Soils containing clay have the capacity to sorb ammonium and phosphate present in secondary effluent. Sandy soils can be amended with clay, loam or if convenient the 'red mud', bauxite-refining residue. The most progressive application of domestic greywater reuse appears to be in California. But even here the minimum prescribed depth of 430 mm for subsurface irrigation "ignore(s) the importance of aerobic bacteria and biota (found in profusion in the top few inches of garden soil) for digesting organic matter, nutrients and possible pathogens found in graywater" (Kourik, 1995).

SIX OPTIONS CURRENTLY UNDER RESEARCH FOR WESTERN AUSTRALIA

Amended Soil Filter

Fremantle Inner City Agriculture (FINCA) developed an 800 square metre community garden and is using the greywater from two adjacent houses to irrigate it. This is part of a water-sensitive, permaculture design approach which also involves harvesting rainwater from the two houses' roofs, heavy mulching and appropriate, low water use species selection for growing food in a perennial polyculture. Design and sizing of the system was generally in accordance with AS1547-1994 but performance monitoring and resident behaviour to date indicates the system is over-sized.

Greywater from the two houses enters a collection tank in the park by gravity. The duty field is a variation of the 'Ecomax' principle (Bowman, 1996) comprising two laterals of 20 m x 1.2 m and 25 m x 1.2 m wide. The plastic lined trenches are filled with a mix of 85% red sand and 15% red mud (with 5% gypsum in the latter to neutralise its alkalinity). The red mud and sand are by-products of bauxite refining to alumina. P is adsorbed into this clay material and N is removed from the system by intermittent drying and wetting causing nitrification-denitrification. Pathogens are filtered and die off. The field is heavily vegetated causing significant nutrient uptake and transpiration. Soil analyses to date indicate there is capacity for heavier liquid and nutrient loading and sludge build-up in the tank is negligible, i.e. application of AS1547-1994 design criteria resulted in over-sizing to the detriment of plant growth.

Sand Filtration

The Envirotech system consists of a receival tank where settling of solids occurs, and a second chamber into which the effluent flows. When this is full effluent is pumped to the top of a deep-bed plastic-lined sand filter. Effluent filters to the bottom of this device under gravity and flows back to a third chamber of the tank, from where the treated effluent is pumped to the irrigation field. General practice is to chlorinate in this final chamber, although it may not be necessary for subsurface irrigation. Systems are being installed in NSW and Indonesia. A system based on Envirotech sand filtration for greywater reuse is now designed and awaiting installation by RADG at a WA site with Health Department approval.

Wet Composting

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) (Anon, 1996). 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. One will be established at Murdoch University in the Environmental Technology Centre's permaculture system.

Constructed Wetlands

Mars (1996) is conducting a comparative trial on the effectiveness of the submergent aquatic plant *Triglochin huegii* and the emergent sedge *Schoenoplectus validus* in constructed wetlands for greywater treatment. Each of these species are reported to have a high ("luxury") nutrient uptake capacity. The former species is used in a surface flow wetland and the latter in a subsurface flow wetland. The aim is not only to verify treatment capability, but to use these local native species in a sustainable polyculture arrangement to produce food, thatching material, fodder and paper-making feedstock. Results to date are being published separately.

Modified Aerobic Treatment Unit

In Cottesloe, Western Australia, also a sewerred suburb, a greywater reuse system that utilised the Biomax aerobic treatment unit was approved and installed in May 1996. Additional baffles have been installed in the anaerobic and aerobic chambers to enable more effective treatment of the lower biomass effluent input (c.f. combined blackwater and greywater). Effluent is irrigated to the front and back yards via 'Dripmaster' subsurface tubing. Monitoring is currently underway to evaluate the performance with the reduced biomass as a result of greywater influent only. Results to date appear to indicate that there is often not a significant reduction in BOD, SS and nutrient levels across the unit. There has been a similar experience with other aerobic treatment units. Research is being conducted to determine what improvements to the system design will be necessary.

Evapotranspiration Systems

Evapotranspiration (ET) systems can be used in those areas where soil is comprised of more silts and clays and absorption fields have failed. These systems cost considerably less and require less maintenance than reticulated systems with lagoons (McGrath *et al.*, 1991). Effluent disposal in the ET trench occurs primarily by soil evaporation and plant transpiration rather than soil percolation - as occurs in conventional leach drains. The trench essentially comprises a layer of gravel for distribution of effluent below a layer of river sand through which capillary action to the surface occurred and in which plants grew.

ET systems receiving all domestic wastewater were installed in Aboriginal communities with community participation at Kwarra (McGrath, Ho & Mathew, 1991), Kalgoorlie, Irrungadji (McGrath, 1992), Halls Creek and Parnngurr School in the Western Desert. Systems in use in the clay soil shires of Perth including Kalamunda, were often inverted to some extent relying largely on evapotranspiration. The RADG ET system was developed to also improve the performance of these (McGrath, Ho & Mathew, 1990). Systems taking greywater only (alongside composting toilets) were installed at Tjuntjuntjarra in mid-1997 with a design intent of supporting native revegetation and orchards. In each case no problems were reported and in some, e.g. Halls Creek, vegetation planted on the fields is flourishing. Most importantly, no cases of ponding have been reported - one of the main reasons for developing this technology. It would be desirable, however, to conduct monitoring of performance over a longer period on these systems. They had generally been installed to the same size as leach drains to gain approval. Comparative monitoring with conventional leach drains would quantify the reduced size possible as a result of the better performance of ET systems and thereby reduce costs and improve irrigation of plants.

Ross Mars' system in the Perth hills suburb of Hovea referred to in Appendix 1 of HDWA (1996) is an 'absorption trench' that conforms with AS1547 and relies largely on evapotranspiration and to a lesser extent on absorption in the clay soil. The sand cover over the whole field of 7m x 7m interconnected piped trenches at 1500 centres is heavily vegetated with the high water demand plants sugar cane, banana, banna grass, canna lilly and vetiver grass. The system has performed satisfactorily without ponding since it was installed in 1994.

PROPOSED SYSTEMS FOR EACH SOIL TYPE

For cost-effectiveness and to most readily enable effluent reuse the following systems are recommended with respect to soil types:

Sand: *modified aerobic treatment units; amended soil filters; sand filters; constructed wetlands* (avoidance of groundwater pollution).

Clay: *evapotranspiration trenches* (avoidance of ponding)

Rocky slopes: *inverted evapotranspiration systems, sand filters* (avoidance of run-off)

The key problem to be overcome in each case is indicated in brackets. Wet or dry composting toilets can be used in conjunction with any of the above.

REMOTE ABORIGINAL COMMUNITIES

There are unique design considerations in the remote Aboriginal community setting. Unlike many of the large urban areas of Australia remote Aboriginal communities in arid lands do not have a diverse range of water sources. Typically there are groundwater sources whose sustainability in the face of growing populations is uncertain. At Coonana, for example, water shortages have been extreme (Race Discrimination Commissioner, 1994). However, there is poor public health in some communities and any reuse proposal needs to take serious consideration of this factor. Nevertheless, wastewater reuse can lead to improved public health. Separation of greywater and blackwater enables decreased loading on treatment systems and therefore results in greater reliability and performance. Dust control is accepted as necessary to alleviate disease, e.g. trachoma, which can be achieved through revegetation. Irrigation systems to establish trees use valuable potable water, are expensive and maintenance intensive. Greywater reuse evapotranspiration systems can be designed for low-cost, durability and low maintenance with sub-surface, gravity-feed, PVC piping.

Wastewater disposal systems often account for a major maintenance cost in remote Aboriginal housing and this is often because of poor initial construction by non-Aboriginal contractors (Pholeros, Rainow & Torzillo, 1993). A holistic response for on-site systems is necessary including separation of blackwater and greywater, use of evapotranspiration instead of absorption, interconnection of houses and systems to spread peak loads, back-up pit toilets to each house to cater for system failure, overcrowding and solids reduction, productive use of treated effluent, strict supervision of below-ground construction works, and effective management and maintenance.

In WA evapotranspiration systems are now fairly common in remote communities with tight soils since RADG commenced their implementation (McGrath, Ho & Mathew, 1991). Composting toilets have been installed at Wilson's Patch in the Goldfields and by Winun Ngari Resource Agency in the West Kimberley. Greywater reuse was recommended for Tjalku Wara in the Pilbara (Swanson, 1996) and a design using evapotranspiration was prepared by a regional permaculture practitioner. A trial greywater reuse system relying on evapotranspiration was approved for Frog Hollow in the East Kimberley (Kinnaird, 1997). However, the tendency has been to install deep sewerage to lagoons when funds become available rather than attempt to implement all of the above principles for a holistic response simultaneously. On-site and community-scale systems using one or more of the above six options need to be established in remote communities for research into their appropriateness and not just their technical suitability. In most cases, however, evapotranspiration systems will be appropriate and these can be adapted for simpler greywater reuse in parallel with blackwater septic systems or dry vault toilets.

Studies were completed for wastewater reuse from lagoons at Warralong and Jigalong in the Pilbara (Mathew & Ho, 1993). There was insufficient wastewater produced for irrigation of a football oval. Groundwater recharge was an option. The most suitable options were revegetation, orchards and vegetable gardens by subsurface or drip irrigation. If surface irrigation was proposed some form of disinfection to eliminate pathogens and enclosed storage to eliminate algae would be necessary. Reuse direct from lagoons could be subsurface from the overflow after the last lagoon or pumped from the lagoon to storage for later irrigation.

HOLISTIC DESIGN

Many concerns have been raised in relation to widespread implementation of greywater reuse without proper management or maintenance: reduced sewer flows, higher concentrations at treatment plants, public health risks, groundwater contamination, mosquito breeding in constructed wetlands, flooding during winter rainfall, sludge build-up and blockages. However, there is another issue for concern that may lead to some of these problems and others indirectly: poor design (or no design). Not just the design of the system itself but the manner by which the

system is integrated into the landscape. Australian standards such as AS 1547 do, for example, specify minimum setbacks from houses and lot boundaries, provide ways of avoiding inundation and give design criteria for terraced disposal fields on slopes.

There are very few practical design methodologies that may serve the case of placement of a greywater recycling system in the house yard or community landscape. Two examples are:

- * *hydroscaping* (Colwill, 1996) for sustainable garden aesthetic design; and
- * *permaculture* (Mollison, 1988) for sustainable food production system design.

Hydrozoning will allow the placement of the greywater system in accordance with a garden layout designed for aesthetics and plant groupings of similar water needs.

Permaculture draws on a wider range of design tools including *zoning* for energy efficiency and *sector analysis* of the natural elements affecting the site (sun, wind, fire, view). Zones 1 to 5 in permaculture refer to areas of planting types (intensive salad beds, low maintenance orchards, through to natural bushland) placed in relation to house or settlement according to frequency of visits. Design with sectors allows the appropriate placement of windbreaks, shadetrees, water tanks, zones and other elements in the landscape.

The use of a design approach prior to installation enables placement of the greywater system in a landscape with respect to the vegetation type that it will support and its position in relation to other elements and natural influences on the site. If such considerations are ignored with a focus merely on the technical design of the system itself then improper management and maintenance and poor performance may still be the longer term outcome.

CONCLUSIONS

For the urban village, small country towns, or group housing a greywater reuse system utilising secondary treatment and disinfection maintained by a supplier may be most appropriate. For on-site greywater recycling at individual houses in a low-density settlement or remote community a primary system with large diameter subsurface irrigation 300 mm below the surface is appropriate using evapotranspiration in soils of low permeability. Filters, pumps and treatment units should be avoided as these may not be adequately maintained by the owner/occupier. Reuse from lagoons is commonly practiced in WA country towns. If nutrient removal is necessary a treatment system such as Aquarius or Ecomax with sufficient vegetation to utilise the nutrient is ideal. Data-gathering on the long term effects of greywater on plants and soils and their nutrient uptake capacity is necessary. Field trials are necessary to optimise the irrigation fields for plant growth, particularly in the case of food species. Evapotranspiration systems, for example, have typically been designed too deep in the past for this purpose. A standard code of practice on greywater reuse should be adopted. If managed correctly wastewater reuse in remote Aboriginal communities can not only result in water savings but also improved public health through dust suppression from revegetation, improved nutrition from locally grown food, and less system failures from decreased loading on treatment systems.

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