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Greywater Reuse: Some Options for Western Australia

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[Submitted Paper]

Introduction

Perth, like many Australian cities, is characterised by a Central Business District of concrete and glass towers surrounded by an ever-expanding suburban sprawl which swallows up bushland and agricultural land. This is a low density, automobile city possibly less car dependent than cities of the United States but more so than European cities (which are well endowed with public transport systems) and the low-energy Asian cities (where walking and cycling are often the norm) (Newman & Kenworthy, 1992). Australian cities are typically located on the coast, where soils are generally more fertile and rainfall more plentiful, and near mouths of major rivers for sheltered ports. Perth lies on the coastline of the Indian Ocean and at the mouth of the Swan River. This pattern of urban development has given rise to centralised wastewater treatment facilities which discharge their effluent through ocean outfalls. Marine ecology was not endangered under current pollution load but an ongoing monitoring program was called for to detect changes that may arise from the anticipated 5% per annum increase in disposal volume (Water Authority of Western Australia (WAWA), 1995). Certainly, this form of disposal represents a significant resource loss and is a major concern to the Western Australian community.

The centralised, large scale approach to water supply, sewerage and stormwater disposal has been described as “big pipes in and big pipes out” engineering from the last century (Newman, 1993) – up to 85% of costs are incurred from piping. This paradigm is inappropriate in the modern world and it may take a major catastrophe to convince the engineering community of this (Beder, 1993). Moreover, it is inappropriate to transfer this expensive, wasteful paradigm to developing countries (Niemczowicz, 1993).

This big pipe/centralised treatment/ocean outfall approach continues with the low-density suburban expansion around modern, industrial cities requiring massive capital works, operation, maintenance and depreciation costs. Some 25% of the Perth metropolitan area was unsewered in 1994 when the State Government commenced an \$800 million sewerage reticulation of these residential properties to treatment plants. Formerly, these households used septic tanks and leach drains

which deposited a considerable amount of nutrients into the groundwater and it was to prevent this and to safeguard public health that the huge expenditure on deep sewerage was justified. The fact that lawns leach a higher nutrient loading through application of fertilisers (Gerritse, 1993) went unquestioned. Many Australian cities, particularly Perth and Adelaide are in semi-arid climates yet there is a cultural tendency towards large areas of lush, green lawns around bungalow-style housing. Lawns are often over-watered and over-fertilised. Lawns consume some 40% of Perth's high quality water supply (WAWA, 1993).

While the fringes of urban Australia continue to push outwards with their associated resource-intensive water, transport and energy systems it is now understood that alternative models for development will be more sustainable. Minimum lot size has been the guiding principle to differentiate between the application of reticulated sewerage and on-site wastewater disposal systems. In Western Australia, the Department for Environmental Protection, generally specifies 2,000 square metres as a minimum lot size for on-site systems in unsewered areas (Middle, 1994). However, studies by Joliffe (1994) have shown that the performance of on-site effluent disposal systems is extremely variable with performance strongly associated with the level of maintenance applied to septic systems as well as to site characteristics such as soil permeability and slope. Joliffe proposed an alternative approach to the application of arbitrary minimum lot size. His six point strategy relies on an alternative planning approach which results in more efficient use of land through cluster housing in rural areas and this could also apply to urban renewal. Peter Cuming's new planning approach for rural settlements with cluster housing also provides a more effective pollution control framework in environmentally-sensitive areas (Sustainable Futures Planning & Design, 1995). These new planning approaches, of course, fit closely with permaculture principles.

The transformation of Australian cities to transit-oriented urban villages will lend itself to community scale, water-based, localised, sewerage systems such as Australian aerobic treatment units, eg. Aquarius, Biomax, Clearwater (for an evaluation of these and other new Australian systems see Gidiuli, Mathew & Ho, 1992). However, the transition period may be many decades and the existing, large treatment plants will have the capacity to serve a number of surrounding villages. Once population size begins to overload these plants sewer mining can divert excess to the new, smaller, village plants so that existing pipe infrastructure can be used until the end of its useful life. At each village the treated wastewater will be reused on community gardens, parks, ovals and green corridors between villages. Treated wastewater can also be returned to individual homes by separate reticulation and used in gardens. These approaches will be preferred by the regulatory authorities as they are able to retain more control.

Following similar practice with industrial wastewaters, the low volume, high strength effluent (blackwater in the domestic case) and the high volume, low strength effluent (greywater) are separated and the most cost-effective technology used for each. Thus, the optimum, low-energy, sustainable approach would be dry/composting toilets and greywater reuse. On-site greywater reuse in low-density housing areas will reduce the rate of flow increase to centralised plants in the transition period and the accelerating pace of water consumption. Low-density housing

areas will be around for decades to come even if new, conventional subdivisions stopped now.

To have a significant impact on water and energy use greywater reuse needs to be coincidental with water-sensitive garden design, reduced lawn areas and growing food at home and in public open space. Greywater reuse can result in cost savings (to both the consumer and state water authority), reduced sewage flows and potable water savings of up to 38% when combined with sensible garden design (WAWA, 1993). The Wastewater 2040 community consultation process carried out by the Water Authority of WA with the CSIRO showed that there was immense community support for reuse of wastewaters.

There will, no doubt, be social factors that prevent the widespread use of composting toilets in the near future. Hand basin flush toilets, where only water-based systems will be accepted, can result in water savings of 19% (WAWA, 1993). The blackwater could then enter a smaller diameter sewer to maintain flow velocities or the same sewer retained with increasing population densities.

Designs for greywater reuse need to be developed that do not cause environmental contamination or present a public health hazard. The purpose of this paper is to briefly review current research and development around Australia that is leading to acceptable designs while focussing on some particular case studies in Western Australia. Most detail is provided on five particular methods being trialed by the Institute for Environmental Science at Murdoch University. The trials are occurring both at the Institute's 1.7-hectare Environmental Technology Centre (a fully integrated permaculture development) and at various residences of permaculture practitioners. A scenario for the future is presented where greywater reuse is not only permitted but in many situations is compulsory.

Current regulation

Domestic greywater reuse, governed by state and local government health acts, is currently not allowed in any of the Australian states although it is acknowledged by the state authorities that 20% of householders engage in this practice in Perth (Lugg, 1994; Stone, 1994). Treated effluent from centralised plants of some country towns located in arid areas is used on municipal ovals and golf courses. More recently, in the state of New South Wales, treated effluent from centralised plants has been allowed in urban areas (New South Wales Recycled Water Coordination Committee, 1993).

In Queensland three options have been developed for possible implementation (Department of Primary Industries, 1996). These were 1) allowing greywater reuse to be continued in unsewered areas with additional monitoring by Local Government; 2) permitting and encouraging greywater reuse in both sewerred and unsewered areas; and 3) extend option 1 to incorporate active promotion of reclaimed water (treated wastewater) through dual reticulation. This was a policy options paper and no technological options were discussed, eg. how to provide for pollution control.

National guidelines for the use of reclaimed water via dual reticulation have been prepared (National Health & Medical Research Council, 1996). Of relevance to this

gathering are the criteria recommended for non-potable uses in urban residential areas, ie. garden watering, toilet flushing and car washing; agricultural food production; and aquaculture food production. The level of treatment recommended is secondary plus filtration and pathogen reduction. The filtration is required to further reduce suspended matter thereby making pathogen reduction via chlorination more effective. Pathogen reduction by disinfection (eg. chlorination) or detention (eg. lagoons) is required. It is possible that artificial wetlands can achieve all of the foregoing as a tertiary treatment method particularly if there are open water areas which will allow pathogenic die-off due to UV sterilisation.

Model guidelines for domestic greywater reuse in Australia have also been prepared (Jeppeson, 1996). These covered hand basin toilets, primary greywater systems (direct subsurface application) and secondary greywater systems (mesh, membrane or sand filtration). Procedures, criteria and components are specified for the design of individual systems.

For primary systems the guidelines have adopted the Californian approach of requiring the use of a surge tank with a screen to remove lint and hair. This is unfortunate in some ways as electrical power is therefore required for the automatic pump system and weekly inspection and clearing of the screen. The requirement for maintenance to these components by the householder resulted in some 80% of Californian systems being in an unsatisfactory condition. Several irrigation area layout designs are provided.

Secondary systems should be installed by licence only as is currently the case for all on-site disposal systems in WA including aerobic treatment units. As with the latter the owner is required to enter into a maintenance contract with the supplier. No pollution control methodologies are prescribed in either case.

System characteristics

A greywater reuse system needs to be able to receive the effluent from one or more households all year round. Where saturation of garden soils of low permeability occurs in winter rainfall, there should be facility to divert to sewer or alternative disposal. The system needs to protect public health, protect the environment, meet community aspirations and be cost-effective (Murphy, 1994).

Current on-site treatment systems have generally adopted the technology of the conventional activated sludge plant for large treatment systems. This is understandable, because the effluent standard for garden surface irrigation is a chlorinated effluent containing not more than 20/30 (BOD/SS). Differences that can be observed are the insertion of a trickling filter in the aeration chamber to cope with variable flows, and the infrequent removal of sludge. The anaerobic decomposition of sludge takes place in the first settling chamber.

If removal of nutrients are required for installation of on-site units in nutrient-sensitive catchments, P can be removed by alum dosing and N by nitrification and denitrification in separate chambers or by intermittent aeration of a modified activated sludge set-up. Hyperchlorination of ammonium in secondary effluent theoretically removes N by oxidation to nitrogen gas.

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 absorb ammonium and phosphate present in secondary effluent. Sandy soils can be amended with clay or if convenient the 'red mud', bauxite-refining residue.

Five different methods of greywater treatment and reuse under trial by the Institute for Environmental Science at Murdoch University are described below and compared with similar projects elsewhere in Australia. Each system can be on-site for individual households or can be scaled up for cluster housing. Each has some capacity for pollution control while being cost-effective. A greywater reuse system currently under trial by the Water Corporation in Geraldton, Western Australia satisfies the model guidelines and disposal standards but does not feature any pollution control strategies and will not be reviewed here.

Options currently under research for Western Australia

Amended soil filter

Fremantle Inner City Agriculture (FINCA) developed a community garden on the Fremantle City Council's 800 square metre King William Park on Marine Terrace in South Fremantle, Western Australia 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 Standards Australia (1994) to gain regulatory authority approvals.

Laundry and bathroom effluent from the two houses enters a collection tank in the park by gravity. The Health Department of Western Australia required the inclusion of this sullage tank prior to distribution. This was to prevent build-up of suspended solids or biological growths in the distribution system. However, the large diameter of the irrigation piping (90 mm) and outlet holes (25 mm) draining into an aggregate surround may have avoided this anyway. Particularly, with the irrigation close to the surface where there is aerobic, biological activity and the presence of earthworms is promoted. From the tank the effluent can be sent to either a duty or duty/standby field by gravity.

The duty field is modelled on the 'Ecomax' principle (Bowman, 1994) and its aim is to result in a tertiary quality effluent entering groundwater so as to avoid contamination by nutrients or pathogens. The plastic lined trench is 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. Phosphorus is adsorbed into this clay material and nitrogen is removed from the system by intermittent drying and wetting causing nitrification-denitrification. Pathogens are filtered and die off. The duty field comprises two laterals of 20 m x 1.2 m and 25 m x 1.2 m wide providing some 70 square metres. The field is heavily vegetated with herbs, flowers and vegetables which will have significant nutrient uptake and

transpiration. Thick mulch prevents any contact between greywater and foliage or vegetables.

The duty/standby field involves discharge of greywater into a heavily mulched and vegetated basin. It is expected that a considerable humus layer will form which will act as an aerobic buffer against nutrients and pathogens. The 40 m of HDPE, 90 mm diameter, perforated, flexible drainage pipe provided an irrigation area of 60 square metres.

Laboratory trials of greywater through soil columns with the red sand mix, humus and the Quindalup dune system sand from the site have been conducted to determine pollutant removal capacity. In the future soil samples from the site at various depths will be analysed.

Ross Mars has had an absorption trench design based on AS 1547 (Standards Australia, 1994) approved for his Hovea property. This design in effect relies on evapotranspiration. Discharge is into parallel pipes in a sand bed on the local clay substrate. It is assumed that nutrients will be absorbed in the clay substrate as well as being taken up by the growth banana, canna lillies, vetiver grass, sugar cane and other plants above. The system performance is currently being monitored.

Sand filtration

The Envirotech system consists of a receival tank where settling of solids occurs, a second chamber into which the effluent flows, when this is full effluent is pumped to the top of a deep bed sand filter, effluent is collected in the bottom and flows back to a third chamber of the tank, from here 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. A system based on the Envirotech sand filtration will be installed at a permaculture residence in White Gum Valley, Western Australia with a large plot size of some 1000 square metres.

Wet composting

The Downmus vermicomposting toilet system can be upgraded to receive wastewaters – both blackwater and greywater – and trials are currently underway. In Canberra, ACT, for example, about 12 households have had trial systems installed for monitoring by ACT Electricity and Water. With current population growth and water consumption patterns a new dam will be required and would cost in the order of \$1 billion. ACTEW have chosen to investigate the alternative, innovative path of water conservation measures.

The system utilises the Downmus tanks modified for wet operation. Blackwater from the toilet enters a wet composting Downmus 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.

A wet composting research project will be established in Perth relevant to local conditions and integrated into a permaculture design.

Constructed wetlands

Glenn Marshall (1995) has conducted research into an on-site system in NSW that successfully integrates greywater, excess liquid from a composting toilet, constructed wetland planted with *Phragmites australis* (common reed), holding pond, flowforms and sub-surface drip irrigation. Long term performance data may still be required.

Tubemakers Water Treatment have recently completed construction of a combined wastewater treatment plant and constructed wetland at Mundaring, Western Australia for the Water Corporation. Mundaring has been served by septic tank systems but is in the water catchment area. A system was deemed necessary that would avoid possible contamination and at the same time allow for safe reuse of the treated wastewater.

The hybrid intermittently decanted, extended aeration (IDEA) system consists of two aerated tanks in series (Turner, Heaton & Meney, 1996). Removal of nitrogen occurs by nitrification/denitrification through control of anoxic/aerobic conditions in the first demand aeration tank and in the second intermittently aerated tank. Chemical dosing with alum allows precipitation of phosphates. Ultraviolet sterilisation provides pathogen reduction. Sludge is periodically removed to drying beds.

The free water surface wetland had to be designed within the constraints of the tender specifications and the site. The selection of plant species was based on their local occurrence in the region and proven performance in wastewater wetlands. Emergent macrophyte zones comprised *Schoenoplectus validus* and *Baumea rubiginosa* and the submergent macrophyte zones comprised *Triglochin procera* and *Potamogeton pectinatus*. The dual planting design fostered aeration in the wetland and optimal nutrient uptake across seasonal variations.

The required effluent characteristics from the wetland are BOD 5, SS 5, total N 10, total P 1 and thermotolerant coliforms 15. This is a very stringent specification and Tubemakers are confident of achieving this from a monitoring program that in future will cover seasonal variations and increasing load. Effluent from the wetland will eventually be reused on parks and gardens in Mundaring if the Council funds the pipework connection. Currently, and in future in periods of low demand, effluent is discharged to a 4 kilometre evapotranspiration trench.

Not far from the Mundaring site in Hovea, permaculture educator Ross Mars is conducting experimentation on constructed wetlands for his PhD research with the Institute for Environmental Science. The focus of the research is on the performance of the submergent wetland plant *Triglochin huegii* compared against emergent *Schoenoplectus validus*. Ross' aim is not only to verify wastewater treatment capability but, in line with permaculture principles, to use these 'bush tucker' species in a polyculture arrangement.

Modified aerobic treatment unit

At the sewered suburb of Palmyra, Western Australia six aged-person, state housing units were chosen to be used for greywater reuse trial out of a larger urban residential redevelopment. Blackwater goes direct to sewer. All greywater from the

six units goes to a single 'Aquarius' aerobic treatment unit. After treatment the effluent is pumped to storage tanks located in the roof of each unit. The effluent is then gravity fed to toilet cisterns after disinfection, and excess is used for garden irrigation either subsurface into amended soil or through large droplet sprinklers. The system was commissioned in August, 1995 and a monitoring program commenced from startup.

Of all the on-site aerobic treatment systems the Aquarius unit is clever in its engineering design and claims to remove nutrients to below 1 mg/l. Aquarius has five chambers: (1) primary sedimentation and aerobic digestion; (2) anoxic chamber for denitrification and chemical phosphorus removal; (3) aerobic biological oxidation including nitrification in subsurface biofilter and denitrification in submerged filter; (4) secondary clarifier and sludge recycle to the anoxic chamber; (5) chlorination and storage for irrigation (Mathew & Ho, 1993). As the unit was treating greywater only the first chamber was eliminated in this application so that biomass could be maximised in the subsequent treatment process.

At 15 Hamersley Street, Cottesloe, Western Australia, also a sewered suburb, a Biomax greywater reuse system was approved by the Water Corporation and Health Department and commissioned by Durrant & Waite Pty Ltd in May this year. 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.

The Institute for Environmental Science will conduct research on the use of a modified Biomax aerobic treatment unit for greywater reuse. A unit will be installed at the Environmental Technology Centre to serve the bathroom/laundry of the new climate-sensible Visitor's Centre (seminar building).

Conclusions

Some general principles can be deduced from current research.

- For the urban village, medium density development or group of houses, a greywater system utilising secondary treatment maintained by the supplier may be most appropriate. Tertiary quality effluent can be achieved biologically where necessary through the use of constructed wetlands. Reuse of treated effluent for low-maintenance garden irrigation would be subsurface up to 300 mm deep and through in-tube emitters or a pressure/drip arrangement.
- For on-site reuse at individual houses in the low-density setting (sewered or not) a primary greywater system with direct discharge into a large-diameter, subsurface irrigation system within 300 – 400 mm from the surface is most appropriate. Tanks, filters and pumps should be avoided as experience shows that these may not be maintained adequately by the owner. A surge tank can be used if retrofitting or topography will not allow gravity flow and if irrigation over a wider area is required. If pollution control for nutrients is necessary a plastic-lined clay bed along the length of the piping can be used. Once phosphorus saturation occurs the clay can be used as a soil amender elsewhere and replaced with fresh material. Phosphorus can be taken up in plants

and harvested if vegetation is used on the field. A duty/standby field can be added in areas where winter saturation may occur. The field should be heavily vegetated and generally inaccessible. Seasonal biomass harvesting is recommended. Design should be region-specific taking into account soils, aquifers and waterways but perhaps standardised within some local government areas to ease administration.

- Flushing toilets, deep sewerage and wastewater treatment plants did not replace night soil collection for economic reasons but for public health. Similarly, greywater reuse technology may not be viable now in purely economic terms. Its introduction needs to be seen in terms of its contribution to sustainable development and resource conservation without compromising public health or environmental quality.

The commencement of research into the above methods of greywater reuse will aim to achieve regulatory approval for on-site systems in WA by gathering further supporting data on the following:

- Long term effects of greywater on plants and soils and their nutrient uptake capacity;
- Long term effects of greywater on disposal area requirements;
- Low cost primary systems.

More information can be obtained from the authors at:

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