HOUSEHOLD GREYWATER WETLANDS

Background

In the past couple of decades, there has been growing interest among governments and industries in utilizing the abilities of constructed wetlands for processing and eliminating many of the harmful waste products of municipal, and even industrial, wastestreams. The use of natural systems for treating waste is called bioremediation, or phytoremedation when plants are involved. Wetland biological communities, with their diverse communities of bacteria and hardy, fast-growing plants that are adapted to taking advantage of high nutrient loads, have proved to be especially capable of biodegrading nutrient-laden domestic sewage and even some toxic industrial effluents, and rendering them less harmful to neighboring ecosystems and human communities. Constructed wetlands have also proved effective at bioremediating urban stormwater runoff, cleaning up polluted river systems as well as treating the toxic runoff from mine tailings and coal piles. Doing an internet search on any search engine for the terms "phytoremediation wetland" will produce thousands of results.

If you have a pond or aquarium, you are probably already aware of the beneficial roles of bacteria and plants in aquatic environments. Although not as visibly active as fish or frogs, plants and bacteria are not inert, but have a powerful stabilizing influence on the complex chemical interactions that go on under the water's surface. Algae, humus, decaying leaves, living roots and other submerged plant structures have complex surfaces with enormously high surface areas. All of these submerged surfaces act as a substrate for the growth of *biofilms* - multispecies colonies of bacteria and other microorganisms. These biofilm communities have complexly linked trophic chains which are the primary engines for transforming complex waste products into simpler forms. One species of bacteria will typically specialize in metabolizing one type of compound, thereby breaking it down into simpler compounds which are in turn metabolized by other bacteria and so on - one bacteria's excretions becomes another's meal. For plants, many of these broken down waste products are vital nutrients, which the plants recycle into their own tissues. Plants also greatly assist in the natural process of volatilization, whereby compounds are removed from the water via the roots, travel up the plant, and enter the air. These symbiotic, self-reinforcing, inter-relationships greatly help to maintain the water quality and stability of aquatic plant and animal communities.

Within larger ecosystems, these wetland communities typically form in areas which are natural nutrient "sinks", or regions where the products of geological and biological decay (like dead leaves and sediment) accumulate, so perhaps it's hardly surprising that wetlands would also prove effective at treating sewage and other organic wastewaters. For wetlands, these wastestreams are not necessarily "toxic" so much as "nutrient rich" - laden with nitrogenous compounds, carbon dioxide, and dissolved minerals which, if given to plants in simple forms and proper concentrations, can serve as fertilizer.

There is a relatively new method of aquaculture called "aquaponics" or "bioponics" which combines the aquaculture of freshwater fish (like tilapia, trout, or eels) with hydroponic agriculture. While not typically based on wetland plants, bioponics typically uses edible vegetation (like basil or lettuce) for similar purposes. The water from the fish tanks, laden with nitrogen-rich fish waste, is pumped into hydroponic plant beds. Once broken down by communities of bacteria living on the plant roots, this nitrogen-rich waste provides nutrients for vegetable or herb crops which clean the water before being recirculated back to the tanks with the fish. Thereby a problematic waste product is not only eliminated but actually turned into a salable commodity. Additionally, by recycling the water, this system of aquaculture uses much less water and produces much less effluent than standard aquaculture (www.growingedge.com). John and Nancy Todd at Ocean Arks International in the US (www.oceanarks.org) design proprietary bioremediation systems for large-scale municipal domestic sewage treatment and food factory waste called "Living Machines" (tm), which are essentially greenhouses filled with tanks of specifically chosen communities of aquatic plants and animals. In these solar aquatic systems, raw sewage goes in and clean water comes out, with no sign of coliforms, suspended solids or other standard indicators of poor water quality. Here in Melbourne, Wetland Ecosystems (www.wetlandecosystems.com.au) is a company that designs and builds wetlands for phytoremediation of urban runoff using indigenous wetland plants. The nursury where their plants are propogated and grown uses nutrient-rich wastewater from the Eastern Sewage Treatment Plant at Callum. These are just a fraction of the businesses and organizations who are exploiting the amazing properties of wetlands.

Why Wetlands?

Wetland ecosystems are some of the most endangered biological communities the world over. Since most of our towns and cities are built along rivers, many, if not most of us, live on land that was formerly wetlands. This is certainly true of most prime agricultural land, as the extensive river floodplains that now produce most of our food used to be complex networks of creeks, swamps and billabongs. While most pre-agricultural cultures were at least partially dependent on wetlands for food and other resources, they are often viewed by high-density agricultural societies as useless, muddy, mosquito-filled wastes. However, we are now realizing that wetlands actually provide vital buffer zones and energy links between aquatic and terrestrial realms, filtering sediments and excess nutrients for plants and animals communities downstream, building wildlife habitat, and recycling and storing energy and nutrients. Without these wetland interfaces, a river's nutrient and sediment loads increase, water quality declines and the river becomes less productive. Often this damage even reaches far downstream to coastal systems. Fertilizers, metals, herbicides, pesticides and other toxins that are concentrated in the runoff from agriculture, roads, and gardens usually end up in the rivers and creeks and greatly compound the problem. However, resiscovering the valuable ecological role of these ecosystems is restoring our society's recognition of their aesthetic, ecological, and economic value which in turn helps to fund the restoration of former wetlands, the preservation of existing wetlands, and even the construction of new ones. Many Australian municipalities are starting to get the message about "nature's kidneys", and it's not too hard to find urban runoff treatment wetlands from central Melbourne to the new suburban developments and golf courses springing up on its outskirts. Luckily, wetlands are highly-productive, resilient and very amenable to restoration - if given half a chance, they bounce back rapidly and spectacularly.

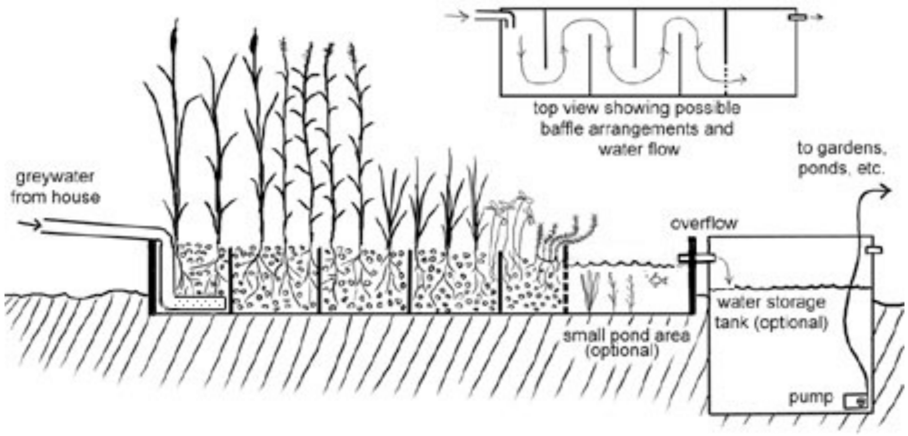
Constructed backyard wetlands can provide a highly effective, partial solution towards sustainable water use. Most wastewater that leaves a house is only slightly tainted with soaps and detergents, though it's all treated the same by sewage systems. The wastewater which goes down the drains of our showers, bathtubs, dishwashers, clotheswashers and most sinks is known as "greywater" (as opposed to the "blackwater" which goes down our toilets). The average Melbourne house consumes over 600 liters of water every day, of which several hundreds of litres leaves the house as greywater. However, once established, a relatively small artificial bog planted with indigenous wetland plants can easily break down and reduce the chemicals from large volumes of greywater, rendering the water clean enough for non-potable uses, like watering the garden. Many of the chemicals in greywater are fertilizers for the wetland plants, turning wastewater into a backyard resource, rather than contributing to pollution in Port Phillip Bay. After travelling through a constructed wetland, the water can be used for aquaria and ponds, watering the garden, or even flushing the toilet. Most people would be very surpised to learn that 1/3 of the drinking-quality water that enters their house is used to flush the toilet. And another 1/3 to 1/2 of the typical household's water is used to water the garden. The rest comes out mostly as greywater. There is little reason to use drinking quality water for watering the garden or flushing the toilet. By recycling the processed greywater for watering the garden, a household can reduce water use by about 1/3. Or more, due to increased water use awareness. Treating your own wastewater certainly tends to make you more aware of not only your household's total water use, but also of the various products that go down one's drain and what potential harm they might cause to downstream ecosystems. After all, you're more likely to select your detergent more carefully if you know its going to eventually wind up in your own downstream ecosystem - like your backyard frog pond. Luckily, wetlands do seem to be pretty robust and can even handle surprisingly dirty and detergent-laden laundry water without ill effects. In fact, if given in reasonable concentrations, there are few household products which would cause an established wetland harm.

Backyard wetlands also help solve one of the main problems of greywater use particular to Australian garden. As this continent's soils tend towards low nutrient concentrations, many Australian native plants are not adapted to dealing with rich soils, and have adverse reactions to overfertilization. This can be problematic for people with indigenous gardens who wish to water their plants with greywater, as buildup of nutrients might kill some of their plants before long. However, australian wetland plants, like nearly all wetland plants worldwide, are fast-growing and adapted to dealing with high nutrient soils and utilizing high concentrations of nutrients. This certainly means the water that leaves as wetland will be somewhat cleaner than the greywater that goes in, perhaps even clean enough for watering more sensitive native gardens.

How to Build One

It is relatively cheap and easy to build a constructed wetland. Even while becoming established, a properly designed greywater wetland will produce absolutely no bad odours or increase mosquito populations. If you live close to good pre-existing habitat, the wetland will likely become colonized by indigenous frogs and other fauna, providing much needed expansion of their populations into the suburban landscape. A wetland garden is really very easy to grow, even for somebody without a green thumb. And very rewarding, as most wetland plants grow very rapidly and a wetland can look established in just a few months. A great starting place for ideas is "Bonking in the Garden" [a publication of frogs.org.au], an excellent resource for information on how to make your yard wildlife- and frog-friendly. Basic construction methods are essentially the same as for a standard garden ponds, and there are many gardening books on that subject. The main component is some sort of waterproof liner to prevent the water from seeping into the surrounding soil, usually either a large, solid plastic pre-formed watertight container or a sheet of flexible pond-liner. Old enameled bathtubs or large, halved plastic drums will do fine. They can be built in-ground or raised above-ground with a wood or cement-block support frame. The only difference between constructing a pond is that a wetland is mostly or completely filled in with some sort of growing medium for the plants.

For the sake of clarity, the diagram below shows a basic rectangular design, with some optional "features". However, there is a lot of flexibility with regard to design, as wetlands themselves are generally very robust and forgiving, so don't feel limited by this specific design. The water storage tank and pump at the outlet of the wetland is certainly optional. In our yard, we simply take water out of the pond area with buckets and use it for watering specific garden plants. Greywater wetlands can be added on to pre-existing ponds or garden features, or be comprised of a series of linked modules.



Schematic diagram of a phytoremediation wetland. Copyright Lawrence Fields. Photograph by Lawrence Fields. Must not be reproduced without permission.

Rather than go into any specific details of wetland construction, I'll describe some of the conceptual guidelines.

1. Substrate

The plants are usually grown in an artificial substrate, such as gravel or scoria (pumice), with granules between .5 to 2.5 cm in diameter, topped with a layer of coarse mulch. One of the cheaper gravels available in the Melbourne region is the local volcanic basalt rock which has been crushed to a size known as "quarter minus". Due to its air bubbles, this gravel has the added advantage of being lighter than most other gravels (and so easier on the back when you're shovelling and wheelbarrowing). But nearly any gravel is suitable, as long as it doesn't have any limestone in it. The relatively large gaps between the gravel allow the water to easily flow through the wetland and prevent clogging of the system. The plant roots grow to fill the spaces between the gravel, and the gravel and roots together provide a vast surface area for the microbial biofilm communities, which are the real "workhorses" of the system. Wetland plants grow in waterlogged soils that are generally anoxic, but most are adapted to pull oxygen out of the air and put it down into their roots, where it diffuses into the surrounding medium, creating locally aerobic zones. This creates a complex 3-dimensional community of aerobic bacteria immediately surrounding the plant roots with anaerobic bacteria further out. These diverse communities of bacteria, mutually exchanging by-products, help ensure complete breakdown of most compounds that might end up down your drains.

If you source your gravel locally, it should only cost a few tens of dollars per cubic meter, plus a little more for delivery. A cubic meter might not sound like much, but it equates to about 15-20 wheelbarrow loads. The gravel granules should be somewhat uniform in size, to allow for some space between the particles for the water to travel though and prevent clogging, so you don't want too much sand mixed with the gravel.

2. Form and Function

The greywater should be retained for several days within the wetland, thereby ensuring thorough treatment. This means that it should take several days for the water entering the wetland to leave it, older greywater gradually getting displaced towards the outlet by new greywater coming in. For this reason, the best designs lean towards long, thin footprints rather than square or circular footprints. However, using baffles (as illustrated in this diagram) can ensure that untreated water does not "short-circuit" through the system, but is instead forced to take the longest route, like food travelling through a circuitous intestine. Baffles can be constructed by placing objects (like stacked bricks or pieces of wood) under the water-proof liner to the height of the soil layer, creating long, thin bumps which act as walls directing the flow. Or you can isolate sections of the wetland by seperating them into modules connected by narrow passages. Yet another option is to nest a smaller module within a larger one, so that when the smaller fills up, it overflows into the larger. Depending on the size of your system and the kind of greywater you plan to put into it, a very complex system of baffles might be overkill, but a few certainly couldn't hurt, and any complexity in the flow of the water will help the wetland to function.

The wetland should be designed so that the plant roots remain submerged at all times. All the greywater should travel through the wetland below the top surface of the gravel or mulch. The greywater is usually introduced at the bottom of the wetland, well underneath the top layer of mulch, generally through a perforated pipe with large holes that won't easily clog. The overflow output pipe is placed on the opposite side, lower than the layer of mulch, so that all the water is forced to flow subsurface through the gravel and no untreated water can short-circuit over the surface of the wetland. This also helps eliminate any potential odours while the wetland is getting established, and prevents the creation of puddles which can become mosquito breeding sites.

3. Estimating Size

Although its not a particularly difficult calculation, the size of the wetland is probably the most critical bit of number crunching. This will determine the amount of materials you'll need, including the volume of gravel, the size of the pond liner and other materials costs, as well as the size of the hole you might have to dig. Not only does the wetland size depend on the amount of greywater you plan to divert into it, but the wetland's efficiency also partially depends on where it's placed (ie. wind exposure and sunlight exposure) as well as seasonal and climate variables.

Sizing of the wetland also depends on the kind of greywater you expect to feed it and the amount of water you'd like for it to produce. You won't get exactly the same amount of water coming out that goes in. A certain percentage of the greywater (especially during warm, sunny weather) will be lost due to evapotranspiration - plants take up water from their roots which is transported up the plant into the leaves where it evaporates into the air through microscopic pores. Should you desire, it's certainly possible (especially in warm climates) to build a wetland large enough that it has no output or overflow, where all the greywater that went in would be lost to evapotranspiration, though this would be more difficult year round in a region with a colder winter, when evapotranspiration would be significantly less.

The biggest available household greywater volumes are generally shower, bath and laundry water. Of those, shower and bath water are generally much cleaner than laundry water. As mentioned before, for the typical australian household, these greywater sources together would generally be quite significant - hundreds of liters a day. To get a feel for the range of volumes you might be dealing with, it might be good to start with one greywater source and then expand to other sources gradually. Or only use selective sources - a little bit of shower water one day, a load of laundry the next. By the way, it's OK to include urine, as dilute urine is a sterile, nitrogen-rich plant fertilizer which your wetland will love.

A wetland should be designed so that it takes several days for one entire day's worth of greywater to travel from one end of the wetland to the other. Four days of retention is generally sufficient to ensure that any compounds are sufficiently broken down. That means the wetland needs to be large enough to hold four days worth of greywater, so a good place to start is to estimate how much greywater your household produces in a typical day. Your waterbill will likely tell you your total quarterly water usage in kiloliters, which you then divide by number of days in the billing period (also usually given on the bill) to give you your household's average daily use of water. If your household is typical, then a significant fraction of that water - perhaps a 1/3 or more - would likely be appropriate for re-use in the wetland.

As an example, we'll use an "outside estimate" for a large, squeaky-clean family that produces 500 litres of greywater a day. If we want the greywater to take 4 days to travel from one end of the wetland to the other, it should be able to contain 2,000 liters of water (not including any pond or storage tanks at the oulet). However, added to this volume of water we must also include the volume of the gravel substrate. As a very rough guideline, 1/3 of the volume of gravel (depending on the its granule size and roughness) is available as space between the grains for the water. So in our example case, we'll say a 60 liter bucket of this gravel would likely have enough space to hold around 20 liters of water before it overflowed (it might be advised to do a bucket test with the actual gravel you were planning on using). So a greywater wetland for processing 500 liters of greywater a day for four days should be about 6,000 liters in volume, or 6 cubic metres (as 1/3 of 6000 liters is 2000 liters). In order to give enough room for the roots to grow, the depth of the wetland should be anywhere between 30 to 70 cm. So at a depth of .5 m, our 500 l/day wetland could be about 2 m wide and 6 m long, or 1 m wide and 12 m long, or any shape that has an area of 12 square meters. It doesn't have to be in a straight line - the wetland could be wrapped around the perimeter of the pond which into which it drains, or even form a border around a yard. Again, this would be quite a lot of greywater - most households would produce less greywater and so require a correspondingly smaller wetland.

If you want to build an entire wetland in one go that will process all of your household's greywater, then I'd say it's best to err on the side of caution and build it a little too big. If plant growth seems slow from too little water or nutrient deficiencies, you can reduce the wetland size by increasing the size of the open water pond section, or increase nutrients by placing an open-bottomed worm compost bin on top of the input side which will leach nutrients into the wetland. Alternatively, you can start small with one greywater source, like the shower, and gradually build several modular wetlands as you add other greywater sources, each "module" connected in series or parallel. Or you could even try simulating an entire water catchment in miniature, from upland marsh to mountain stream to lowland creek to salt marsh to mangrove lagoon. Remember, wetland ecosystems are very forgiving, so there's a lot of room for experimentation and aesthetics.

4. Use Gravity Flows and Large Pipes

Wastewater streams tend to contain hair and other detritus which clog up intakes and wrap around the shafts of powered centrifugal pumps, shortening their working life and making them prone to failure. So it's best to transport the greywater to the wetland by gravity rather than by powered water pumps. This means that optimally your wetland should be placed lower than the lowest greywater drain in your house. Sometimes, that can be the biggest design problem - especially incorporating shower and bath water into a backyard that's perfectly flat or even slopes upward. In our basically flat yard with a below grade shower drain, we made a raised "surge bucket" located near our wastewater sources with a hole in its bottom drained by polypipe to our wetland some 30 meters away. We pour buckets of bathwater into this surge bucket so we don't have to carry it all the way to the wetland. We also selectively put the drain hose from our clotheswasher into this surge bucket so most of our laundry water goes to the wetland as well. I say "selectively" because we have a two-year-old child and wash the cloth nappies, and decided not to subject our relatively new wetland to the first rinse of a nappy load! Perhaps when its a bit more established...

Building the wetland on a slight incline can help gravity due its job and make sure the greywater flows in the direction you want. If you use a buried overflow storage tank and/or pond, it's also a good idea to have the surface of the wetland be somewhat higher than ground level, so that the overflow from the wetland can be at least slightly higher than the storage tank or pond. That way the cleaned water flows into the storage tank or pond by gravity. It is generally OK to have a standard submersible waterpump in the pond or tank which holds the treated water, as any solids and hair in the greywater should be filtered out by the wetland before reaching the storage tank or pond.

Use large diameter pipes or hoses for transporting the greywater from your house to the pond, especially if its going a long distance. I was cheap and bought 3/4" (20mm) garden polypipe, which drains our "surge bucket" far too slowly and will likely get clogged before long. 1 1/4" (30mm) would have been better, and something around 2" (50mm) would be better still. As I've heard about problems with PVC plastic and the leaching of dangerous chemicals, I try to avoid using PVC pipes whenever possible.

5. Flexible Pond Liners

Flexible sheet pond liners are very useful for freeform designs, (though it can be difficult to add overflow pipes to them). They are available in various kinds of plastic or rubber. EPDM rubber is generally considered the best as it has a very long life (20+ years), very high puncture resistance and high UV resistance, but it is somewhat expensive. Avoid PVC or other vinyl plastic liners, as although they are cheaper than EPDM liners, there have been questions of PVC plastics leaching chemicals into the water.

If you're a cheapskate (like me), or for smaller, temporary wetlands (like on rented property), go for several layers of black polyethylene builder's plastic instead. It's more stable than PVC and typically sold as "vapor barrier" for house construction. Get the thickest you can find. Unlike the rubber liners, polyethylene sheeting does puncture relatively easily, so protect it well with lots of old carpeting underneath and use two or three layers of plastic just in case.

6. Greasetraps and Worms

To keep grease and other solids from entering the system and gumming up the works, most greywater irrigation systems incorporate greasetraps and sediment tanks. If the wetland is only recieving bathwater, the amount of grease and solids going into it will generally be minimal. Laundry water would likely have a bit more. The introduction of compost worms into a wetland might help reduce the need for a greasetrap for some wastewaters, as they can keep the system from becoming clogged by tunnelling through the spaces in the gravel medium, helping to break down any trapped solids into smaller pieces. Worms have extremely powerful symbiotic gut bacteria which outcompete and thereby help kill pathogenic microorganisms, so they're good to have in your wetland. In general, its a good idea to introduce as many organisms into your wetland as you can, as the more diverse your microbial and faunal communities are, the more robust your wetland will be. Pouring a bucketful of leaves, muck and mud from the bottom of an established pond onto your wetland will provide a good starter culture. The microorganims will reproduce, spread and eventually form a stable community on their own.

7. Solar Aspect, Climate and Seasons

As long as they have "wet feet", nearly all wetland plants thrive in full sun, so try to locate your wetland where it will get lots of direct sun year round. Remember that the angle of incoming sunlight varies by 45 degrees from summer to winter, so a location that gets a lot of direct light in one season might be blocked by trees or the neighbors house 6 months down the line. However, you want to prevent overheating of the open water area , so try to position any pond where it will be at least partially shaded by the taller plants, fences or nearby trees, at least in the summer.

8. Choosing and Placing the Plants

Several wetland plant species have a nearly global distribution, especially those that have seeds adapted to hitching rides in the digestive tracts or feathers of migrating ducks. However, you should use indigenous plants and animals as much as possible. Indigenous plants (as differentiated from simply "natives") are plants that are (or would be) naturally located in your immediate vicinity. While a wetland plant from Western Australia might be considered an Australian native, its not necessarily indigenous to the Dandenong region. Source your plants as close to your home as possible, preferably less than a kilometer or two. The practice of using indigenous plants recognizes the idea that, for example, even though a particular Myriophyllum species from the east Melbourne suburbs might be the same species as one indigenous to the west Melbourne suburbs, there might be subtle genetic differences between the two which optimizes each of them for their respective regions. This is especially true in Melbourne which lies at the meeting point of at least two different biogeographic zones. Transplanting one species to another region fosters interbreeding between the two strains, reducing biodiversity by fostering homogeneity in the gene pool. Using indigenous plants also means that your wetland will function more efficiently, as local species are already adapted to your particular micro-environment and climate. It also ensures that you are maximizing faunal biodiversity, as indigenous fauna are more likely to have co-evolved symbiotic relationships with indigenous flora. There are over 40 indigenous plant nurseries and cooperatives scattered thoughout the greater Melbourne region, some of which specialize in indigenous wetland plants. Go to the website "www.greeningaustralia.org.au" to download a full list and map of Melbourne indigenous nurseries.

So far, nearly all the indigenous plants that I've tried growing in my greywater bog have done well, though some better than others. They include *Typha orientalis* (or cumbungi-related to european "bullrush"), *Triglochin* (water ribbons, in their emergent form), *Mentha australis* (river mint), *Avicennia marina* (grey mangrove), *Crassula helmsii* (swamp stonecrop), *Schoenoplectus, Eleocharis sphacelata* (tall spikerush), *Myriophyllum* (milfoil), *Marsilea mutica* (nardoo), *Alisma* (water plantain), *Restio tetraphyllus* (tassel cordrush), *Carex tereticaulis* (a sedge), and several *Juncus* species, to name a few. It's likely that many, if not all, other wetland species will do well in a greywater wetland, even wetland tree species, like swamp paperbark.

A word of warning: although the bamboo-like common reed (*Phragmites australis*) is a beautiful plant that thrives in greywater wetlands, it should be avoided as I have learned from personal experience that it has a strong tendency to puncture pond liners. Replacing a punctured pond liner is not something I would wish on my worst enemy. I have even heard that it will grow through cement. I'm also keeping my eye on my *Schoenoplectus.*

Some of the more vigorous growing "habitat plants", like *Typha orientalis* and *Eleocharis sphacelata*, will thrive in areas closest to the greywater inlet, near the highest nutrient concentrations, while others might prefer the cleaner water more downstream. It also might be a good idea to seasonally harvest the faster growers, which will promote the rapid growth rates that ensure maximum nutrient uptake. For the same reason, it's good to have a fair amount of wetland area set aside for these habitat plant species, as they have already proven to be very effective in constructed wetlands - not that other species would be less effective; it is certainly likely that a greywater wetland might function perfectly well if it didn't contain any *Typha*, it's just that this particular species has a proven track record thus far. Since these species are known to grow more vigorously than others, you might want to take precautions to prevent them from taking over the whole wetland, like planting them in large mesh containers or isolating them in seperate wetland "modules". *Typha orientalis* is also one of the taller wetland plants, so its a good idea to place them in the back of your wetland if you want to see the smaller species. For some species you might need to pay attention to the depth of root immersion, as some wetland plants have a range of depth which they find optimal. Its also possible that some more delicate species might not grow well until other "keystone" symbiotic species have become established, so if a particular plant species doesn't thrive right away, try it again in a few months.

9. Cooling Tank

Unless the pipe or hose to your wetland is particularly long, it's probably a good idea to have a cooling tank incorporated upstream from the inlet to the wetland, to temporarily store the incoming greywater. This will allow any hot shower or laundry water to cool before it flows into the wetland. Very hot water might harm plant roots, bacteria, worms and other organisms. This tank should be at least as big as the volume of a typical shower or bath, but no greater in volume than the amount of water your household produces in a day, as you should never store greywater for longer than 24 hours, as it will rapidly foul and increase risks of pathogens. If you are going on a vacation or will not be home for more than a day, it a good idea to empty this tank or flush it with fresh water.

10. Open Water Areas

Once the wetland is well established, a small open-water pond area at the outflow end of the wetland, with immersed aquatic plants, indigenous fish and other animals is a good idea, as the health of the pond and behavior of the fish can act as an indicator of water quality and help alert you to any problems. If indigenous frogs turn up and successfully breed, and the wetland is supporting a healthy population of indigenous fish, then it's likely that the wetland is working pretty well.

11. Choosing Detergents

Although most books on the use of greywater for backyard irrigation say that it's important to avoid using detergents with high levels of phosphates and certain other elements and compounds (especially since most Australian natives are not adapted to dealing with high nutrient soils), this is not neccesarily be the case with greywater wetlands. Wetland plants naturally grow in nutrient "sinks", or places where nutrients and other chemicals accumulate to high levels, and so they have adapted to deal with and even utilize them. What substances you can and cannot put in a greywater wetland is certainly an interesting area for investigation and discussion. I've yet to put anything in my wetland that has caused any apparent harm, but then again we use very few products in our house. To be on the safe side, it might be best to stick to general greywater garden usage guidelines and select detergents with the lowest salt, phosphate, and boron levels you can find, especially if you are reusing the wetland water on a native garden.

12. Overflow Failsafes

If your system is automated, then the greywater wetland must be designed with a fail-safe overflow, so that should the system become overloaded, it will drain into the municipal sewage system rather than flood you or your neighbor's property. Not only can uncontrolled greywater flows caused eutrophication to nearby streams, they can also undermine building foundations and cause other serious public hazards.

However, if your application of water to the wetland is manual (ie. via buckets or other selective greywater inputs), then uncontrolled overflow is unlikely and a failsafe overflow isn't really necessary.

13. Pathogen Risks

Dealing with household wastewater can potentially be dangerous. You are dealing with a complex biological community that can potentially contain pathogenic organisms. Shower, bath and laundry water usually contain traces of human blood and faecal matter, which can potentially be hosts to pathogens. Do not store the greywater for more than 24 hours before it goes to the wetland, as it will rapidly foul. Even though it has passed through the wetland and might look clean, its should still be treated as greywater. Do not use the treated water for drinking, cooking or bathing. Councils also generally advise against using greywater for watering food plants, mostly from risk of pathogen-containing water splashing onto vegetables. As a precaution, wash your hands after digging in the gravel substrate or after performing other maintenance in the wetland.

Although constructed wetlands have actually been used to process raw sewage, its probably best for the DIY wetlander to avoid attempting to process household blackwater. If you are interesting in processing all of your wastewater, including blackwater, you should hire a professional to design your system. The Victorian EPA suggests only using "low-risk" sources for greywater irrigation (ie. shower, bath and laundry rather than kitchen sink and dishwater).

That said, an Australian company called Biolytix (formerly Dowmus) manufactures a variety of wonderful, worm-based aerobically-composting wastewater systems for *all* of a household's (or community's) wastestreams (including organic waste and sewage), producing pathogen free water at a much better quality than standard septic systems. The Biolytix waste systems aren't constructed wetlands as such, but they're based on similar concepts. Yet, even the standard failing septic system can be cheaply improved with a constructed wetland. Some of the excess nutrients getting into our rivers and streams are from poorly functioning, overloaded or misused septic and trench disposal systems which are leaching nutrients into groundwater. A wetland "water polishing" system placed downstream from a standard, pre-existing septic system can help clean the effluent before it enters an irrigation or trench disposal system and reduce pollution of groundwater. However, Victorian regulations demand that such a system must be designed and installed by professionals.

14. Check Local Regulations

Check your local council's regulations and permit requirements concerning the onsite use or treatment of greywater. In Victoria, the using greywater to water a garden wetland is well within the law; technically it's legal (even promoted) to divert greywater for use in the garden, as long as no household plumbing is structurally modified. If plumbing is to be modified, and/or a "treatment system" is to be installed, then legally it must be done with council approval and by licensed plumbers. However, there are legal devices which can divert greywater without significantly altering a house's plumbing. One is a simple rubber cone (which can be inserted through a drainpipe clean-out) with an end that can be attached to a hose for watering the garden. These are available in most hardware stores. And while a greywater wetland will help clean the water so that it can be used harmlessly on your pond or native garden without causing eutrophication or salinity in your soil, a wetland would more appropriately be considered a "garden feature" (like any other pond), rather than a "treatment system", and therefore not controlled by current regulations. In other words, diverting greywater into your wetland is comparable to watering your garden with it, and providing you have not altered your household plumbing, is completely legal in Victoria.

15. Reduce Household Water Use Before You Begin

Do what you can to conserve and reduce your household water use before you begin construction. Install low-flow showerheads and dual-flush toilets, fix leaky faucets, and incorporate sensible water conservation habits into your daily routine, like keeping the tap turned off while you shave or brush your teeth. Aim to get your household water consumption under 150 litres a day per person. Mulch your garden to reduce evaporation from the soil. Become sensitized to runoff or potential runoff from your property to your local water catchment. For example, all road drains aren't part of the sewage system - road runoff ends up directly in nearby creeks and rivers. So watering your car on the street, or pouring paint buckets or other chemicals into the gutter will be directly polluting nearby waterways. Not only is water conservation and pollution reduction the whole point of building the greywater wetland to being with, but using less water means you won't need as large a wetland, which will reduce material costs and the wetland's footprint in your yard.

16. Other Uses for Constructed Wetlands

Similar systems work well in other aquatic systems of various scales, like cleaning ponds,dams and aquaria. A hydroponic biofilter with an established plant or two can create very clean aquarium water and greatly reduce the need for regular water changes. It is especially useful for those aquarists who have a lot of trouble growing immersed plants in their aquaria, perhaps because they have fish that are aggresive herbivores (like goldfish or cichlids), or for filtering water in biotope aquaria that naturally don't have many plants, like fast-moving mountain streams. It's also highly effective for tanks or ponds with very large fish or other creatures which produce substantial amounts of excrement (like turtles or koi). There are many potential effective designs, from small plastic troughs placed on top of the tank, to bucket "refugia" placed next to the tank, to gravel-filled mesh containers placed inside the tank itself.

The basic design concept, however, is to circulate the water from the tank, through the plant roots and then back into the tank, much as you would with a regular filter. In fact, many standard aquarium filter systems can easily be modified to become a hydroponic biofilter. Since the water is in constant motion, it will also become well oxygenated, so many plant species (rather than only wetland species) will grow in such a system, though slower growing perennials might do better than annuals in systems with lower nutrient levels. Any book on hydroponics can provide further design ideas based on the types of plants you wish to grow. If indoors, it's best to place these aquaria near northern- or eastern-facing windows, with the top edge level with the window ledge, so the plants get plenty of natural light. Once established, the plant's dense mass of living roots (covered with billions of microscopic root hairs) has a much higher surface area than cotton or artificial filter media, making it far more effective than a standard filter (which can only reduce nitrogenous wastes to simpler forms and cannot actually remove them from the water). Using mangroves and other halophytes, such as system can even be effective in brackish or saltwater aquaria.

17. Other Informational Resources

Phytoremediation is a relatively new field, but despite that, there are hundreds of studies and papers available in any library with a good periodical section (many of them pertaining to "reed-bed sewage treatment systems"). Several of the experts in the field are consultants, or designers of their own proprietary systems, and while their endeavors are inspiring, getting practical do-it-yourself information is sometimes difficult, which is why I wrote this article. There are also several more general books about reusing greywater for lawn and garden irrigation, some even with sections about greywater wetlands with useful information (like "Not Just Down the Drain" by Stuart McQuire). A store called "Going Solar" near the Queen Vic Market has several greywater recycling books, as well as other water saving resources, like greywater diverter pipes, rainwater tanks, solar-powered water pumps, and even buckets of compost worms. And of course, trawling internet search engines is worthwhile, especially for scientific paper abstracts and bits of information (especially the underlying science of wetland function), though specific details of DIY backyard wetland design are rather sparse online. CERES, a sustainable living center in East Brunswick, has a continuously growing and evolving greywater wetland that's worth visiting, as well as an indigenous nursury that usually stocks a few regional Melbourne wetland plants. They can also direct you to other cooperative indigenous nurseries that might be closer to your home. But beyond that, I'm hoping that this article will inspire people to start experimenting with their own greywater wetlands so that we can all begin exchanging real experience and practical and creative ideas.

The Fine Print (Disclaimer)

The reuse of domestic waste water has the potential to create risks to human health and ecosystems. This article is written for general informational purposes only, and should not be used as a design manual or for constructing systems not built within the guidelines of local regulations.

References

Davison, Leigh, Mark Bayley, Tony Kohlenberg and John Craven. *Performance of Reed Beds and Single Pass Sand Filters with Characterisation of Domestic Effluent - NSW North Coast*.

Davison, Leigh. *On-site secondary treatment by reed bed: five years experience in northern NSW*.

McQuire, Stuart, 1995. *Not Just Down the Drain*.

Mobbs, Michael, 1998. *Sustainable House: Living for Our Future*. Marrickville, N.S.W: Choice Books.

Reuse Options For Household Wastewater (Publication 812). EPA Victoria, November 2001

Further reading

A personal account of Lars's introduction to phytoremediation, *Greywater - the why and wherefore*, is available as a feature article within the Victorian Frog Group project.