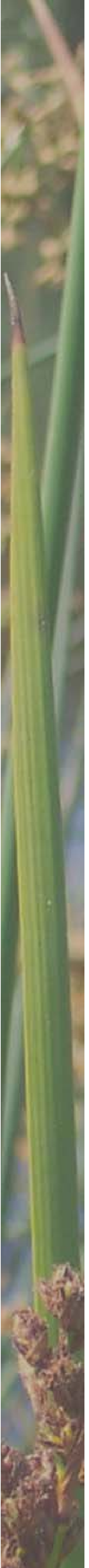

Water Sensitive Urban Design (WSUD) fact sheets

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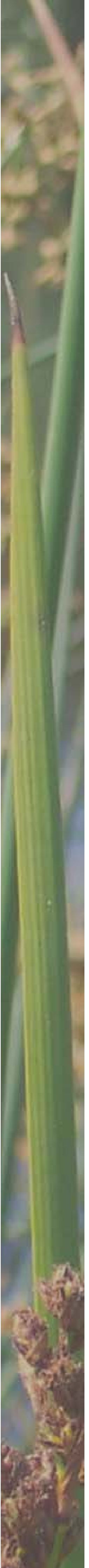


This section describes WSUD elements and outlines likely benefits, different configurations, constraints and design considerations for a range of WSUD elements that could be employed in the City of Yarra. The fact sheets present photos and general diagrams of likely configurations for common applications.

The fact sheets cover a wide variety of WSUD elements ranging from water conservation initiatives (fact sheet 1), water way rehabilitation programs (fact sheet 2) and treatment technologies. The treatment technologies can be broadly grouped into stormwater treatment (fact sheet 3 to 10) and wastewater reuse treatment (fact sheets 10 to 16). The main characteristics for each treatment WSUD elements are summarised in Table 1.

Table 1 WSUD elements, their fact sheet number and characteristics

Key characteristics **Fact sheet**	Pollutant separation by physical process	Pollutant removal by biological treatment	Designed for water flow (conveyance)	Water retention	Urban Design qualities
3. Gross pollutant trap	**√**	X	X	X	X
4. Sedimentation (settling)	**√**	X	X	**√**	√
5. Ponds and lakes	**√**	√	X	√	**√**
6. Rainwater tanks	**√**	X	X	**√**	X
7. Vegetated swales and buffer strips	**√**	√	**√**	X	**√**
8. Bioretention systems (swales and basin)	**√**	**√**	**√** (swale)	√	**√**
9. Free surface flow wetlands	**√**	**√**	X	√	**√**
10. Subsurface flow Wetlands	**√**	**√**	X	√	**√**
11. Suspended growth biological processes	X	**√**	X	X	X
12. Fixed growth biological processes	X	**√**	X	X	X
13. Biological filter	X	**√**	X	X	X
14. Membrane filtration	**√**	X	X	X	X
15. Depth filtration	**√**	X	X	X	X
16. Disinfection	X	**√**	X	X	X

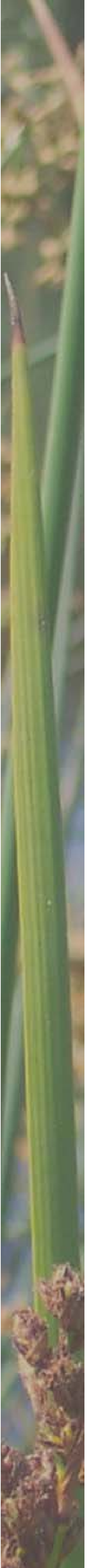
√ – Primary purpose

√ – Some impact but not primary purpose

X – Does not contribute

Elements discussed in this section cover a wide variety of applications on different scales. There are three main scales on which WSUD elements can be employed; site, precinct and regional. Site elements can be applied to runoff from single sites, precinct elements have application to groups of houses or streetscape scale and regional elements are only applicable for larger scales, where larger catchment areas are involved.

Sizing curves are produced for the City of Yarra to provide an initial estimate of land area required. The limiting design parameter is relates the required treatment area to the catchment area.



Fact Sheet 1: Water conservation initiatives

Supplying potable (drinking) water to Melbourne is becoming an increasingly difficult task. There is already a strain on existing water resources and new development will put further pressure on potable water resources unless demand for potable water is reduced.

The most significant savings of potable water demand can come from matching the intended use of the water to its required quality (and therefore its source). The majority of domestic, commercial and industrial water does not need to be of potable quality. Depending on what water is required for, it could come from different sources, some of these are:

- Roof runoff/ rainwater tanks
- Greywater (from laundry and bathroom)
- Reclaimed water (from local wastewater treatment plants)
- Recycled plant water (at an industrial premise).

To determine an appropriate source of reuse water, the following issues require consideration:

- availability of the secondary source
- proximity to the use
- potential construction of extra infrastructure
- risk of cross connections (health impacts)
- treatment requirements before reuse
- behaviour emission
- broader environmental objectives including greenhouse emissions.

Preferences for alternative water sources and appropriate uses

A hierarchy of options for water reuse, grading from the easiest to implement to the most extensive water reuse options is ordered below. Determining the best suited option for a development will depend on the scale of the development, the proximity to treatment facilities and the pressure on potable water demand.

The recommended hierarchy for household reuse options is:

1. Rainwater reuse for toilet and garden
2. Rainwater for hotwater, household greywater for garden and toilet
3. Reclaimed (recycled) water to toilet and garden, rainwater for hot water

Demand Management

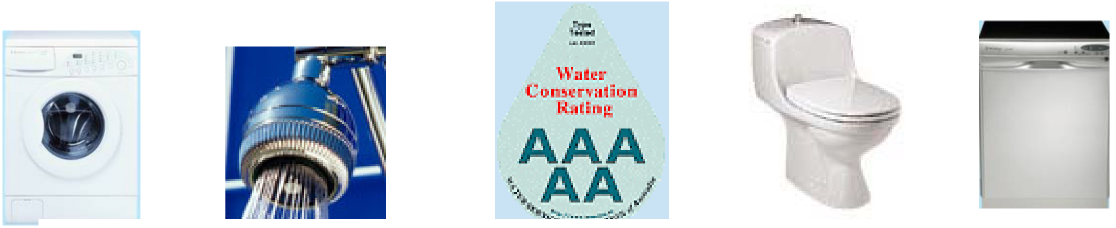
Regardless of the sources of water, significant savings can be made by making better use of water. This can be achieved by changing practices of consumers and through the use of water efficient devices. Education initiatives are considered the best way to change behaviour and are generally best carried out by local authorities such as Melbourne City Council.

Education on matters such as tap maintenance can save potable water supplies.

Waterless urinals can be used in commercial buildings – requiring no flushing water

Melbourne households generally use water inefficiently. A National Water Conservation Labelling Scheme has recently been developed for water appliances such as showerheads, washing machines, toilets and dishwashers ('A's are used as a rating out of five) to increase the use of water efficient devices and to encourage improved practices in residential dwellings,. The system is administered through the Australian Water Services Association. The more water efficient that product is, the more 'A's a product has. 'AAA' is the minimum requirement for a water efficient product. Up to AAAAA labels can be found on some water efficient dishwashers and washing machines.

By adopting AAA (or better) rated appliances, and with education, a reduction of up to 15% in water consumption can be obtained.



Water efficiency ratings assess the water use of common appliances. By requiring AAA or better appliances up to 15% of potable water demand can be reduced

Garden designs that use water efficiently through plant selection and zoning of vegetation types can also reduce water demands considerably.

Water efficient gardens using indigenous vegetation can vastly reduce irrigation needs whilst enhancing landscape.

Fact Sheet 2: Waterway rehabilitation

Waterway rehabilitation aims to mimic the natural waterway system. Vegetation selection, stabilisation of the waterway, adequate flood conveyance and an appropriate hydrologic regime are important considerations.

Rehabilitated waterways can be very popular recreation areas in communities (eg. Merri Creek and the Yarra River). Frequently used as linear parks they attract walkers, bike riders, bird watchers as well as providing a natural retreat from urban activities. They also help to promote appreciation of waterways and their ecological values, and can improve property values of surrounding areas.

In the City of Yarra, the hydrologic regime of waterways has been drastically changed and returning a waterway to pre urbanisation conditions is not possible. In this case, a rehabilitated waterway is designed to use the existing hydrologic conditions as well as possible. The waterway will need to be stable from erosion, provide habitat for aquatic and terrestrial species and enhance the local environment.

Upstream runoff frequently requires some pollutant control, particularly for litter, debris and coarse sediments. These can impact the aesthetics of a waterway as well as smothering habitats, generating odours, attracting pests and depositing dangerous materials.

Stabilisation of a waterways is critical for its rehabilitation.

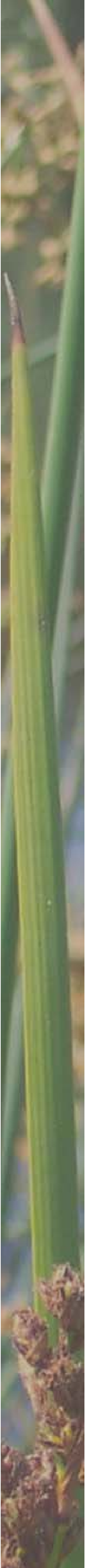
Riparian vegetation plays an important role in erosion control.

Waterways can provide features in the landscape for wildlife and recreation.

Waterway rehabilitation can involve community members and increase ownership of an area.

Pool and riffle systems provide varied habitat for aquatic species.

Vegetation should be selected to compliment any remnant vegetation.



Fact Sheet 3: Gross pollutant traps (GPTs)

Gross pollutant traps (GPTs) are commonly installed by council and developers for stormwater pollution management. GPTs are intended to retain litter and debris from stormwater systems primarily through screening. Some GPTs also remove bed load sediments and some suspended sediments through rapid sedimentation.

GPTs have mainly been used in existing conventional drainage systems either in pipes, at outfalls or in open channels, but can also be used as pretreatments for other WSUD elements. They are intended to retain solid litter that has washed into the system but not retard flows or increase water levels in the drainage system considerably. Many WSUD elements do not require a GPT (especially those with streetscape and source control measures buffering the stormwater drainage system from contributing areas), as the entry of litter and debris to the stormwater system is restricted by filtration media. However, GPTs can be used in WSUD as a pre-treatment device when piped systems discharge into waterways or wetlands.

Unlike other WSUD elements, a wide range of commercial GPT products are available (from more than 15 suppliers in Australia). Different GPTs employ varying mechanisms of litter separation and containment and their performances can vary greatly. There are also GPTs intended for different catchment scales from less than one hectare to more than 100 hectares. It is important to select an appropriate GPT depending on site conditions.

Selection issues

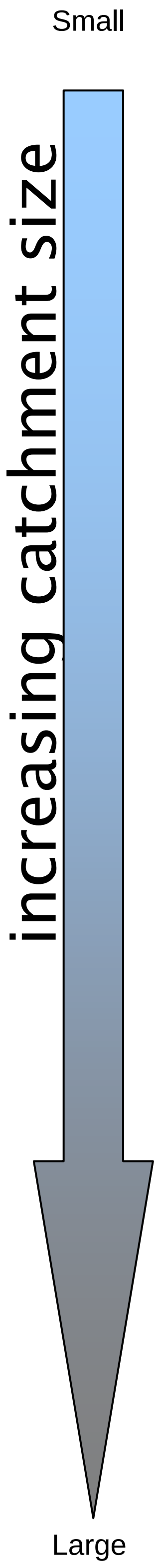
Isolating high pollutant load generation areas is the key to locating a GPT. They are primarily sized on hydraulic considerations, so the amount of 'clean' water that is treated should be minimised. GPTs are generally sized to treat between the 3-month to 1-year ARI peak flow and are work best with catchment areas less than 100 hectares. These design flow rates are based on treating more than 95% of annual runoff volume.

A decision of which type (and brand) of GPT to select is a trade-off between the life cycle costs of the trap (ie. by combining capital and ongoing costs), expected pollutant removal performance in regard to the values of the downstream waterbody and any social considerations.

A life cycle cost approach is recommended that allows ongoing operation costs to be considered and the benefits of different traps assessed over a longer period. The overall cost of GPTs can often be determined by maintenance costs rather than capital costs.

Design issues

Regular maintenance of GPTs is essential for their successful operation. When installing a GPT, the owners need to recognise the required maintenance commitment. Generally this is at least a clean out every 3 months, but depends on the catchment characteristics and any source reduction initiatives that may be active in the area. A poorly maintained GPT will not only cease to trap pollutants, but may release contaminants by leaching from the collected pollutants.



Litter retained near sources

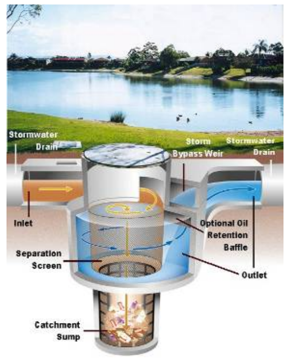
Side entry pit traps used in local areas

Grates used to prevent entry of gross pollutants

GPTs for precinct drains

Maintenance of GPTs is critical to their performance

Many GPTs come in precast form, reducing construction times



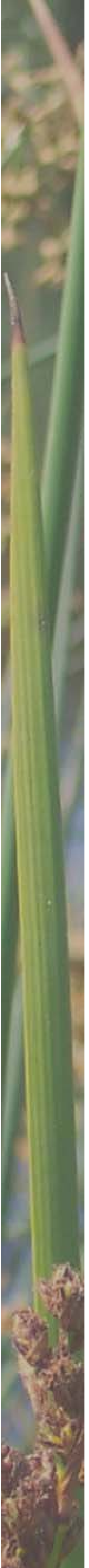
GPTs can be installed underground - out of site

Older style GPT with sediment trap upstream

Nets can be used on open channels

Floating traps are used in estuaries to capture highly buoyant material

Cleaning booms can be difficult



Fact Sheet 4: Sedimentation (settling)

Sedimentation removes pollutants by gravity settling. Sedimentation occurs at reduced flow velocities and thereby encourages particles to settle. Typically coarser particles are more removed easily than finer particles. Enhanced sedimentation enables finer particles to aggregate and then settle.

Sedimentation occurs in many WSUD elements including:

- Sediment basins
- Tanks (storage tanks, balancing tanks, rainwater tanks, stormwater tanks)
- Ponds, lake
- Wetlands

All elements reduce flow velocity, thereby increasing the retention time and settling.

Design considerations

The key design parameters are the sediment's terminal settling velocity (primarily dependent on size) and the hydraulic information (water velocity, flowrate and retention time). The sediment separation device can then be sized. Typically sedimentation targets coarser particles. Finer pollutants require additional treatment due to more complex interactions. Their size, shape, structure and charge have a greater impact on its removal.

Sediment basins

Sediment basins are used to retain coarse sediments from runoff. They are typically incorporated into pond or wetland designs such as the exclamation mark wetland at NAB's forecourt at Docklands. They can drain during periods without rainfall and then fill during runoff events. They are frequently used during construction activities and as pre-treatment for elements such as wetlands (eg. as an inlet pond). They are sized according to the design storm discharge and the recommended target particle size is 0.125mm for trapping coarse sediments only.

The large volumes of coarse sediments carried in stormwater require regular removal from the basin. These have generally low contaminant concentrations and should be kept separate from the fine sediments. The fine sediments contain the highest contaminants (hydrocarbons and metals) concentrations therefore incurring higher waste disposal costs. Thus sediment basins are designed to retain predominantly the coarse sediment fraction.

Maintenance of sediment basins is required every two to five years, dependent on the catchment. Maintenance generally involves draining the basin and excavating collected sediments for landfill. To drain the basin either underdrains are required in the design or it can be pumped, depending on its size. For construction sites that produce very large sediment loads, desilting is required more frequently. A sediment basin will generally require resetting after development in the catchment is complete.

Selection issues

Locating a sediment basin is generally a function of available space and suitable topography, although temporary basins can be constructed as 'turkey nest' basins. Outlet controls are important for the basin's extended detention function as well as ensuring adequate settling time. Outlet structures should be designed for even detention times, for example typically a multiple level off-take riser will regulate flow to wetland or pond.

Design issues

The depth is usually set to minimise vegetation (weed) growth and to allow for adequate collected sediments storage, usually a minimum of 1 metre. Detailed design are available from Melbourne Water's Draft WSUD Engineering procedures: stormwater[1].

Sediment basin as an inlet pond to constructed wetland system, to remove coarse sediment and provide even flows to the macrophyte zone.

Sediment basins can be used in the landscape to improve aesthetics, and in this case also treat highway runoff.

The outlet structure of a sediment basin is an important consideration in design. Flows should be retained sufficiently to remove all coarse sediments.

Tanks, Ponds and Wetlands

Physical separation by sedimentation occurs in tanks, ponds and wetlands primarily due to reduced flow velocities and still conditions. Refer to the appropriate fact sheet for additional information.

Advanced sedimentation systems

More advanced sedimentation devices such as clarifiers can be incorporated into black, grey and sewer mining water treatment processes. These devices are typically a combination of mechanical and physical designs enhancing sedimentation with the main advantage being the reduced footprint required.

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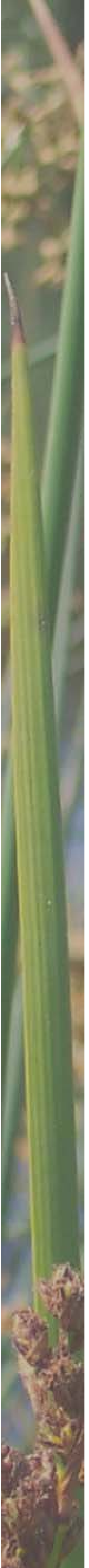
[1] Available from Melbourne Water's website (http://wsud.melbournewater.com.au/).



Fact Sheet 5: Ponds and Lakes

Ponds and lakes are artificial bodies of open water usually formed by a simple dam wall with a weir outlet structure. Ponds in the City of Yarra can be integrated into the WSUD strategy. Not only do they provide an asthetic quality but also provide a function. Typically the water depth is typically greater than 1.5 m. There is usually a small water level fluctuation, although newer systems may have riser style outlets. This allows for extended detention and longer temporary inflows storage.

Ponds promote particle sedimentation, adsorption of nutrients by phytoplankton and UV disinfection. They can be used as storages for reuse schemes and urban landform features for recreation as well as wildlife habitat. Often wetlands will flow into ponds and the water body enhances the local landscape.

Ponds can be used for water quality treatment. Typically in areas where wetlands are unfeasible for example very steep terrain. In these cases, ponds should be designed to settle fine particles and promote submerged macrophyte growth. Aquatic vegetation has an important function in water quality management in ponds and lakes. Fringing vegetation, are necessary to reduce bank erosion and are aesthetically pleasing, but contributes little to the water quality improvement.

Ponds provide a valuable storage of water that can potentially be reused, for example as irrigation. Ponds or lakes can be focal points in developments, with houses and streets having aspect over open water.

Ponds are seldom used as “stand-alone” stormwater treatment measures. As a minimum, ornamental ponds require pretreatment with sediment basins. The sediment basins require regular maintenance refer to the ‘Sedimentation fact sheet’ for more details. In many cases, these ponds ultimately become the ornamental waterbody that require water quality protection.

There have been cases where water quality problems in ornamental ponds and lakes are caused by poor inflow water quality, especially high organic load, infrequent waterbody “turnover” and inadequate mixing. Detailed modelling may be necessary to track the fate of nutrients and consequential algal growth in the waterbody during periods of low inflow (and thus long detention period). As a general rule, it is recommended that the mean turnover period for lakes during the summer periods should be of the order of 30 to 40 days, i.e. the lake volume should not be greater than the volume of catchment runoff typically generated over a 30 to 40 day period in the summer months. In the absence of these hydrologic conditions, it may be necessary to introduce a lake management plan to reduce the risk of algal blooms during the dry season. In spite of this, there is often an urban design desire to maximise the size of the pond as a focal water feature for the residential development.

Ponds can incorporate edge vegetation to reduce the risk of bank erosion and improve habitat values.

Ponds can be incorporated into retarding basins to add water treatment to their flood retardation function

Ponds can be installed at different scales, providing regional water sources for irrigation

Fact Sheet 6: Rainwater tanks: general

Rainwater tanks collect water runoff from roof areas. They can provide an underutilised resource of non-potable water in the City of Yarra.

Tank design

Tanks can be incorporated into building design so they do not impact on the aesthetics of a development or surrounding environment. Tanks can be selected to suit heritage areas, they can be located underground and some newer slim line designs incorporate tanks into fence or wall elements.

Tank sizing

Tanks are generally sized according to their intended demand and available roof catchment. For example, if tank water is intended to be used for toilet flushing and hot water systems, a desired level of reliability can be achieved with the selection of an appropriated sized tank.

Figures 6a – 6c have been derived from Melbourne rainfall data and use typical demand values (using AAA rated appliances). The curves size tanks relative to the roof area and the occupancy rate. Generally rainwater harvesting becomes unfeasible if the roof area is less than $15m^2$ per person.

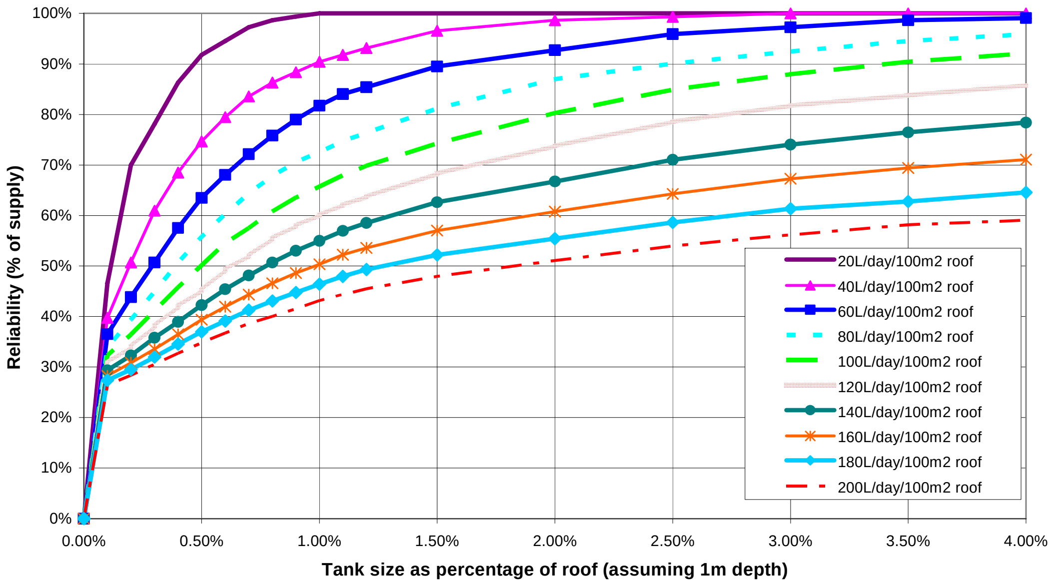


Figure 6a. General use tank sizing curve for Melbourne

If the water demand (or occupancy) and roof areas are known, a tank can be selected with reference to Figure 6a. Optimal tank size can be assessed by evaluating the reliability of supply (percentage of water supplied). Note that marginal gain is attained by installing a tank larger than approximately 2-4% of roof area (dependent on demand). The increased tank size and cost must be evaluated against additional potable water conservation. A worked example is provided on the following page. Typically an inner city residential is tank 1.5 to 3 kL, though dependent on roof area and water use. The shortfall in demand can be covered by using a top up from potable water supplies. This is achieved by plumbing potable water into the tank with an air gap, having a float activated switch as well as ensuring no cross contamination can occur by using appropriate valves. Integrated management systems can automate rainwater use throughout the household such as the RainBank[2] system or similar.

Tank installation

Rainwater tanks can be fitted with 'first flush diverters'. These are simple mechanical devices that divert the first portion of runoff volume (that typically carries debris and contaminants) away from the tank. After the first flush diversion, water passes directly into the tank.

Collected roof runoff water is suitable for direct use for garden irrigation or toilet flushing with no additional treatment. Tank water can also be used in hot water systems, although some additional treatment to remove the risk of pathogen contamination is required. This generally involves UV disinfection and ensuring that the hot water service maintains a temperature of at least 60-70°C, subject to City of Yarra approval.

A licensed plumber is required to install the rainwater tank with all installations conforming to Australian standards (*AS3500.1.2 Water Supply: Acceptable Solutions*)[3].

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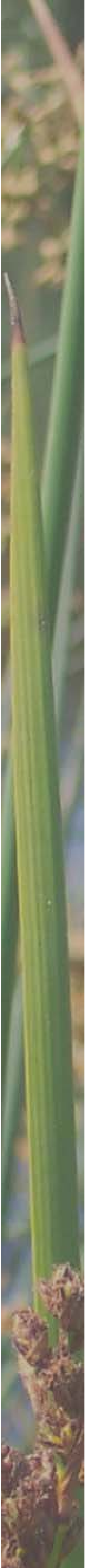
[2] Refer to Davey's RainBank website (www.davey.com.au/rainbank/)

[3] Refer to the Green Plumbers (www.greenplumbers.com.au) and the Plumbing Industry Commission (www.pic.vic.gov.au) for additional information



Fact sheet 6: Rainwater tanks for the household

Rainfall patterns, that is rainfall frequency (how often it rains) and rainfall intensity (how hard it rains) influences the effectiveness installing a rainwater tank. Rainwater tank size is dependent on;

- Your roof area.
- What water is to be used for (toilet flushing or outdoor (garden) use).

The sizing curves below (Figure 6b and 6c) consider these two options for Melbourne. They have been developed using a software program called MUSIC that uses historical rainfall data for Melbourne. The water use is constant (e.g. toilet flushing) or varies with season such as garden watering. Outdoor use is typically greater in the summer and the 'outdoor curve' accommodates this variation. Connecting the rainwater tank to the toilet is preferable as the flushing creates a constant yearly demand and hence maximise use of the tank volume.

Steps to calculate appropriate sized tank:

1. Calculate roof area (m^2)
2. Decide whether you are using the water for toilet flushing or the garden
3. Refer to the appropriate curve
    a. Toilet flushing – calculate how many people per 100m^2 of roof area. Then read off the supply reliability for desired tank size.
    b. Outdoor use – calculate the garden area that you water. Then determine garden area per 100m of roof area. Then read off the supply reliability for desired tank size.

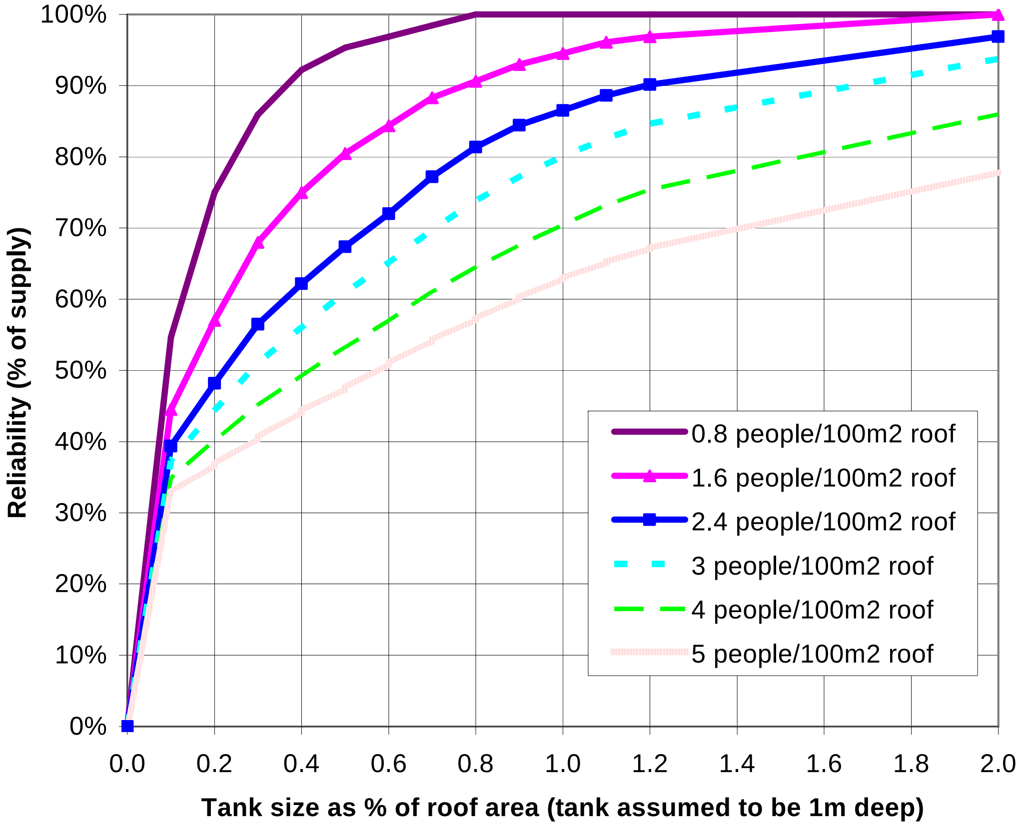


Figure 6b. Rainwater tank sizing curve for toilet flushing in Melbourne

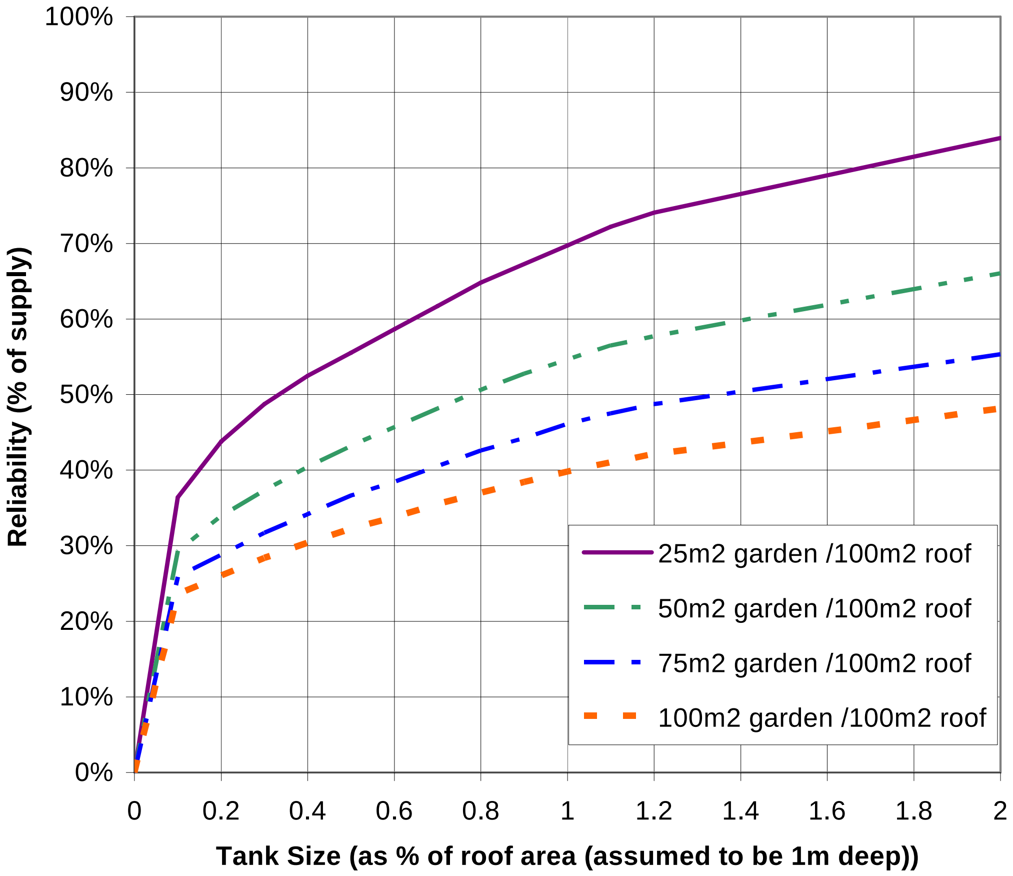


Figure 6c. Rainwater tank sizing curve for outdoor use in Melbourne

Typical household example – TOILET FLUSHING (left)

Roof area = 250 m^2

Rainwater is used for **toilet flushing** with 4 people in the household.

Now, converting the number of people to a standard basis (per 100m^2 roof area)

4 people per 250 m^2 = 1.6 people per 100m ^{2}

Using the toilet flushing tank sizing curve to achieve 90% reliability I will need a tank that is approximately 1.0% of the roof area (250m^2) = 2.5 m^3 (=2.5 kL).

So on average my 2.5kL rainwater tank will supply 90% of my outdoor watering requirements.

Typical household example – OUTDOOR USE (above)

Roof area = 150 m^2

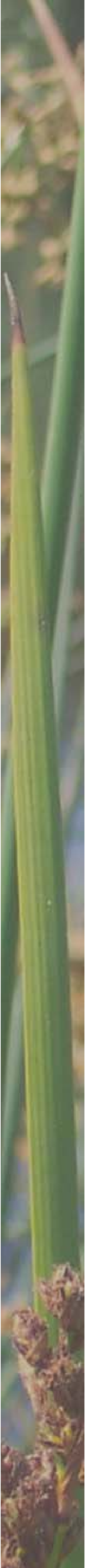
Rainwater is used for **outdoor use** – garden area – 250 m^2 but I only water 120m^2 of my garden and this is what I use for my calculations.

Now, converting our garden area to a standard basis of 100m^2 roof area in this case we must divide our roof area by 1.5 (150m^2/1.5 = 100m^2). Likewise for the garden area,

120/1.50 = 80 m^2 garden area per 100m^2

Using the outdoor tank sizing curve to achieve 50% reliability I will need a tank that is approximately 1.5% of the roof area (150m^2) = 2.25 m^3 (=2.25 kL).

So on average my 2.25kL rainwater tank will supply 50% of my outdoor watering requirements.



Fact Sheet 7: Vegetated swales and buffer strips

Swales

Vegetated swales can be used instead of pipes to convey stormwater and provide a ‘buffer’ between the receiving water (eg. Port Philip Bay, river, wetland,) and the impervious areas of a catchment. They could be integrated with landscape features in some of the City of Yarra’s parks and gardens. The interaction with vegetation facilitates an even distribution and slowing of flow thus encouraging pollutant settlement and retention in the vegetation. Total nitrogen (TN) is generally the limiting pollutant in swale systems. Swales can be incorporated in street designs and add to the aesthetic character of an area.

To convey flood flows, in excess of the treatment design flow, pits draining to underground pipes can be used. Water surcharges from the swale into a pit.

The longitudinal slope of a swale is an important consideration. They generally operate best with slopes from 2% to 4%. Slopes milder than this can tend to become waterlogged and have stagnant ponding, although the use of underdrains can alleviate this problem. For slopes steeper than 4%, check banks along swales, dense vegetation and/or drop structures can help to distribute flows evenly across the swales as well as slow velocities.

Selection issues

Road or driveway cross overs are an important consideration. Driveway cross overs can provide an opportunity for check dams (to provide temporary ponding) or can be constructed at grade and act like a ford during high flows.

A variety of vegetation types can be used in swales. Vegetation should cover the whole width of the swale, be capable of withstanding design flows and be of sufficient density to provide good filtration. It should also be selected to be compatible with the landscape of the area and maintenance capabilities. For best performance, vegetation height should be above the treatment flow water level. Some examples are shown in the pictures.

Maintenance is typical of landscaping,with vegetation growth the key objective.

Buffer strip with flush curve without setdown

Different arrangements of kerbs with breaks to distribute inflow

Swales are typically limited by TN reduction, as such sizing curves for TN reduction in Melbourne are shown in Figures 7a and 7b. The sizing curves relate the swale performance to a percentage of the impervious catchment area to be treated. They relate the vegetation height (Figure 7a) and the swale slope (Figure 7b) to the TN removal. Note the sizing curves are used to assess the top width of the vegetated swale.

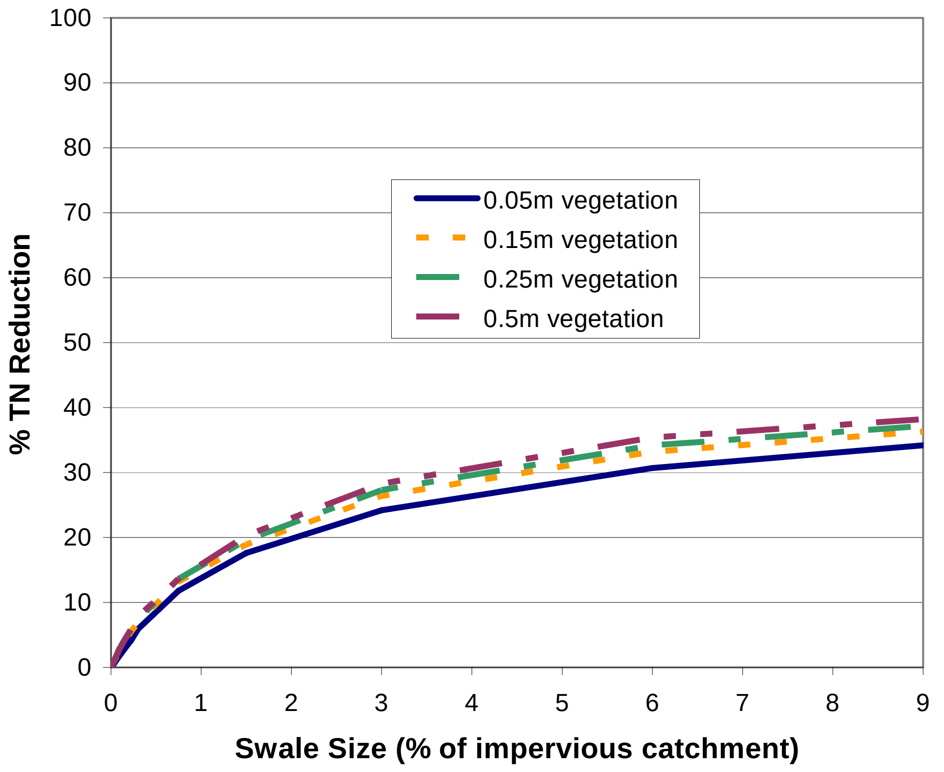


Figure 7a.TN reduction by a swale in Melbourne as vegetation height varies (3% slope)

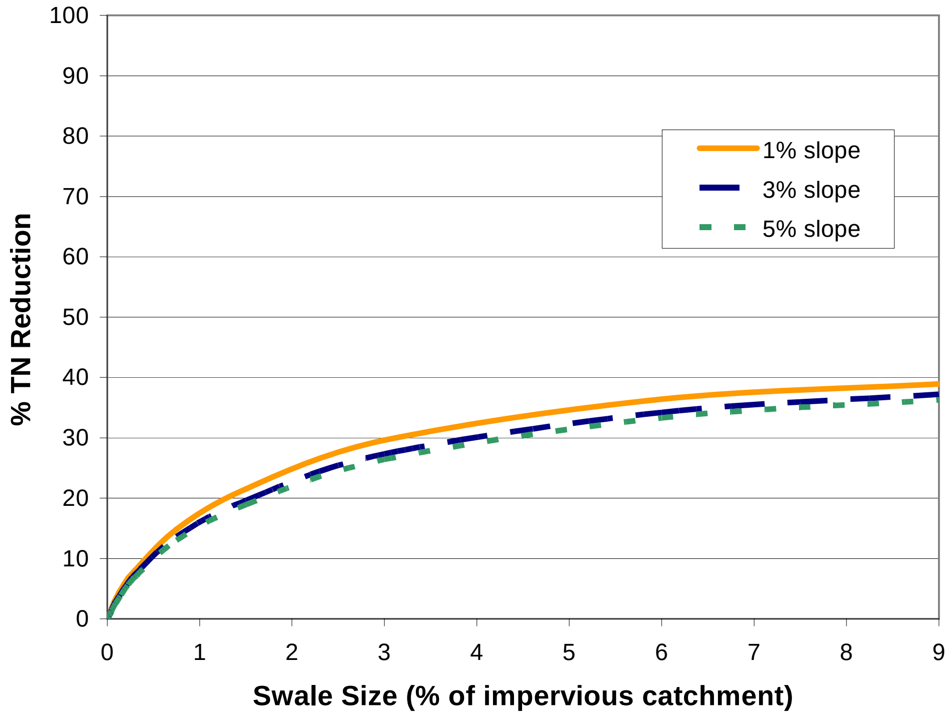
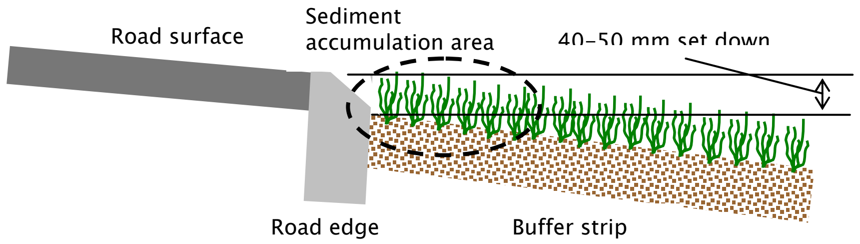


Figure 7b. TN reduction by a swale in Melbourne as slope varies (0.25m vegetation height)

Buffer strips

Buffer strips are intended to provide discontinuity between impervious surfaces and the drainage system. The key to their operation, like swales, is an even shallow flow over a wide vegetated area. Buffers are commonly used as a pre-treatment for other stormwater measures.

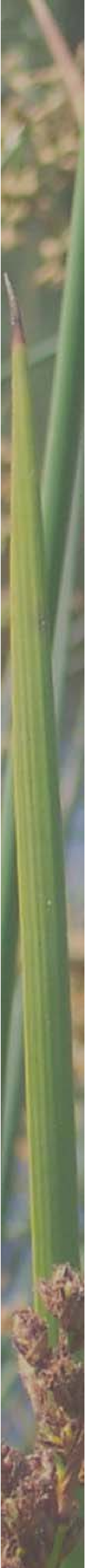
Buffer strips should be set down from the road surface to account for sediment accumulation over time. The set down required is a trade off between creating scour from runoff and providing sufficient build up space for accumulated sediment. Generally between 40 and 50 mm set down from the paved surface will be adequate with a pavement surface that is tapered down towards the buffer strip (as illustrated in the adjoining diagram).



Breaks in a kerb can provide distributed flows though a buffer strip, thus spreading the hydraulic loading.

Figure 7c. Typical buffer strip arrangement

For detailed information, refer to Chapter 8 of Melbourne Water's Technical manual WSUD engineering procedures: stormwater. (2005)



Fact Sheet 8: Bioretention systems

In bioretention systems stormwater runoff is filtered through a vegetated soil media layer and is then collected via perforated pipes and flows to downstream waterways or storages for reuse. Temporary ponding above the soil media provides additional treatment. Bioretention systems are not intended to be infiltration systems in that the dominant pathway for water is not via discharge into groundwater. Any loss in runoff is predominantly attributed to maintaining filter media moisture (which is also the vegetation's growing media).

Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system and providing biofilms on plant roots that pollutants can adsorb to. Selection of an appropriate filtration media is a key issue that involves a trade-off between providing sufficient hydraulic conductivity (ie. passing water through the filtration media as quickly as possible) and providing sufficient water retention to support vegetation growth (i.e. retaining sufficient moisture by having low hydraulic conductivities). Typically a sandy loam type material is suitable, however the soils can be tailored to a vegetation type.

Bioretention systems are typically limited by their TSS removal. Figure 8c presents a design curve for preliminary sizing of bioretention systems in Melbourne, relating typical performance to a percentage of the impervious catchment.

Bioretention Basins

The treatment process in bioretention basins is similar to bioretention swales. Typically flood flows bypass the basin thereby preventing high flow velocities that can dislodge collected pollutants or scour vegetation. These devices can be installed at various scales, for example, in planter boxes, in retarding basins or in streetscapes integrated with traffic calming measures.

Swale bioretention system

Swale bioretention systems (refer to Figure 8b) provide both stormwater treatment and conveyance functions. A bioretention system is installed in the swale's base. The swale component provides stormwater pretreatment to remove coarse to medium sediments while the bioretention system removes finer particulates and associate contaminants.

A bioretention system can be installed in part of a swale, or along the full length of a swale, depending on treatment requirements. Typically, these systems should be installed with slopes of between 1 and 4 %. In steeper areas, check dams are required to reduce flow velocities. For milder slopes, it is important to ensure adequate drainage is provided to avoid nuisance ponding (a bioretention system along the full length of the swale will provide this drainage).

Runoff can be directed into conveyance bioretention systems either through direct surface runoff (eg. with flush kerbs) or from an outlet of a pipe system.

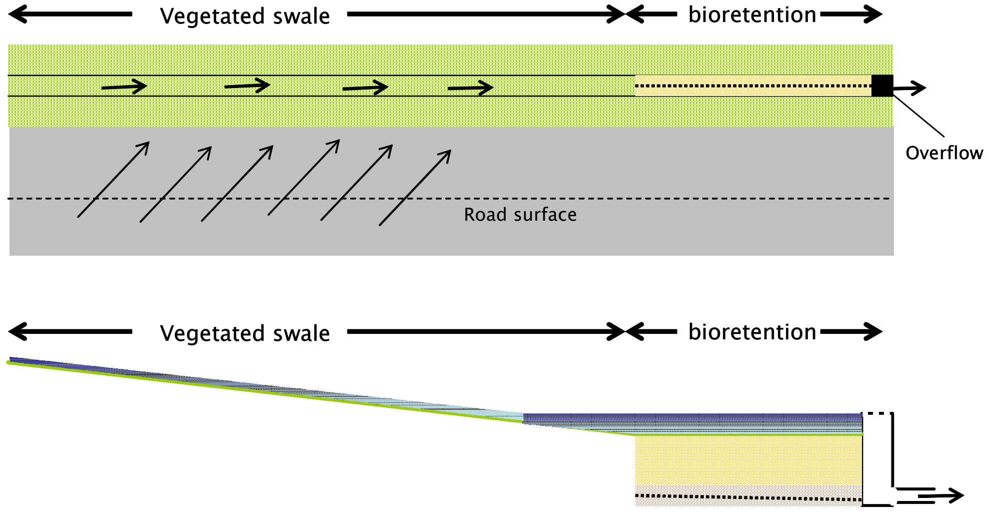


Figure 8a.Bioretention system adjacent roadside

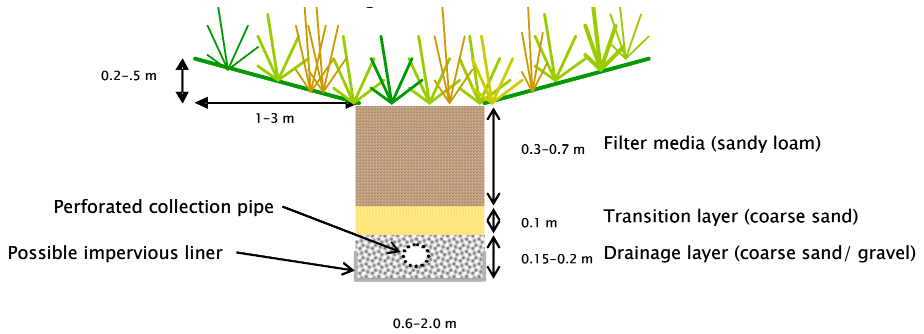


Figure 8b. Swale bioretention system – section

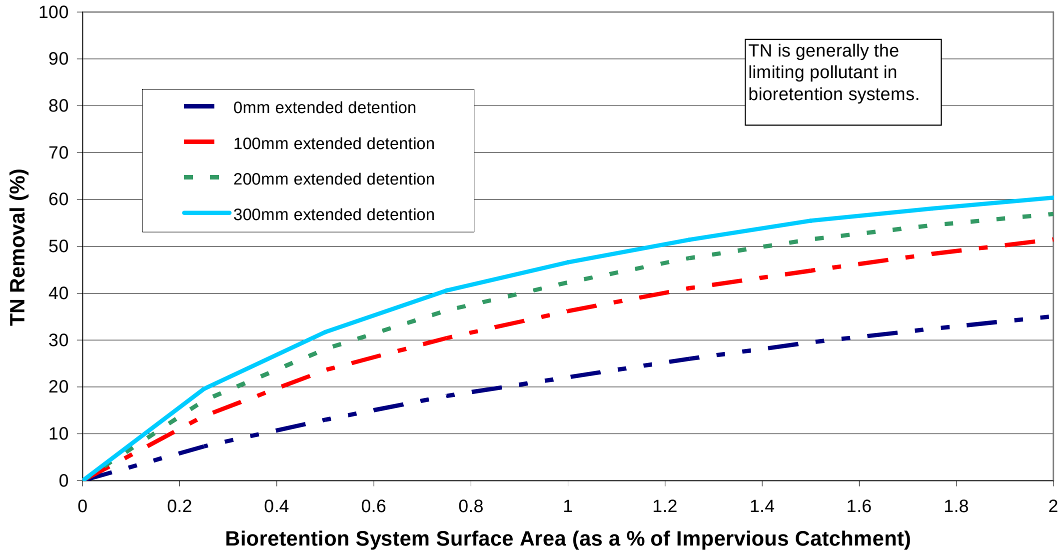
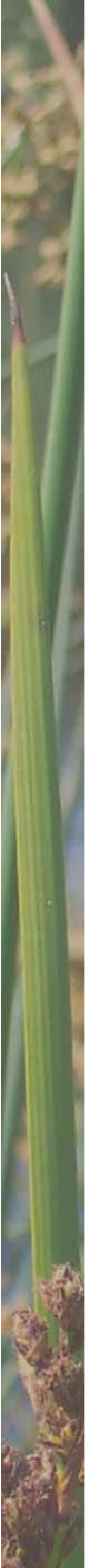


Figure 8c.TN removal by bioretention systems in Melbourne



Fact Sheet 9: Surface wetlands

Constructed surface wetland systems use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. They generally consist of an inlet zone, that is a sediment basin to remove coarse sediments (refer to fact sheet 4), a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake of soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone).

The wetland processes are engaged by slowly passing runoff through heavily vegetated areas where plants filter sediments and pollutants from the water. Biofilms that grow on the plants can absorb nutrients and other associated contaminants. While wetlands can play an important role in stormwater treatment, they can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and resting areas. They can also improve the development aesthetics and can be a central landscape feature.

Wetland systems provide flood protection when incorporated into retarding basins. Additionally an open water body or pond at the downstream end of a wetland can provide water storage for reuses, such as irrigation.

Wetlands can be constructed on many scales, from small scales, house block scale (pictured left) to large regional systems. In highly urban areas they can have a hard edge form and be part of a streetscape or building forecourts. In regional settings they can be over 10 hectares in size and provide significant habitat for wildlife.

Inlet zone

The wetland inlet zone (or sediment basin) is designed to regulate flows into the macrophyte zone and remove coarse sediments. The inlet zone also enables a bypass pathway to be engaged once the macrophyte zone has reached its operating capacity.

The inlet zone reduces flow velocities and encourages settling of sediments from the water column. They can drain during periods without rainfall and then fill during runoff events. They are sized according to the design storm discharge and the target particle size for trapping.

Sediment basin maintenance is usually required every two to five years. Sediment basins should be designed to retain coarse sediments only (recommended particle size is 0.125mm). The highest contaminant concentrations are associated with fine sediments and therefore waste disposal costs for this material can be much higher.

Macrophyte zone

An important operating characteristic of macrophyte zones is even well distributed flows that pass through various bands of vegetation. Strong vegetation growth is required to perform the filtration process as well as withstand flows through the system. Vegetation selection is heavily dependant on the regional climate. Flow and water level variations and maximum velocities are important considerations and can be controlled with an appropriate outlet structure.

Different zones in a macrophyte system perform different functions. Ephemeral areas are often used as organic matter traps. These areas wet and dry regularly and thus enhance the breakdown process of organic vegetation. Marsh areas promote epiphyte (biofilms) growth and filtration of runoff. Epiphytes use the plants as substrate and can effectively promote adhesion of fine colloidal particulates to wetland vegetation and uptake of nutrients. Generally, there are areas of open water surrounding the outlet of wetlands. These can increase UV disinfection and provide habitat for fish and other aquatic species.

Optimal detention times in the wetland (typically designed for 72 hours) ensure desired performance. The macrophyte zone outlet must be sized to accordingly. Multiple level orifice riser outlets are considered to give the most uniform detention times for wetlands. Sizing curves for wetlands are presented in Figure 9a, with TN the limiting design parameter. For a desired performance (typically 45% TN reduction), the required wetland surface area is calculated as a percentage of the impervious catchment area to be treated.

High flow bypasses are important to protect vegetation

Vegetation provides a key pollutant removal role

A high flow bypass is essential to protect vegetation

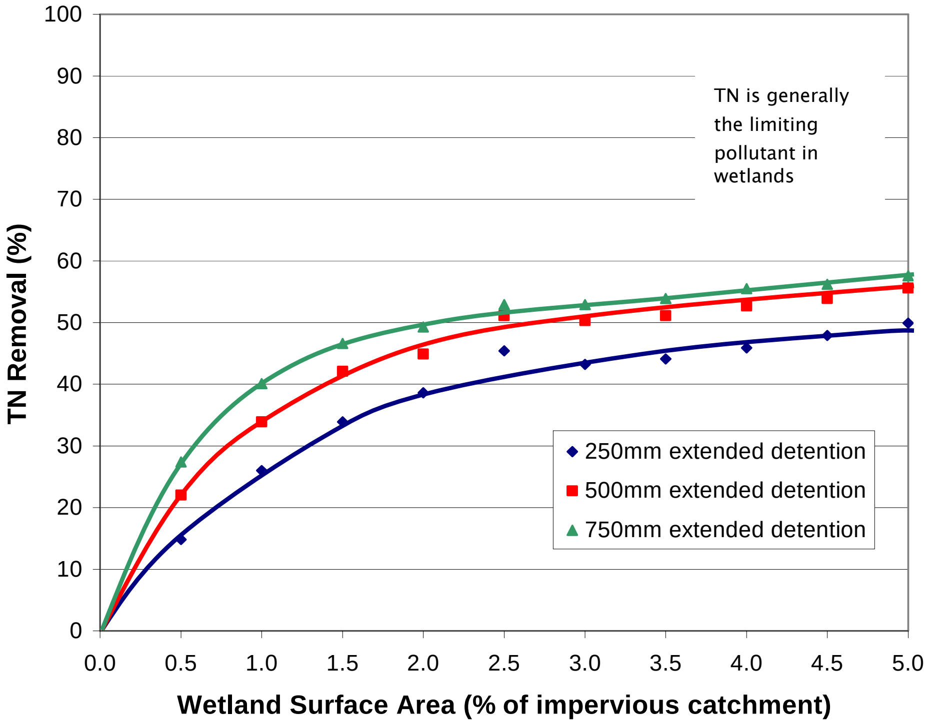
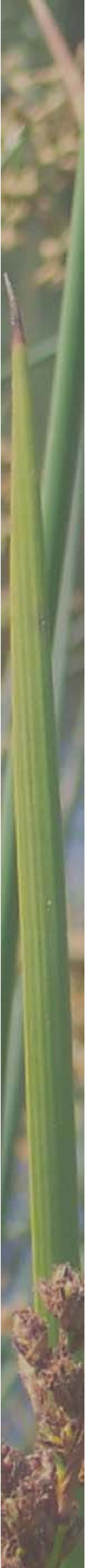


Figure 9a. Sizing curve for wetlands in Melbourne



Fact sheet 10: Subsurface flow wetlands

Wetlands are a complex assemblage of water, soils, microbes, plants, organic debris, and invertebrates. Subsurface wetlands are a proven technology to adequately remove organic matter and suspended solids. In subsurface flow wetlands all the flow is through the soil substrata (refer to Figure 10a). The soil typically has a high permeability and contains gravel and coarse sand. The bed is planted out with appropriate vegetation. As the flow percolates through the wetland biological oxygen demand (BOD) and total suspended solids (TSS) are predominately removed by biological decomposition.

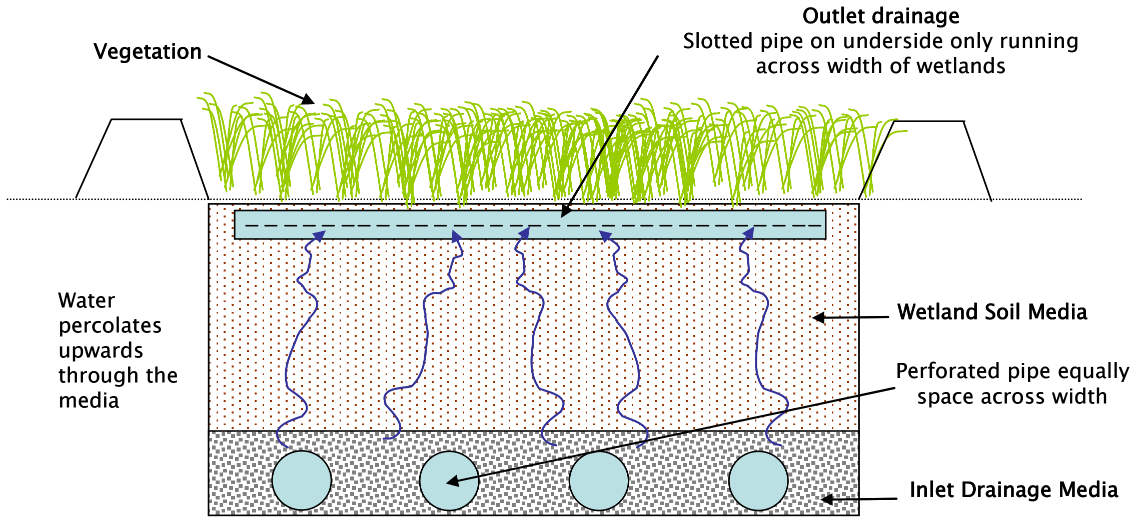


Figure 10a.Typical subsurface flow wetland

Subsurface wetlands are typically applied in wastewater treatment systems where there is a relatively consistent influent flow rate. In comparison, surface wetlands used to treat stormwater flows must be able to cope with variations in flows as a results of rainfall patterns. Subsurface flow wetlands provide a low cost, very low energy, natural treatment system.

Subsurface wetlands are a proven technology to adequately remove organic matter and suspended solids from greywater and blackwater. They are commonly used in Europe to treat greywater in high density developments. Subsurface wetlands have also been used in Australia to treat greywater from colleges and building at Charles Sturt University. A subsurface wetland is proposed to treat laundry water from the Department of Human Services housing to irrigate Fitzroy Gardens. Wetlands proved a good quality effluent with typical average effluent BOD and TSS less than 20 mg/l.

The environment with a subsurface wetland is mostly anoxic or anaerobic. Some oxygen is supplied to the roots which is likely to be used up in the bio mass growing there rather than penetrate too far into the water column and, for this reason, subsurface wetlands are effective in denitrification.

A frequently reported problem with subsurface wetlands is blockage of the inlet zones which then leads to short circuiting and surface flow. Attention needs to be given to good inflow distribution and the placement of larger aggregate within this inlet zone. Inlet apertures need to be large enough to avoid being blocked by algal growth.

Primary design criteria for subsurface flow wetlands are as follows:

- detention time
- organic loading rate
- hydraulic loading rate
- media size
- bed depth
- aspect ratio.

Typical Sizing

A rule of thumb sizing for wetlands is 1-2m^2 of surface area per person. The design is dependent on water quality, specifically BOD concentration. Depths of SSF wetlands are typically half a metre but no more than 0.6 m.

Maintenance

SSF wetlands require routine operation and maintenance. Maintenance procedures include routine monitoring of the distribution and collection systems, and removal of settled sludge from the pre-treatment tank. Dead plant material does not need to be removed from the wetland, however routine weeding of the wetland system is required.

Typical Cost

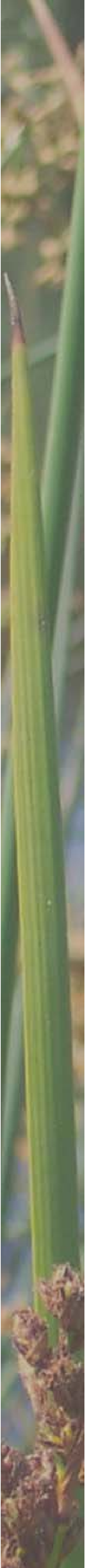
Typical cost for a wetland to treat greywater for 500 people are $100,000 to $150,000, although costs will vary depending on the actual site.

References

The CERES biofilter employs a reed bed to treat its wastewater. Subsurface wetlands typically form a component of the landscape on the site and thus form an integral part of the aesthetics of the residential development. CERES biofilter – www.ceres.org.au

Typical overseas design criteria are provided in Crites and Tchobanoglous (1998) Small & Decentralized Wastewater Management Systems, McGraw-Hill.

Note: The general guidance on subsurface flow wetlands has been broadly sourced from DNRM (2000).



Fact Sheet 11: Biological processes – suspended growth systems

Biological treatment is engineered to accelerate natural biological processes and efficiently remove soluble and some insoluble pollutants for water. Suspended growth systems refer to those where micro-organisms are freely suspended in water. They are primarily designed to oxidise both organic and ammonium-nitrogen (to nitrate nitrogen), decrease suspended solids concentrations and reduce pathogen concentrations. Two examples of suspended growth system, the activated sludge process and the sequencing batch reactor, are described below.

Activated sludge process

Activated sludge is a suspension of micro-organisms in water. The micro-organisms are activated by air that provides oxygen and hence the activated sludge process is an aerobic suspended-growth process. The process usually occurs in 2 distinct phases and vessels; aeration followed by the settling. A relatively high proportion of micro-organisms are maintained by recycling settled biomass back into the treatment.

The activated sludge process is typically continuous-flow with aerobic suspended-growth. The process maintains a high population of micro-organisms (biomass). There are two main mechanisms that remove organics:

1. Biomass oxidises and synthesizes the soluble and colloidal organic matter into cell mass and metabolic materials.
2. Suspended organics are flocculated with biomass and settle.

Aeration, typically supplied by air and dispersed through the reactor is essential to encourage metabolism and enhance mixing. By-products formed are substrate removal and growth and products of microbial maintenance and cell lysis. Treatment efficiency can be assessed by comparing total BOD to soluble BOD (or COD).

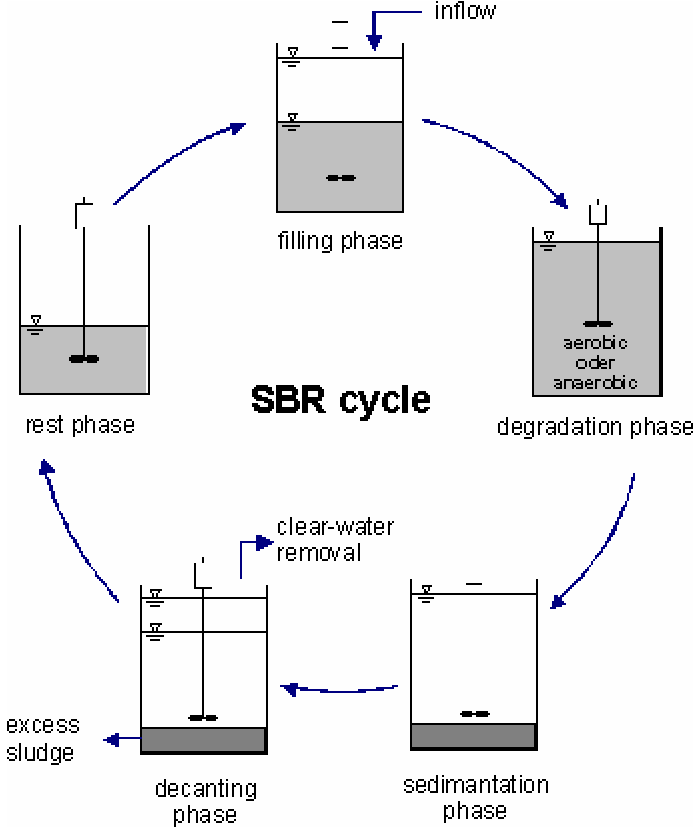
Natural flocculation and biomass settling characteristics will separate sludge in a sedimentation device typically a clarifier or sediment basin. Recycling a portion of the sludge to the aeration basin is essential to maintain a healthy ‘stock’. Processing and disposal of the relatively large sludge must be considered in the design and operation.

The mixing regime within the reactor is critical for optimal performance. Reactors can either be a well-mixed or plug flow reactor. The Retention time influences food to micro-organism ratio sludge age. Higher sludge age cause endogenous decay.

This treatment is suited to blackwater treatment due to the high organic concentration. A minimum nutrient level is also required for optimal performance. Hence more suited to black water rather than grey water.

Sequencing batch reactor (SBR)

A sequencing batch reactor (SBR) is an activated sludge process where all the main treatment steps occur in the same reactor (refer to the figure). A sequence occurs within a batch reactor of filling with influent, react (usually with aeration), settle, draw and decant and then idle. The fill time depends on the reactor volume. Operation, specifically the aeration and idle times, anoxic or anaerobic fill period. The variation on this true batch reactor is a continuous flow reactor that fills and withdraws during the cycle.



Treatment variations

Pure oxygen activated sludge process aerate with conventional activated sludge processes with pure oxygen and usually requires supplementary mixing due to the decreased gas flow rate.

Powdered activated carbon activated sludge process add activated carbon to enhance treatment particularly by adsorption and provide a surface for biofilm growth.

Advanced biological processes create conditions to suit specific microbial processes targeting enhanced Nitrogen removal and phosphorus uptake.

Typical Sizing

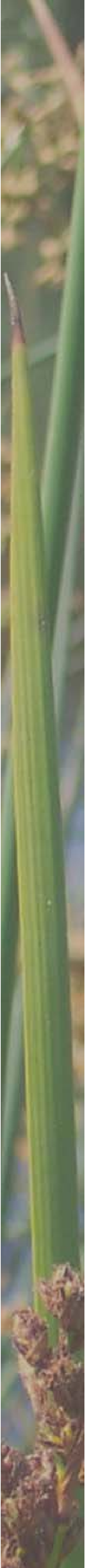
For a flow of 40-50 kl/d an area of $20m^2$ is typically required. As a typical rule of thumb the footprint of for a suspended growth system is about $0.1m^2$/person.

Maintenance

All mechanical inputs will require regular maintenance. De-sludging of the reactor vessels will also be required periodically. Operation costs include pumps and energy costs to operate the aerator.

Typical Cost

$150,000-200,000 for a complete suspended growth system.



Membrane Bioreactor (MBR)

A membrane bioreactor (MBR) combines the process of a biological reactor and a membrane filtration (refer to fact sheet 14) into one process. The treatment process has a small footprint and high quality effluent with low TSS, BOD, and turbidity. These are relatively new processes with a demonstration plant installed at Werribee.

There are two basic configurations for a MBR: a submerged integrated bioreactor that immerses the membrane within the activated sludge reactor and a bioreactor with an external membrane unit.

MBRs provide a proven and reliable treatment technology and have been used extensively in Japan for greywater and blackwater reuse systems. MBRs that combine filtration and biological treatment in one system provide a small footprint and replaces the need for a separate filtration process. MBRS also provide very high quality effluent and will meet almost all health criteria guidelines.

Membrane life is an issue due to the cost to replace the membrane. In some cases, operating experiences has shown membranes need to be replaced every 2 years as opposed to the design of 5 years. Control of membrane fouling is an important operational issue. If fouling is not controlled, membranes will wear quicker, and there will be increased energy costs and decreased in effluent quality. MBRs also have higher capital cost and energy costs than other treatment systems.

Typical Sizing

MBRs have a small compact footprint with less than 0.1 m^2 per person required.

Typical Cost

$400,000 for a 100kL/day plant with operating costs for maintenance and membrane replacement approximately $25,000 per year.

Suppliers

There are a range of suppliers of MBRs including:

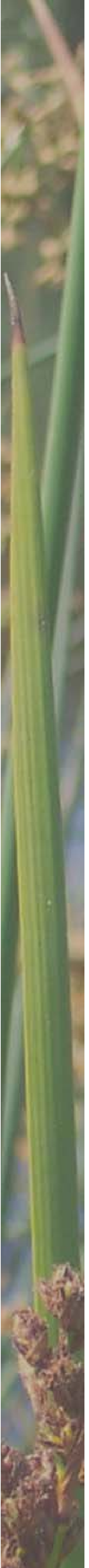
- Environmental Solutions International: www.environ.com.au/ (Supplier of Kubota MBR's)
- Aquatec-Maxcon: www.aquatecmaxcon.com.au/sewagetreatment/
- Vivendi's package treatment plant - The membrane bioreactor consists of an activated sludge process followed by a microfiltration plant housed as a skid mounted package plant. An optional chemical dosing system for phosphorous removal can be included (www.vivendiwater.com.au).

Refer to www.membrane-bioreactor.com for more information.

Other treatments and references

This fact sheet presents a summary of the key biological treatments suited to the City of Yarra. There are other technologies such as anaerobic digesters suitable for high organic loads which may be suitable for certain applications.

- Environmental Solutions International – www.environ.com.au/sbr.shtml
- Testech Engineering Group www.te-group.net/ – BIOJET™ SBR system
- Aeroflo activated sludge process 'IDEA' www.aeroflo.com.au/index.html – single reactor batch system.



Fact sheet 12: Biological processes - Fixed growth

Biological treatment systems are primarily used to remove dissolved and colloidal organic matter from water. Biological treatment promotes natural processes to breakdown high nutrient and organic loading waters. Fixed growth refers to systems where the micro-organisms are attached to a surface that is exposed to the water. Typical fixed film growth systems are trickling filters, rotating biological contactors, and membrane bioreactors; each are briefly discussed in the fact sheet.

Trickle filter

A trickle filter is an aerobic fixed film biological reactor. In a trickle filter, water trickles over a bed of media. The fixed biological film is attached to the media's surface. Oxygen is provided by the natural or forced aeration through the media. The soluble organic matter is transported to the biological film. Here the biofilm attached to the porous media metabolise the soluble and colloidal organic matter. Thereby reducing the organic content and treating the water.

A large surface area and high void volume promotes efficient treatment. This ensures good contact between the organics in the water and a high oxygen concentration for metabolism. A highly variable microflora populate a trickling filter, with bacteria the main microbial group. Synthetic media is used for efficient biofilm growth however it is expensive and typically rock or plastic pieces are used. The voidage enables aerobic growth as the trickling water naturally aerates as it passes over.

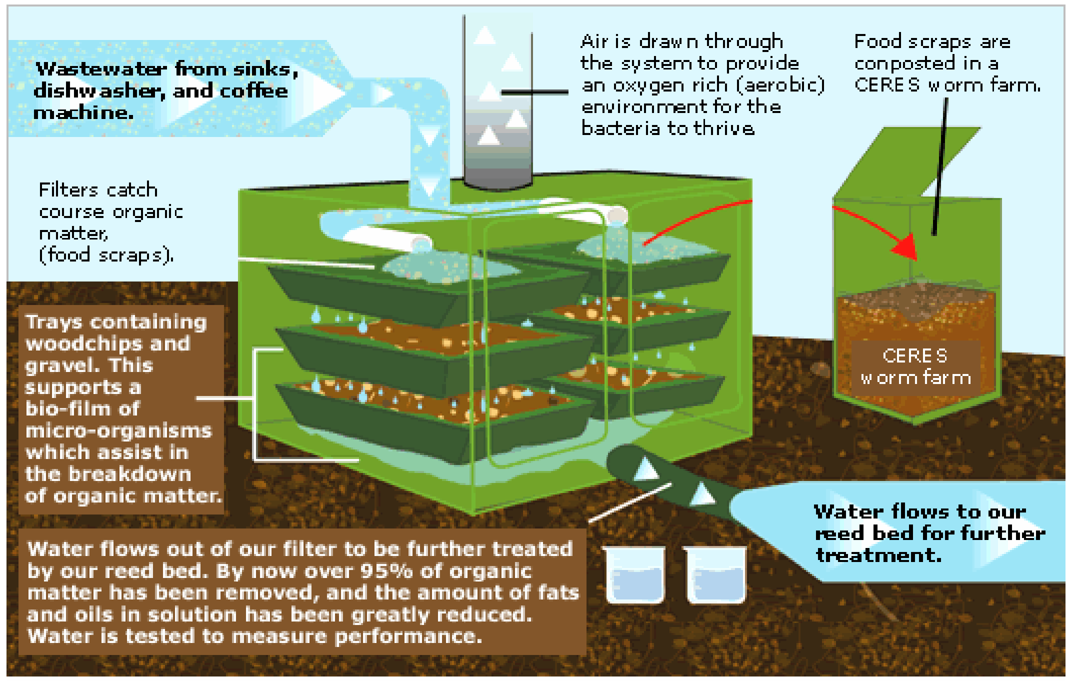


Figure 12a. An example of a trickle filter – the CERES biofilter (www.ceres.org.au)

After treatment, the biomass (combination of the biological products) can be separated by settling or wetland. Filtration is not a significant removal mechanism in this biological process. Variations of the process include 1 or 2 stage trickle filters with the incorporation of clarifiers (a sedimentation separation device with smaller space requirements).

Rotating biological contactor (RBC)

The rotating biological contactor (RBC) is a modified form of a trickling filter. It uses rotating discs to support active biofilm growth. This biofilm metabolises and hence removes organic material from the wastewater.

RBCs are available in "package treatment plants" which allow for ease of installation and operations. These plants contain a primary sedimentation tank, the biological chamber, a secondary clarifier and a sludge storage zone. They come packaged in containers with their own electrical device and remote telemetry systems.

The rotating shaft naturally aerates the biomass. Typically wastewater flows perpendicular to the discs and flows under gravity and displacement. The RBC has a number of baffled chambers to ensure a well mixed reactor. Rotation also causes biomass "sloughing" (excess biomass sliding) from the discs. Thus to remove the biomass and suspended solids sedimentation typically clarification is required.

Figure 12b. Example of a rotating biological contactor

For the City of Yarra application, the RBC typically has a small footprint making them suitable for medium to high density applications. Water quality and quantity determine media sizing and hence unit size.

Typical Sizing

Fixed growth biological systems have a small compact footprint. They require a footprint of approximately $30-40m^2$ to treat a flow of 20 kl/d with a minimum height of 2m. They are suitable for location in the basement, and require adequate ventilation.

Maintenance

Maintenance requirements shows that approximately 2-3 hours are required each month with an annual maintenance check of 6-8 hours is required. Generally fixed growth systems are self cleaning on a day to day basis and alarms can be connected to telemetry systems.

Typical Cost

$150,000-200,000 for a complete fixed growth system.

Suppliers

There are a number of suppliers of RBC and trickling filter package treatment plants in Australia. Further information about specific systems can be obtained from the following suppliers:

- EPCO Australia www.epco.com.au/
- Water Recycled Group: www.waterrecycle.com.au (slightly modified RBC package plant)
- Diston Sewage Purification www.distonsewage.com.au/RBC.htm
- The Novasys Group: www.novasys.com.au/ (supplier for Gmbh – a supplier of RBCs used in Germany for greywater reuse)
- Aquapoint's Bioclere: www.aquapoint.com
- Enviroflow: www.enviroflow.com.au

Fact sheet 13: Recirculating media filters

Recirculating Textile or Sand Filters

Recirculating textile filters (RTF) and recirculating sand filters (RSF) are both biological treatment processes removing organic material from the wastewater. The main difference being the filtration media, namely sand or textile. Recirculating textile filters are similar in nature to trickling filters, however the media used for the growth of biofilms are textiles rather than plastics or rocks. RTFs are available in small compact footprint package plants, suitable for decentralised treatment.

The RTF and RSF consist of two major components. The first component is the biological chamber and low pressure distribution system (shown on right). The wastewater flows between and through the non-woven light-weight textile material in the RTF and through a bed of sand in the RSF.

The second major component is a recirculating tank and pump which pumps typically 80% of the filtrate back to the chamber. The pump fills the chamber every 20 to 30 minutes. The remaining effluent can be diverted to a storage tank or disposed of.

The recirculating filters are packaged systems; the media, the container, the distribution system, recirculating tanks and pumps and also a telemetry system for external monitoring.

Recirculating filters (RF's) can provide reliable low maintenance treatment system for decentralised wastewater systems. Recirculating filters can also provide a high quality effluent of less than 10 mg/l BOD and TSS. RFs have been proven for single lot dwellings but their applicability to the treatment of greywater in high density applications is not well studied, although results from single dwelling lots show good results.

Recirculating sand filters have been used for treatment of greywater with good results in single dwelling houses. The Healthy Home in Queensland is one example where effluent quality of treated greywater has been high with less than 10 mg/l BOD and TSS and for faecal Coliforms less than 10cfu/100ml.

A variation on the design is the single pass sand/textile filters. In this case, no recirculation tank or pump is required. A larger filter is required for equivalent performance.

Maintenance

Recirculating filters require routine maintenance systems. The maintenance requirements are typically low and are not complex. Maintenance should include monitoring the distribution system to the filter, maintaining and replacing the filter surface as necessary and flushing the distribution system manually.

Typical Sizing

RTFs are available in small compact footprint package plants. To treat a flow of 20 kL/d, an RTF requires 15-20m^2 with a hydraulic loading of 100 to 180 cm/d. Compares to a RSF requiring a 100m^2 with a hydraulic loading of 20 to 30 cm/day.

Typical Cost

These systems typically cost $100,000-200,000 for a complete re-circulating filter system.

Suppliers

Innoflow technologies www.innoflow.co.nz/ (Australian and NZ Supplier of Orenco Systems)

Figure 13a. Water distribution for a recirculating textile filter

Fact sheet 14: Filtration – sand and depth

Filtration is a tertiary treatment process that typically occurs after the secondary biological process. Filtration may be required to remove residual suspended solids and organic matter for more effective disinfection. There are two major types of filters; sand and depth filtration (fact sheet 14) and membrane filtration (fact sheet 15).

Introduction

Filters have been used for water treatment for over 100 years. Sand (or other media) filters typically treat settled wastewater effluent. For onsite treatment, sand filters are usually lined excavated structure filled with uniform media over an underdrain system. The wastewater is dosed on top of the media and percolates through to the underdrain system. Design variations include recirculating sand filters where the water is collected and recirculated through the filter (refer to fact sheet 13).

Sand filters are essentially aerobic, fixed film bioreactors. Straining and sedimentation also occur, removing solids. Chemical adsorption to media surfaces removes dissolved pollutants (e.g. phosphorous).

Sand Filtration

The water is applied to the top of the filter and allowed to percolate through the media. With time the headloss builds up and the filter media has to be cleaned by backwashing. The principal removal mechanism is by straining where particles larger than the pore space are strained out and smaller particles are trapped within the filter by chance.

The hydraulic flow rate determines the dominant pollutant removal mechanisms. Pollutants are physically removed by infiltration. Larger particles are retained within the filter media by filtration. If organic they will be decomposed during low dose periods.

Typically a biofilm forms on upper layers. This layer assists in the adsorption of colloidal pollutants and encourages oxidation of the organic material. For effective microbial control, low flow is desired through the sand filter. This ensures contact between the sand media's biofilm and water. During low flow, the interstitial spaces between the sand granules enable oxygen to diffuse to the biofilm and encourage oxidation of organic material.

There are a number of different designs for sand filters based on the type of media, whether the operation needs to be taken off line to be backwashed, and whether the flow is up or down through the sand filter.

Design considerations

- Type and size of filter media
- Filter bed depth
- Hydraulic loading rate
- Organic loading rate
- Dosing frequency and duration

Maintenance

Maintenance needs to ensure that:

- there is no build up of oil and grease on the filter media,
- agglomeration of biological flocs, dirt and filter media into mudballs which cannot be effectively backwashed does not occur, and
- loss of filter media is controlled.

Typical Cost

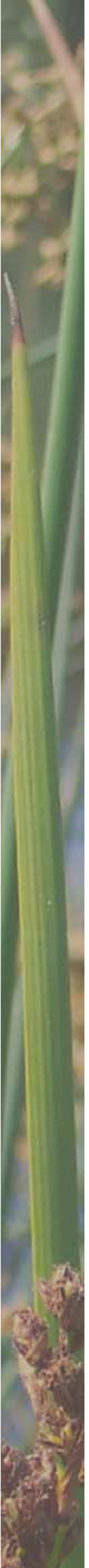
A simple sand filter product with a small footprint can be provided as a package system. For example Aquatec Maxcon provide a small footprint pressure sand filter for approximately $20,000. These systems have an automatic backwash system built in which is controlled by headloss or effluent quality. It may be possible to adapt cheaper pool filters ($1000) used for filtering swimming pool and spa water for the purpose of tertiary filtration also.

Depth Filtration

Depth filtration is a variation of a sand filter. Depth filtration uses a granular media, typically sand or a diatomaceous earth, to filter effluent. Typically there are four layers of filter media. The particle size decreases through the filter's layers. The coarser top layer removes larger particles and finer material is removed towards the lower layers. Thus pollutants are filtered throughout the bed and increasing the efficiency overall filter efficiency (compared to a conventional sand filter).

Maintenance and design considerations are similar to sand filtration.

Figure 14a. Typical sand filtration plant



Fact sheet 15: Membrane Filtration

Membrane (or cross flow membrane) filtration is a physical separation process to filter pollutants using a semipermeable media. There are four classes; micro-filtration (MF) has the largest pore size, decreasing to ultra-filtration (UF), nano-filtration (NF) and finally reverse osmosis (RO). As water is passed through a membrane under pressure, it 'squeezes' through the structure. The membrane selectively traps larger pollutants. The feed stream is effectively split into two effluents: a purified stream and a waste stream.

Membrane filtration processes can remove particles, bacteria, other micro-organisms, particulate matter, natural organic matter (NOM) and salt (desalination) with removal determined by the membrane's pore size as shown in the figure below. As the pore size decreases smaller pollutants can be removed and pressure requirements increase. The smaller pore size requires greater pressure and hence greater energy requirements for effective treatment. The pressure requirements, pore size and typical pollutant removal are summarised in Table.

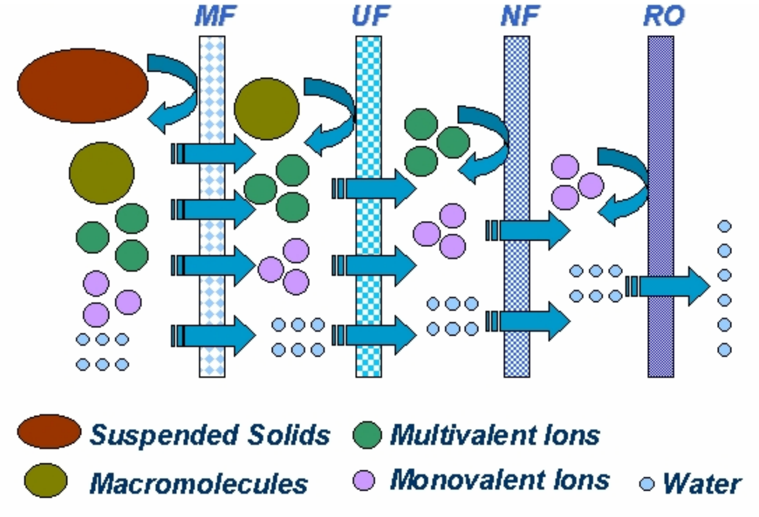


Figure 15a. Types of membranes and membrane selectivity reproduced from Bhattacharjee et al (1999).

The continued innovation and modular design of membrane filtration processes is advantageous for small scale applications from an operational and economic perspective. Now membrane filtration systems are available in modular package treatment plants, well suited for sewer (water) mining, grey water treatment and groundwater treatment.

Selection issues

Desired water quality, and water end use, pollutant size and type present will influence the chosen membrane process.

Membrane fouling is expected and occurs due to pollutant build-up on the membrane surface. Fouling is typically managed by a quick backwash system, integrated into the plant's operation. Periodically chemical cleaning is required to rejuvenate the membranes. Membranes have a finite life and are typically replaced every 2-5 years.

Design issues

Water quality and space available will determine membrane configuration. Pre-treatment may be required to remove larger particles, natural organic impurities and thereby improve process effectiveness. UV disinfection after filtration is recommended for microbial control.

Higher operating pressure increases permeate flow thereby increasing efficiency but also increases the fouling rate. Higher flow velocity across the membrane reduces the fouling. Thus an optimal operating condition exists between flow and pressure.

Adequate provision for the waste disposal stream is necessary. Membrane processes produce a waste stream, typically 15% of feed but can be as high as 50% in some RO operations. Waste disposal must be considered during design. For sewer mining, the waste stream is typically directed back into the sewer.

Table 15a Membrane filtration key features summary

Filtration	Pore size	Operating pressure	Typical target pollutant
Micro filtration	0.03 to 10 microns	100-400 kPa	Sand, silt, clays, *Giardia lambia, Cryptosporidium*
Ultra filtration	0.002 to 0.1 microns	200-700 kPa	As above plus some viruses (not an absolute barrier) Some humic substances
Nano filtration	Approximately 0.001 microns	600-1,000 kPa	Virtually all cysts, bacteria, viruses and humic materials
Reverse Osmosis	Approximately 4 to 8 Å	300 - 6,000 (or 13,000kPa - 13.8 bar) kPa	Nearly all inorganic contaminants Radium, natural organic substances, pesticides, cysts, bacteria and viruses Salts (desalination)

Reverse Osmosis

Reverse osmosis (RO) is the finest membrane filtration process with the smallest pore size, estimated to be around 4 to 8 Angstroms (about the size of a molecule) and thus has the highest pressure requirements. RO removes most pollutants including pathogens, viruses and salts. It is typically used for sewer mining or desalination. RO can separate ions (dissolved salt) from water and hence produces very high quality water. A very high pressure (determined by the osmotic pressure and ionic concentration) is required. This high pressure results in a high energy requirement. The small pore size can be more readily blocked (or fouled) and thus regular maintenance is required. Fouling can be managed by upstream water treatment such as sedimentation. Reverse osmosis units are particularly effective when used in a series configuration.

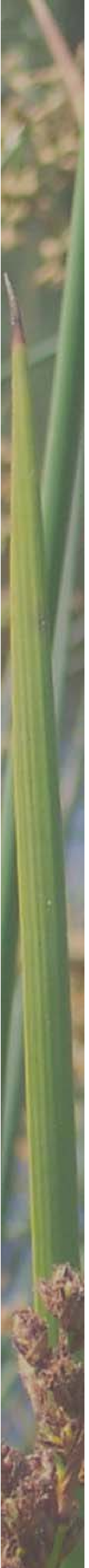
RO membranes are typically constructed from cellulose acetate and polyamide polymers. Chlorine concentration has the potential to damage RO membranes. The cellulose acetate can tolerate chlorine levels used for microbial control whereas any chlorine present will destroy the polyamide polymers.

Typical costs

Membrane filtration plants range dependent on pore size and operating pressure. Membrane filtration plants start from approximately $60,000 for a 50kL/day with a typical cost for a combined microfiltration and reverse osmosis plant to treat 100kL/day is $750,000.

Suppliers

- Waste Technologies of Australia: www.wastetechnologies.com/MWR.htm
- Veolia Australia – www.vivendiwater.com.au
- GE water – Osmonics – www.gewater.com/
- US Filter – Memcor – www.water.usfilter.com/



Fact sheet 16: Disinfection

Disinfection minimises pathogenic microorganisms and thereby ensures public health. Disinfection destroys pathogenic microorganisms in water. Eradication of waterborne pathogens is the most important public health concern for water treatment.

Disinfection ranges from boiling water to large scale chemical treatment for water supplies. The three most common disinfection methods are UV radiation, chlorination and ozonation.

UV disinfection

Ultraviolet (UV) disinfection uses UV light to inactivate micro-organism in water. The short UV wavelength irradiates the micro-organisms. When the UV radiation penetrates the cell of an organism, it destroys the cell's genetic material and thus its ability to reproduce. UV disinfection has low capital and operating cost, easy to install and operate and is well-suited to small-scale water treatment processes.

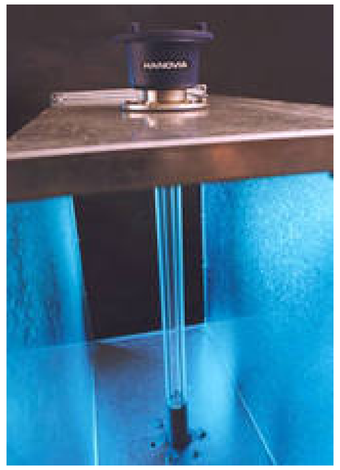


Figure 16a. UV disinfection – small scale

UV provides reliable a low maintenance disinfection system without the need to handle or store hazardous materials.No chemicals are required and odour minimised. This eliminates hazardous chemical handling and storage on site. Additionally no harmful by-products are formed. UV disinfection is a physical process and it is independent of pH and temperature has minimal impact.

UV disinfection effectiveness depends on the water quality and characteristics. The main characteristics determining UV disinfection's effectiveness are:

- Intensity of UV radiation
- Amount of time exposed
- Reactor configuration
- Concentration of colloidal and particulate constituents.

UV radiation intensity is dependent on source, typically the distance between the lamp and water. Thus reactor design should ensure uniform flow with maximal radial motion. This ensures a well mixed water flow that is well exposed to the UV radiation. In natural system, UV radiation supplied by the sun provides limited disinfection.

Usually UV disinfection systems are installed towards the end of the treatment train to minimise fouling and interference with colloidal and particulate constituents. Suspended solids reduce UV effectiveness by reducing transmission and shielding bacteria. Cleaning is essential to ensure effective UV transmission. Maintenance program is required to manage UV tube fouling.

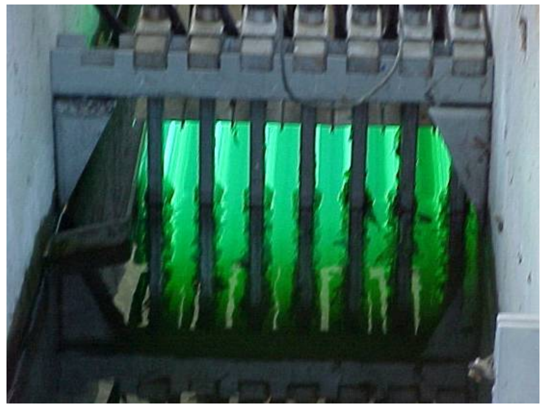


Figure 16b. UV disinfection – large scale

Chlorination

Chlorine is the most common water disinfectant. Chlorine, a strong oxidant, can either be added in the gaseous form (Cl_2), hypochlorous acid or as hypochlorous salt (typically $Ca(OCl)_2$). Chlorine addition requires chemical handling and storage. By-products of chlorination could be carcinogenic, with particular concern and research to understand trihalomethanes (THM's).

Chlorine provides residual microbial control, that is, it continues to disinfect water after it has passed through the treatment process. It is typically selected for potable water supply systems. Optimal chlorination dosage is dependent on the concentration and water pH and temperature. The pH exerts a strong influence on the chlorination performance and should be regulated.

Chloramination is the mix of chlorine dosing with ammonia for disinfection. It is designed to reduce by-product formation and reduce THM concentrations. Chloramines are longer lasting in water and provide a degree of residual protection.

The disadvantage of chlorination water lies in the residual unpleasant taste and odour.

Ozonation

Ozone is a more powerful oxidising agent that other disinfectants. Ozone is created by an electrical discharge in a gas containing oxygen, i.e. $3O_2 \rightarrow 2O_3$

Ozone production depends on oxygen concentration and impurities such as dust and water vapour in the gas. The breakdown of ozone to oxygen is rapid. It is impossible to maintain free ozone residuals in water for any significant time.

Reference

US EPA (1999) Ultraviolet disinfection, report EPA 832-F-99-06.