

Exploring pre-filtering for water sensitive urban design systems in Australia

L'exploration des pré-filtres pour une conception durable de la gestion de l'eau urban en Australie

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RESUME

La conception urbaine sensible de l'eau est une nouvelle philosophie de la gestion de l'eau étant développée dans l'Australie qui embrasse des principes de sustainability pour réduire les impacts du développement sur tout le cycle de l'eau. Critique à l'exécution réussie d'un système de WSUD est la première identification des polluants prévus, de l'évaluation des contraintes d'emplacement et de l'adoption des commandes appropriées dans des "trains de traitement". Cet papier présente les commandes qui peuvent être employées comme pré-filtre et assemble des résultats et les recommandations au traitement efficace de document s'exerce en utilisant le pré-filtrage et d'autres bonnes pratiques en matière de conception.

ABSTRACT

Water Sensitive Urban Design (WSUD) is a new philosophy of water management being developed within Australia that embraces sustainability principles to reduce the impacts of development on the total water cycle. Critical to the successful implementation of a WSUD system is the early identification of expected pollutants, assessment of the site constraints and the adoption of appropriate controls in "treatment trains". This paper presents controls that can be used as a pre-filter and collates results and recommendations to document effective treatment trains using pre-filtering and other good design practices.

KEYWORDS

water sensitive urban design, pre-filter, source control, treatment train

1. INTRODUCTION

Since the introduction of water sensitive urban design (WSUD) philosophies in Australia, a number of WSUD systems have been installed that integrate various controls into “treatment train systems”. Some of these WSUD systems have been very successful. However, many have been poorly designed, primarily due to the lack of an integrated approach in their design, operation and management and a failure to identify the expected pollutants and site constraints at the beginning of the process. Consequently, some of these systems are becoming long-term liabilities to the community, and this can act as an impediment to the future adoption of WSUD.

Extensive studies have been undertaken to better understand these treatment systems and the situations in which they are most effective. In both New South Wales and South Australia rainwater tanks, stormwater infiltration systems, and wetlands have been studied extensively (Coombes, 2002, Beecham, 2001, and Argue, 2001). In Victoria, the Cooperative Research Centre for Catchment Hydrology has been researching bio-retention systems, swales, wetlands and ponds (Lloyd, 2002, Fletcher, 2002, and Wong, 2000).

This paper documents effective treatment trains using pre-filtering and other good design practices based on these and other case studies.

2. THE SUNBURNT COUNTRY

Australians live on the driest inhabited continent on earth. Because of this, our population has settled where water is most available with approximately 80% of Australians living near the coast. There is enormous variability in rainfall and stormwater runoff across Australia from year to year, however in its cities up to 90% of rainfall can potentially become stormwater runoff.

Traditional potable water supply and separate wastewater and stormwater drainage infrastructure systems have been developed in Australia since settlement. These engineered potable, wastewater and stormwater systems are efficient at collecting and transporting water, however they represent a profound change from the natural water cycle. For the two largest cities in Australia, Sydney and Melbourne, the volume of discharged stormwater is similar to the amount of water imported into the area for water supply (see Figure 1).

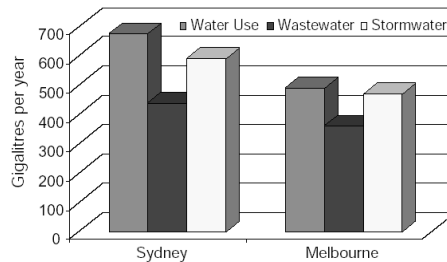


Figure 1 - Water Flows in Melbourne and Sydney (from Mitchell et al, 1999)

With Australia’s rapidly growing urban population, there is an increased demand for new infrastructure and increasing pressure on the current aging infrastructure and receiving waters. Many of Australia’s rivers, lakes and coastal waters are currently degraded due to the effects of urban stormwater infrastructure and runoff. Major

changes are needed in the way urban areas in Australian cities are designed and how water, in all its forms, is managed.

3. WSUD - A NEW WATER MANAGEMENT PHILOSOPHY

WSUD emerged in Australia during the early 1990s as a new approach to water management that embraces sustainability principles to reduce the impacts of development on the total water cycle. WSUD embraces the concept of integrated land and water management, and in particular integrated urban water cycle management. WSUD is a natural systems based approach comprising controls in “treatment trains” which use a combination of source, conveyance and discharge controls. Controls used in WSUD treatment trains employ the use of primary, secondary and often tertiary treatment devices, including:

Primary	Secondary	Tertiary
rainwater tanks	grass swales	wetlands
litter baskets	filter strips	ponds
racks and booms	infiltration trenches and basins	sand filters
sediment traps	porous pavements	bio-infiltration
gross pollutant devices	extended detention basins	
catch basins	bio-infiltration	
oil and grit separators		

Table 1 - Typical Primary, Secondary and Tertiary Treatment Devices

Source controls are used to minimise the generation of excessive runoff and pollution of stormwater at or near its source. Source controls are located at the allotment scale and can apply to single dwellings, multi-storey apartment complexes, commercial and industrial premises, and to roads. Source controls are typically a combination of primary and secondary treatment devices. It is now well documented that physical trapping of gross pollutants, coarse sediments and sedimentation should occur before any biological or chemical processes can be applied effectively (Lloyd, 2002).

Conveyance controls are used in transporting the flows from the allotments, roads and public open spaces. These controls use a combination of primary and secondary treatment devices.

Discharge controls occur at the point where stormwater leaves the total site or catchment. These controls usually employ a combination of secondary and tertiary treatment devices.

4. PRE-FILTERING – A FORGOTTEN STEP?

One of the major problems associated with the failure of WSUD systems has been a lack of adequate pre-filtering of stormwater flows (Beecham, 2001). It is estimated that in Sydney, an average of 5kg of sediment is generated on a typical single dwelling residential roof every year (Beecham, 2001).

The purpose of a pre-filter is to remove litter, organics and sediment from the stormwater prior to further treatment or discharge. Therefore pre-filters are typically used as a primary treatment device prior to reuse, infiltration or conveyance.

The primary treatment devices presented in Table 1 could all be considered as pre-filtering systems. Grass swales or filter strips can also be considered as pre-filters for other secondary and tertiary treatment devices.

4.1. Rainwater Tanks

Rainwater for reuse is usually collected from roofs and stored in tanks for both indoor and outdoor uses. The use of the rainwater determines the water quality requirements and the necessary treatment train. Subject to pre-filtering of the first flush and appropriate treatment systems, water quality that meets the National Health Guidelines can be achieved for both potable and non-potable uses. It has been demonstrated at Figtree Place in Newcastle (Table 2) that rainwater that is used for hot water purposes is safe for consumption (Coombes, 2000).

Parameter	Unit	Rain Water Quality	Roof Water Quality *	Supply Point Water Quality	Hot Water Quality	Australian Drinking Water Guideline
Fecal Coliforms	CFU/100 ml	0	146	20	0	0
Total Coliforms	CFU/100 ml	0	425	166	0	0
pH		5.95	5.35	6.06	4.44	6.5 - 8.5
Dissolved solids	mg/L	21	97.50	114.38	10.03	250
Suspended solids	mg/L	8.4	12.60	1.61	6.24	3
Sodium	mg/L	9.9	7.65	5.36	94.43	500
Calcium	mg/L	2	1.75	8.39	0.78	500
Chloride	mg/L	7.53	11.15	10.48	10.02	50
Nitrate	mg/L	0.15	0.15	<0.05	<0.05	250
Sulphate	mg/L	3.5	4.30	7.31	9.56	180
Ammonia	mg/L	0.295	0.11	0.27	0.18	0.5
Lead	mg/L	<0.01	0.01	<0.01	<0.01	0.01
Iron	mg/L	<0.01	<0.01	0.10	0.02	0.3

* Measured at a depth of 2-3mm

Table 2 - Water Quality Results, Figtree Place (from Coombes, Kuczera and Kalma 2003)

4.2. Litter Baskets, Racks and Booms

A litter basket is a wire, plastic or geo-fabric collection device that is installed within a stormwater pit that collects litter, organic material and coarse sediments either from a paved surface or from the piped stormwater system.

Litter baskets and pits require regular maintenance, particularly after storm events and in the autumn months. When full these devices reduce pit inlet capacities and cause flooding upstream. This can also remobilise captured material.

Litter racks are a series of metal bars located perpendicular to the flow across a channel or pipe. These devices capture large sized litter, organic matter and debris and are usually used upstream of other secondary or tertiary controls. Sediment is also usually trapped upstream of the rack, although rarely by design.

Litter racks require regular maintenance, particularly after storm events, to eliminate potential flooding upstream due to blockages, pollutant breakdown, odours and remobilisation. Litter racks are often difficult to clean.

Litter booms are floating devices that have mesh skirts attached and weighted below the float to capture floating litter and debris. These devices are usually placed downstream of outlets within channels or creeks.

These devices require frequent maintenance particularly after storm events and are can be difficult to maintain, especially if they are only accessible by boat.

4.3 Sediment Traps and Catch Basins

Sediment traps (or sediment basins) contain a permanent pool of water to slow down stormwater flows and trap coarse sediment. These devices can be in the form of a tank or a pond and can therefore be above or below ground. These traps provide limited fine sediment and soluble pollutant removal, and pollutants can be remobilised. For this reason, frequent maintenance of sediment traps is required to ensure sediment mobilisation in storm events.

Catch basins are stormwater pits located offline from the stormwater drainage system. They have depressed bases that accumulate sediment.

These devices are appropriate for highly trafficked areas with small catchments. Catch basins require regular maintenance (cleanouts are generally required quarterly and potentially after large storm events) as there is potential for sediment re-suspension and nutrient release.

4.4. Oil and Grit Separators

Oil and grit separators consist of a series of underground retention chambers to remove coarse sediment, hydrocarbons and floatables including oil and litter.

These devices are appropriate for small catchment areas with significant vehicular or hydrocarbon pollution such as car parking areas, workshops and service stations.

Oil and grit separators require regular maintenance to remove oil and floating debris to avoid re-suspension in storm events. As reported by NSW-EPA (1996), these systems do not provide a high level of performance generally, due to infrequent maintenance and the passage of high flows. Discharges from these traps, including overflows, should ideally be diverted to wastewater treatment facilities (Wong, 2000).

There has recently been a comprehensive study of Australian proprietary source control devices undertaken by Blacktown City Council to assess the effectiveness of a range of litter baskets, sediment traps and grease and oil products. The results are summarised in Table 3.

Pollutant	Device
Litter	Dencal, Ecosol
Litter + Sediment	Enviropod, Pit Bull, Suntime Technologies
Sediment	Streamguard
Sediment + Grease & Oil	Streamguard, Gullywasher, Suntime Technologies
Grease & Oil	Fossil Filter, Streamguard
Grease & Oil + Sediment + Litter	Streamguard, Suntime Technologies

Table 3 – Assessment of Source Controls (from Morison, 2000)

4.5. Gross Pollutant Traps

A gross pollutant trap (GPT) is a sedimentation trap and litter rack combined into a single device that can typically remove 80-95% of organic matter, litter and sediments greater than 2mm.

These devices are easily retrofitted and generally do not require a large footprint. They do require regular maintenance (typically every 3-4 months) and can be expensive to clean.

There are a number of different proprietary products available in various sizes that treat stormwater either in-line perpendicular to flow or offline by using mechanisms such as continuous deflection. The continuous deflection products claim to have higher rates of collection efficiency and can capture smaller particle sizes (depending on the screens used) than the in-line devices. However, these devices also retain trapped pollutants in a water column which may enable ongoing release of certain pollutants.

Hornsby Shire Council has a number of different proprietary GPT devices installed within their Council area. They have been monitoring these devices to determine the effectiveness of various types of traps.

Pollutants	In-line Device (m ³ /ha/yr)	Off-line Device (m ³ /ha/yr)
Organic Matter	0.04	0.28
Litter	0.01	0.06
Sediment	0.37	0.03

Table 4 – GPT Capture Rates (from Hornsby 2002)

4.6. Pre-filter Pits

The concept of a pre-filter pit has been developed and evaluated over recent years. A pre-filter pit is in itself a treatment train combining primary and tertiary controls. Anything entering the pit must first pass through a litter basket or bag before percolating through a filter and discharging downstream. Typically the filter media comprises layers of progressively porous material which is then wrapped in geotextile fabric. These pits are used where high rates of sediment removal are required to ensure the effective operation of devices downstream. These pits also concentrate the maintenance at the pit rather than over an extensive area (as in filter strips or grass swales) to allow for easy and regular maintenance.

A detailed investigation of the migration of pollutants in a pre-filter pit that contained sand overlying gravel has been undertaken at UTS (Heagney, 2002). The pit is located within a car park in Woy Woy, on the coast of New South Wales. This investigation found that the pre-filter pit was acting effectively for removal of gross pollutants and fine sediments. It was found that the first 5cm of the sand media contained the greatest concentration of pollutants

Pollutant	0cm Depth	5cm Depth	10cm Depth
Zinc (mg/kg)	950	72	56
Phosphorus (mg/kg)	1320	530	470
Organic Matter (%weight)	17	-	-

Table 5 – Pre-filter Pit Pollutant Loads (from Heagney 2002)

4.7. Filter Strips

Filter strips are grassed or vegetated areas that treat overland flow by removing sediments, particulate matter and associated pollutants like nutrients, metals and bacteria.

The use of filter strips to reduce particulates and associated pollutants has shown variable results, despite similar parameters being used during experimental testing. Parameters such as length of filter strip, slope angle, vegetative characteristics, catchment characteristics and runoff velocity are all recognised as factors which affect the pollutant removal efficiency of filter strips.

Work undertaken in the Tarago catchment in Victoria reported removal efficiencies of 98% for sediment regardless of the initial sediment load and overland flow rate with the sediment leaving the filter strips predominantly fine graded. The removal efficiency of total phosphorus was found to decrease significantly with increasing sediment input load and higher flow rates (Wong, 2000).

4.8. Grass Swales

Grass swales are grass-lined channels for conveying runoff from roads and impervious areas and can be used as an alternative to or in combination with a conventional kerb and gutter system.

One advantage of grass swales is that they decrease stormwater flow velocities. Grass swales also settle out suspended particulates due to the lower velocities and the grass acting as a filter. Work on the pollutant removal efficiencies of grass swales has been carried out by the Cooperative Research Centre for Catchment Hydrology on swales in both Brisbane and Melbourne. The 65m long grass swale at Pinjarra Hills residential estate in Brisbane recorded average reductions of total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) as 83%, 65% and 52% respectively (Fletcher, 2002). The 35m long bio-filtration swale at Lynbrook Estate in Melbourne, found similar results for TSS and TP removal with respective average reduction rates of 74% and 55%. There was however no effective removal of TN (Lloyd, 2001), although this could have been due to the short length of the swale.

5. RECOMMENDED TREATMENT TRAINS

Based on the research above a number of treatment trains are presented in Table 6. These treatment trains are specific to certain controls and end uses.

Control and Use	Treatment Train
RAINWATER TANKS	
Outdoor, Toilet and Hot Water	First Flush Filter + Rainwater Tank
Indoor (excluding drinking water)	Screened Roof Gutters + First Flush Filter + Rainwater Tank
Drinking Water	Screened Roof Gutters + First Flush Filter + Rainwater Tank + Point of Use Filter (UV or micro filter)
INFILTRATION TRENCHES	
Rainwater from Roofs	First Flush Filter + Infiltration Trench
Stormwater Runoff	Grass Filter Strip or Pre-filter Pit + Infiltration Trench
VELOCITY REDUCTION	
Residential Conveyance	First Flush Filter + Rainwater Tank + Grass Swale

DISCHARGE REDUCTION	
Urban Development	Grass Swale + Detention Basin + Pre-filtering Pit + Infiltration Basin
Limited Pervious Area	Porous Pavement + Bio-filtration Trench
HIGH QUALITY DISCHARGE	
Natural System Replication or Open Channel	Litter Rack or Boom + Sediment Trap + Wetland
Urban Development	Grass Swale + Bio-filtration Trench + Sedimentation Pond + Wetland
Reuse	Litter Baskets or GPT or Pre-filter Pit + Detention + Sand Filter
FINE PARTICULATE REMOVAL	
Residential Areas	Grass Swale + Bio-retention Trench
Commercial Areas	Pre-filter Pit + Bio-retention Trench

Table 6 – Recommended Treatment Trains

6. CONCLUSION

This paper has presented a number of source controls that act as pre-filters within a treatment train. Recent data on the effectiveness of particular devices has been presented to highlight the conditions under which these best operate.

The future development of WSUD in Australia is reliant on the development of effective treatment trains that are cognisant of their potential interaction with the water cycle. These treatment trains need to be integrated as part of the development to ensure that there are limited adverse impacts as a result of their implementation. Careful consideration of the potential pollutant loads and site constraints are therefore required in order to ensure efficient treatment trains and effective water sensitive urban design.

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