MID-TERM REVIEW

Indicators and approaches to monitor the performance of stormwater wetlands

Healthy Waterways Strategy 2018-2028 Port Phillip & Westernport, Victoria | Melbourne Water | RMIT University A3P

Strategic alignment

Regional Performance Objectives

RPO-18: Critical waterway health assets including stormwater treatment systems, fishways and erosion control structures, are maintained for their designed purpose or the same outcomes are delivered by alternative means.

Key Research Areas

Water Quality:
Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region.

Stormwater management and flooding: Improving stormwater treatment performance and determining the optimal maintenance of WSUD systems.

Stormwater management and flooding: What are the most effective stormwater treatment systems and locations to protect waterway biodiversity, amenity and recreation?

Summary

Water Sensitive Urban Design (WSUD) assets such as stormwater treatment wetlands and biofiltration systems are commonly constructed to help mitigate the impacts of urban stormwater on waterway health and to pre-treat stormwater for harvesting schemes that provide alternative non-drinking water. Stormwater wetlands are designed to function in the management of flows, treatment of nutrients, and detention of sediments and toxicants. They need to be managed appropriately to ensure long term performance is maintained. In collaboration with the Melbourne Waterway Research-Practice Partnership (University of Melbourne), this project identifies which toxicants are most problematic in stormwater wetlands in terms of desilting costs and impacts on wetland performance. It also seeks to develop cost-effective tools for ongoing monitoring of toxicants and associated impacts on wetland performance. Ultimately, there are 3 major themes that this project aims to address:
1) water quality treatment performance and optimal design,
2) managing unintended ecological risks and impacts and
3) reducing costs associated with desilting and waste disposal.

Knowledge of toxicant concentrations in wetlands enables better decision making in terms of frequency of maintenance (e.g., desilting) as well as identifying particular wetlands and catchments that may be the source of pollution. This knowledge also enables accurate quantification of risks associated with stormwater reuse and recycling. In addition, understanding how toxicants in wetlands affect biological indicators will assist in identifying specific wetlands at risk of failing performance objectives (e.g., nitrogen removal, vegetation cover).

Recommendations

- Concentrate management efforts on stormwater wetlands that have been identified as problematic in terms of toxicant concentrations and poor performance.

- Set targets in the Healthy Waterways Strategy (HWS) for measuring specific toxicants in wetlands (e.g., priority metals and Total Petroleum Hydrocarbons (TPH) in sediments and water; pesticides in water). This could be achieved through either the development of specific performance objectives relating to the measurement of toxicants in wetlands and/ or the development/ incorporation of a wetland toxicant monitoring program into the HWS Monitoring, Evaluation, Reporting and Improvement (MERI) framework and associated Monitoring and Evaluation Plans (MEPs).

- Enable flexible maintenance regimes for wetlands, so the maintenance schedules can be tailored to avoid sediment loads exceeding priority waste categories. This could be achieved through a wetland toxicant monitoring program, with triggers based on EPA priority waste categories or other relevant guideline values.

What did we do?

Literature review

A literature review provided a general description of stormwater management in Melbourne and a summary of existing knowledge of problematic toxicants in Melbourne stormwater wetlands. The review also outlined suitable research methods and types of biological indicators that could be used for monitoring wetland performance, which became the basis of the research monitoring program.

Identification of toxicants present in the sediment and water of wetlands

Toxicant screening using sediment, surface waters and passive samplers has been undertaken at 26 different wetlands around Melbourne, to identify which toxicants are present in sediments and waters and compare them to historic data as well as ecological and sediment disposal guideline values.

Are toxicants concentrations related to sediment particle size?

Poloso (2021) undertook sampling at 10 wetlands in 4 locations (Inlet, Macrophyte 1 & 2 and Outlet zones) to determine if toxicant concentrations vary according to sediment particle size and locations within the wetland treatment chain.

What features of the surrounding catchment are pollutants associated with?

Following an intensive sampling effort at more than 120 wetlands in late 2020, consistent with those wetlands sampled in the original Centre for Aquatic Pollution Identification and Management (CAPIM) 100 wetlands study in 2015, analysis of various catchment characteristics was undertaken to understand relationships between catchment landuse, age and the presence/concentrations of toxicants in these wetlands.

Monitoring the effect of toxicants on wetland ecology

Laboratory based pilot studies were undertaken to look at the toxicity of selected metals and pesticides on macrophyte growth and survival (as a critical component of stormwater wetland treatment performance), with the plan to develop these tests further with indigenous wetland species.

Impacts of pollution on biofilms and zooplankton in constructed wetlands

A study investigated the bioindicator potential of biofilms and zooplankton in constructed stormwater wetlands, using a crossed design microcosm study. Biofilms and zooplankton were collected from sites with varying levels of nutrient and pesticide pollution and exposed to different water quality conditions (Faraone, 2022).

What did we find?

Literature review

The literature review identified several factors that can influence toxicants in wetlands, including physicochemical properties, particle size distribution, surrounding catchment landuse activities and catchment geology.

The literature review also identified a list of indicators that can be used to determine wetland performance including:

- Direct measurement of water and sediment concentrations of TSS, TN, TP and toxicants
- Particle size distribution
- Algal growth and toxicity
- Macrophyte composition and biomass
- Microbial community composition and function (periphyton biomass, biofilms)
- Biomarkers of aquatic organism health

Research has continued to test several of these indicators, including direct measurements of toxicants in water and sediments, particle size distribution and relation to toxicant concentrations, lab-based ecotoxicity testing of algae and macrophytes to common wetland toxicants (metals and pesticides), and characterisation of periphyton and biofilm communities in wetlands. Biomarkers are also being developed for measuring oxidative stress in macrophytes (duckweed).

Indicators and approaches to monitor the performance of stormwater wetlands

Key findings: Constructed wetlands around Melbourne contain several different contaminants in water and sediments. Nine separate wetlands contained toxicants at concentrations that exceed 'clean fill' waste disposal guideline values and are expected to incur additional costs for disposal: 8 sites exceeded Zn values, 3 exceeded Ni values, 3 exceeded Cu values and 1 exceeded TPH values.

The most frequently detected contaminants (percent occurrence) across all wetlands – based on the CAPIM 100 wetlands study were:

- Metals (zinc, nickel, lead, copper, chromium 100%)
- Total petroleum hydrocarbons, (94%)
- Insecticides (bifenthrin, 77%, permethrin, 21%)
- Herbicides (diuron, 47%, prometryn, 17%)
- Personal care products (DEET, 65%, triclosan, 31%)
- Fungicides (pyrimethanil, 16%, trifloxystrobin, 10%)

Long term sediment quality monitoring in streams, wetlands and estuaries commissioned by Melbourne Water reported similar findings, with zinc, nickel, copper and lead found to be widespread and commonly exceeded ecological guideline values, whilst mercury, arsenic and cadmium tended to be more localised to specific sites within some catchments. Total petroleum hydrocarbons occur in high concentrations whilst other toxicants that have been measured include pesticides such as bifenthrin.

Identification of toxicants present in the sediment and water of wetlands

For several metals (Cd, Cr, Cu, Pb, Ni, Zn, Hg) and TPH, the concentrations in sediment exceeded Australian and New Zealand Fresh and Marine Water Quality guideline values (ANZG, 2018). The Default Guideline Value (DGV) is the concentration of a toxicant below which adverse ecological impacts are not expected. The Guideline Value-high (GV-high) is the upper guideline limit, and values that exceed this level are expected to be highly toxic to biota and cause adverse ecological effects. Results indicate variable concentrations of toxicants between inlets and outlets, but generally higher concentrations near the inlet and lower concentrations near the outlet, as shown in the example of total petroleum hydrocarbons (Figure 1).

Sampling conducted at 26 wetlands as part of this A3P study shows agreement with the previous findings for metals and TPH in surface waters and sediments:
Toxicants detected in:

- surface water: metals – Cd, Cr, Cu, Pb, Mn, Ni, Zn, Hg
- sediments: metals – Cd, Cr, Cu, Pb, Ni, Zn, Hg – all exceeded sediment quality guidelines for at least one site, and total petroleum hydrocarbons (TPH) exceeded sediment quality guidelines at some sites.

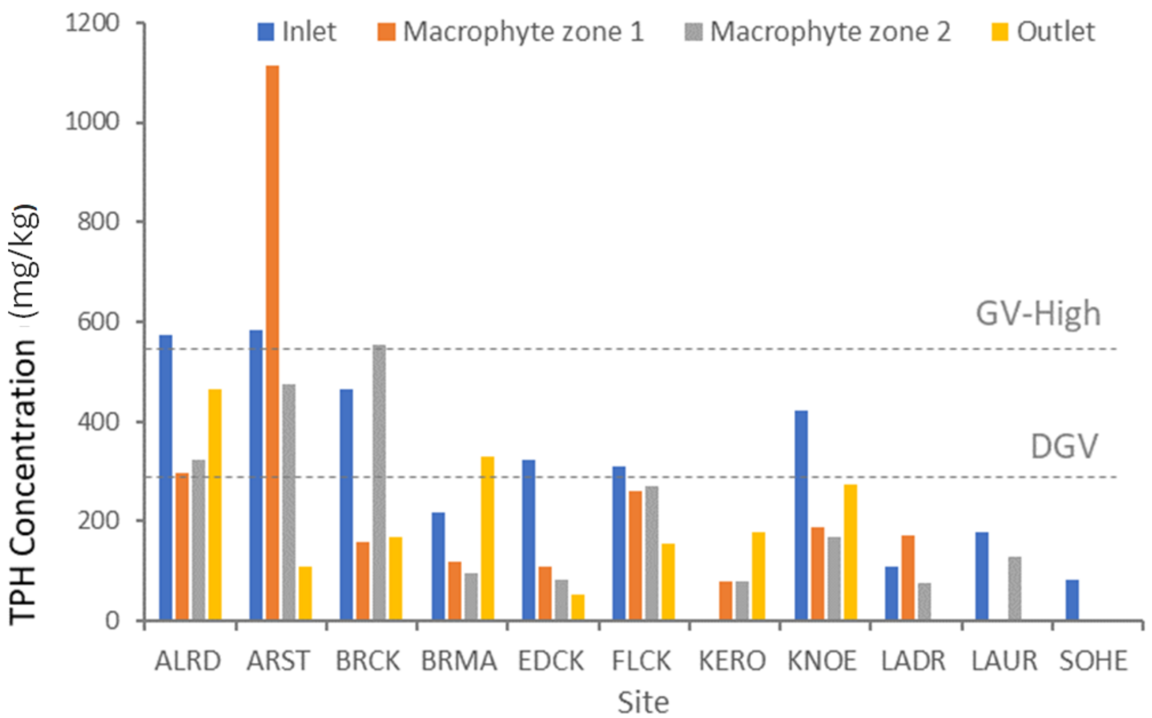

Figure 1. Total petroleum hydrocarbon (TPH) concentrations in sediments collected from different sections within stormwater wetlands around Melbourne. DGV – default guideline value and GV-High – guideline value high. The Default Guideline Value (DGV) is the concentration of a toxicant below which adverse ecological impacts are not expected. The Guideline Value-high (GV-high) is the upper guideline limit, and values that exceed this level are expected to be highly toxic to biota and cause adverse ecological effects (ANZG, 2018).

Indicators and approaches to monitor the performance of stormwater wetlands

- Some pesticides including bifenthrin, permethrin, tebuconazole and piperonyl butoxide were detected, although no ecological guidelines are available. Synthetic pyrethroids and their formulations are used in termite control (bifenthrin, permethrin and piperonyl butoxide), and tebuconazole is a broad-spectrum fungicide widely used in agricultural and urban settings
- Concentrations of some metals (Cd, Cu, Ni, Zn) exceeded 'clean fill' waste disposal guidelines and are thus considered 'priority waste' contaminants with additional costs associated with disposal.
- No metals exceeded Category C upper limit guideline values for waste disposal.
- Concentrations of all pesticides measured were below 'clean fill' waste disposal guidelines and therefore not problematic for disposal.
- Concentrations of TPH exceeded 'clean fill' waste disposal guidelines, and at some sites approached concentrations close to the Category C upper limit guideline value of 10,000 mg/kg, with additional costs associated with disposal.

The most frequently detected pesticides in passive samplers were:

- Herbicides: diuron, simazine, metolachlor, propyzamide, atrazine
- Fungicides: tebuconazole, carbendazim, propiconazole, iprodione
- Insecticides: fipronil, chlorantraniliprole, imidacloprid

Data from this study combined with additional sampling data from other wetlands around Melbourne. The complementary project looked at a total of 111 constructed wetlands and identified 19 pesticides that were associated with urban landuses. All of the pesticides listed above (detected in passive samplers) were present, as well as herbicides bromacil and paclobutrazol; fungicides metalaxyl, azoxystrobin, and trifloxystrobin; and insecticides bifenthrin, thiamethoxam and permethrin. Predominant urban sources include residential areas, increased imperviousness, roads and presence of ovals in the catchment (Pettigrove et al., 2023)

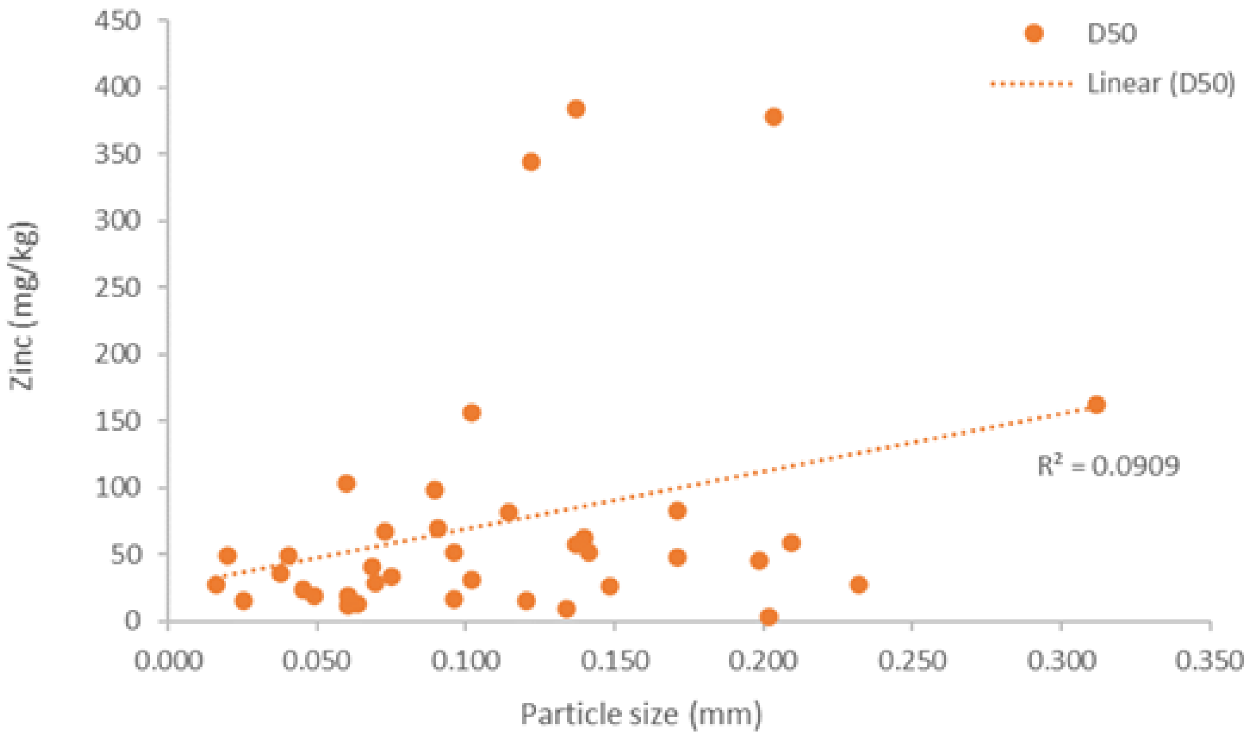

Figure 2. Zinc concentrations in sediment samples from different wetlands. Each dot represents the D50 value, which represents the value of which 50% of the sample is smaller than that particle size.

Are toxicant concentrations related to sediment particle size?

Particle size analysis was done to determine if particle sizes changed from inlets to outlets, and if toxicant concentrations were associated with particular size fractions (Poloso, 2021).

There were no correlations between particle size and toxicant concentrations (e.g., Zinc Figure 2). These finding were somewhat unexpected given the general assumption that toxicants will be concentrated in the fine clay and silt fractions (<64um). Further investigation is recommended.

What features of the surrounding catchment are pollutants associated with?

The following relationships have been detected between metal concentrations in wetlands and features of the surrounding catchment, including landuse, catchment age and wetland geology:

- Positive correlations exist between major metal (Cu, Pb, Ni, Zn, Hg, Cd) concentrations and landuses including effective imperviousness, industrial, residential, commercial and public space.
- Other metals (As, Co, Cu, Fe, Ni, V, Sn) showed positive correlations between concentration and the percentage of roads in the catchment. Further investigation is required to determine if this is associated with vehicle materials or from other sources.
- There were no consistent patterns in metal concentrations in sediments based on catchment age. For some metals, such as As, Ba, Pb and Zn, the concentrations were lower in newer wetlands, whilst for other metals, such as Al, Cr, Co, Fe, Mn, Ni, Sr, Ti and V the concentrations were higher in newer wetlands.

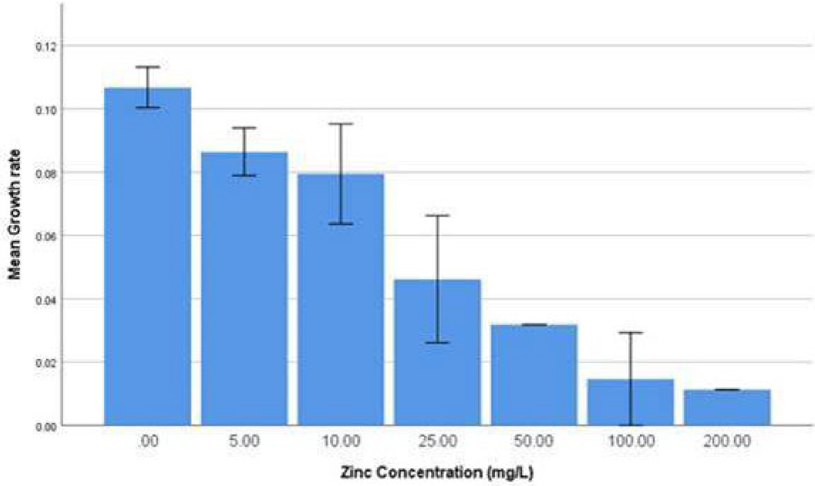

Figure 3a. Mean (±SEM) growth rate of Spirodela punctata (duckweed) exposed to different concentrations of zinc (metal) in a 7-day laboratory toxicity test.

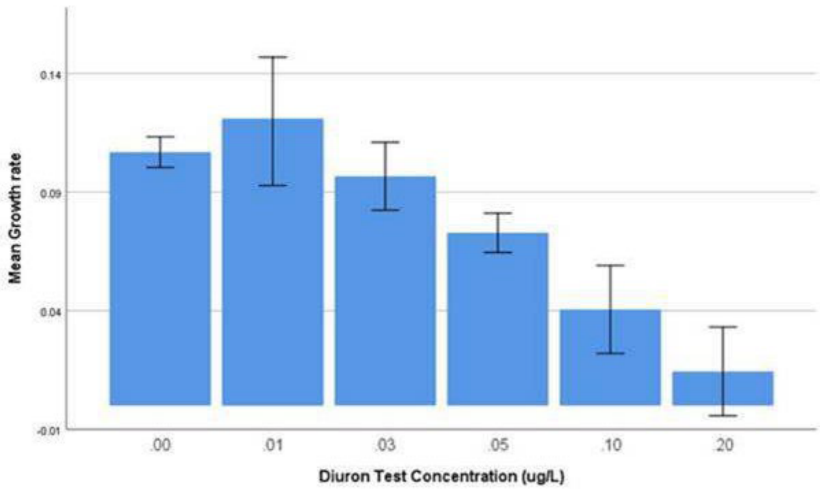

Figure 3b. Mean (±SEM) growth rate of Spirodela punctata (duckweed) exposed to different concentrations of diuron (herbicide) in a 7-day laboratory toxicity test.

Monitoring the effect of toxicants on wetland ecology

Laboratory based pilot studies looking at the toxicity of selected metals (zinc) and pesticides (diuron) on macrophyte growth (duckweed) showed decreased growth with increasing concentrations (Figure 3). All zinc concentrations that have been measured in stormwater wetlands through this project have been <5.0 mg/L and diuron concentrations have been <0.05 mg/L, which is within the range observed to cause growth reductions in duckweed.

Tests like these enable us to determine toxic thresholds for different toxicants, and we hope to use the findings to infer likely toxicity towards other wetland macrophytes typically incorporated into stormwater wetland vegetation communities.

Impacts of pollution on biofilms and zooplankton in constructed wetlands

The results showed changes in community structure and abundance when these organisms were moved from moderate to higher quality water. Biofilms from higher quality water became more heterotrophic and bacteria dominated in poorer quality water, while zooplankton showed a decrease in total abundance. Conversely, biofilms from poorer quality water remained stable in higher quality water, and zooplankton showed an increase in total abundance. These findings suggest that biofilms and zooplankton are sensitive to pollution changes, indicating their potential as bioindicators in future studies on constructed stormwater wetlands and other waterways (Faraone, 2022).

Future direction and knowledge gaps

- Continue monitoring of toxicants in wetlands, to enable changes through time to be quantified and identify opportunities for sediment removal prior to exceeding ecological or clean fill guidelines.
- Continue to investigate cost effective indicators of wetland toxicant contaminants, including identification of most problematic toxicants (e.g., certain metals and pesticides).
- Combine knowledge of what contaminants accumulate in wetland sediments and how they influence desilting, waste disposal and maintenance costs to help inform management protocols.
- Desk based analysis of current waste disposal costs associated with wetlands maintenance to identify improved management options, including optimal frequency of desilting activities or investigations to understand the major catchment inputs of contaminants and deal with them 'at source'.
- Continue the program of monitoring the effects of toxicants on wetland performance e.g., biofilms, sediment bacterial communities.
- Expand sampling to include receiving waters downstream of stormwater wetlands investigating what is currently not being treated.
- Use knowledge of toxicant concentrations in water to inform stormwater reuse and recycling schemes.
- Concentrate management efforts on wetlands that are identified as problematic (in terms of toxicant concentrations and poor performance).
- As initial results were contrary to expectation, consider a more thorough sampling protocol/ regime to characterise particle size variation across and within wetlands to further understand the relationship between particle size and toxicants.

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