21 August 2023

Brad Dalrymple
E: bradd@oceanprotect.com.au
P: 1300 354 722

RE: Should PFAS treatment be recommended for urban wetlands & waterbodies ?

This document describes how PFAS treatment may be recommended for 'natural and 'constructed' wetlands (and other waterbodies) in urban environments to minimise the negative impacts of toxicants (e.g., PFAS) to the health of wildlife that inhabit these environments. Investigations into changes in policy and planning provisions may also be considered to support the planning and design of urban areas to minimise the generation of contaminated runoff entering these environments, thereby addressing the root cause of the issue.

This recommendation is based on recent research by Curtin University, CSIRO and the Western Australian Department of Water and Environmental Regulation which found that tiger snakes (*Notechis scutatus*) inhabiting wetlands in Perth are bioaccumulating high levels of PFAS (per- and polyfluoroalkyl substances), impacting the venomous reptiles' overall health. Whilst this world-first study focused on tiger snakes, it is likely that the health of other wildlife that inhabit (either permanently or temporarily) with these (and/ or other) urban wetlands may also be negatively impacted by chemical (e.g. PFAS) bioaccumulation.

Where wetlands and waterbodies (both 'natural' and 'constructed') are present or proposed in urban environments, it may be subsequently recommended to significantly reduce and/ or avoid the discharge and/ or presence of chemical pollutants (e.g. PFAS) likely to cause a decline to the biodiversity values of these environments. Alternatively, the application of constructed wetlands and waterbodies in urban environments may need to be reconsidered given the potential negative impacts to the wildlife that inhabit these environments where chemical (e.g. PFAS) bioaccumulation is likely to occur.

Further information is provided on the following pages. However, please contact me if you would like to discuss further.

Yours faithfully

Brad Dalrymple
Principal Environmental Engineer

Background

Wetlands

Wetlands and other waterbodies are a common and highly valued feature in urban environments providing a range of environmental, economic and social benefits (Water by Design, 2013). Constructed wetlands are also a widespread form of stormwater treatment, often preferred by designers and regulators for their amenity and habitat benefits (Water by Design, 2017) relative to other stormwater treatment assets (e.g. bioretention systems or biofilters). To assist in the planning and design of constructed wetlands, a range of guidelines have been published by various groups such as Water by Design (2017), Cooperative Research Centre for Water Sensitive Cities (2014), Melbourne Water (2020), and Cooperative Research Centre for Catchment Hydrology (1999), as illustrated in Figure 1.

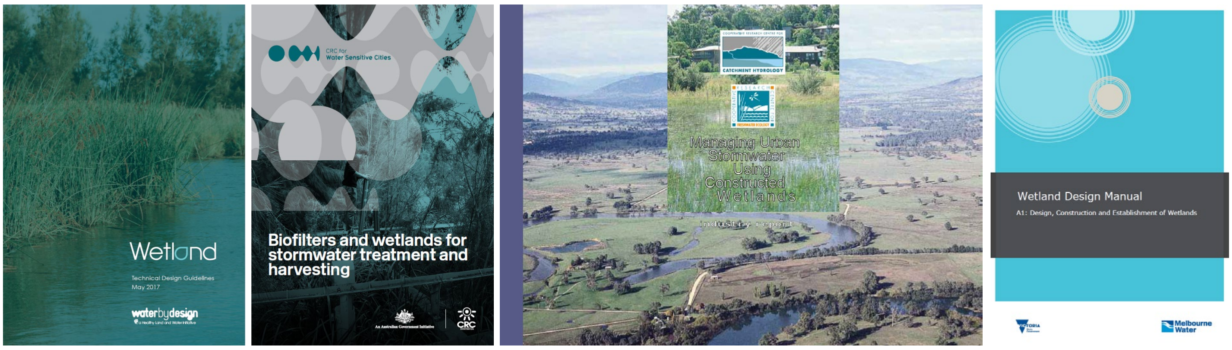

Figure 1 Examples of guidelines for the planning and design of constructed wetlands

Whist stormwater treatment is often the primary function of constructed wetlands, providing habitat for local wildlife is also an often-cited objective (Water by Design, 2017). Despite this, there is limited information in relation to the impacts to wildlife inhabiting these wetlands from pollution entering and/ or being retained within them. Furthermore, no guidance is given in relation to how potential risks to wildlife within constructed wetlands can (and likely should) be appropriately protected from pollution – including commonly recognised urban stormwater pollutants (e.g. heavy metals) and 'emerging contaminants' such as PFAS.

PFAS

PFAS are a class of manufactured chemical compounds, containing the perfluoroalkyl moiety C_nF_{2n+1} (Buck et al 2011, Uriakhil et al 2021). Polyfluorinated PFAS also contain non-fluorinated carbon chain regions, such as –CH2-CH2-, which are known as fluorotelomers (Buck et al 2011, Uriakhil et al 2021). PFAS, fluorotelomers, and other polymers break down in the environment to form perfluoroalkyl acids (PFAAs), which are highly resistant to further degradation (Helmer et al 2021).

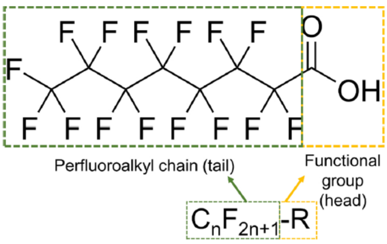

Figure 2 Basic structural features of a perfluoroalkyl substance (from Blake et al 2020)

PFAS have very strong Carbon-Fluorine bonds (Garg et al 2021), which provide PFAS with tremendous thermal and chemical stabilities, unique wettability, and friction properties, supporting their role as additives in the manufacturing of flame retardants such as aqueous film-forming foams, flame-resistant materials, across the semi-electronic, packaging, anti-adhesive, and metal finishing areas (Garg et al 2021, Jin et al 2015). PFAS have been produced since the 1940s and are used in various products such as aqueous film-forming foams (AFFFs), oil and water repellents, paper, and textiles (Prevedouros et al 2006). In particular, AFFFs have been used to extinguish hydrocarbon-based fuel fires at defence bases and airports which has resulted in PFAS-contaminated groundwater at these sites (Houtz et al 2013, Natarajan 2021, NSW Environmental Protection Agency 2022).

PFAS, also known as "forever chemicals", are listed as persistent organic pollutants (POPs) under the Stockholm Convention, due to their ubiquity, persistence, toxicity, and bio-accumulative nature in the environment (Jin et al 2021). This persistence has led to the bioaccumulation of PFAS in biota, aquatic and land life as well as humans (Ahrens et al 2014). Since their genesis in the 1940s, PFAS have been detected in the ambient environment, wildlife, and human serum around the globe (Blake et al 2020). Due to the widespread presence of PFAS in the environment, its unusual chemical properties, the uncertainties associated with its potential risks, and the resulting need for a precautionary approach to protect the environment and human health, the environmental management of PFAS is a high priority for environmental regulators around the world (HEPA 2020).

Recent study

Last month, biologists from Curtin University, CSIRO and the Western Australian Department of Water and Environmental Regulation published a study in the Science of the Total Environment Journal entitled *Bioaccumulation and metabolic impact of environmental PFAS residue on wild-caught urban wetland tiger snakes (Notechis scutatus)*. In this study by Lettoof et al (2023), the research team quantified the concentrations of twenty eight (28) PFAS in surface waters of four wetlands in Perth, Western Australia, and in the livers of resident western tiger snakes (*Notechis scutatus occidentalis*).

The four wetlands receive surface and groundwater flows. One wetland (in Yanchep National Park) is in a largely undeveloped catchment. The other three wetlands are in highly urbanised catchments, although it is worth noting that the catchment draining to Lake Joondalup has two fire stations and Herdsmann Lake is understood to receive landfill leachate – noting that the fire stations and landfills are likely sources of PFAS loads entering the downstream wetlands.

The wetland in Yanchep National Park detected no PFAS in surface waters above limits of reporting, and low concentrations of PFAS were observed in the livers of snakes. The other three wetlands detected elevated PFAS concentrations in surface waters and high concentrations of PFAS in the livers of snakes. Further analyses by the researchers demonstrated that that the high concentrations of PFAS within the snakes is impacting the venomous reptiles' overall health, with liver PFAS concentrations associated with lower snake body condition and impacted energy production pathways in muscle tissues of PFAS-exposed snakes.

Whilst this world-first study focused on tiger snakes, it is likely that the health of other wildlife that inhabit (either permanently or temporarily) with these (and/ or other) urban wetlands may be similarly negatively impacted by chemical (e.g. PFAS) bioaccumulation.

Head Office (NSW)
60 Lyn Parade, Prestons NSW 2170
PO Box 75, Casula Mall NSW 2170

QLD Office
29 Chetwynd St, Loganholme QLD 4129
PO Box 5292 Stafford Heights QLD 4053

VIC Office
PO Box 2633 Cheltenham VIC 3192

IES Stormwater P/L trading as Ocean Protect
ABN: 79 101 258 182

Phone: 1300 354 722
Fax: 1300 971 566
enquiries@oceanprotect.com.au
www.oceanprotect.com.au

Implications to the design & management of wetlands

From a preliminary review of guidance in relation to the planning, design and management of constructed wetlands, the only recommended pre-treatment of stormwater recommended (if any) is the application of a 'gross pollutant trap' (GPT). Whilst GPTs can be highly effective at removing 'gross pollutants' (typically defined as pollutants equal to or greater than 5mm) and sediment, they would be largely ineffective at removing PFAS.

From this review, only Water by Design (2017) appears to provide any advice in relation to mitigating risks associated with any chemical pollution. Specifically, Water by Design (2017) states that:

> When the system is likely to be exposed to toxic substances (e.g. herbicides, solvents or industrial contaminants), biological function will be compromised. Structural separation should be used to exclude contaminants from the stormwater system.

The aforementioned Water by Design (2017) advice subsequently appears to be largely related to protecting the stormwater treatment function of the wetland, and not wetland wildlife.

To the best of my knowledge, to date, no wetland guidelines provide any reference to PFAS or any advice in relation to assessing and/ or managing risks associated with PFAS contamination. This is likely a significant omission, particularly given the ubiquity, persistence, toxicity, and bio-accumulative nature of PFAS and other unknown and emerging contaminants and toxicants in the environment. Regardless, where wetlands are present or proposed in urban environments, it may be recommended to significantly reduce and/ or avoid the discharge of chemical pollutants (e.g. PFAS) likely to negatively impact the wildlife that inhabit these environments. Alternatively, the application of wetlands in urban environments may need to be reconsidered given the potential negative impacts to the wildlife that inhabit these environments where chemical (e.g. PFAS) bioaccumulation is likely to occur.

Recommendations for further study

Further investigations into the potential impacts of chemical pollutants (e.g. PFAS) and other unknown and emerging contaminants and toxicants on the biota of urban wetlands and surrounding ecological infrastructure should be undertaken, particularly through ecotoxicological and food web analyses aimed at understanding bioaccumulation and its effects in heterotrophic fauna (e.g. snakes, frogs, turtles, birds).

Conflict of interest

I acknowledge that I have a conflict of interest in relation to the contents of this document, noting I am employed by Ocean Protect who design, install and manage stormwater treatment technologies, including the StormFilter PFAS which has been developed to target the removal of PFAS from contaminated waters. Where possible, references have been provided throughout the document and are also given below.

References

Ahrens, L. and Bundschuh, M., 2014. *Fate and effects of poly- and perfluoroalkyl substances in the aquatic environment: A review*. Environmental Toxicology and, 33(9), pp.1921-1929.

Head Office (NSW)
60 Lyn Parade, Prestons NSW 2170
PO Box 75, Casula Mall NSW 2170

QLD Office
29 Chetwynd St, Loganholme QLD 4129
PO Box 5292 Stafford Heights QLD 4053

VIC Office
PO Box 2633 Cheltenham VIC 3192

IES Stormwater P/L trading as Ocean Protect
ABN: 79 101 258 182

Phone: 1300 354 722
Fax: 1300 971 566
enquiries@oceanprotect.com.au
www.oceanprotect.com.au

Blake B E, Fenton S E, 2020, *Early life exposure to per- and polyfluoroalkyl substances (PFAS) and latent health outcomes: A review including the placenta as a target tissue and possible driver of peri- and postnatal effects*, Toxicology 443 (2020) 152265.

Buck R C, Franklin J, Berger U, Conder J M, Cousins I T, Voogt P, De Jensen A A, Kannan K, Mabury S A, van Leeuwen S P J, 2011, *Perfluoroalkyl and polyfluoroalkyl substances in the environment: terminology, classification, and origins*. Integrated Environ. Assess. Manag. 7, 513–541. https://doi.org/10.1002/ieam.258.

Deletic et al ,2014,. *Biofilters and wetlands for stormwater treatment and harvesting*, Cooperative Research Centre for Water Sensitive Cities, Monash University, October 2014.

Garg S, Wang J, Kumar P, Mishra V, Arafat H, Sharma R, Dumée L, 2021, *Remediation of water from per-/poly-fluoroalkyl substances (PFAS) – Challenges and perspectives*. Journal of Environmental Chemical Engineering, 9(4), p.105784.

Heads of EPA Australia and New Zealand, *2020 PFAS National Environmental Management Plan Version 2.0*. Canberra

Helmer R W, Reeves D M, Cassidy D P, 2021, *Per- and Polyfluorinated Alkyl Substances (PFAS) cycling within Michigan: Contaminated sites, landfills and wastewater treatment plants*, Water Research.

Houtz E F, Higgins C P, Field J A, Sedlak D L (2013). *Persistence of perfluoroalkyl acid precursors in AFFF-impacted groundwater and soil*. Environmental Science & Technology, 47(15), 8187–8195.

Jin T, Peydayesh M, Messenga R, 2021, *Membrane-based technologies for per- and poly-fluoroalkyl substances*. Environment International 157.

Lettoof D C, Nguyen T V, Richmond W R, Nice H E, Gagnon M M, Beale D J, 2023, *Bioaccumulation and metabolic impact of environmental PFAS residue on wild-caught urban wetland tiger snakes (Notechis scutatus)*, Science of the Total Environment 897 (2023) 165260.

Melbourne Water, 2020, *Wetland Design Manual*.

Natarajan M, Dodds S, Allard S, Kaksonen A H, Heitz A, Joll C A, 2021, *Point-of-entry water filter for removal of per- and poly-fluoroalkyl substances and precursors*, AWWA Water Science, DOI: 10.1002/aws2.1257

New South Wales Environmental Protection Agency, 2022, *The NSW Government PFAS Investigation Program*, https://www.epa.nsw.gov.au/your-environment/contaminated-land/pfas-investigation-program

Prevedouros K, Cousins I T, Buck R C, Korzeniowski S H, 2006, *Sources, fate and transport of perfluorocarboxylates*. Environmental Science & Technology, 40(1), 32–44.

Jin T, Peydayesh M, Mezzenga R, Kotthoff M, Müller J, Jürling H, Schlummer M, Fiedler D, *Perfluoroalkyl and polyfluoroalkyl substances in consumer products*, Environ. Sci. Pollut. Res. 22 (2015) 14546–14559.

Uriakhil M A, Sidnell T, De Castro Fernandez A, Lee J, Ross I, Bussemaker M, 2021, *Per- and poly-fluoroalkyl substance remediation from soil and sorbents: A review of adsorption behaviour and ultrasonic treatment*. Chemosphere 282 (2021) 131025

Water by Design, *Waterbody Management Guideline (Version 1)*, Healthy Waterways Ltd, Brisbane.

Water by Design, 2017, *Wetland Technical Design Guidelines,* Healthy Land and Water, Brisbane.

Wong T H F, Breen P F, Gomes N L G, Lloyd S D, 1999, *Managing urban stormwater by using constructed wetlands*, Cooperative Research Centre for Catchment Hydrology.

Head Office (NSW)
60 Lyn Parade, Prestons NSW 2170
PO Box 75, Casula Mall NSW 2170

QLD Office
29 Chetwynd St, Loganholme QLD 4129
PO Box 5292 Stafford Heights QLD 4053

VIC Office
PO Box 2633 Cheltenham VIC 3192

IES Stormwater P/L trading as Ocean Protect
ABN: 79 101 258 182

Phone: 1300 354 722
Fax: 1300 971 566
enquiries@oceanprotect.com.au
www.oceanprotect.com.au