NTS Treatment: Human Virus Removal in Biofilters

- What virus removal credit (if any) should be assigned to stormwater biofilters?

Biofilter set up at Monash University

Eric Huang, UCI

Sunny Jiang, UCI

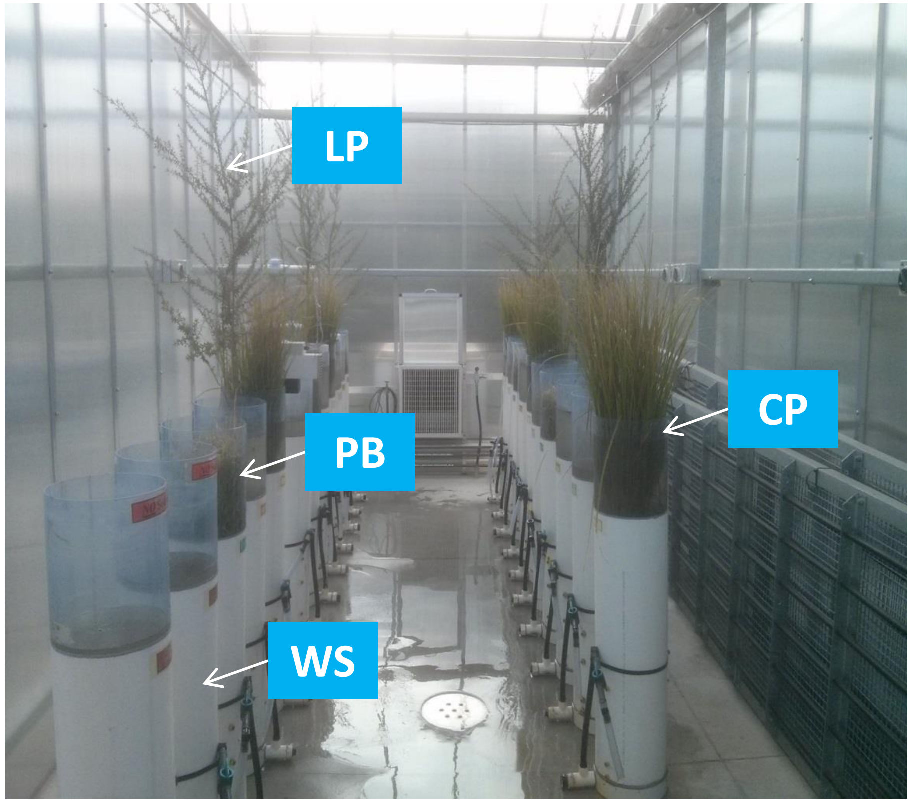
David McCarthy, Monash U.

Ana Deletic, Monash U.

CRC for Water Sensitive Cities

MONASH University

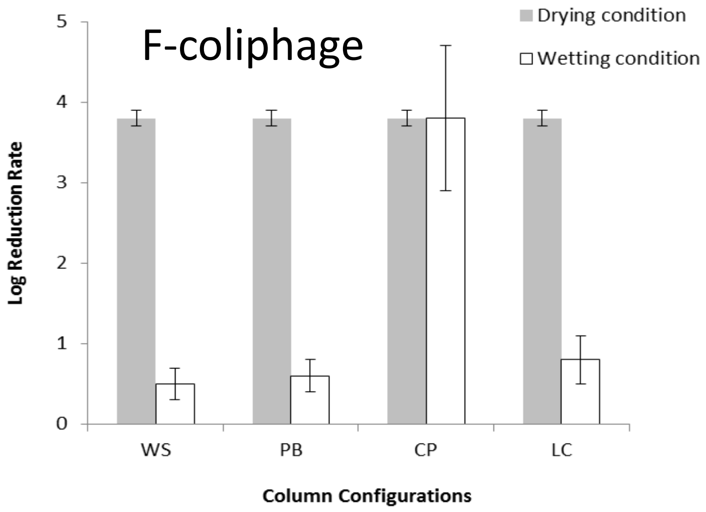
Removal of adenovirus and indicator microorganisms by lab scale biofilters

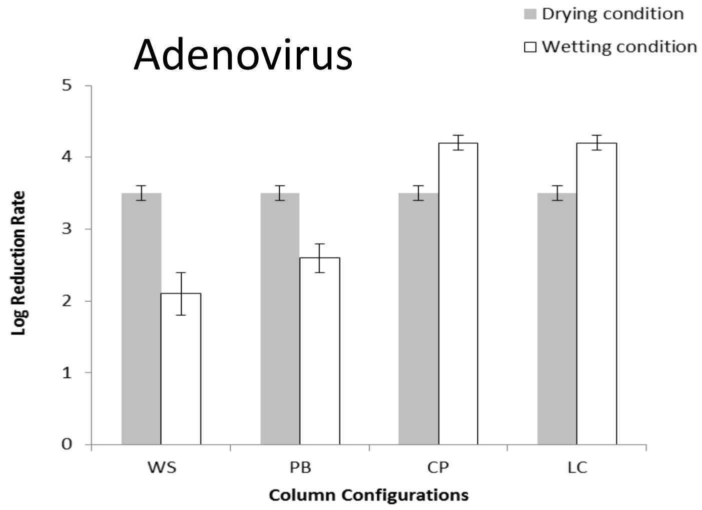


WS: Wash sand; PB: *Palmetto buffalo*; CP: *Carex appresa*; LC: *Leptospermum continentale*

- Study the removal efficiency of biofilters for human pathogenic virus (adenovirus 5), indicator virus (f-coliphage) and indicator bacterium (*E.coli*).
- Study the impact of dry (3 weeks after last watering) and wet (3 days after) conditions on biofilter performance.

Results: Virus log reduction rate under dry and wet conditions





WS: Wash sand; PB: *Palmetto buffalo*;
CP: *Carex appresa*; LC: *Leptospermum continentale*

- A greater than 3-log_{10} viral reduction was achieved by all biofilters during dry condition.
- Under wet condition, ***Carex appresa*** has the best performance among the tested biofilters indicating the root system may play an important role in viral removal.
- Compared to adenovirus, the removal rate of F-coliphage was lower, showing its utility as worst-case model.

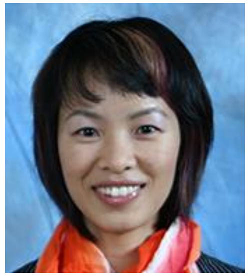
NTS Treatment: Pathogen Removal in Wetlands

- What pathogen removal credit (if any) should be assigned to constructed wetlands?

Royal Park Wetland in Melbourne, Australia

Eric Huang, UCI

Sunny Jiang, UCI



Yiping Cao, SCCWRP

Approach

- Field sampling for pathogens in natural and engineered wetlands for urban stormwater treatment
- Six different wetlands in Melbourne, Australia and two constructed wetlands in Orange Country, California were sampled at inlet, middle and outlet sites
- Recovery of multiple pathogens using a concentration and elution method was evaluated
- Human pathogens, including adenovirus, norovirus, *E. coli*, enterococcus, *Crytosporidium* and *Giardia*, as well as fecal indicator bacteria were targeted for testing.

Pathogenic microorganisms tested by PCR

Raw Samples

Cartridge Filtration (20L) → Elution and pH adjustment (50~70mL) → Centricon Plus 70 (2~10 mL) → DNA/RNA Extraction (PowerSoil)

Disc Filtration (250~600mL) → Elution and pH adjustment (10mL) → DNA/RNA Extraction (PowerSoil)

DNA/RNA Extraction (PowerSoil) → qPCR/ddPCR

- *Rotavirus*
- *Norovirus GII*
- *Cryptosporidium spp.*

- *Salmonella*
- *Campylobacter*

Indicator bacteria results by Culture Assay

		E.coli (CFU/100mL)	*Enterococcus* (CFU/100mL)
Royal Park	I1	3775	148
	M1	116	131
	O1	363	97
Lynbrook	Inlet	360	1600
	Pond A	84	450
	Pond 6	<2	5
	Lake	148	108

Pathogen data are forthcoming

Summary: Biofilters and Wetlands

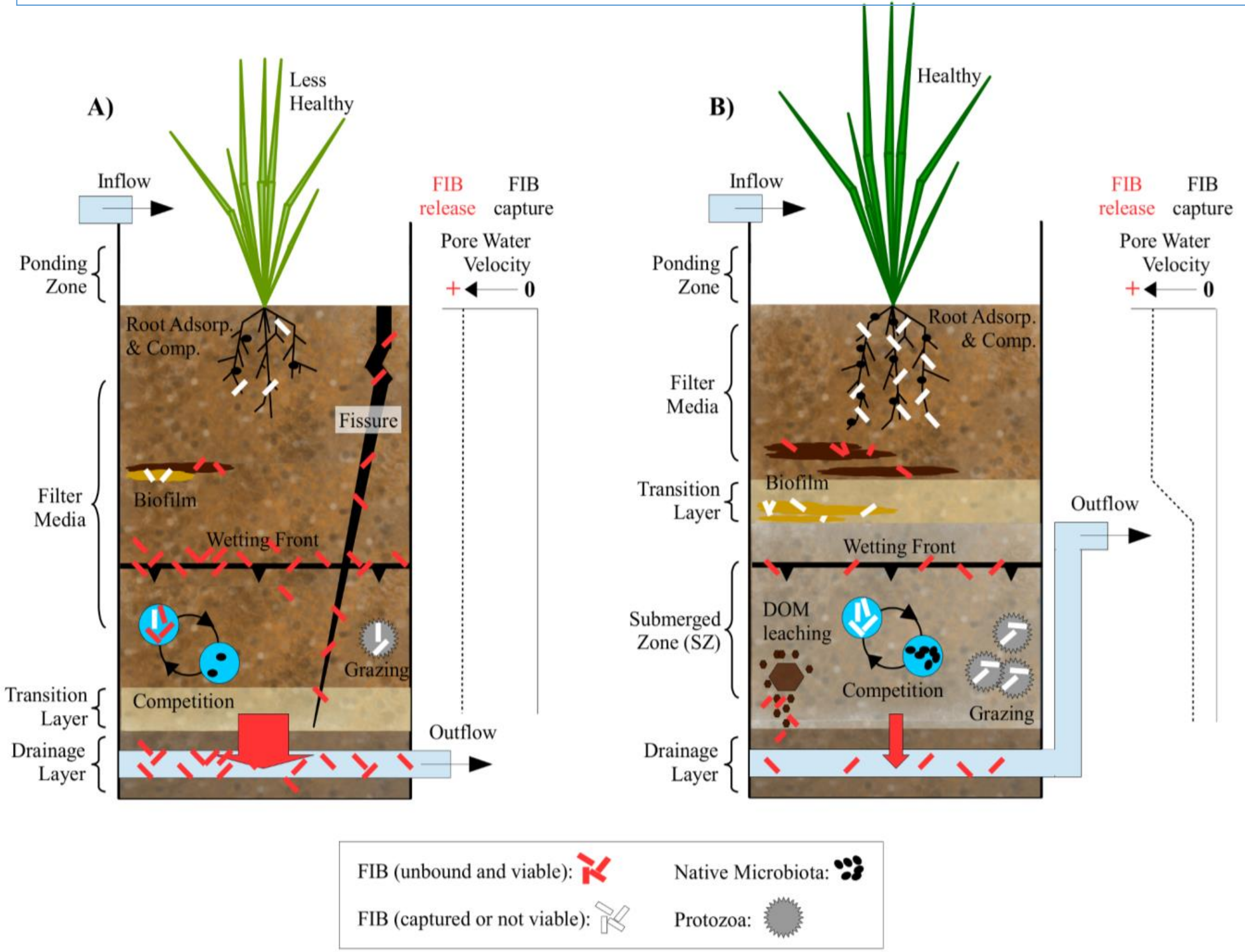
- Biofiltration can achieve at least 3-log reduction of viruses during dry conditions
- Biofilter plant species play an important role in viral removal during wet conditions
- Wetlands reduce fecal indicator bacteria concentrations in most of cases
- Molecular detection of pathogens in wetlands is challenging due to high concentration of inhibitors that co-concentrate with the target organisms
- Adaption of droplet digital PCR (ddPCR) method may eliminate environmental inhibition. Quantitative data on pathogen removal in wetlands are forthcoming.

Products

- Manuscript
  - Removal of human viruses and other microbial pathogens in lab-scale biofilters and natural wetlands for stormwater treatment. X. Huang, Y. Cao, D. McCarthy, A. Deletic, and S. Jiang. In preparation.
- Proposal
  - Establishing Pathogen Log Reduction Credits for WWTPs. Submitted jointly with SCCWRP to WateReuse Research Foundation. PI: Sunny Jiang, co-PI Yiping Cao

NTS Treatment: Fecal Indicator Bacteria

- Does the inclusion of a submerged zone improve the removal of fecal indicator bacteria in biofilters?



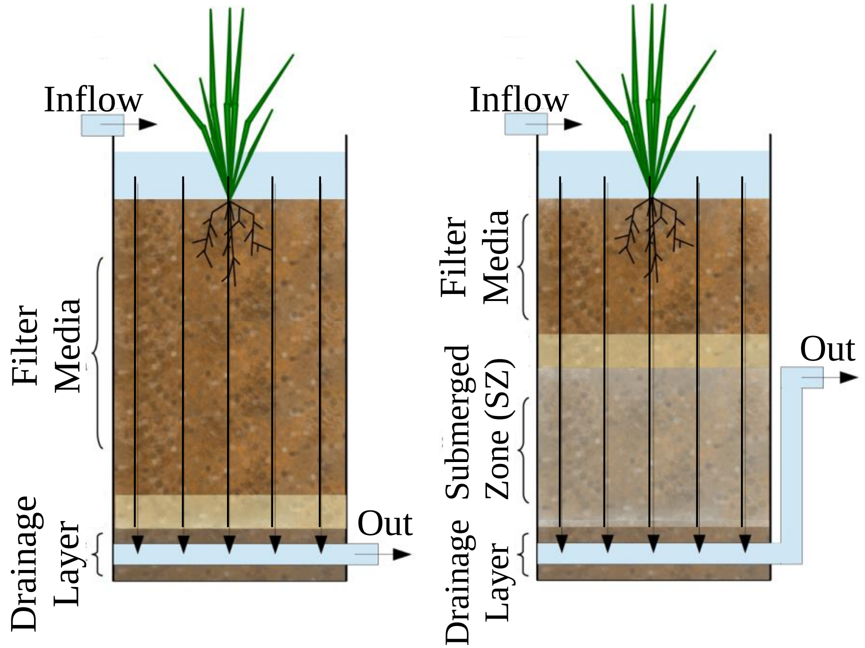
Meg Rippy
UCI

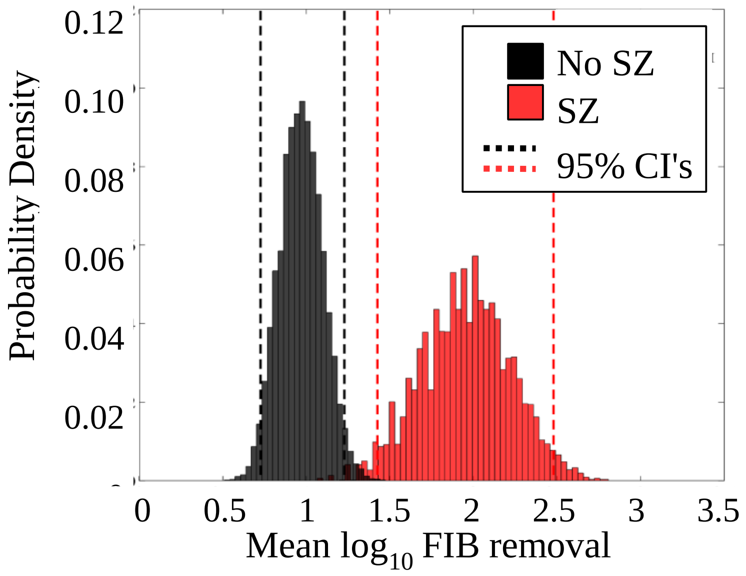
Linking Engineering Design to Stormwater Treatment Efficacy

Submerged Zone (SZ) biofilters (advocated in AU) have a re-engineered drainage layer that:

- increases moisture retention in the base of the biofilter

- decreases oxygen content, favoring anaerobic metabolic processes





A meta-analysis of biofilter literature revealed that design significantly impacts treatment efficacy

- Fecal indicator bacteria removal is 10 fold higher in SZ designs

- Multiple mechanisms may be responsible

Linking Engineering Design to Stormwater Treatment Efficacy

Likely mechanisms explaining enhanced FIB removal in SZ systems:

1) decreased fissure formation during dry periods

2) decreased flow velocity in saturated media

3) decreased scouring of previously captured FIB by propagating wetting fronts

4) increased protist survival and grazing pressure

5) increased biofilm formation and removal by straining

6) increased plant health and root development, which promotes root adsorption and competition with root microbiota

Rippy, M. A. Meeting the Criteria: linking biofilter design to pathogen removal performance, **invited submission to *WIREs Water***.

FUTURE DIRECTIONS: Identify the exact mechanisms responsible for improved FIB removal in SZ biofilters.

Use layered (unsaturated-saturated) flow models to evaluate and compare the different mechanisms proposed above

NTS Treatment: Stormwater Pesticides

- What concentrations and varieties of pesticides are common in stormwater?

Megan Rippy, UCI

Ana Deletic, Monash University

Wolfgang Gernjak, University of Queensland

Jane-Louise Lampard, Griffith University

CRC for Water Sensitive Cities

MONASH University

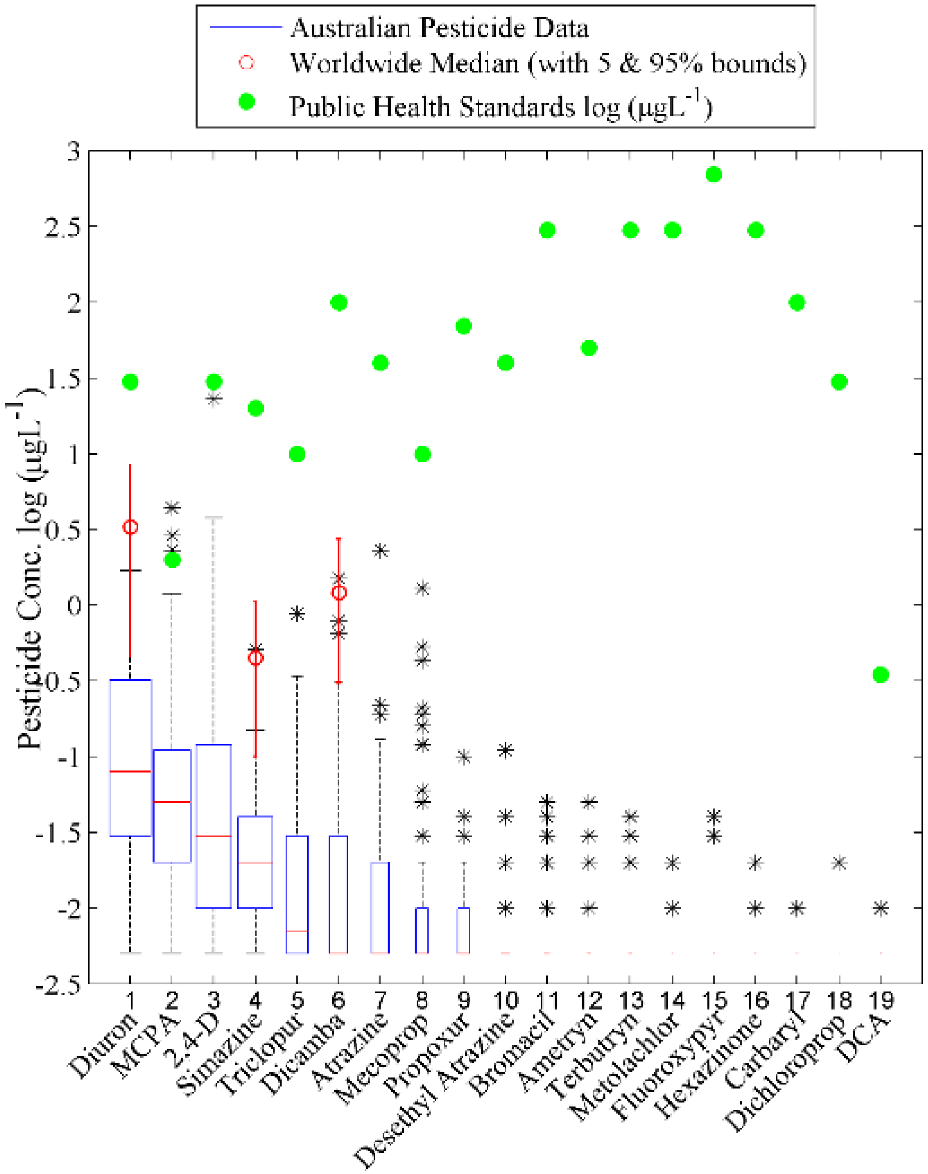
Approach

- Stormwater sampling campaign across Australia
  - Years: 2011-2013
  - 10 sites in four States: QLD, VIC, NSW, WA
  - Samples tested for 19 Pesticides (DL=0.01 ppb for all)
- Used Resample/PCA to identify “pesticide fingerprints” and determine dominant spatial and temporal patterns

- Diuron
- Simazine
- 2, 4-D
- MCPA
- Triclopyr
- Atrazine
- Desethyl Atrazine
- Hexazinone
- Metolachlor
- Bromacil
- Ametryn
- Terbutryn
- DCA
- Propoxur
- Carbaryl
- Dichlorprop
- Mecoprop
- Fluroxypyr
- Dicamba

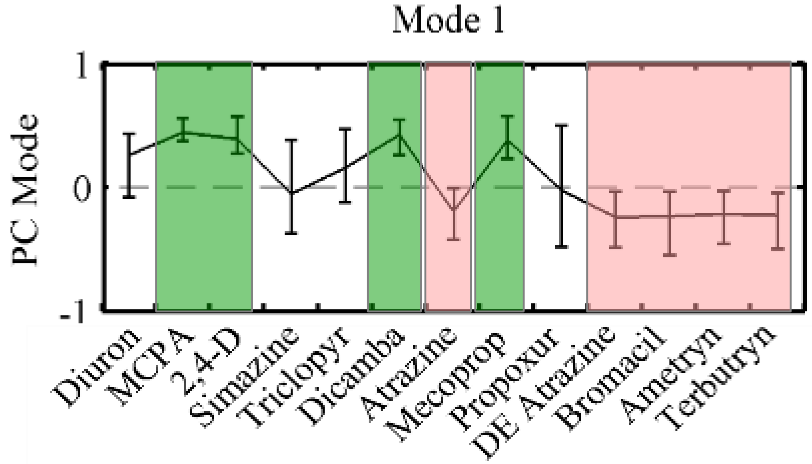
Results: Pesticide Concentrations

- Stormwater pesticide concentrations were low (< 1 ppb) but highly variable
  - Below health standards (except MCPA)
  - Generally below global averages for stormwater

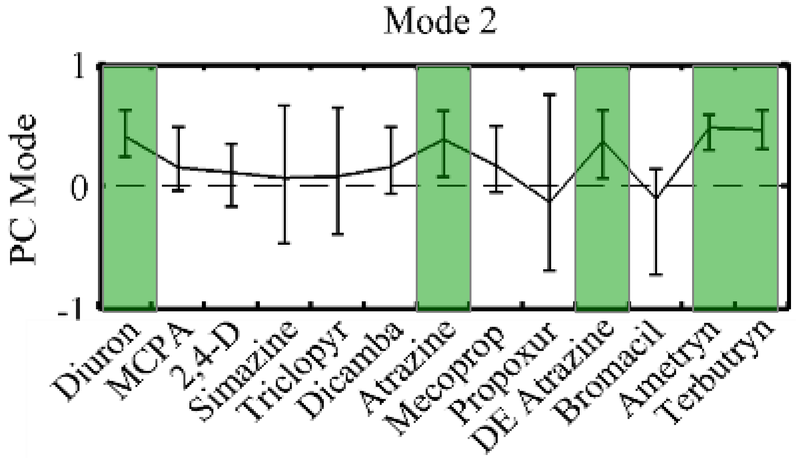


Results: Principal Component Analysis

- Pesticide “fingerprints” are site (not state or year) specific
- Mode 1: positive for phenoxy herbicides, negative for triazine pesticides
- Mode 2: positive for diuron and triazine pesticides



Positive Mode 1 sites contain degradable pesticides (NTS may be useful)



Mode 2 characterizes Anvil Way (the one site with an unusual pesticide fingerprint)

Conclusions

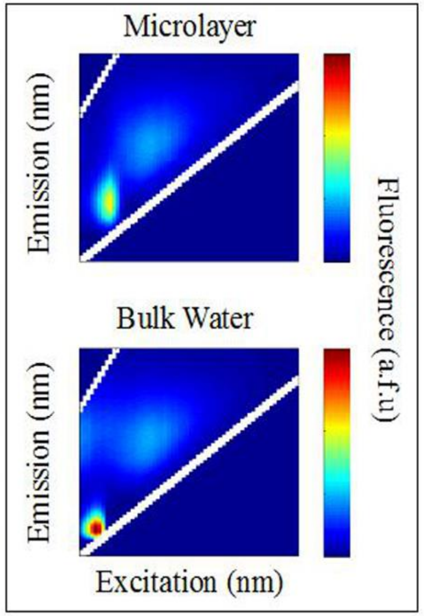
- Low pesticide concentrations in stormwater may not pose a barrier to potable substitution
- Pesticide fingerprints are site (catchment) specific therefore management should be site-specific as well
  - NTS may be appropriate for removing pesticides in “mode 1” catchments

Products

- Rippy, M.A.; Gernjak, W.; Deletic, A. et al., “Catchment-specific fingerprints: characterizing pesticide variability in urban stormwater runoff”, in prep for *Environmental Science and Technology*
- Additional papers in the planning stage

NTS Treatment: Are Surface Microlayers Micropollutant Hot Spots in Natural Treatment Systems?

- Do microlayers form in Natural Treatment Systems?
- Are microlayers hot-spots of micro-pollutants?



Megan Rippy, UCI

Stanley Grant, UCI

Laura Weiden, UCI

Bill Cooper, UCI

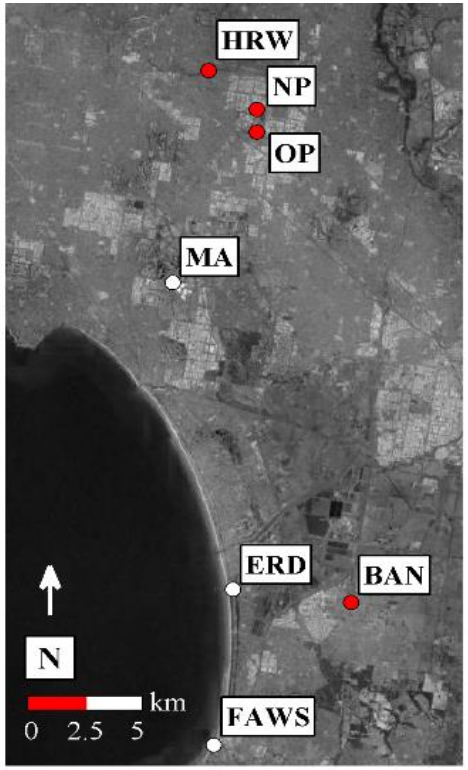
Ana Deletic, Monash Uni

Surface microlayers are naturally occurring surficial thin-films (~ 60 μm thick)

Ecologically & biogeochemically important:
- Regulate air-water gas exchange
- Habitat for larval invertebrates and fish

Can be enriched in pollutants (heavy metals & pesticides)
– *marine systems* –

Approach



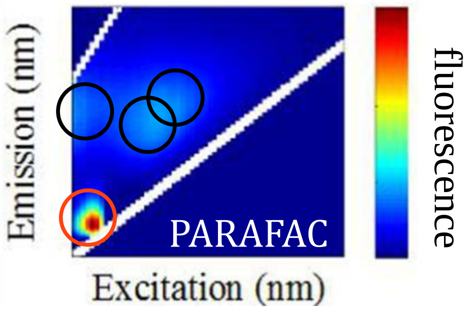
4 NTS were sampled in Melbourne, AU

Paired subsurface & microlayer samples (Glass Plate technique)

Samples were analyzed for:

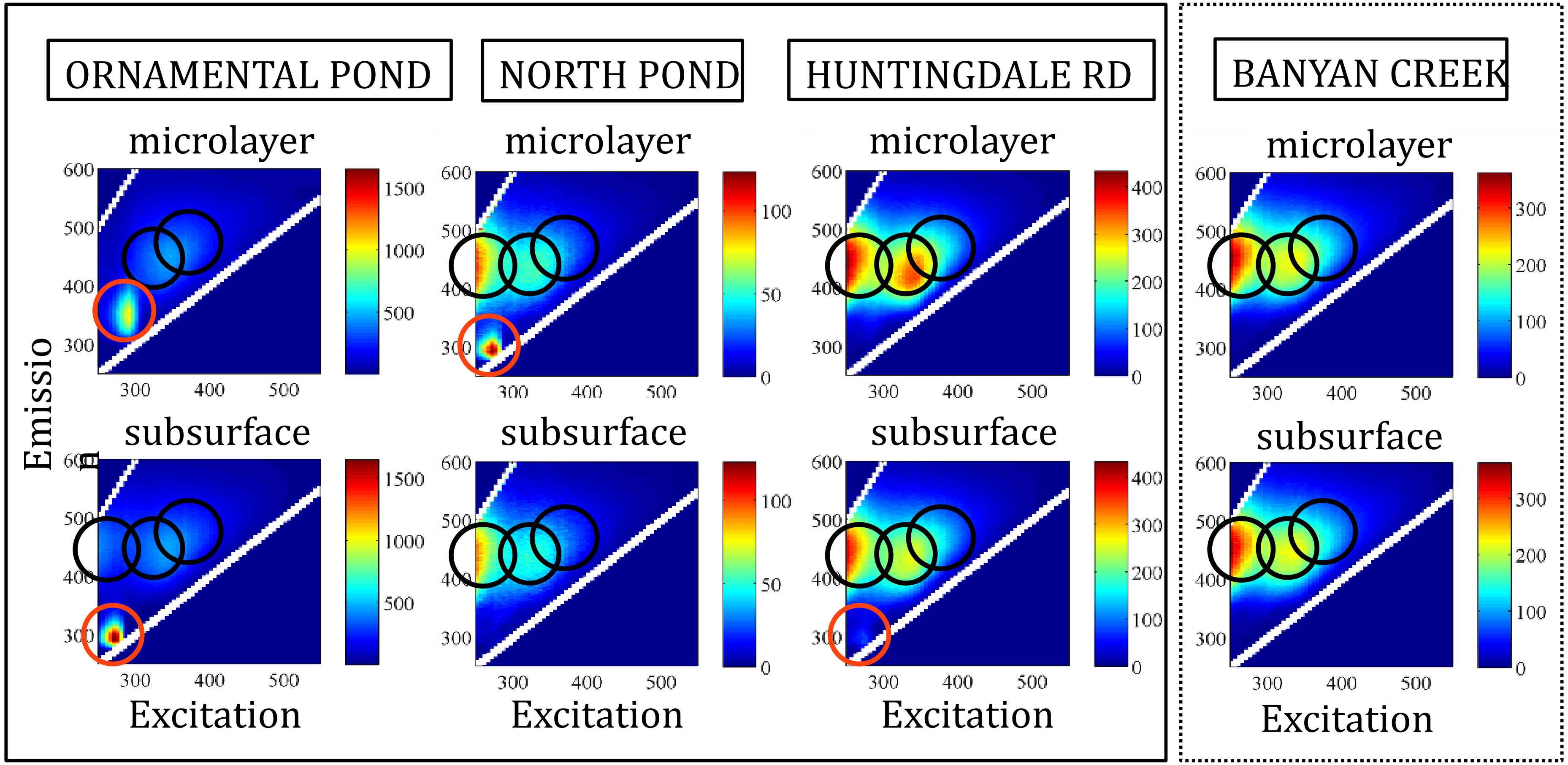
1) Fluorescent DOM (microlayer detection)

2) Micropollutants: TPH, THM, & PAH



GC-MS & GC-FID

Do microlayers form in natural treatment systems?
YES, but not ubiquitously



Protein-like peaks distinguish microlayer and subsurface waters

Humic/Fulvic-like peaks are more stable

Microlayer Present

No Microlayer Evident

Do contaminants partition into the microlayer?: **YES**

MICROLAYER	ANALYTES	ORNAMENTAL POND (µg/L)	NORTH POND (µg/L)	HUNTINGDALE RD (µg/L)	BANYAN CREEK (µg/L)
Petroleum Hydrocarbons	**TPH** C6-C9 (BTEX)	--	--	--	--
	TPH C10-C14	492	--	--	--
	TPH C15-C28	17220	410	--	--
	TPH C29-C36	1230	--	--	--
Polycyclic Aromatic Hydrocarbons	Total PAH	--	--	--	--
Trihalomethanes	Chloroform	--	4.1	7.8	--
	Total Trihalomethanes	--	4.1	7.8	--

SUBSURFACE	ANALYTES	ORNAMENTAL POND (µg/L)	NORTH POND (µg/L)	HUNTINGDALE RD (µg/L)	BANYAN CREEK (µg/L)
Petroleum Hydrocarbons	**TPH** C6-C9 (BTEX)	--	--	--	--
	TPH C10-C14	--	--	--	--
	TPH C15-C28	--	--	--	--
	TPH C29-C36	--	--	--	--
Polycyclic Aromatic Hydrocarbons	Total PAH	--	--	--	--
Trihalomethanes	Chloroform	--	--	--	--
	Total Trihalomethanes	--	--	--	--

No Microlayer

Contaminants were **NEVER** detected at Banyan Creek

Contaminants were **NEVER** detected in subsurface water

Contaminants **WERE** detected in microlayer water

Conclusions:

- Surface microlayers exist in NTS and can be hotspots of micropollutants
- Micropollutants were below health standards (not a risk to human health)
- Micropollutants could pose ecological risk:
  - Pollutants accumulate where sensitive life history stages of invertebrates and fish reside
  - Pollutants may alter microlayer viscoelasticity, impacting air-water gas exchange

Products:

Rippy, M. A *et al.*, Micropollutants as hot-spots in low impact development (LID) systems: linking the surface microlayer to urban water quality. *Environ. Sci. and Tech.* **revision requested.**

Rippy, M. A *et al.*, Micropollutants as hot-spots in low impact development (LID) systems: linking the surface microlayer to urban water quality. 3rd Symposium on Urbanization and Stream Ecology, 2014, Portland OR.