Emerging contaminants (ECs) – testing downstream from wastewater treatment plants (WWTP) in central and northern Queensland

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Queensland Water Regional Alliance Program

ENVIROLAB GROUP

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

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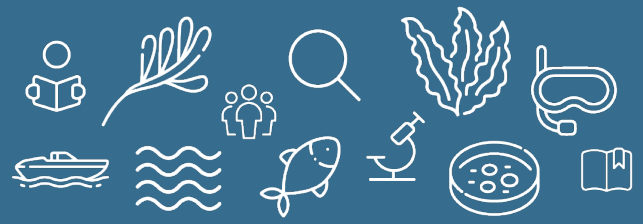

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ACKNOWLEDGEMENT OF COUNTRY

CQUniversity acknowledges Traditional Owners and Custodians and pays respect to the Elders of all First Nations peoples of Australia.

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Working with nature to build an economically and sustainable future to enrich our coastal communities

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Emerging Contaminants (ECs)

- ECs pose a major challenge to regulatory agencies
- Global demand for products containing synthetic chemicals continues, driving up production
- 350,000 anthropogenic chemicals produced globally (Wang et al., 2020)
- Limited information on break-down products, longevity and impacts to environment and human health

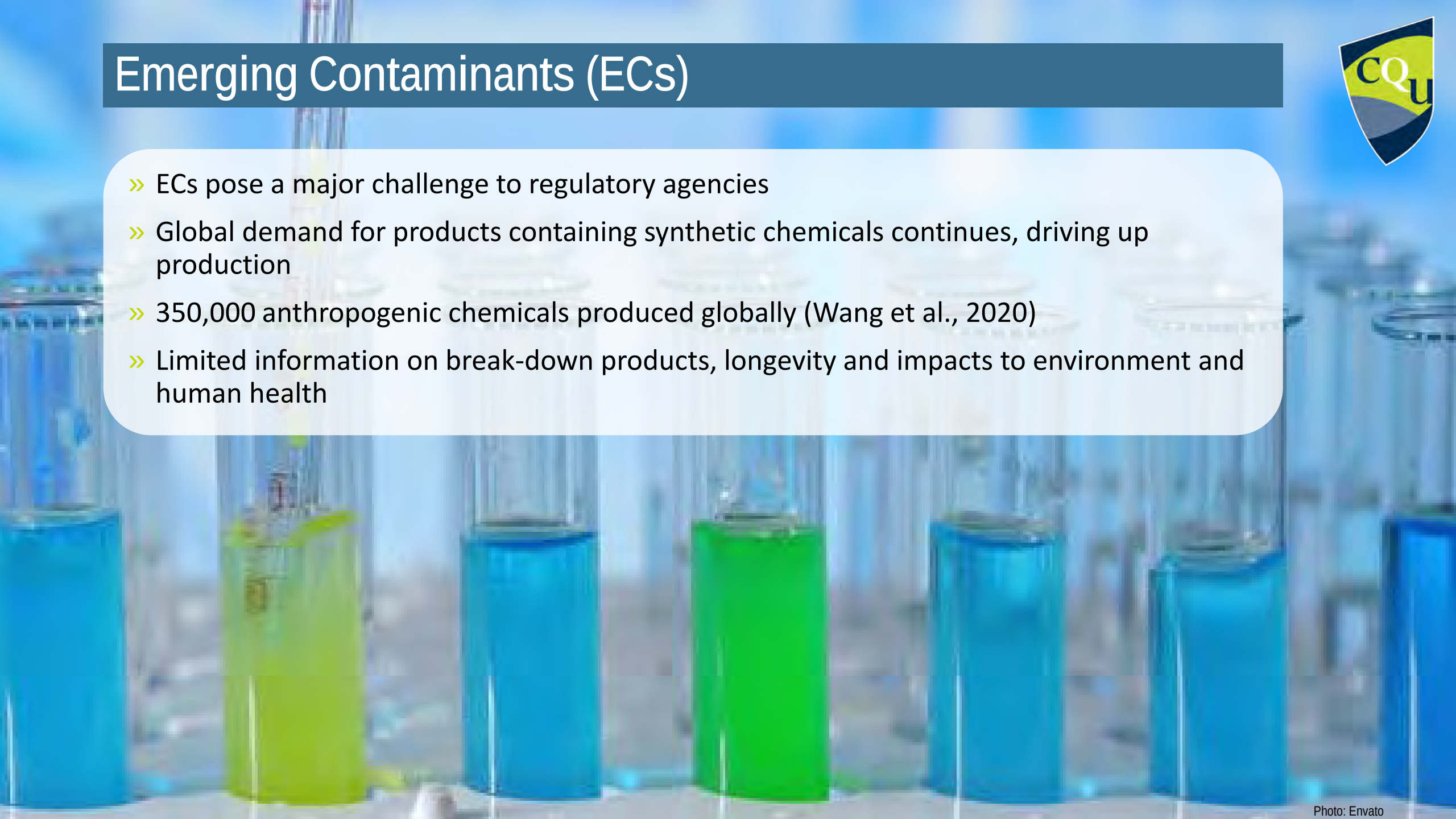
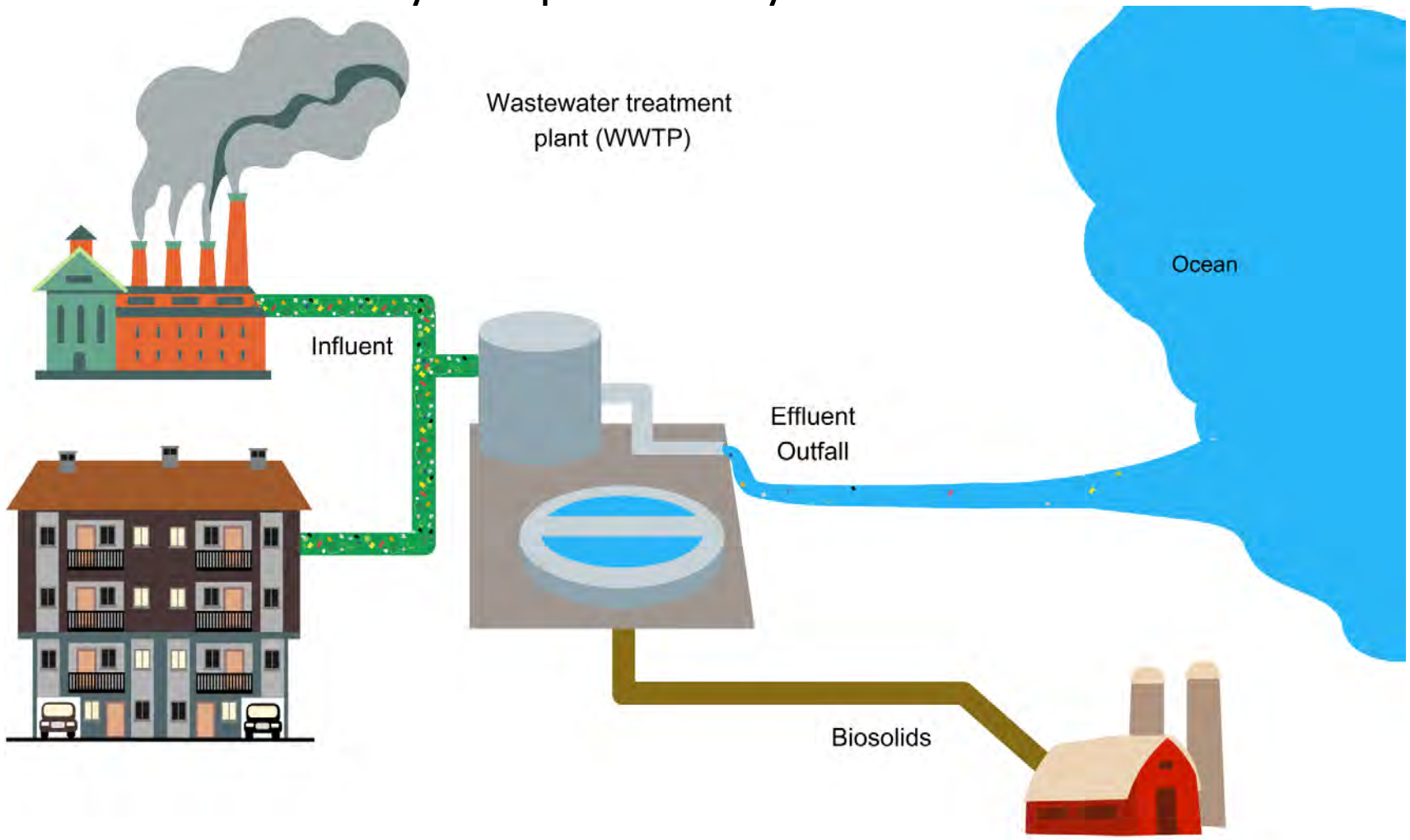


Photo: Envato

ECs in aquatic environment

» WWTP act as a conduit for release of ECs from industrial and urban environments directly to aquatic ecosystems



Aims

- Determine temporal variations in multiple suites of ECs from WWTP effluent discharge across wet and dry seasons in three Northern and Central Qld regions
- Determine dispersion of ECs from WWTP effluent point of discharge to two diffuse points downstream

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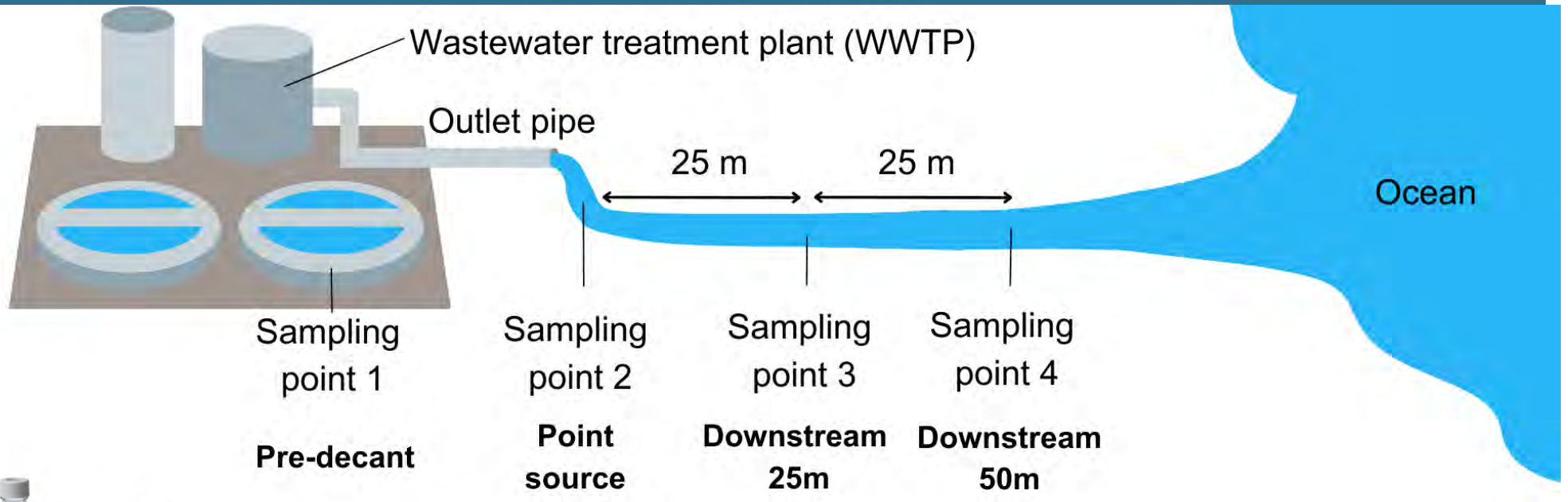
Methods – Pharmaceuticals and Personal Care Products (PPCPs) and other chemicals

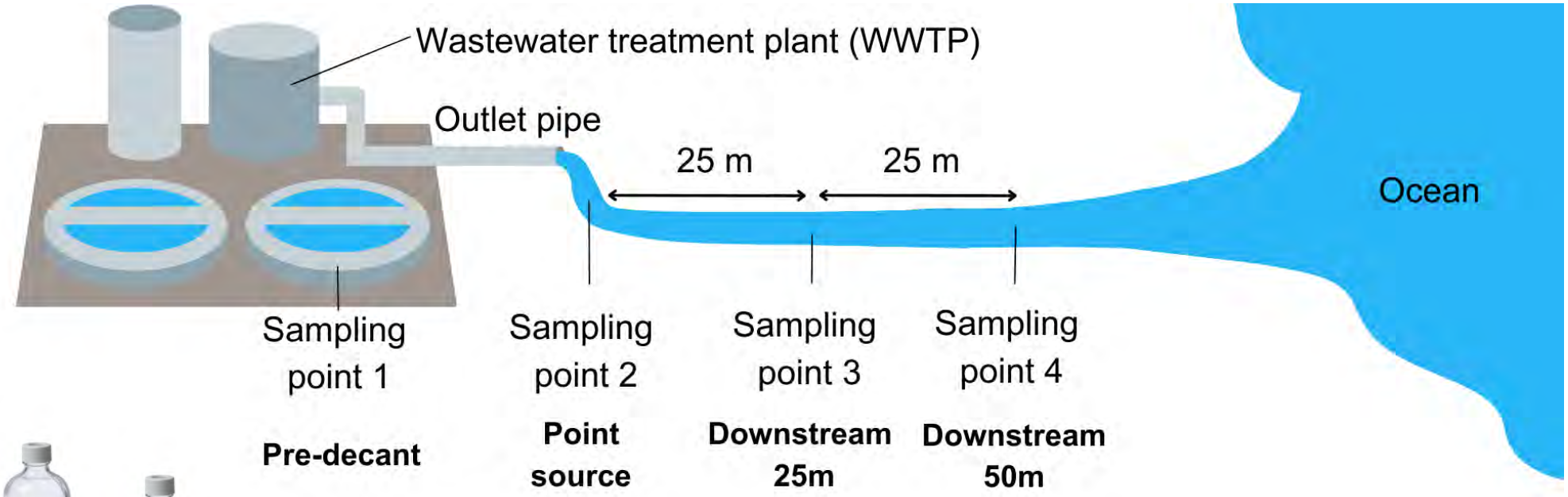


3 x 2 L replicates
x 4 sample collection points

3 x WWTP sites

2 x collection time points
wet vs. dry season

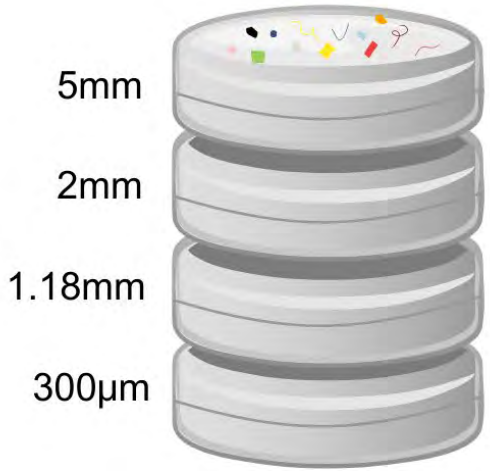
Methods - Microplastics

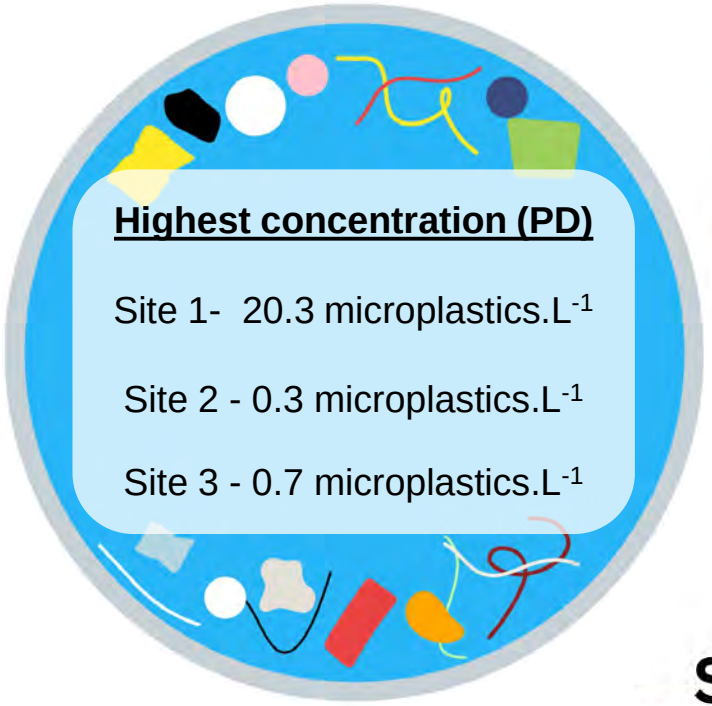


3 x 2 L replicates
x 4 sample collection points

3 x WWTP sites

2 x collection time points
wet vs. dry season



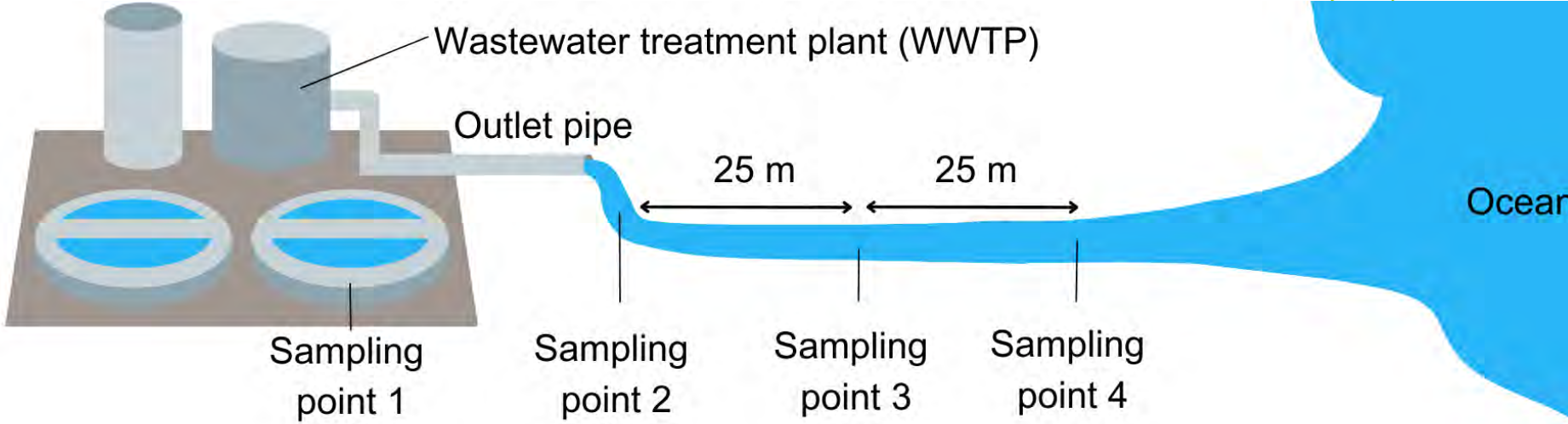


Highest concentration (PD)

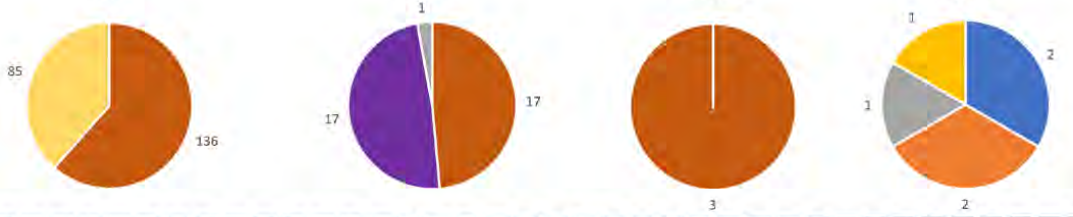
Site 1- 20.3 microplastics.L^{-1}

Site 2 - 0.3 microplastics.L^{-1}

Site 3 - 0.7 microplastics.L^{-1}



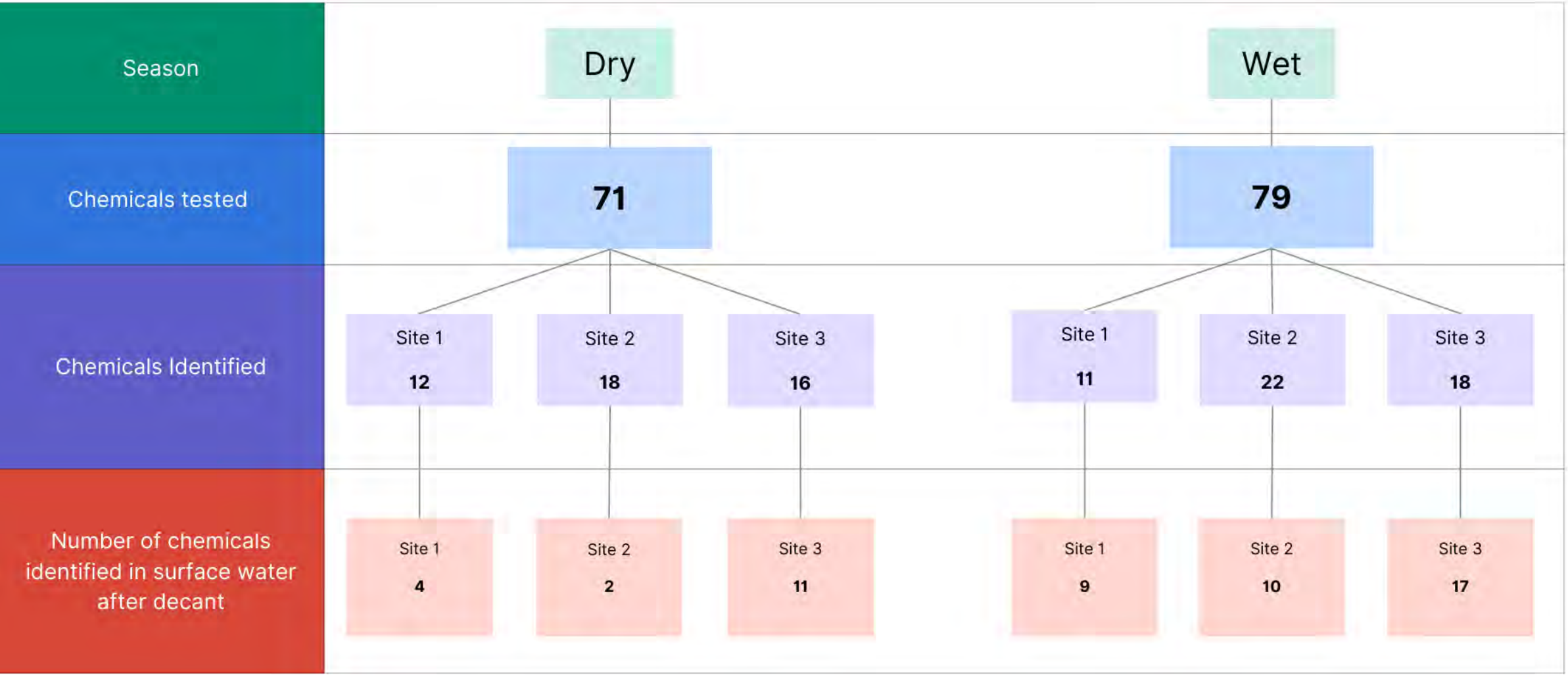
	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4
Site 1	221 MPs	35 MPs	3 MPs	6 MPs
Site 2	4 MPs	0 MPs	0 MPs	5 MPs
Site 3	8 MPs	0 MPs	1 MPs	3 MPs



- paint fragments
- polystyrene fragments
- polyethylene fragments
- rubber fragments
- cellophane fragments
- polyester fibres
- polypropylene fibres
- polyethylene fibres
- polyurethane fibre
- polyethylene fibre

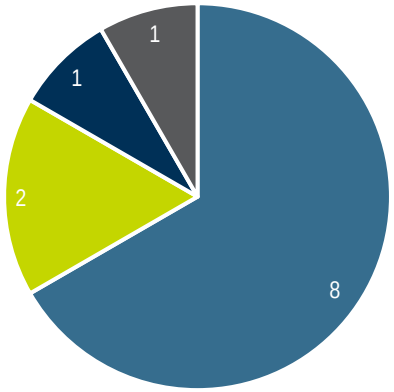
Results for PPCPs and other chemicals

- Pharmaceuticals
- Food additives
- Hormones
- Fragrances
- Beauty products
- Insect repellant

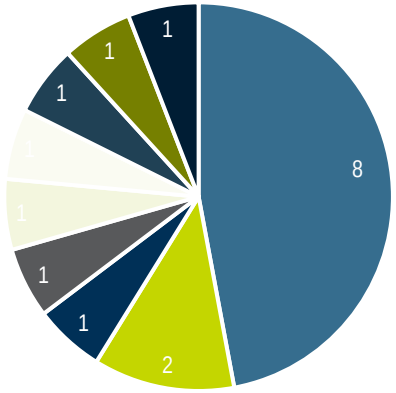


PPCPs and other chemical categories

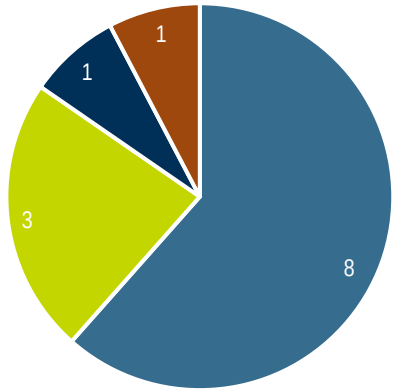
Site 1 dry season



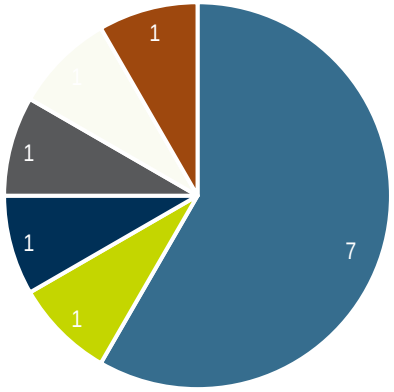
Site 2 dry season



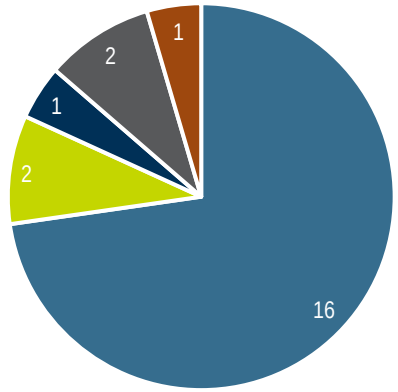
Site 3 dry season



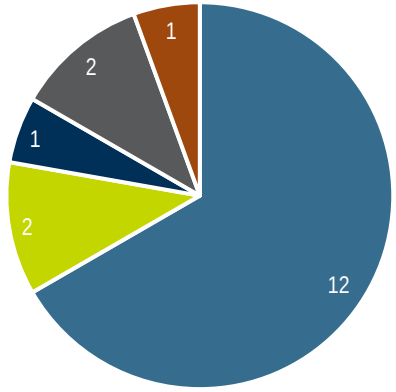
Site 1 wet season



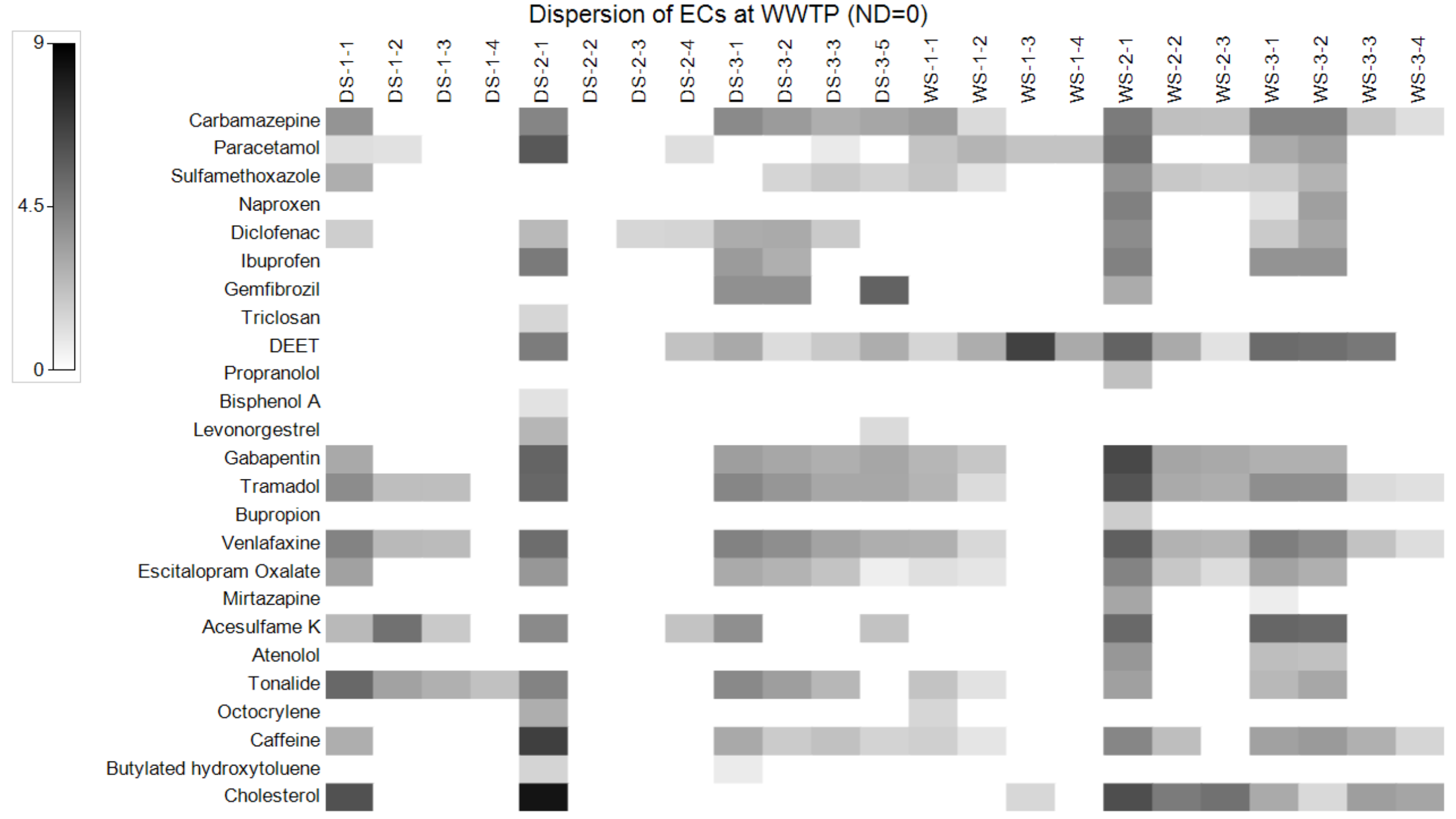
Site 2 wet season



Site 3 wet season



- Pharmaceuticals
- Food additives
- Fragrances
- Human excretion
- Hormones
- Beauty products
- Anti-bacterial
- Insect repellent
- Plastic additive


Dispersion of ECs at WWTP (ND=0)
9
4.5
0
DS-1-1
DS-1-2
DS-1-3
DS-1-4
DS-2-1
DS-2-2
DS-2-3
DS-2-4
DS-3-1
DS-3-2
DS-3-3
DS-3-5
WS-1-1
WS-1-2
WS-1-3
WS-1-4
WS-2-1
WS-2-2
WS-2-3
WS-3-1
WS-3-2
WS-3-3
WS-3-4
Carbamazepine
Paracetamol
Sulfamethoxazole
Naproxen
Diclofenac
Ibuprofen
Gemfibrozil
Triclosan
DEET
Propranolol
Bisphenol A
Levonorgestrel
Gabapentin
Tramadol
Bupropion
Venlafaxine
Escitalopram Oxalate
Mirtazapine
Acesulfame K
Atenolol
Tonalide
Octocrylene
Caffeine
Butylated hydroxytoluene
Cholesterol

Most common ECs observed across all sites

Analyte	Site 1 (ng.L^{-1})	Site 2 (ng.L^{-1})	Site 3 (ng.L^{-1})
Carbamazepine	210 – 460	290 – 460	290 – 350
Gabapentin	90 – 410	880 – 1700	59 – 140
Tramadol	280 – 450	830 – 1300	260 – 330
Venlafaxine	370 – 530	700 – 1000	380 – 440
Escitalopram oxalate	120 – 130	180 – 360	79 – 120
Tonalide	115 – 810	132 – 455	109 – 399
Caffeine	45 – 90	346 – 2800	100 – 150

- >2,000 ng.L^{-1}
- 1500-2000 ng.L^{-1}
- 1000-1499 ng.L^{-1}
- 500-999 ng.L^{-1}
- 1-499 ng.L^{-1}

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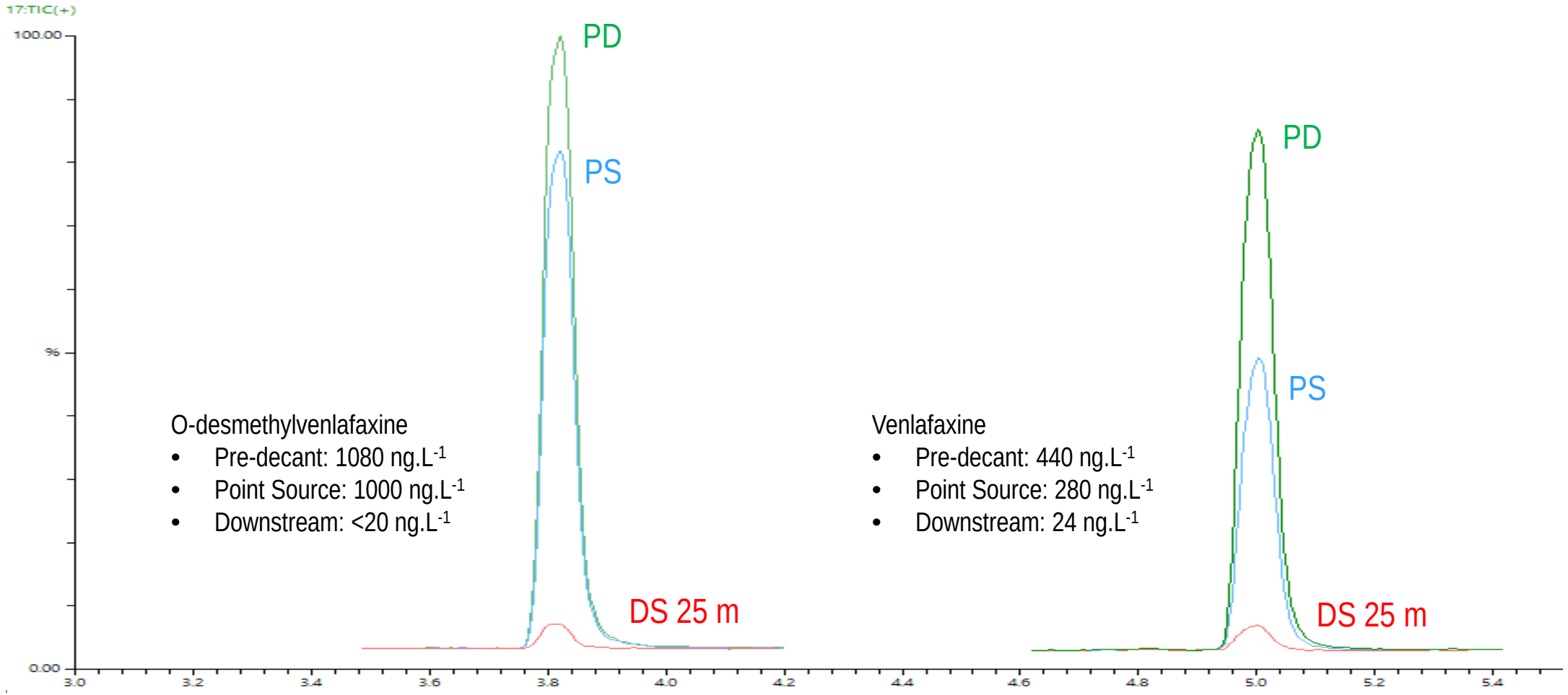
Site 3

Wet Season



O-desmethylvenlafaxine

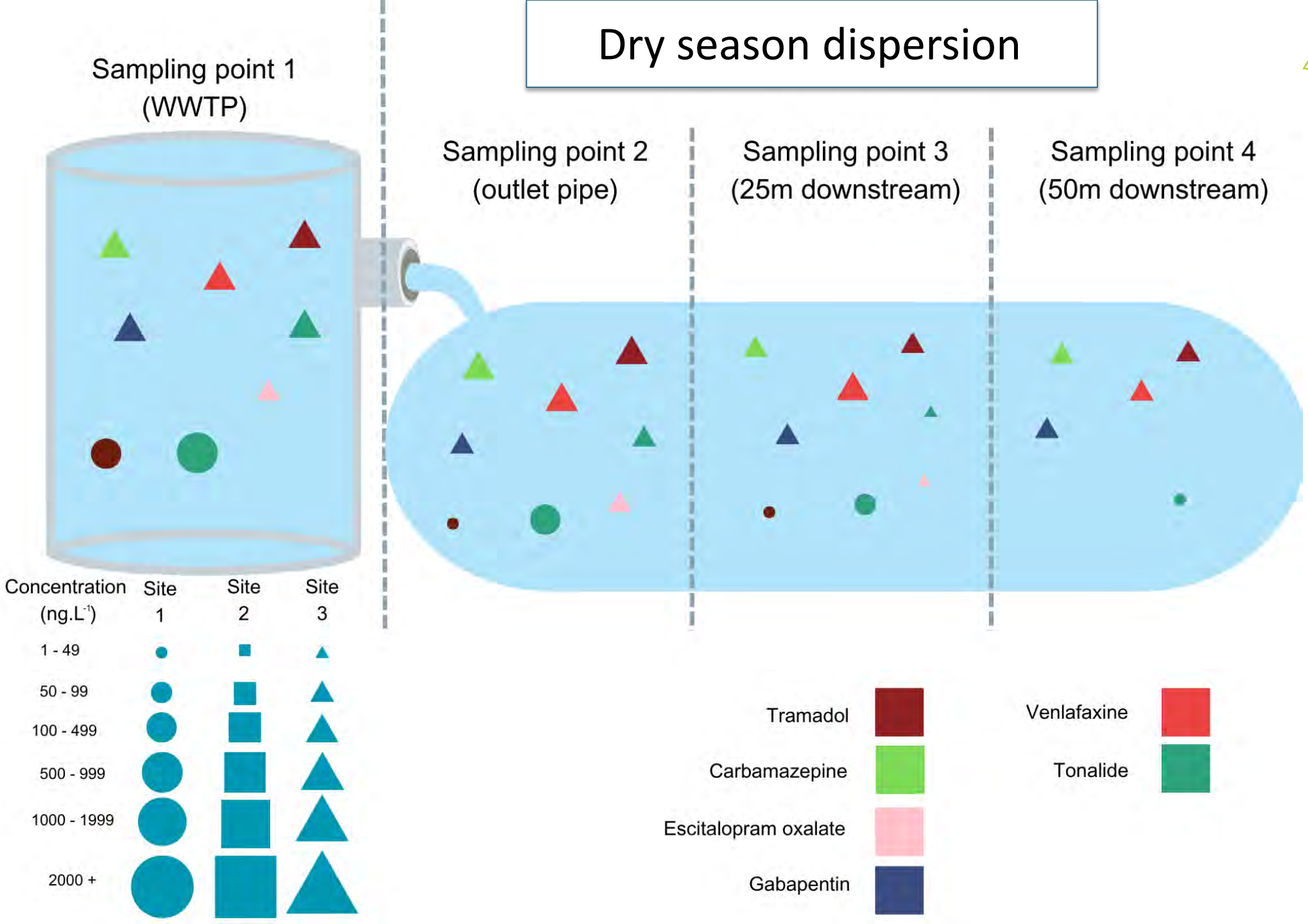
- Pre-decant: 1080 ng.L^{-1}
- Point Source: 1000 ng.L^{-1}
- Downstream: <20 ng.L^{-1}

Venlafaxine

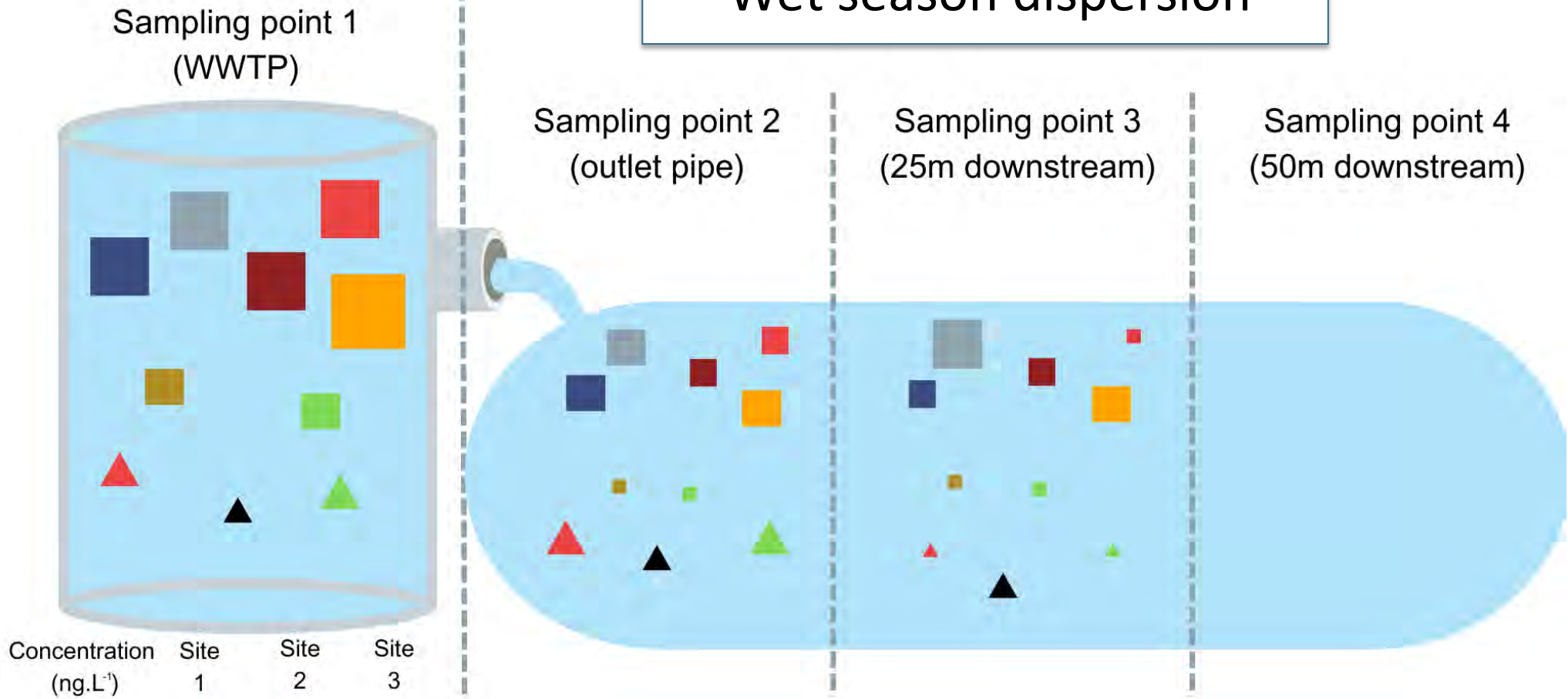
- Pre-decant: 440 ng.L^{-1}
- Point Source: 280 ng.L^{-1}
- Downstream: 24 ng.L^{-1}

Non detected in 50 m

Dry season dispersion



Wet season dispersion



Concentration ($ng.L^{-1}$)	Site 1	Site 2	Site 3
1 - 49			
50 - 99			
100 - 499			
500 - 999			
1000 - 1999			
2000 +			

- Tramadol
- Carbamazepine
- Sulfamethoxazole
- Gabapentin
- Venlafaxine
- O-desmethylvenlafaxine
- Cholesterol
- Caffeine

How do these concentrations compare to other Australian locations?

Use	Chemicals	Max conc. in effluent (PD) this study ($ng.L^{-1}$)	Concentration range in effluent in other studies ($ng.L^{-1}$)	Max conc. in receiving waters (PS, DS 25, 50 m) this study ($ng.L^{-1}$)	Max. conc. in receiving water in other studies ($ng.L^{-1}$)
Anti-convulsants	Carbamazepine	474	288-676[b];80-550[e]; 380-860[f];158-**3205**[h]; 1970 (max)[l]; 702[j]; 425-893[k]	411	682[a]; 2.7[g]; 1[k]; 106[l]; **930**[m*]
	Gabapentin	1740	50-3900[e]; 1000-**1800**[f]	200	118[l]; **2,370**[m*]
Painkillers	Tramadol	1320	359-703[k]	306	6[g]; 4[k]; 81[l]; **900**[m*]
Anti-depressants	Venlafaxine	1050	100-270[e]; 330-**1200**[f]; 736[j]; 441-598[k]	348	32[g]; 1[k]; 86[l]; **700**[m*]
	Escitalopram oxalate	390		83	
Fragrances/Musk	Tonalide	810		172	
Stimulant	Caffeine	2800	**15,200**[n]	343	**3,770**[a]
Painkillers	Paracetamol	1700	8.2-102[b]; **17000**[e]	182	**7150**[a]; 67[g]; 34[l]
Antibiotic	Sulfamethoxazole	223	200 (max)[c]; 320 (max)[d]; 10-80[e]; 170-**380**[f]	84	67[a]; **2000**[c]
Anti-inflammatories	Diclofenac	726	38-272[b]; 10-90[e]; 60-260[f]; **550** (max)[i]	427	**590**[m*]
	Ibuprofen	661	44 (max)[a]; 20-457[b];**1660** (max)[i]: 4.6-120[j]	233	44[a]
Anti-depressant metabolite	O-desmethylvenlafaxine (metabolite of Venlafaxine)#	6180		1,220	**3430**[m*]
Artificial Sweetener	Acesulfame K	3028		49,848	114[g]; 114[l]
Laundry detergent	Triclosan	340	23-**434**[i]; 5[j]		**87**[a]; 75[i]; 3[l]
Birth control	Levonorgestrel	225	0.6[o]	243	

Adapted from Kroon et al. (2016)

How do we know these levels are harmful?

- No regulatory guidelines for maximum permissible limits for PPCPs and many other emerging contaminants in Australia in environmental waters such as rivers
- If predicted environmental concentration (PEC) is < 0.01 $\mu g.L^{-1}$ assumed no risk for environment
- If PEC > 0.01 $\mu g.L^{-1}$ – environmental fate and effects analysis

Evaluate PEC:PNEC

Physical chemical properties and fate
(biodegradability, bioaccumulation, adsorption)

Aquatic effect studies
(fish, *Daphnia*, algae)

Chronic exposure
Continuous exposure via WWTP

Apply assessment factor (AF)
(degree of uncertainty)

How do these concentrations compare to LC_{50} tests

Use	Chemicals	Highest recorded in this study ($ng.L^{-1}$)	Species	Known LC_{50} ($ng.L^{-1}$)
Anti-convulsants	Carbamazepine	474	Midge Zebrafish	200,000* ≥ 245,000,000
	Gabapentin	1740	Zebrafish	599,000,000,000
Painkillers	Tramadol	1320	Zebrafish Crucian carp Sharptooth catfish	Not detected 6,200,000 (24 hours) 63,340,000 (96 hours) 213,000,000 (24 hours)
Anti-depressants	Venlafaxine hydrochloride	1,050	Rainbow trout	>100,000,000 (96 hours)
	Escitalopram oxalate	390	Zebrafish	Reported as non-toxic
Fragrances/Musk	Tonalide	810	Zebrafish Copepod (embryo)	35,000 (34 d NOEC) 7,000
Stimulant	Caffeine	2800	Zebrafish (embryo)	59,000,000

Use	Chemicals	Highest recorded in this study ($ng.L^{-1}$)	Species	Known LC_{50} ($ng.L^{-1}$)
Anti-inflammatories	Diclofenac	726	Zebrafish (larvae) Zebrafish (juvenile) Zebrafish (embryo)	1,970,000 156,000,000 3,630,000
	Ibuprofen	661	Zebrafish (embryo)	8,060
Artificial sweetener	Acesulfame K	3,028	Zebrafish	1,800,000,000 (96 hours)
Birth control	Levonorgestrel	225	Zebrafish	0.47 (NOEC)
Anti-depressant metabolite	O-desmethylvenlafaxine (metabolite of Venlafaxine)#	6180	?	?

*$ng.kg^{-1}$

Levonorgestrel (243 ng.L^{-1})

Larval zebrafish
↓ Post-hatch survival
(>0.47 ng.L^{-1})

Fat head minnow
↓ Egg production (5 ng.L^{-1})
Infertility (0.8 ng.L^{-1})

Diclofenac (427 ng.L^{-1})

Larval zebrafish
Disrupts lipid
breakdown (30 ng.L^{-1})

GISD

Green crabs
Metabolic impacts
(10 ng.L^{-1})

Mirtazapine (103 ng.L^{-1})

Larval zebrafish
Impair development
(46 ng.L^{-1})

Venlafaxine (1,050 ng.L^{-1})

Freshwater snails
Foot detachment
(313 pg.L^{-1})

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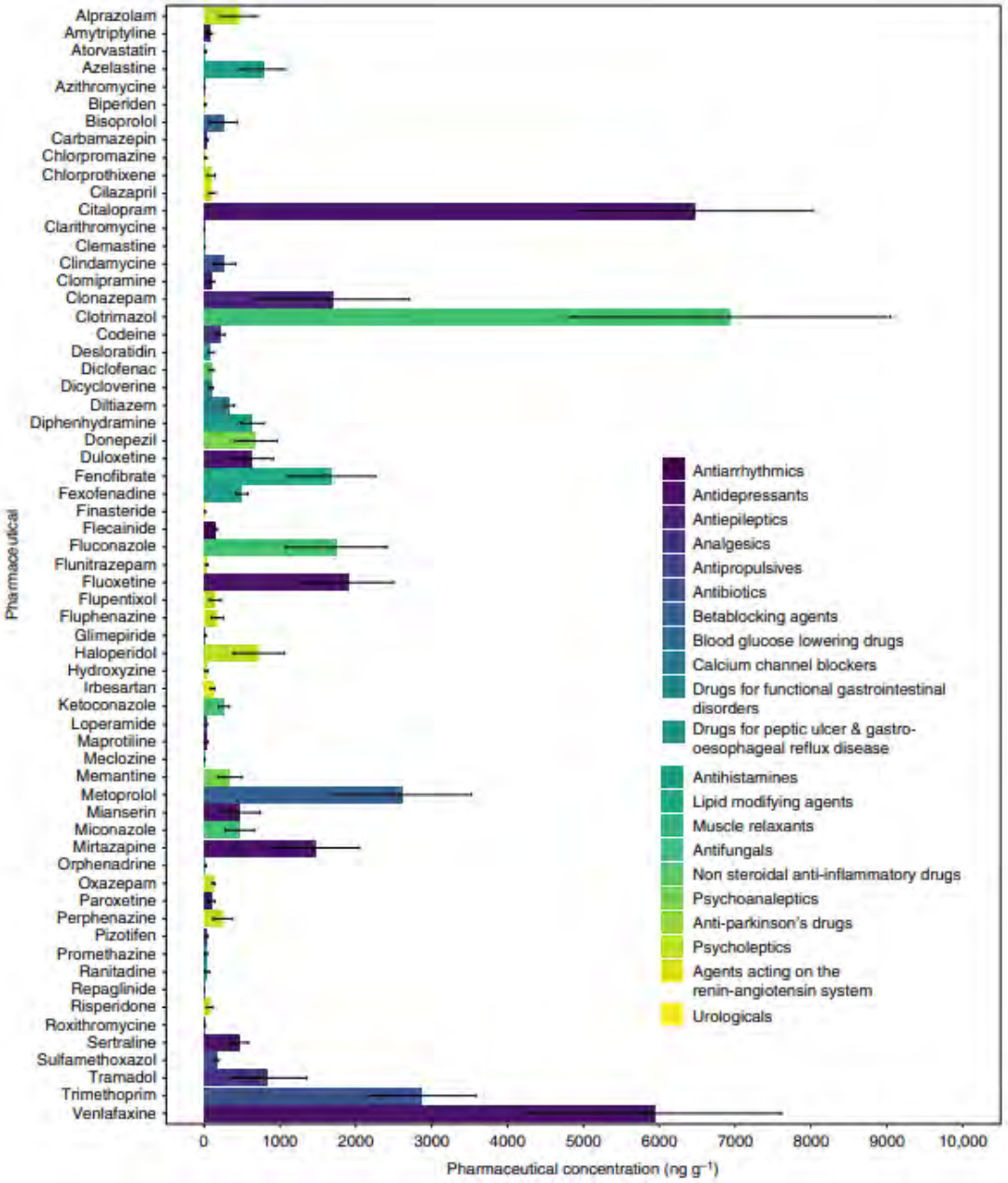
What about concentrations in aquatic organisms?



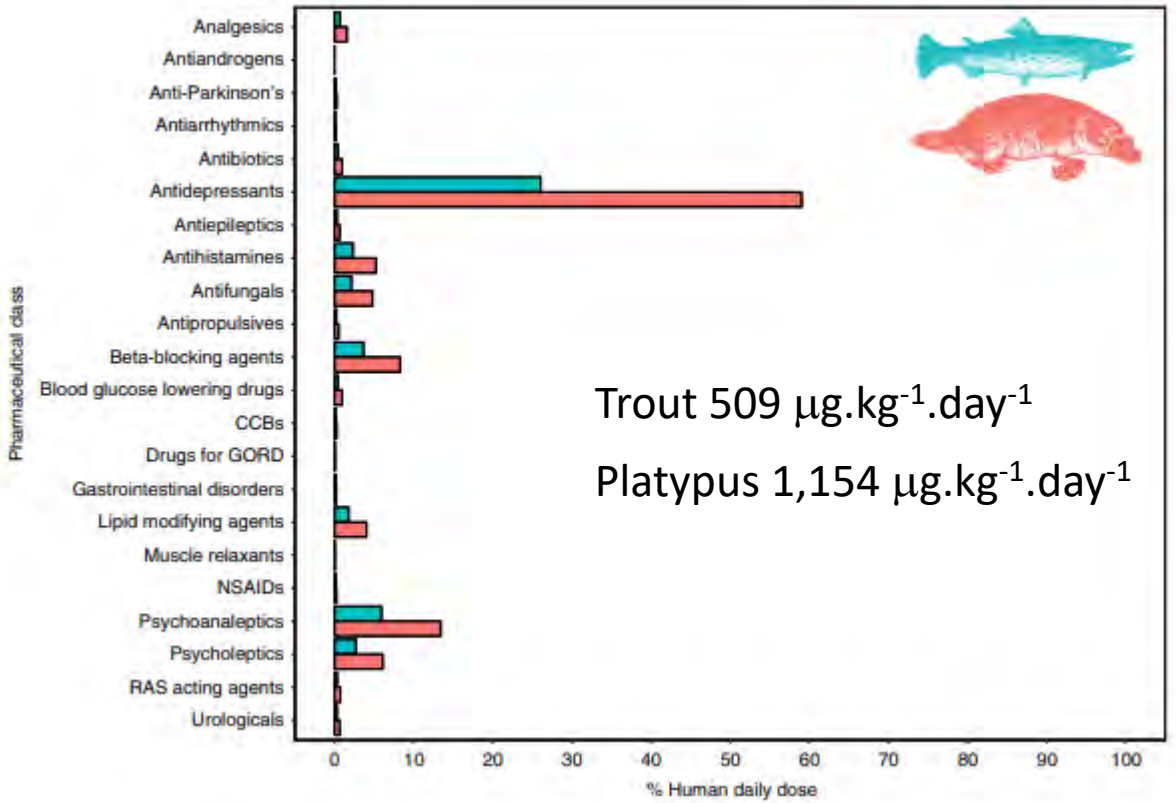
nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-06822-w OPEN

A diverse suite of pharmaceuticals contaminates stream and riparian food webs

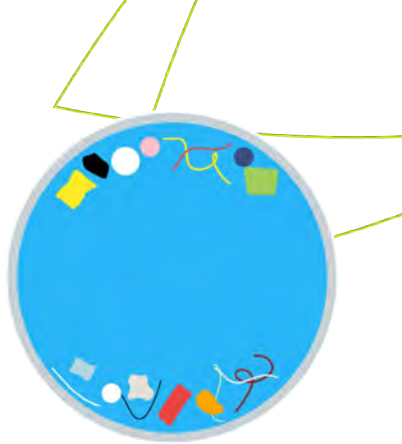
Erinn K. Richmond[1], Emma J. Rosi[2], David M. Walters[3,8], Jerker Fick[4], Stephen K. Hamilton[2,5], Tomas Brodin[6,7], Anna Sundelin[4] & Michael R. Grace[1]



Trout 509 $\mu g.kg^{-1}.day^{-1}$

Platypus 1,154 $\mu g.kg^{-1}.day^{-1}$

Conclusions



- Microplastics at much lower levels than expected – 0.7 to 20.3 MPs.L^{-1}
- Dry season: 17 - 23% of 71 targeted chemicals detected
- Wet season: 22% - 32% of 79 targeted chemicals detected
- Regardless of season, seven chemicals consistently detected
- Site 3 – 17/18 chemicals were detected downstream (some up to 1 km)
- Concentrations are below LC_{50} by orders of magnitude for some chemicals
- But concentrations are at levels detected in aquatic organisms – potential for synergistic effects and sub-lethal impacts?
- Only a ‘snapshot’ for two events – more consistent monitoring is required

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