Seasonal Dynamics, Removal Efficiencies, and Environmental Risks of Contaminants of Emerging Concern (CECs) in Four Australian WWTPs

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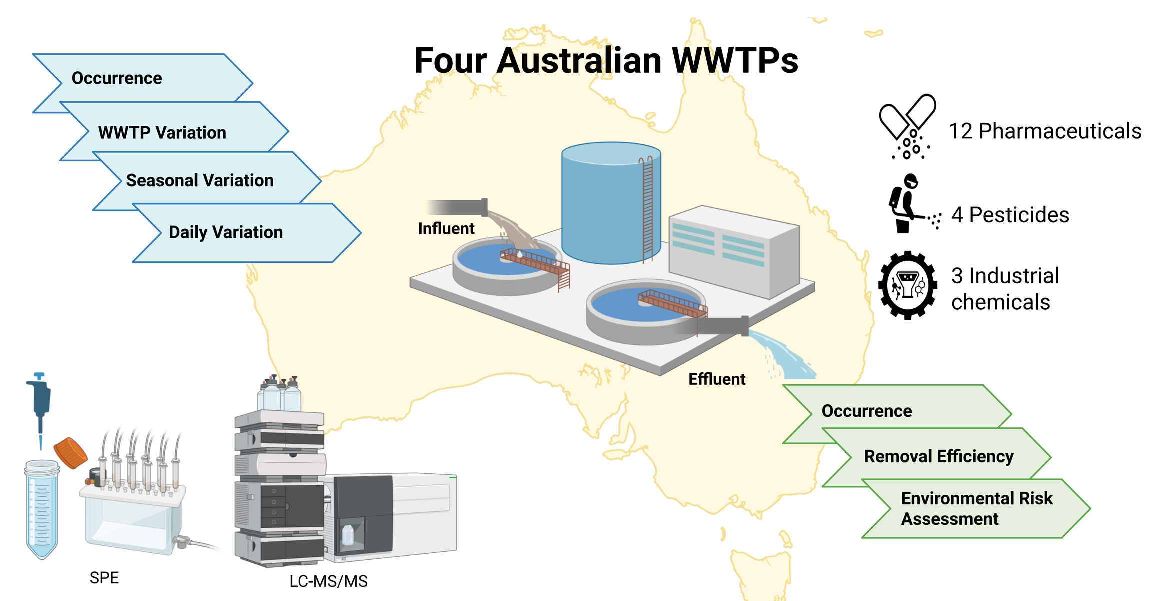
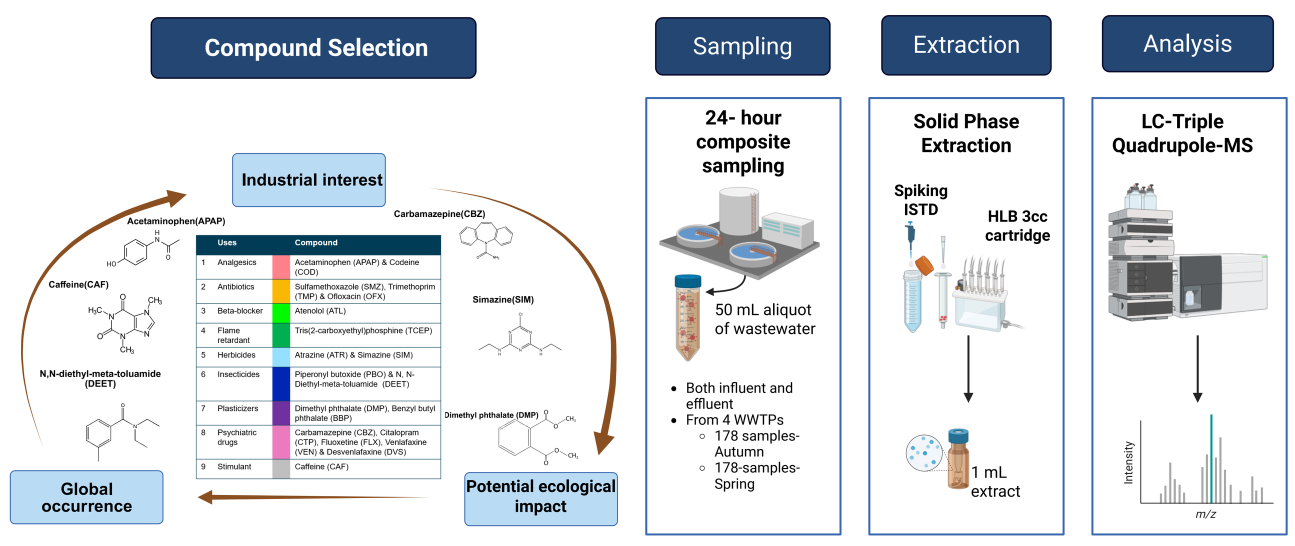
Graphical Abstract



Background

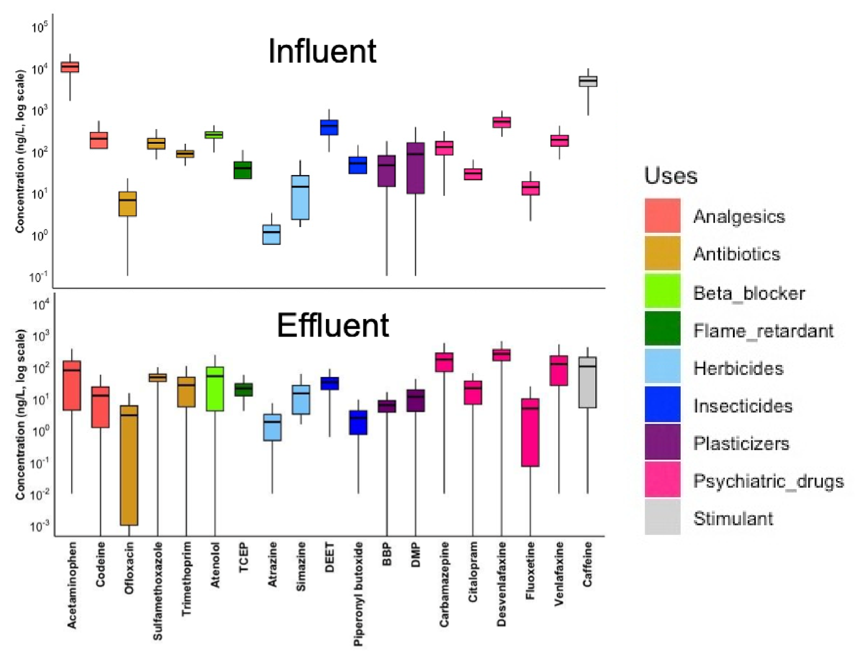
- **CECs in focus:** Pharmaceuticals, pesticides, plasticizers, and flame retardants are widely used but not routinely monitored in wastewater
- **WWTPs as pathways:** Effluent discharge is a primary source of CECs entering aquatic environments
- **Treatment challenge:** Many CECs persist due to resistant chemical structures; conventional WWTPs often remove <70%
- **Environmental concern:** Risks include bioaccumulation, endocrine disruption, antibiotic resistance, and chronic toxicity to aquatic organisms
- **Knowledge gap:** Seasonal CEC dynamics are poorly studied in Australia
- **This study:** First comprehensive evaluation of occurrence, removal, seasonal variation, and ecological risk of multi-class CECs in Australian WWTP

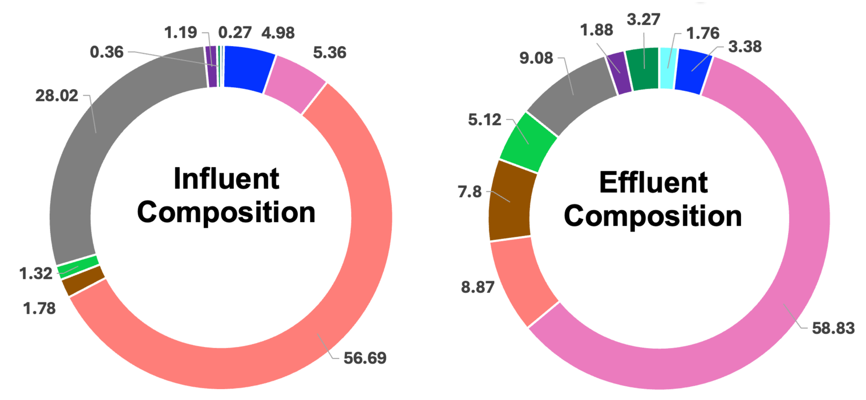
Methodology



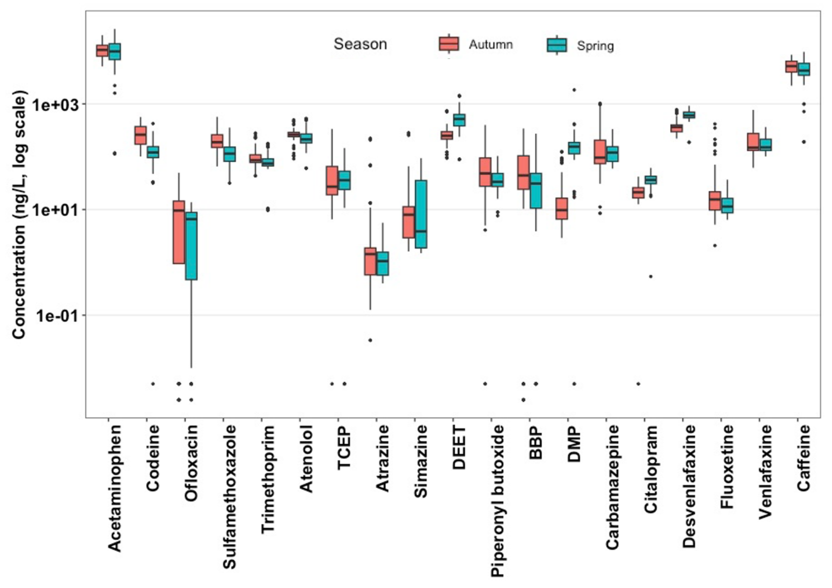
Details of target compound selection, sample extraction and analyses of 19 CECs from WWTP influent and effluent samples

Results and Discussion

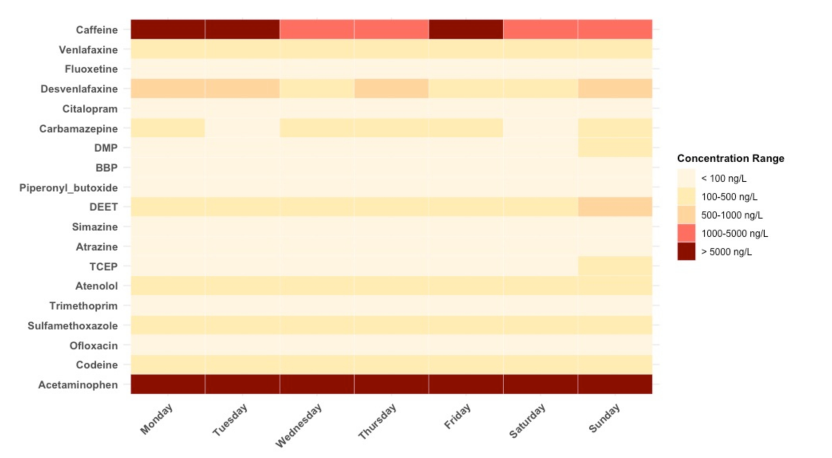




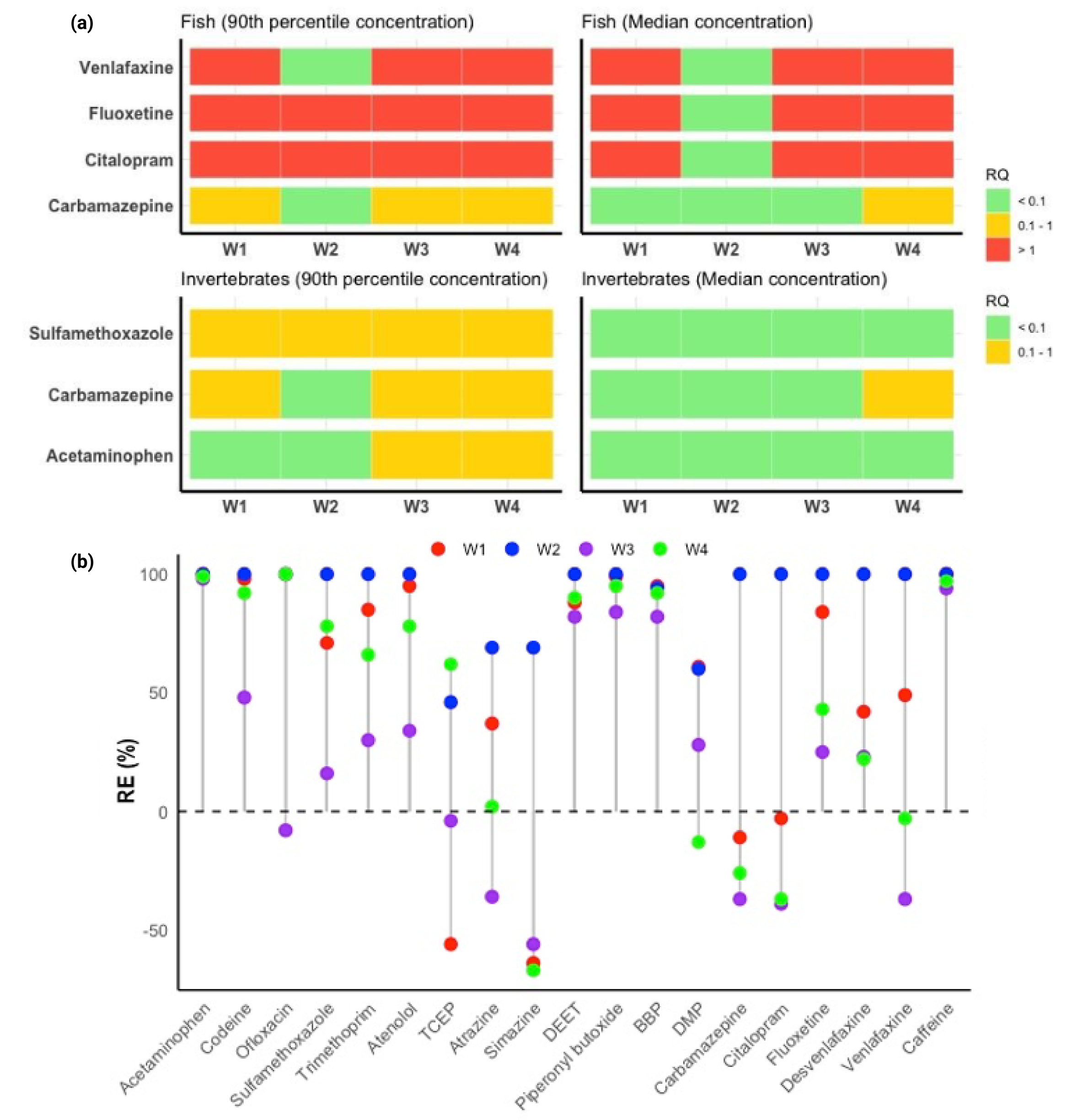
Influent and effluent composition of target CECs (n=19)



Seasonal variation of target CECs (n=19), across Autumn and Spring



Daily variation of target CECs (n=19) over seven consecutive days



Effluent quality variation: (a) Environmental risk characterization based on RQ; (b) Removal efficiencies (REs)

Influent and effluent concentrations

- All 19 CECs detected in influent (> 73%); lower detection in effluent
- Acetaminophen (<26,000 ng/L) and caffeine (<9,720 ng/L) dominated influent loads

Seasonal variation

- Autumn - elevated codeine and antibiotics (sulfamethoxazole, trimethoprim and ofloxacin)
- Spring - higher levels of psychiatric drugs (desvenlafaxine and citalopram) and, DEET

WWTP variation

- W4 (domestic-dominated) showed highest levels of pharmaceuticals (acetaminophen, codeine, antibiotics, psychiatric drugs)

Removal Efficiency (RE)

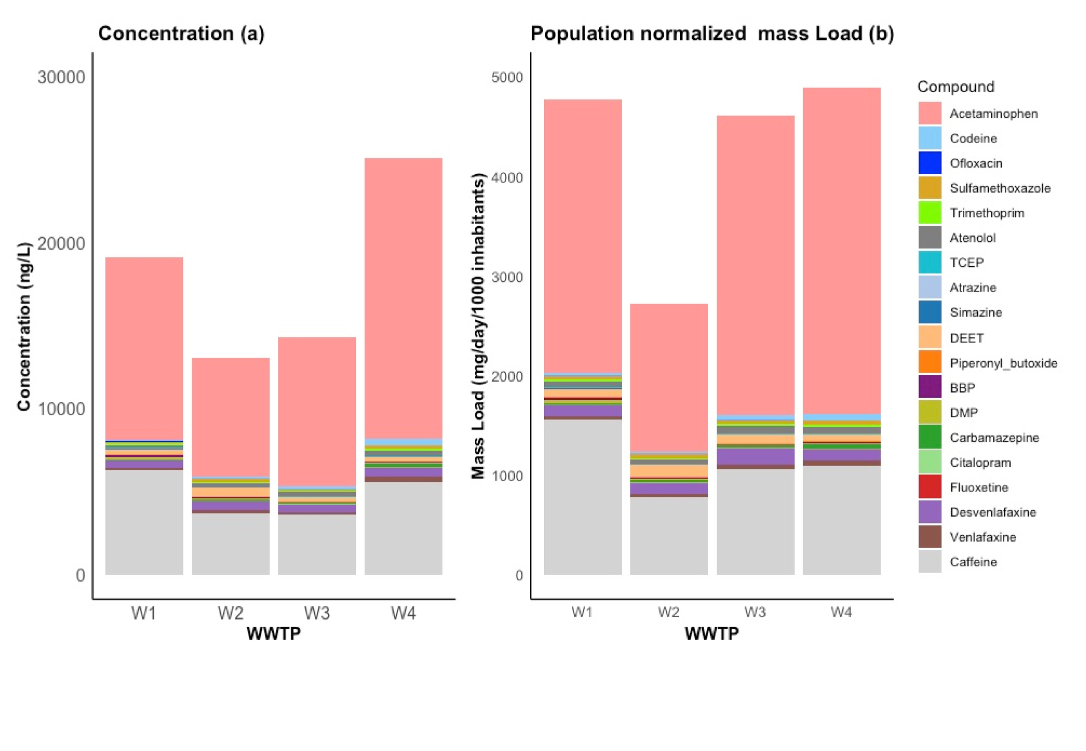
- RE varied widely across compounds and WWTPs

Daily variation

- Caffeine peaked midweek; several pharmaceuticals, pesticides, and plasticizers peaked on Sundays

Environmental risk characterization (Risk Quotient)

- No acute risk
- High to medium chronic risk to fish and invertebrates by certain compounds (fluoxetine, citalopram and venlafaxine)



Total concentration |(a) and population normalized mass load of target CECs (n=19) detected in influent wastewater from four WWTPs (W1-W4)

Conclusion

Occurrence

- Highest **influent** concentration- **APAP** and **CAF**
- Highest **effluent** concentration- **DVS** and **CBZ**

Seasonal Variation

- The highest **DEET, CTP, and DVS** concentration- **Spring**
- The highest **COD, SMZ, TMP, and OFX** concentration- **Autumn**

WWTPs Variation

- **Different influent profiles** depending on sources/ inputs
- **Different effluent profiles** depending on treatment technologies

Removal efficiencies Variation

- RE varied across compounds and WWTPs
- **W2** (advanced tertiary treatment) achieved **>97% RE 14/19** compounds

Ecological Risk Characterization

- **FLX** posed **high to medium** ecological risk for fish (no dilution considered)

Future work

Management implications:

- Domestic catchments → end-of-pipe treatment/ product restrictions
- Trade-waste & legacy sources → upstream intervention

Analytical improvement:

- SPE-LC-MS/MS method was developed and validated for 45 compounds

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