Pharmaceuticals in a Rural Scottish Highlands Wastewater Treatment Plant

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Introduction

Pharmaceuticals (pharma), a class of emerging environmental contaminants, are extensively used and introduced into municipal sewers and waterways. Many pharma are recalcitrant to removal during wastewater treatment. Conventional, less advanced wastewater treatment plants (WWTPs), such as those employed in rural areas, are unable to fully degrade these pollutants. This research investigated pharma presence and persistence in municipal wastewater in Wick, Caithness (Fig 1). Average removal in the WWTP, and correlations with flow and water quality were determined.

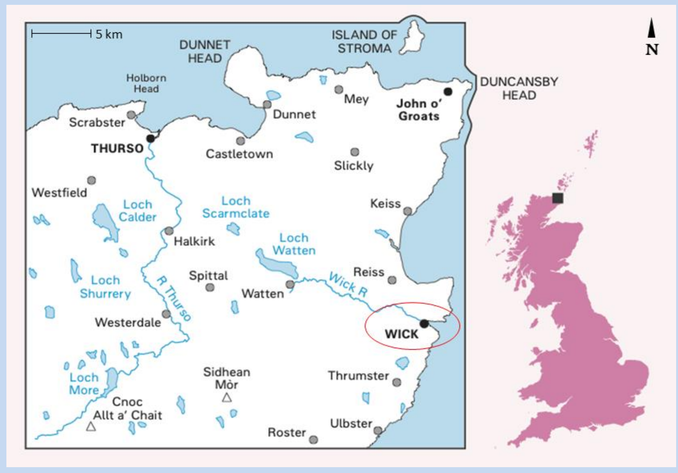


Fig 1. Caithness, Scotland with study site (Wick) indicated.

Target pharma:

- ***Analgesics***: paracetamol (PAR), ibuprofen (IBU), diclofenac (DCF)
- ***Antibiotics:*** clarithromycin (CLAR), trimethoprim (TRI)
- ***Psychiatric drugs:*** carbamazepine (CBZ), fluoxetine (FLX)
- ***Estrogen contraceptive***: 17α-ethynylestradiol (EE2)

Methods

- 2 L WWTP influent and effluent samples collected daily (n = 19), Feb 2018 (Fig 2)
- Monitored 8 pharma and 25 water quality parameters (physical properties, nutrients and dissolved metals)
- WWTP flow to full treatment (FFT, m^3 per day, CMD) accessed through Scottish Water

Fig. 2: Sampling raw influent at the Wick WWTP (left). Filtered (0.7µm GF) samples (top middle), solid phase extraction (bottom middle) and pharma analysis with Triple Quadrupole LC-MS/MS (top right). TOC-L analyser for dissolved organic and inorganic carbon analysis (right bottom).

Results

- Pharma detection: PAR and CBZ in 100% influent and effluent samples; IBU and TRI in 100% influent samples; CLAR in 100% effluent samples
- Significant difference between PAR and CBZ between WWTP influent and effluent samples (Fig 3)
- Avg removal spanned <0% (Clar and CBZ) to 87% (PAR)

Flow and Water Quality Correlations

- Significant correlation between CBZ effluent conc and FFT (linear regression modelling, p = 0.029) with high conc observed during low flow (Fig 4B)
- Significant pharma-WQ correlations: PAR and pH, turbidity, dissolved organic carbon (DOC), total suspended solids (TSS), chemical oxygen demand (COD) in Fig 5; indicated in PCA biplot (Fig 6).

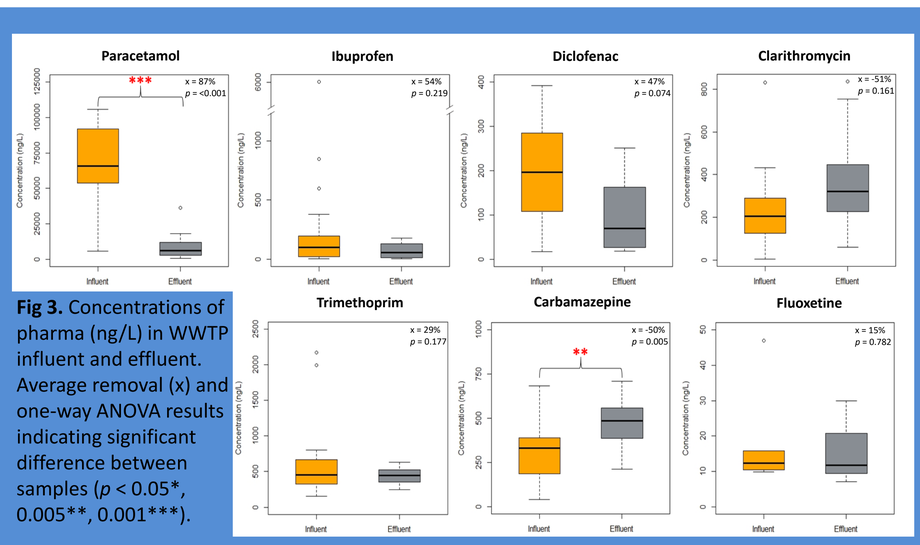


Fig 3. Concentrations of pharma (ng/L) in WWTP influent and effluent. Average removal (x) and one-way ANOVA results indicating significant difference between samples ($p < 0.05$*, 0.005**, 0.001***).

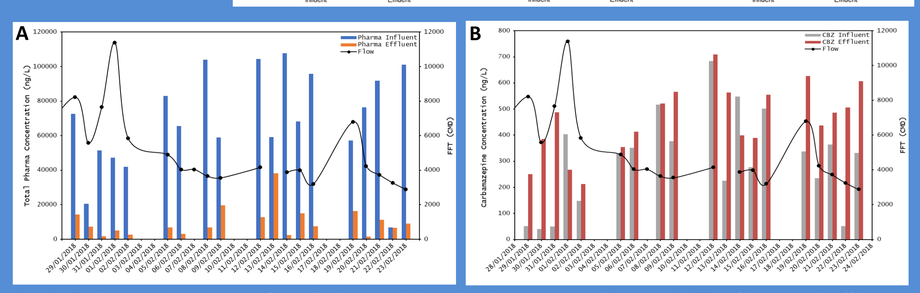


Fig 4. Daily concentrations of total pharma (A) and carbamazepine (B) in WWTP influent and effluent plotted against daily Wick WWTP flow to full treatment (FFT, m^3 per day (CMD)).

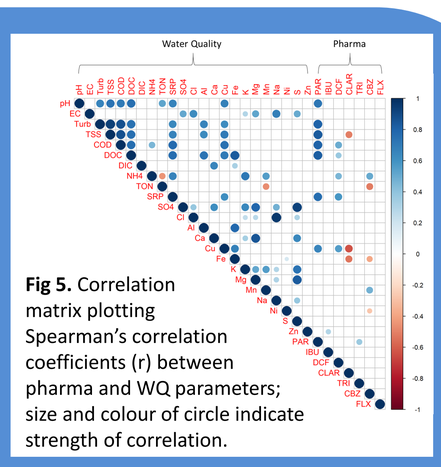


Fig 5. Correlation matrix plotting Spearman's correlation coefficients (r) between pharma and WQ parameters; size and colour of circle indicate strength of correlation.

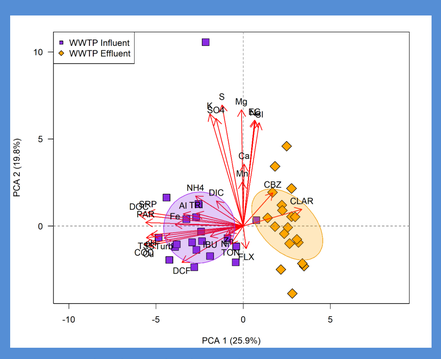
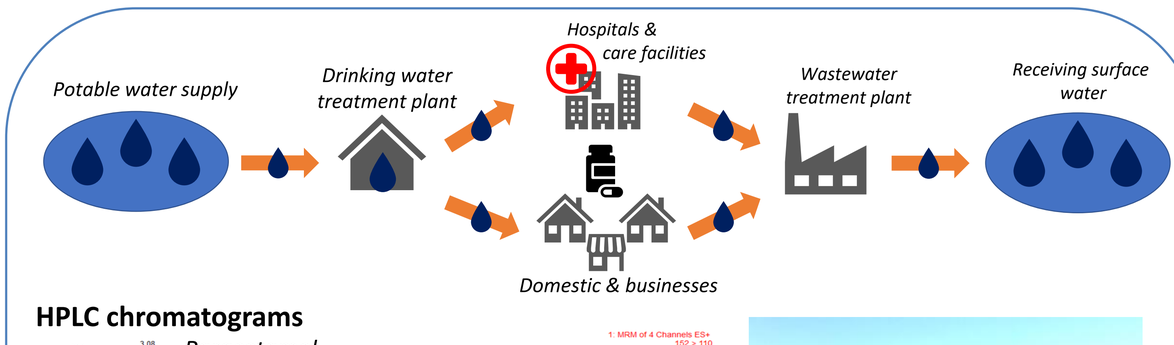


Fig 6. PCA biplot which explains >45% variation in dataset, with confidence ellipses (at 95% level).

Conclusions & Future

- ***Antibiotics and analgesics:*** most frequently detected target pharma in Wick WWTP influent and effluent
- ***Antibiotics and psychiatric drugs:*** poor removal in Wick WWTP with avg removal <0% CBZ and CLAR, <30% TRI and FLX
- ***CBZ and flow correlations:*** dilution effects (e.g., from rain) may cause reduced CBZ concentration in WWTP effluent
- ***PAR and WQ correlations:*** PAR sorption behaviour and association with aqueous-phase wastewater may be related to sample pH, turbidity, DOC, TSS, COD
- ***Further investigation*** into pharma behaviour and degradation in separate stages of a conventional WWTP; particularly identification of potentially harmful transformation products



HPLC chromatograms

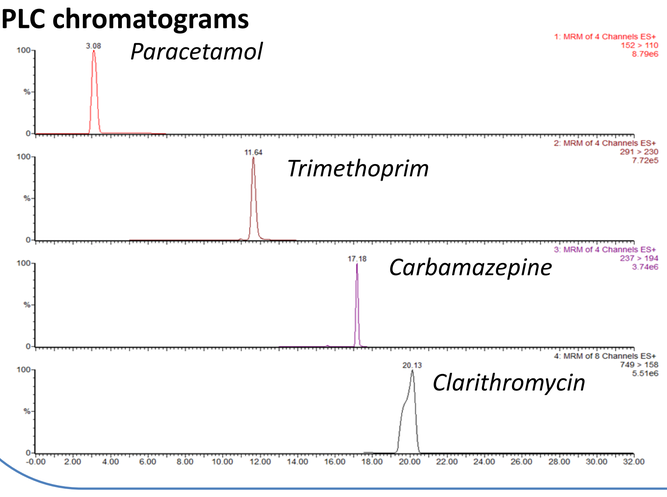


Fig 7. Proposed pharma pathway into surface water (top centre). HPLC separation of pharma detected in WWTP effluent (left). Conventional WWTP in Wick, Caithness (right).

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