Assessment of the Degradation Pathway, Persistence and Eco-Toxicological Impacts of Pharmaceuticals and Degradation Products in the Aquatic Environment

Lydia Niemi, Prof. Stuart Gibb[1], Dr. Zulin Zhang[2], Dr. Mark Taggart[1], Dr. Kenneth Boyd[1]

1. Environmental Research Institute, Castle Street, Thurso, KW14 7JD
2. The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8HQ

Corresponding Author Email: Lydia.Niemi@uhi.ac.uk

This research is funded by the Hydro Nation Scholars Programme, in association with the Centre of Expertise for Waters (CREW) and the Scottish Government.

Introduction

Pharmaceuticals (pharma) are extensively used in everyday life, and are introduced into wastewater treatment (WWT) where inadequate removal leads to the release into surface water via effluent. The effects of WWT on pharma behaviour are not fully understood – especially the removal, formation and fate of degradation products (Mathon et al., 2016). Advanced tertiary treatment methods such as chemical oxidation, photodegradation and disinfection are of concern due to the formation of potentially toxic and bioactive degradation and by-products (Kosma et al., 2016; Michael et al. 2013). Therefore, to protect water quality and aquatic ecosystems ***research is needed to investigate pharma degradation products and the distribution, persistence and eco-toxicity in waters.***

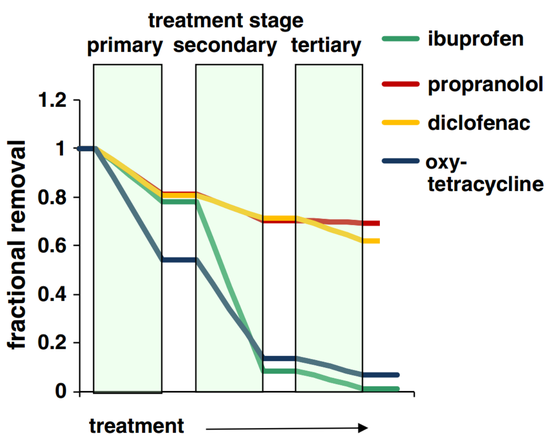


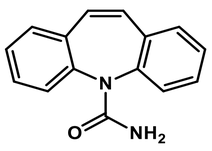
Figure 1. Depiction of influent concentrations (%) removed during separate stages of the WWT and discharged in effluent (Gardner et al., 2013)

UK Focus:

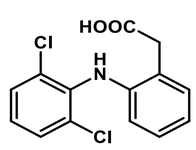
- *Scotland, 2015-2016*: 102.6 mil prescriptions dispensed (ISD, 2016).
- *Water Framework Directive (WFD)*: Est. to control pollution and increase effluent quality, Environmental Quality Standards (EQS) max. limits set for pharma in environmental water.
- *Gardner, 2013*: Operational efficiency WWTPs evaluated in meeting criteria of WFD and EQS. ***Even if treatment leads to complete removal, hazardous by-products can form and should be investigated.***

Research Objectives

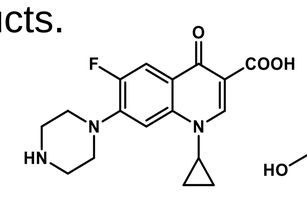
1. Selection of target compounds for monitoring and degradation studies.
2. Optimise existing analytical techniques to characterise pharma behaviour and degradation during WWT and in receiving waters.
3. Develop novel methods to assess the eco-toxicity of select degradation products.



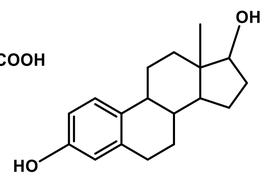
Carbamazepine



Diclofenac



Ciprofloxacin



17β- Estradiol

Significance of Research

- Identify advanced solutions to increase WWT pharma removal
- Improve water quality
- Lessen pharma environmental impact
- Promotion of green policies in Scotland

Innovative research supporting Scottish water governance

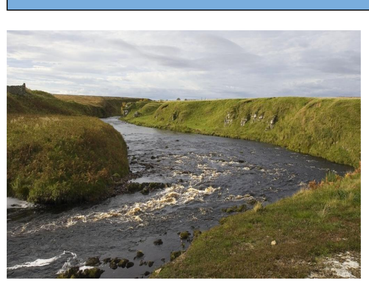
Proposed Methodology

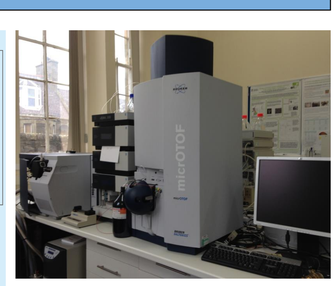
- **Polar Organic Chemical Integrative Sampler (POCIS)**
  - Effective passive environmental sampling vs grab
  - Time weighted environmental data of pharma distribution at study sites
- **Solid Phase Extraction (SPE)**
  - Analyte extraction from wastewater, surface water and environmental media
  - Clean-up and pre-concentration of samples
- **Liquid Chromatography + High Resolution Mass Spectrometry (Orbitrap, Time of Flight, Quadrupole MS/MS)**
  - Identification, quantification and structural elucidation for degradation studies (Boix et al., 2016)
- **E-SCREEN Cell Proliferation**
  - Bioassay method for eco-toxicological tests

Two Field Study Sites: Rural vs. Urban

River Thurso, Caithness: Peatland origin, high concentrations DOC, ideal for degradation studies

River Dee, Aberdeen: Agricultural/urban stresses, increased population, ideal for pharma monitoring





Expected Results

- Development of sensitive and effective techniques for sampling, degradation studies and toxicological tests.
- Understanding of pharma removal and degradation during WWT at separate stages (primary, secondary, advanced treatment).
- Understanding of pharma behaviour and degradation in surface waters at two field sites.
- Evaluation of environmental and eco-toxicological risk of pharma and degradation products in two field sites.
- Possible computational modelling of pharma drug degradation pathways in two water matrices.

Acknowledgements

The Hydro Nation Scholars Programme, Centre of Expertise for Waters (CREW), The James Hutton Institute (Aberdeen) and Environmental Research Institute.

References

Boix, C. et al., 2016. *J. Hazard Mater*, 302 pp. 302-340
Information Services Division (ISD), 2016. Prescription Cost Analysis Financial Year 2015/16
Gardner, M. et al., 2013 *Sci Tot Environ,* 456-57 pp. 359-369
Kosma, C. et al., 2016. *Sci Tot Environ*, 569-70 pp.732-750
Mathon, B. et al., 2016. *Sci Tot Environ,* 551-2 pp.712-724
Michael, I. et al., 2013. *Water Res*, 47 pp. 957-995