Evaluating HPC ingredients in WWTPs & surface water of the Songhua Catchment using monitoring & high tier modelling tools

John Kilgallon1, Antonio Franco2, Colin Hastie2, Claudia Lindim2, Roger van Egmond3, Olivier Jollivet2, Chris Sparham1, Lucy Spiers1, Cédric Wannaz2, Zileng Zhang1, Juliet Hodges1

1Safety & Environmental Assurance Centre (SEAC), University of Michigan, Ann Arbor MI, USA
2Unracco Research, 3127 Village Circle, Ann Arbor, 48108, MI, USA
3Environmental Health Science, School of Public Health, University of Michigan, Ann Arbor MI, USA

Introduction

Ingredients commonly used in home and personal care (HPC) products can enter the aquatic environment after use if they are not completely removed during wastewater treatment. We investigated the occurrence and fate of four ingredients used in HPC products in wastewater treatment plants (WWTPs) and surface waters of the Songhua River catchment (China) using a high tier modelling framework and monitoring. The ingredients studied were a high volume surfactants (Linear Alkyl Benzene - LAS), antimicrobials-preservatives (Triclosan - TCS, Methyl Paraben - MP), and UV filters (Benzophenone-3 - BP-3), with use in China and Asia ranging from 0.01 (BP-3) to 1235 mg/person/day (LAS).

The aim of our study was to advance understanding of the occurrence and fate of ingredients found in HPC products in the Songhua catchment, in particular 1) to assess spatial trends in the catchment, and 2) to evaluate and improve modelling predictions.

Methods - Monitoring

A monitoring campaign was carried out by International Joint Research Center for Persistent Toxic Substances (IURC-PTS), Harbin Institute of Technology, China in the Songhua River catchment undertaken from June-July and October-November 2017, sampling WWTPs and catchments (Figure 2). Raw influent and effluent wastewater samples were collected over three weekdays across 10 WWTP sites (six in Harbin, two in Jiamusi, one in Mudanjiang, one in Qiqihar) with triplicate samples. Surface river grab samples were taken at 27 sampling locations across the catchment using boats at a depth of approximately 50 cm. Solid phase extraction (SPE) followed by ultra-high-performance liquid chromatography coupled with tandem quadrupole mass spectrometry was used for the analysis of samples.

Methods - Modelling

Total market estimation estimates were generated for each ingredient based on 2016 product sales data for China. The modelling framework (Figure 1) considers spatial ingredient use characteristics (ScanAT [1,2]), removal mechanisms (SimpleTreat [3]) and local hydrology/partitioning processes (Pangea [4]) to determine predicted environmental concentrations across the geographic modelling domain. HydroBASINS is a global hydrology database, based on long-term annual averages, with a catchment-based geometry, which enables high to low resolution grids to be defined across a region. Ten layers (levels) of resolution, provide consistent parameterization across scales, covering large water basins at level 4, down to higher resolution level 10 water basins (Figure 3). This hydrological database has been integrated within the Pangea multiscale multimedia modelling framework, using the hydrological flow between each basin and its downstream basin to parameterize the transfer rates from the corresponding water compartments.

Results

Modeled influential concentrations show good agreement with measured concentrations for all materials, demonstrating emission estimates are reasonable. WWTP median measured removal rates range from 95.6% for TCS up to 99.8% for LAS. In comparison with SimpleTreat, measured removals are higher, leading to model overestimation in effluent concentrations. In the freshwater compartment there is generally good agreement with the modelling framework outputs (Figure 4).

The multiscale implementation of HydroBASINS within the Pangea framework proves well suited for Pangea’s multi-scale paradigm, and for comparison with monitoring data as it allows for refining the terrestrial geometry around regions of interest (e.g. monitoring locations), thus alleviating typical discrepancies (mismatch stream monitoring location) associated with gridted hydrological data sets.

This may be because these areas were highly urbanised and the river systems were more impacted. Furthermore, due to changes in societal preference on ingredients such as Triclosan, it is expected its use in China will have decreased over time.

Conclusions

Monitoring data can help understand environmental levels of HPC ingredients. Our combined modelling and monitoring approach is advantageous for assessing exposure, as monitoring data can be used to evaluate model predictions and refine parameterization while modelling provides feedback to improve the representativeness of sampling. This method enables a more detailed analysis of the key sources of uncertainty and variability at each step of the modelling framework (i.e. influent, effluent and river concentrations). Results indicate that modelled concentrations in river water are overpredicted due to difference in modelled removal in WWTP compared to measured (monitored) values. Further work to understand the uncertainties in both monitoring and modelling (inputs and model parameters) will be carried out.