A Prospective Approach for Assessing Chemical Mixtures in River Catchments with Diverse Land Uses

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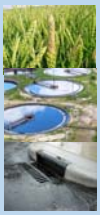
INTRODUCTION

- Field-based ecological risk assessments incorporate risks from chemical mixtures and a multitude of physico-chemical stressors. Considering the large number of contaminant-stressor combinations, assessing mixtures would seem insurmountable.
- At the SETAC Pellston Workshop, Valencia, Spain (2015) a rationale to support the simplification of assessing mixtures via exposure scenarios was developed.
- Exposure scenarios: Agriculture, Domestic Wastewater and Urban Runoff

WORKING HYPOTHESIS

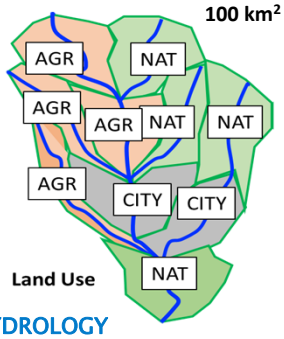
- Chemical mixture 'signatures' are scenario-specific, including chemical composition, exposure levels and temporal aspects
- Emissions of 37 chemicals were combined into daily mixture profiles over a 20-year period assessed at the bottom of a hypothetical catchment containing a changeable configuration of sub-catchments defined by three land use types:



  - Agricultural: winter wheat applications, real pesticide usage statistics
    - 13 compounds
  - Domestic: "down-the-drain" chemicals, typical city of 10,000 people and treatment plant
    - 14 compounds
  - Urban: constituents in storm water runoff
    - 10 (of 77) compounds

MIXED LAND USE CATCHMENT

- 10 sub-catchments with different land uses
- Simplified river network model
  - Connectivity, 1 day travel time, no degradation
- Modeling:
  - Emission loads + hydrology
- Outputs:
  - Concentrations (multiple)
  - Mixture assessment
  - Daily = 7246 days / model



CATCHMENT HYDROLOGY

- Based on the USDA Soil and Water Assessment Tool (SWAT)[1]
  - Predicts the effect of management decisions on water, sediment, nutrient and pesticide yields on large, ungauged river basins
  - SWAT scales up beyond the 1-ha field (simulated for the AGR scenario) and incorporates effects of baseflow and runoff in urban areas
- Modeled runoff volume for AGR, developed (CITY), and natural (NAT) areas (land uses with no significant application of chemicals)
- Modeled one soil type (from the EFSA FOCUS model[2])
  - Urban - 30% land area impervious surface connected to a drain system
- Utilized measured daily rainfall data (FOCUS R1 scenario)
- March 1, 1975 to December 31, 1994 (7246 days)

[1] http://swat.tamu.edu/
[2] https://www.efsa.europa.eu/en/applications/pesticides/tools

SCENARIOS

DOMESTIC

- Continuous discharge to surface water of "down the drain" chemicals via wastewater treatment plant
- Assumptions
  - 200 L of water use per day per capita
  - 10,000 people inhabiting a sub-catchment of 10 km²
  - WWTP removal efficiencies based on activated sludge treatment

URBAN

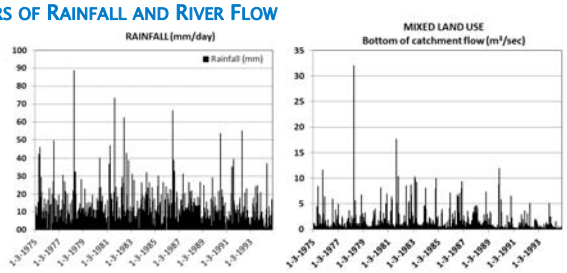
- Emissions (e.g., PAHs, metals) from roads, parking lots, buildings and roofs
- Data from three major water monitoring studies in UK and US
  - 95th percentile daily intensity (10.3 mm rainfall)
  - This means 362 runoff events in 20 years modeled
- Different rainfall threshold event, urban runoff:
  - more frequent with lower loads (lower rainfall threshold)
  - less frequent with a higher load (higher rainfall threshold)

AGRICULTURE

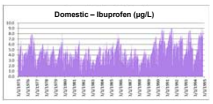
- Applied according to defined agricultural practices with application dates/rates derived from actual use statistics
- Edge-of-field stream based on regulatory modeling practices (FOCUS)

RESULTS

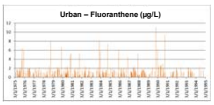
20 Years of Rainfall and River Flow



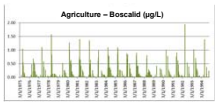
SUB-CATCHMENT PECS



- PECs vary due to changing river flows



- Episodic & variable river concentrations due to runoff events

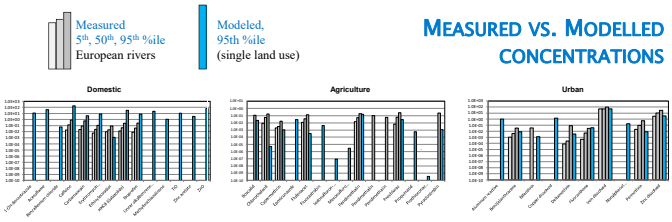


- Episodic conc. driven by application dates (spray drift) and rainfall events (runoff)
- Variable river concentrations, cyclic in nature

Measured Concentrations

- Measured Environmental Concentrations (MECs) from :
  - EMPODAT database, designed and managed by the NORMAN network (http://www.norman-network.net/empodat/)
  - European Environment Agency Waterbase database (http://www.eea.europa.eu/data-and-maps/data/waterbase-water-quality/)
- Fractions of river water samples with MECs higher than the limit of quantification was 59.8% for DOM, 1.4% for AGR, and 14.1% for URB
- The percentiles of the MEC-distributions refer to the subset of samples with quantifiable concentrations, i.e., these are highly skewed
- PECs: P95 value at the outflow of a sub-catchment

Measured vs. Modelled Concentrations



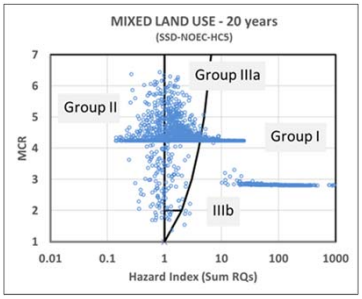
- Domestic: PEC generally > MECs; Agriculture: MECs > PECs (but only 1.4% samples > LOQ); and Urban: Variable.
- Similarity of PECs and MECs suggest land use scenarios are reasonable

Mixture Risk Characterization

- Mixture toxic pressure from SSD-NOEC-HC5 multi-substance Potentially Affected Fraction (msPAF)
- Combine daily results into Hazard Index (HI) across 37 chemicals
- Simplification: single daily PECs, not time-weighted averages
- Visualization of mixture risk used approach by Vallotton & Price (2016)
  - Group I (risks posed by individual chemicals)
  - Group II (no concern for additive cumulative risks)
  - Group IIIa (risk driven by one chemical); IIIb (risk driven by multiple)

Summary

- Majority of risk was driven by a few chemicals
- Land use with temporal aspects delivers "signature" of exposure
- Placement of land types in the model (not shown) had no significant impact on results
- Simple tool provides novel insights into mixture risk dynamics and can be upgraded (e.g., degradation, loss kinetics) especially as it relates to land use



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Workshop information: http://pellston.setac.eu/?contentid=824

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