Development of a Steady-State Non-Equilibrium Chemical Fate Model for Trickling Filters

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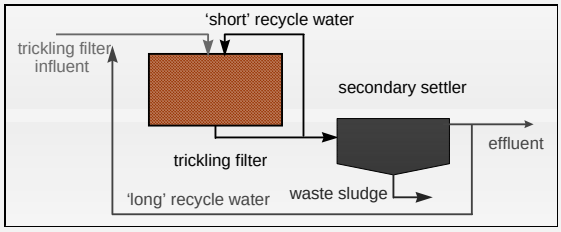
Introduction

- In **GREAT-ER** (Geo-referenced Regional Exposure Assessment Tool for European Rivers), there is a need for a **trickling filter (TF) chemical fate model**.
- To develop such a model, a **methodology**: analogous to the activated sludge fate model ***SimpleTreat*** was adopted.
- In this work, a TF fate **model was developed**; a **sensitivity analysis** (to model structure and model parameters) was performed; and a **preliminary calibration** was worked out for the fate of the surfactant Linear Alkylbenzene Sulphonate (LAS) in two full-scale TF plants in the United Kingdom (Yorkshire).

Modeling Approach

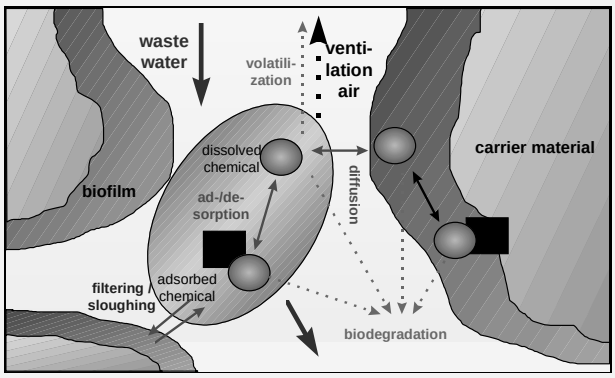
Trickling Filter Plant Configuration

(primary settler: not considered in this model)

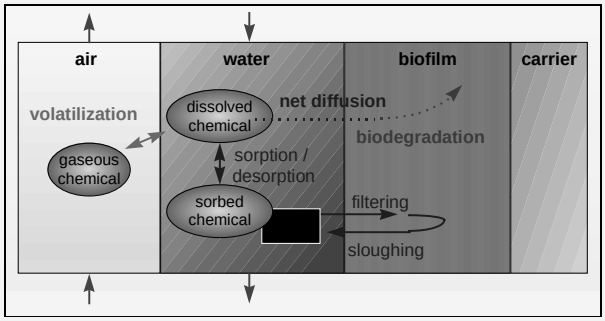


Model Description

- **TF plant** → modeled by several **interconnected boxes**
  - concept derived from ***SimpleTreat*** [(1)] (steady-state, non equilibrium, mass balance)
  - **boxes** = different **chemical phases** in filter unit + secondary settler (air, water, suspended particles)
  - **horizontal layering** of filter unit → plug-flow hydraulics
- Fate Processes



  - non-equilibrium exchange (sorption, volatilization) → **fugacity calculations**
  - advective transport → derived from TF plant flows
  - simplifications: ˙**chemical degradation** → joint biofilm diffusion + biodeg. model [(2)]
    ˙no net filtering or sloughing
- Model Scheme (processes within one horizontal layer of the filter unit)



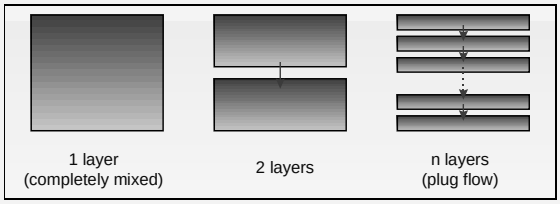
[(1)] Struijs, J., Stoltenkamp, J. & van de Meent, D. (1991). A spreadsheet-based box model to predict the fate of xenobiotics in a municipal wastewater treatment plant. Wat. Res. 25(7), 891-900.

[(2)] Melcer, H., Parker, W.J. & Rittmann, B.E. (1995). Modeling of volatile organic contaminants in trickling filter systems. Wat. Sci. Tech., 31(1), 95-104.

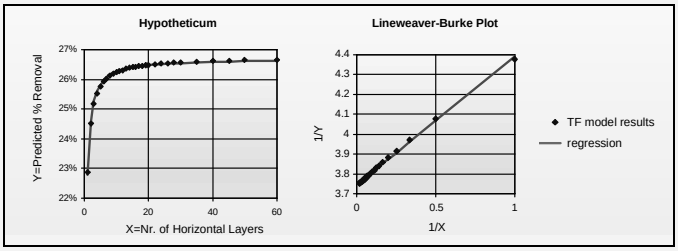
Sensitivity Analysis

experimental conditions
- 3 **hypothetical substances**:
  - hypotheticum (*SimpleTreat* default substance)
  - a volatile chemical A
  - a degradable + sorbing chemical B
- **realistic TF plant**

Model Structure: number of horizontal layers



Predicted removal *R* is related to nr. of layers *n* by **saturation curve** (e.g. for hypotheticum):



- ***R* at ∞ layers** (perfect plug flow) can be derived from any 2 points on the curve
- for acceptable accuracy (>95%) → **required nr. of layers: n ≥ 4**

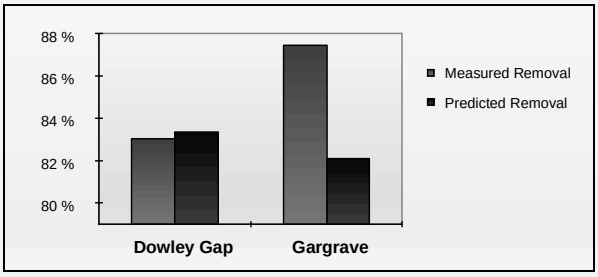
Model Parameters

- general: **highest sensitivities** for:
  - **contact time**: filter volume and flow rate, carrier material porosity, amount of water in filter
  - **sorption / solids**: settling efficiency, suspended solids, sorption constant
  - **degradation**: biodeg. rate, biofilm density, biofilm thickness, specific surface area
- implication for **data requirements**:
  - **chemical** phys./chem./biochem. properties: all important except diffusion
  - TF plant **dimensions**: only volume is important
  - TF plant parameters: **biofilm** properties and suspended **solids** are important (biofilm information → difficult to obtain !)

Preliminary Calibration / Corroboration

- **LAS removal data** from **GREAT-ER UK monitoring study**
  → **preliminary calibration** of trickling filter fate model
- **2 TF plants**: **Gargrave** (1,500 i.e.) and **Dowley Gap** (30,000 i.e.)
  - known: dimensions, flow, recycles, carrier material specific surface area
  - defaults: biofilm properties, suspended solids, settler efficiency
- **LAS chemical properties**:
  - known: sorption coefficient, Henry's Law constant; default: diffusion constant
  - **estimation** of double 1st order **biodegradation rate**: ($dC/dt = -KCX$) **from standard activated sludge 1st order rate**, corrected for higher biomass density
- **calibrated parameters**: .....value
  - amount of water in filter (i.e., pore fraction filled with water) .....5 %
  - biofilm thickness .....250 µm

  → **realistic values** could be applied



Conclusions

- *SimpleTreat* **methodology could be applied** to Trickling Filter plants
- a **limited number of horizontal layers** (for plug flow hydraulics) was required
- preliminary **calibration** for LAS was possible with **realistic parameter values**

- Further Research:
  - fine-tuning + calibration by means of **lab-scale pilot plant experiments**
  - **full-scale validation** (+ parameter collection) by means of UK monitoring data

GREAT-ER
Geography-referenced Regional Exposure Assessment Tool for European Rivers

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