Estimating Marine Chemical Emissions from Discharges of Sewage Treatment Plants directly and from Freshwater Rivers

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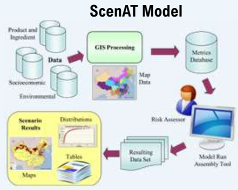
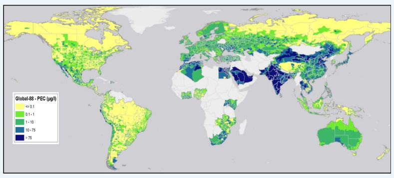
Introduction

- Many Home and Personal Care Products (HPCPs) are disposed of down the drain by the consumer and typically released into freshwater rivers after passing through a sewage treatment plant (STP)
- There is a need to estimate the emission of HPCPs into the coastal environment from **direct sources** (STP effluent and direct discharge to coastal water) and **indirect sources** (inland freshwater STP effluent and direct discharge)
- We present a spatially explicit **fate and transport extension** to the 88-country **ScenAT model** (Hodges et al, 2012) to estimate emissions directly and indirectly to the marine environment
- The model provides insight into the source, treatment, transport, and fate of ingredient mass, reporting emissions to the marine environment at **several spatial scales**, including **mass lost** during hydrologic transit from source to coast

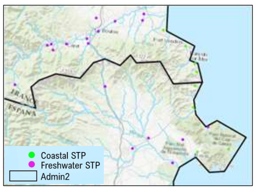


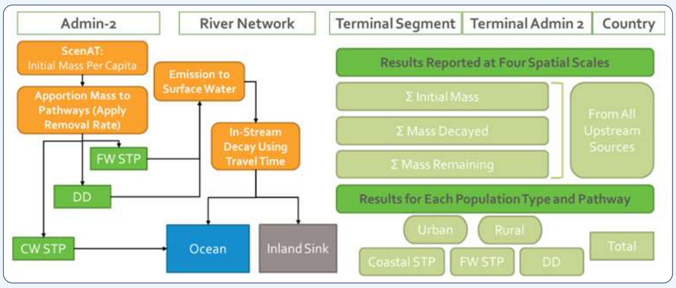


Model Data and Pre-processing

- Over 44,000 STPs from 34 countries serving ~800,000 people (Holmes et al, in prep) were spatially assigned to **HydroAtlas** river segments (Linke et al, 2019) and ScenAT administrative units (**Admin2**)
  - STPs were attributed as freshwater (FW) or coastal water (including estuarine emissions) (CW)
- The **ScenAT model output** provide data on ingredient tonnage, STP removal rates, and pathway fractions for each Admin2, including both **urban and rural** discharges
- Residence time and **time of travel to the coast** (or endorheic sink) was calculated for each HydroAtlas segment along the network

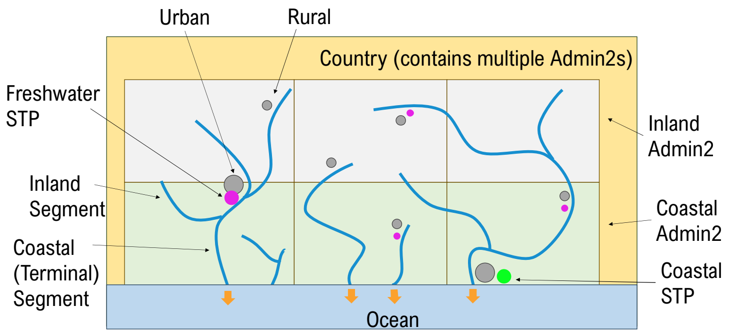
	Count of Facilities	Population Served (1000's)
EU-27 + UK	22,741	420,075
United States	14,039	225,979
Canada	2,053	24,292
Australia	183	12,318
Singapore	4	778
Brazil	2,820	71,746
Mexico	2,526	40,751
Total	44,366	795,939





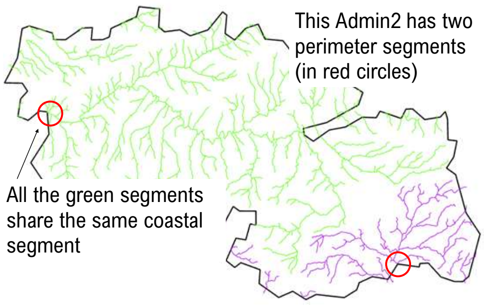
Model Processing

- Mass is input into the river network and **routed downstream** to the terminal coastal segment, which discharges to the ocean or an inland sink
- Mass can originate from an STP or from direct discharge (DD) to surface water



Discharge Assumptions: Admin2s with Untreated Mass or No Point STPs

- Direct (untreated) discharge is input into the river network at "perimeter segments"
- **Perimeter segments** have shortest travel time of all segments in the Admin2 and terminate in the same **coastal segment**
- DD mass is **proportioned** to perimeter segments based on the upstream river length within the Admin2
- The same process is applied for treated mass within Admin2s in **countries not in the point STP database**



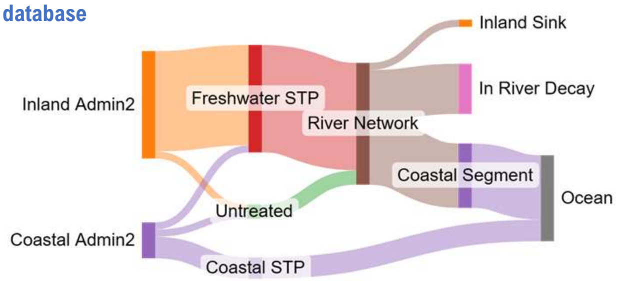
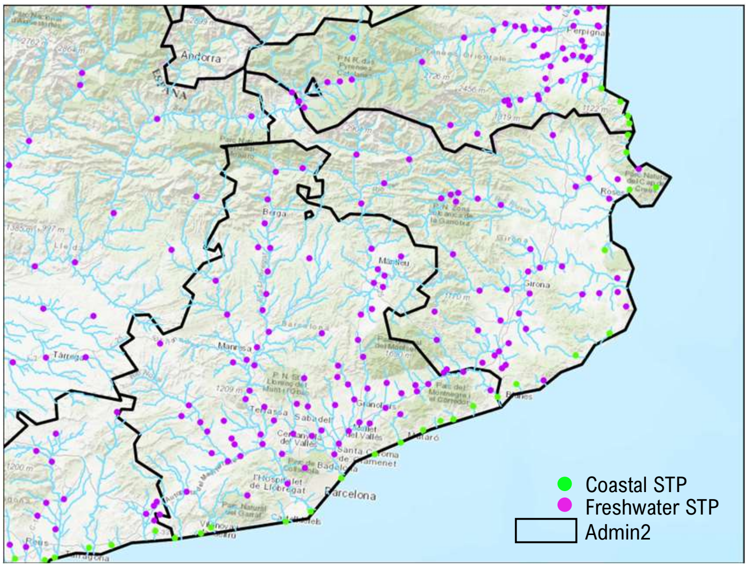


Diagram of spatial units and pathways from emission to final disposition of chemical

Model Outputs

- The model reports a **steady state annual mass** summarized at **four scales**:
  - Individual STP
  - Coastal discharge river segment
  - Admin2
  - Country
- Marine mass is further broken down by demographic source (urban, rural, or both) and pathway (freshwater STPs, coastal STPs, and untreated DD)



Discussion

- This model allows for refinement of freshwater exposure, as well as informing marine emissions from both direct and indirect STP emissions
- This model can be used to describe situations such as:
  - For a single STP, how much mass was input into the river network and what percentage of that mass made it to the coastal environment?
  - For a single coastal river segment:
    - Total upstream mass discharged to the freshwater environment
    - Total mass emitted to the marine environment from upstream
    - How much mass from all upstream sources was removed during transport?
  - What are the relative proportions of urban and rural populations contributing to mass entering coastal areas?
  - What portion of the total mass entering the marine environment came from untreated vs treated populations?

Hodges, J.E.N., Holmes, C.M., Vamshi, R., Mao, D., Price, O.R., 2012. Estimating chemical emissions from home and personal care products in China. Environmental Pollution 165, 199–207.
Holmes, C.M., Insinga, I., Sandhu, S. and Hodges, J.E.N., 2024. Modelling global marine emissions covering STPs discharging directly in marine waters combined with emissions from river networks. (in prep)
Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283

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