Estimating global spatially resolved marine emissions and exposure to down the drain chemicals

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Domestic wastewater discharged to the environment will contain chemical substances from personal care, home cleaning and medications. While many discharges are to freshwater, rivers and lakes, some facilities in coastal areas **discharge directly** into the **marine environment**. Additionally, chemical substances which are discharged into freshwater may travel through the **hydrological network** to the marine environment.

There is a need to estimate the emission 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). Here 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.

Building on these marine emissions two **exposure screening models** were developed to calculate potential environmental concentrations from down the drain scenarios into coastal waters allowing an assessment of marine ecological risk.

Materials and Methods

- Over 44,000 Sewage Treatment Plants (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**). Figure 1 shows the following
  - STPs were attributed as freshwater (FW) or coastal water (CW)
  - Mass is inputted into the river network and **routed downstream** to the terminal segment, which discharges to the ocean or to an inland sink
  - Mass can originate from an STP or from untreated wastewater (UTWW) to surface water
  - Residence time and **time of travel to the coast** was calculated for each HydroAtlas segment along the network, allowing for optional in-river decay.
- **2 exposure models** (Figure 2 and 3) were created to generate Predicted Environmental Concentrations (PECs). In coastal waters.
  - The **Moving Prism Model** is a steady-state box model that calculates a PEC by advecting a triangular wedge of coastal water past a chemical discharge point, with the speed of advection being determined by net ambient current speeds using bathymetry data, long term (365 day average) scaler current speeds and near coast hydrodynamics.
  - The **Mixing Zone Model** is an alternative steady-state box model that calculates a PEC allowing for the conservatism if a chemical is discharged ambient current speed is very low.

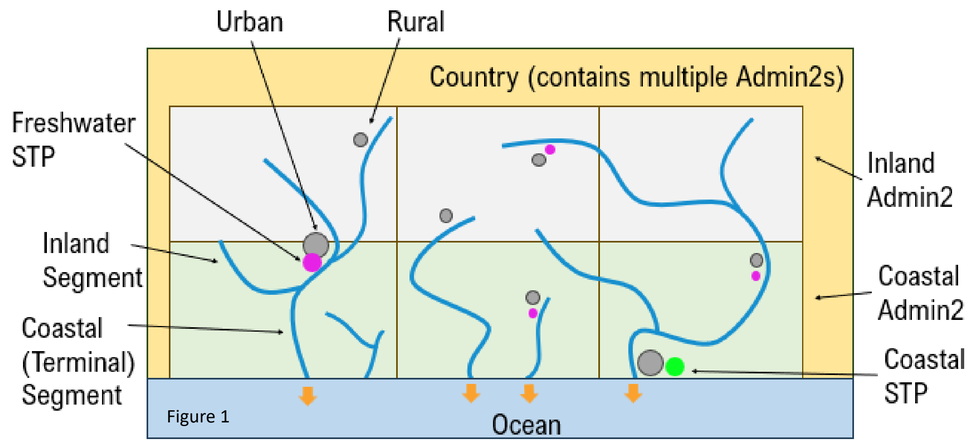

Figure 1

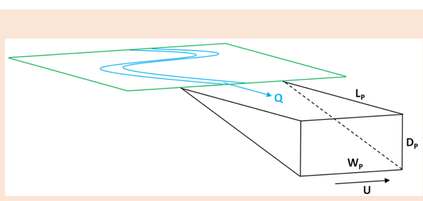

Figure 2

Moving Prism Model

- Q = discharge rate (flux) of chemical (mg/s)
- U = ambient current speed (m/s)
- LP = length of prism (m)
- DP = maximum depth of prism (m)
- WP = width of prism (m)

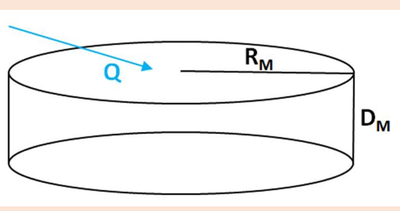

Figure 3

Mixing Zone Model

- Q = discharge rate (flux) of chemical (mg/s)
- R_M = radius of mixing zone (m)
- D_M = depth of mixing zone (m)
- T(s) = Period over which mixing zone is assumed to build up

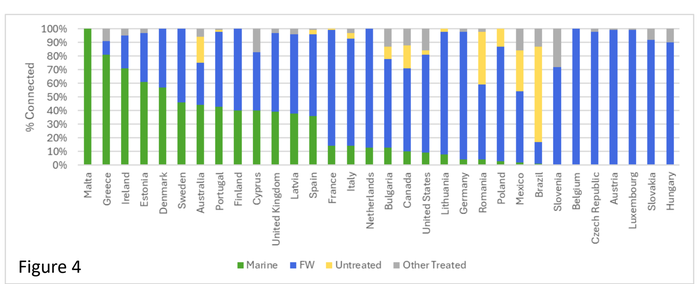

Figure 4

Results

The final STP database calculates over 130 million of the total 790 million population covered discharge their wastewater directly into the marine environment. Figure 4 shows the break down per country

Figure 5 shows the detailed emissions for Mexico with 21.5% of chemical mass beginning emitted to the coastal compartment with 21.2% and 0.3% coming from the freshwater hydrological network and coastal STP's directly respectively.

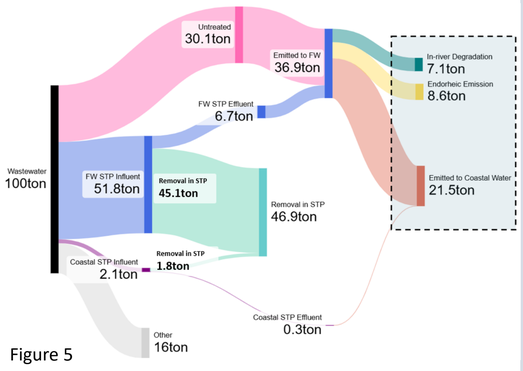

Figure 5

The exposure model utilises 2 different methodologies which calculates PEC's for 3,436 regions covering a total of 75 coastal countries and this was run for Linear Alkyl Benzene Sulphonate (LAS) using 3g/cap/day. The maps (Figures 6 and 7) shows the distribution of PEC's for LAS generated using the mixing mode (South Asia) and the PRISM Model (Canada). The highest PEC's (red areas) can be seen around the mouth of the major rivers Ganga, Brahmaputra, Indus and Godavari and St. Lawrence, Mackensie and Nelson. For South Asia the capital coastal cities of Mumbai and Colombo which have a high level of waster water from STP also have high relative PEC's.

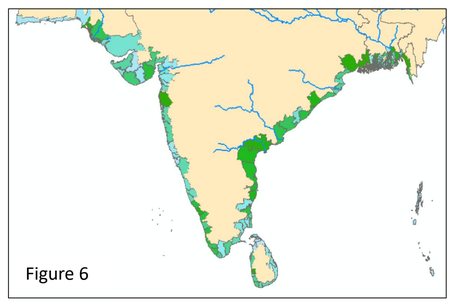
Figure 6

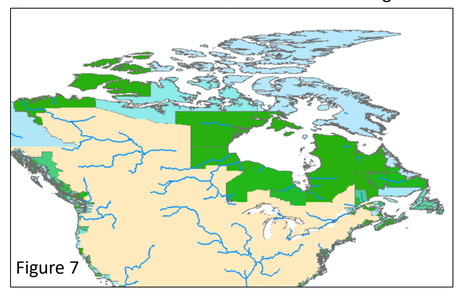

Figure 7

Conclusion

The emission model shows that you can use country-based datasets, geo-referenced STP and wastewater discharge types to refine marine emissions estimates to use in risk assessments at a refined sub-country spatial scale. Many exposure models assume 100% of the substance mass emitted via STPs and UWWD is released into the freshwater environment, and do not account for both direct coastal emission and eventual freshwater loadings after hydrologic travel. The exposure model can assess comparative risk between different areas and initial evaluations appear to predict higher PEC's at large coastal cities and at the mouth of large rivers. One of the next steps will be to further evaluate the predictions from the exposure model.

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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