Down-the-Drain Exposure Assessments In Canada And Mexico With iSTREEM®

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The iSTREEM® model (https://www.istreem.org/) integrates the locations of municipal wastewater treatment plants (WWTPs) with a hydrologic river network, providing a framework to assess environmental risk in a spatial context. The model has been widely applied for ecological risk assessments of down-the-drain (DtD) chemicals in the U.S. To address growing challenges outside the U.S., the model was recently expanded to include Canada and Mexico by integrating country-specific WWTP infrastructure data with river hydrology from global datasets. WWTPs are a major exposure route for a wide range of DtD chemicals that are treated and discharged to surface water. To include populations not connected to municipal WWTP, the model utilizes a framework to account for wastewater discharged to septic/onsite systems and direct discharge to surface water. Sensitivity analyses were performed to understand the effect of varying model inputs to the results. This work highlights the practical application of spatially resolved and probabilistic distributions by the model as a ready-to-use tool for exposure assessments. Evolution of the model reflects scientific advances in DtD exposure modeling to address current global challenges – assessment over broad geographies, incorporation of probabilistic variability, spatially explicit distributions, and accessibility of this enhanced utility for end users.

Model Framework

A spatially explicit framework was developed[1] for global implementation of the iSTREEM® DtD aquatic exposure model. This framework was applied with case studies for China and Japan recently published[1]. River flows for level-12 catchments at global scale were estimated[2] using the USDA Curve Number approach. Here we discuss the application of the framework for Canada and Mexico, utilizing the level-12 catchments from HydroBASINS[3] and the river network from HydroRIVERS[4].

The model includes 74,000 level-12 catchments for Canada and 15,000 for Mexico, with catchments parameterized for:

- River flow for the entire hydrologic network was extracted from the Global Flow[2] data
- WWTP spatial locations and effluent volume – from publicly available country sources
- Water use – from publicly available country sources
- Population connected to WWTP – estimated from effluent volume and water use
- Onsite discharge population – to account for people connected to septic systems
- Direct discharge population – to account for all non-connected people

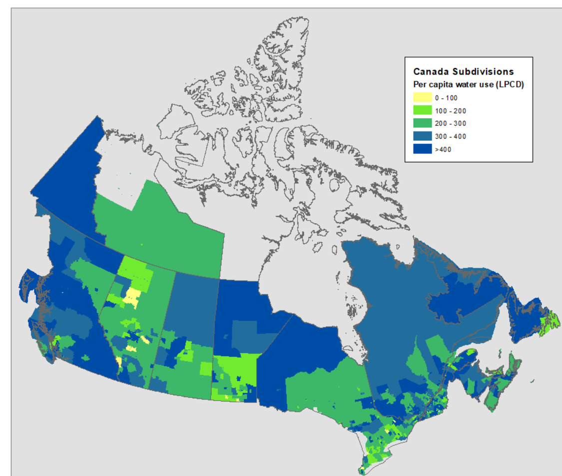

Figure 1: Per capita water use at subdivision-level in Canada

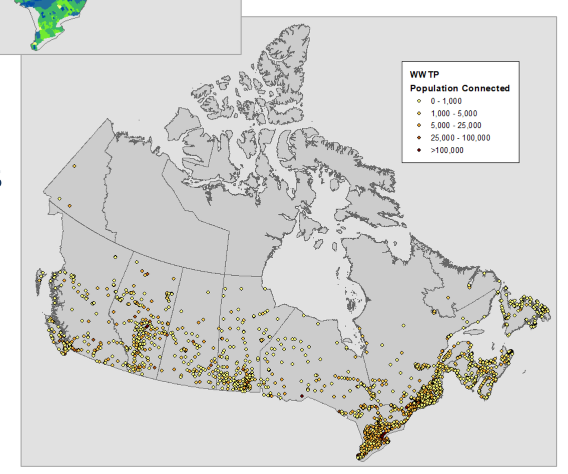

Figure 2: WWTPs classified based on population connected in Canada

Treatment Methods

The model framework estimates DtD chemical removal from WWTPs, onsite or septic systems, or direct discharge to the environment. In-river removal is handled through a first order decay parameter. The population in catchments without WWTPs were assigned to onsite treatment and direct discharge based on statistics from WHO-JMP[5].

Canada

- Per capita water use at census subdivisions (Figure 1) and WWTPs were accessed from the Wastewater Systems Effluent Regulations[6] (Figure 2)
- 81% of the population was estimated to be connected to WWTP infrastructure
- Onsite treatment systems cover about 11%, and 8% of the population has direct discharge to receiving waters

Mexico

- Per capita water use at province-level obtained from (Figure 3) and WWTPs were accessed from the National Water Information System[7] (Figure 4)
- 52% of the population was estimated to be connected to WWTP infrastructure
- Onsite treatment systems cover about 33%, and 15% of the population has direct discharge to receiving waters

	Canada		Mexico	
	# Facilities	Pop. Connected (million)	# Facilities	Pop. Connected (million)
WWTP	2,075	30	2,638	66
Onsite Discharge	11,176	4	13,909	20
Direct Discharge	11,176	3	13,909	42

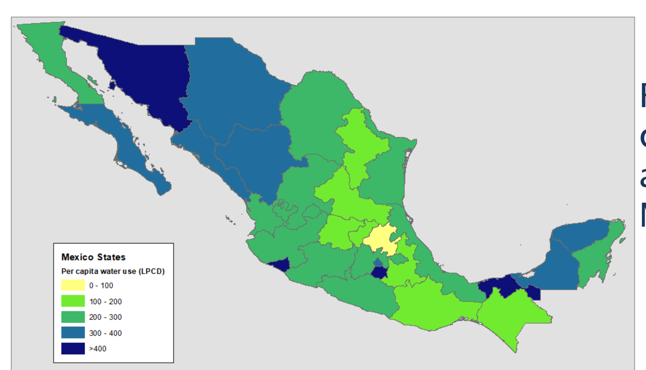

Figure 3: Per capita water use at state-level in Mexico

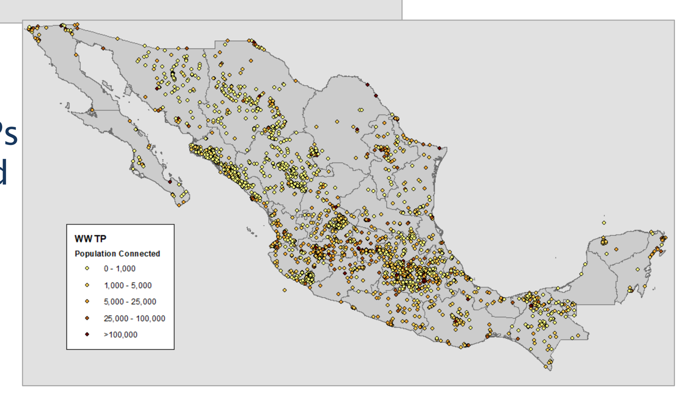

Figure 4: WWTPs classified based on population connected in Mexico

Modeling Scenarios and Parameters

A variety of scenarios were created to simulate the changes in modeled environmental concentrations based on different removal methods by the model: WWTP, onsite, direct discharge; or in-river decay. Unit loading (1 g/capita/day) was used for illustrative purposes for all scenarios. Each removal option was tested separately to understand the model sensitivity to each parameter.

Runs/Inputs	No Removal	ASR 50	ASR 90	DDR 50	DDR 90	OSR 50	OSR 90	River Decay 1	River Decay 10
Loading factor (g/capita/day)	1	1	1	1	1	1	1	1	1
WWTP/Activated Sludge Removal (%)	0	50	90	0	0	0	0	0	0
Direct Discharge Removal (%)	0	0	0	50	90	0	0	0	0
Onsite Removal (%)	0	0	0	0	0	50	90	0	0
River Decay (/day)	0	0	0	0	0	0	0	1	10

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Results and Discussion

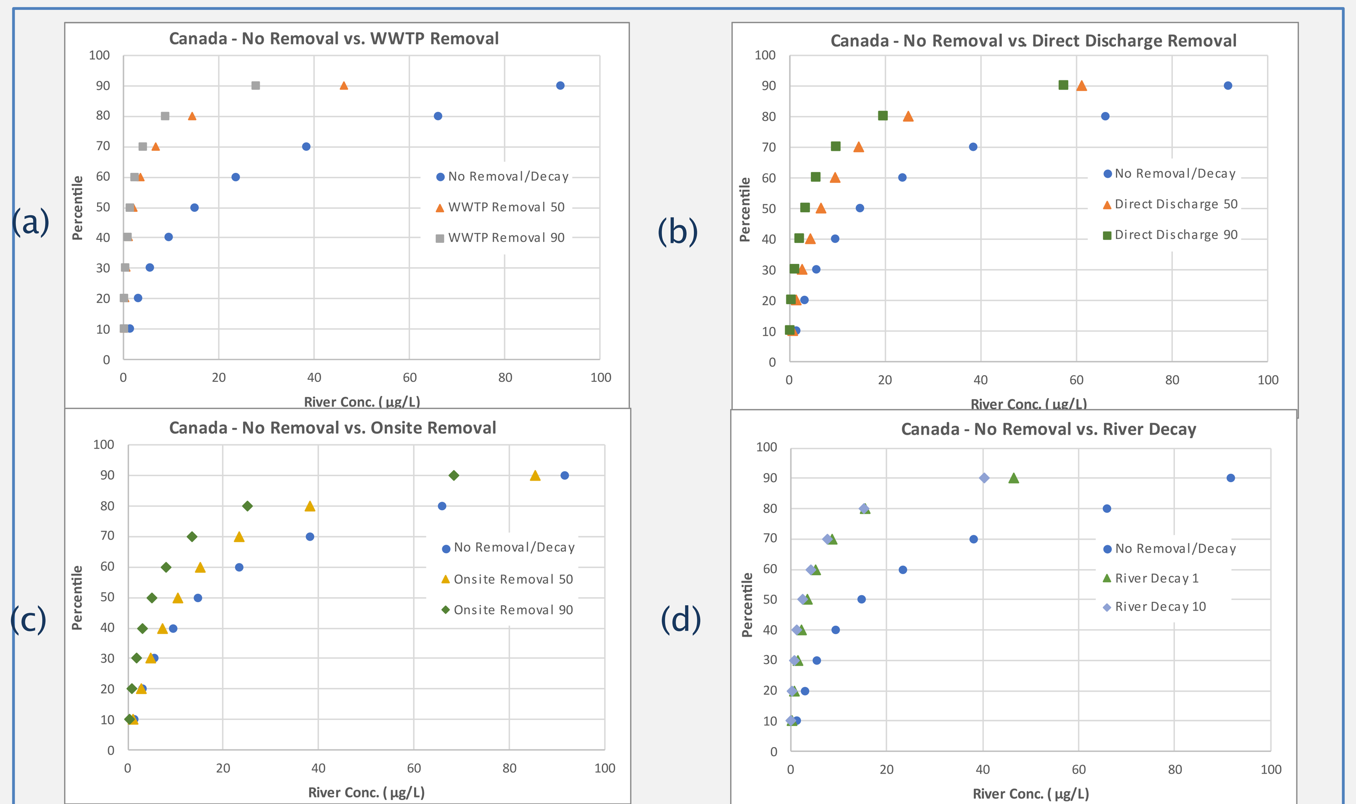

Figure 5: Estimated river concentrations in Canada

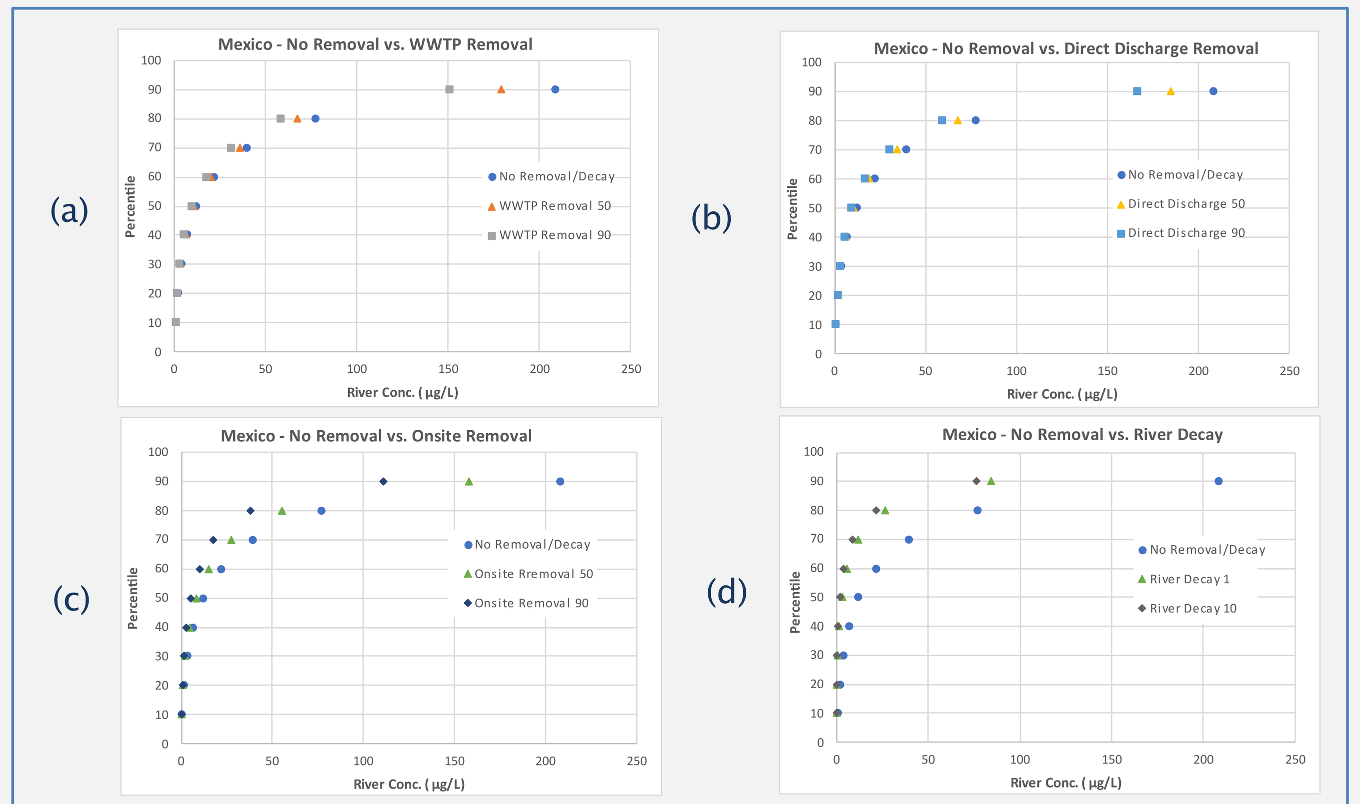

Figure 6: Estimated river concentrations in Mexico

- For sensitivity analysis, a no-WWTP removal and no in-river decay scenario was considered the base scenario for comparison.
- In Canada, when onsite and direct discharge removal were varied from 50% to 90%, little impact was observed on river concentrations (Figure 5 a–d). If WWTP removal varied from 50% to 90%, a 3X decrease in river water concentration was observed (Figure 5a). This is due to catchments with 81% population connected to WWTP was significantly higher than catchments with 11% population for onsite and 9% population for direct discharge; thus, significantly greater impact when WWTP removal is varied. In-river decay had similar reduction as WWTP removal.
- In Mexico, when WWTP, onsite and direct discharge removal were varied from 50% to 90% (Figure 6 a–d), little impact was observed on river water concentrations. If direct discharge was varied from 50% to 90%, the decrease in river water concentration was minimal. This is due to the catchments with 52% population connected to WWTP was only slightly higher than catchment population of 33% with direct discharge. However, the variation of in-river decay rate from 1 to 10 per day brought about a significant reduction in river concentration (Figure 6d).

Summary and Outlook

- A spatially explicit modeling framework based on the iSTREEM® model was applied for Canada and Mexico. Serves as an important step towards developing broad scale environmental exposure models for DtD assessments across North America and the globe
- Sensitivity analysis was performed to evaluate the impact of key model input parameters (% removal during treatment and in-river decay) – modeling results for Canada and Mexico show that for different chemicals, treatment removal and in-stream decay rates can vary the range of estimated river concentrations
- This analysis provided insights into how country-specific parameterization for wastewater treatment types across the two countries can impact model results
- Case studies of modeled results are currently being performed, and there is a need for DtD chemical monitoring data for model validation in Canada and Mexico

Need DtD monitoring data

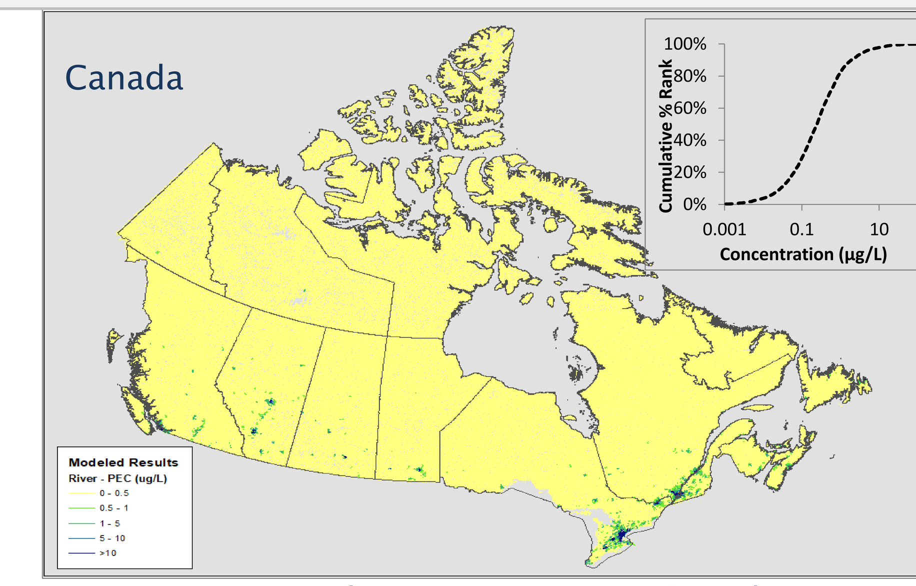

Figure 7: Estimated river conc. across Canada

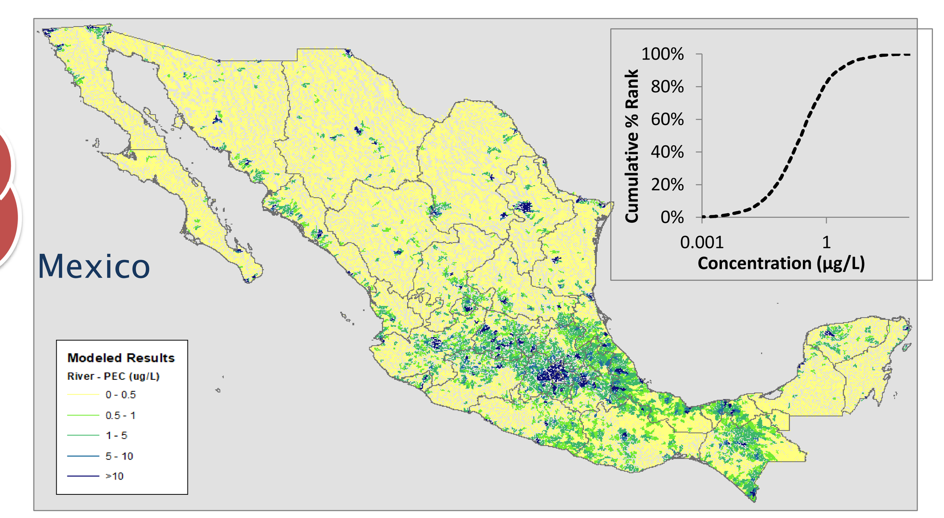

Figure 8: Estimated river conc. across Mexico

References:

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