High-Granularity Data Powering a Tiered Framework for NGRA Environmental Exposure Modelling

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Next Generation Risk Assessment (NGRA) benefits exposure assessments, remaining protective and regulation compatible while better reflecting real-world spatial variability. We present a tiered exposure modelling framework and examples, covering data and models, enabling proportionate, traceable refinement from screening models to spatially resolved routed approaches.

Example 1

Tier 2 Data into Tier 0 (EUSES-type) Models:

Deriving Characteristic Parameters

Many exposure parameters show spatial heterogeneity; to avoid reliance on national averages, we derive characteristic values using a **moving window approach**.

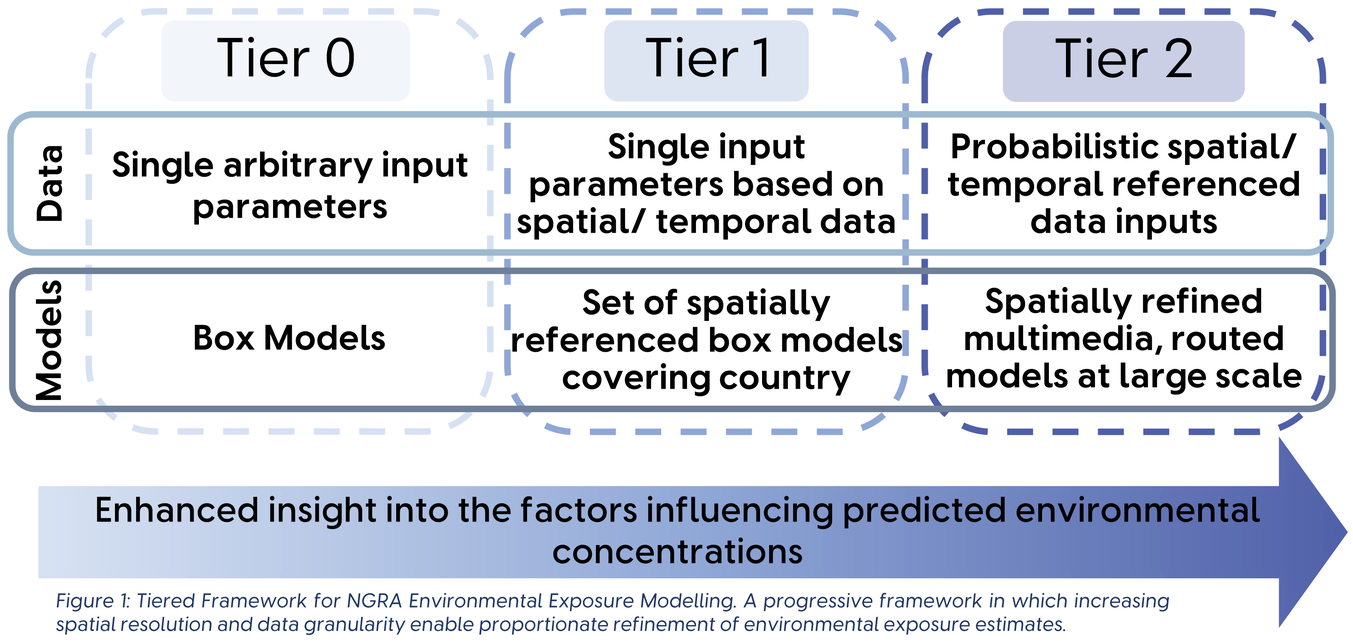


Figure 1: Tiered Framework for NGRA Environmental Exposure Modelling. A progressive framework in which increasing spatial resolution and data granularity enable proportionate refinement of environmental exposure estimates.

Regional variation is summarised by moving a **fixed-size window** across the study area and calculating the parameter of interest within each window (Price et. al.) [2]. This produces **distributions of regional conditions**, from which characteristic values (e.g., median/mean) are selected for spatially referenced exposure modelling.

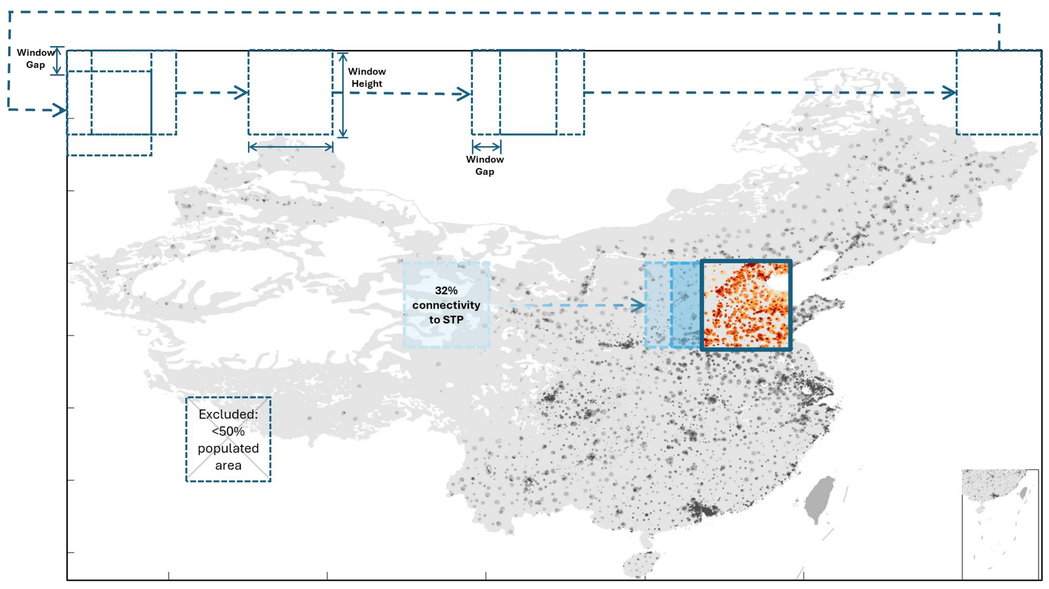


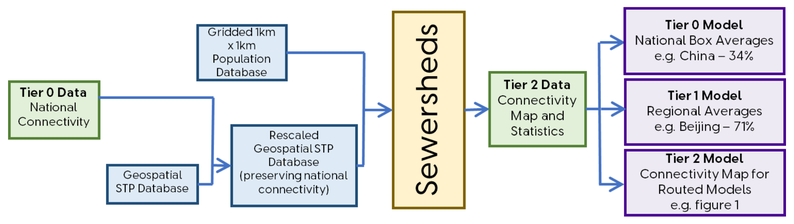
Figure 2: Illustration of the Moving Window Approach applied to a connectivity map to summarize Sewage Treatment Plant (STP) connectivity.
Square windows of fixed size move systematically across the study area with a defined step size. For each window position, the proportion of the population connected to STPs - derived using the sewersheds approach - is calculated. To ensure meaningful results, windows where less than 50% of the area contains population (e.g., those covering sparsely inhabited regions such as deserts or extending beyond national borders) are excluded from the analysis.

Example 2

Tier 2 Data:

Refining Population STP Connectivity

To refine national-average assumptions of sewage treatment plant (STP) connectivity, we apply a **sewersheds-based spatial allocation approach** [1]. Population grid cells are assigned to STPs using a **simultaneous, capacity-constrained, nearest-STP allocation** to define realistic wastewater service areas.



To maintain regulatory traceability, STP served populations are rescaled to align with Tier 0 national connectivity, while introducing spatial granularity.
These sewersheds define realistic wastewater service areas with outputs providing **Tier 2 data**, including spatial connectivity maps which can be aggregated to **Tier 0 box average data** and **Tier 1 city/ province level outputs.**

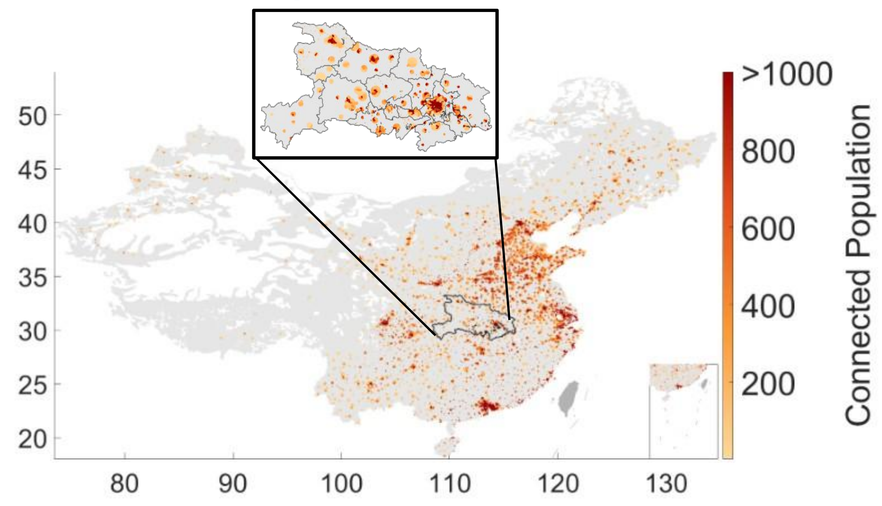


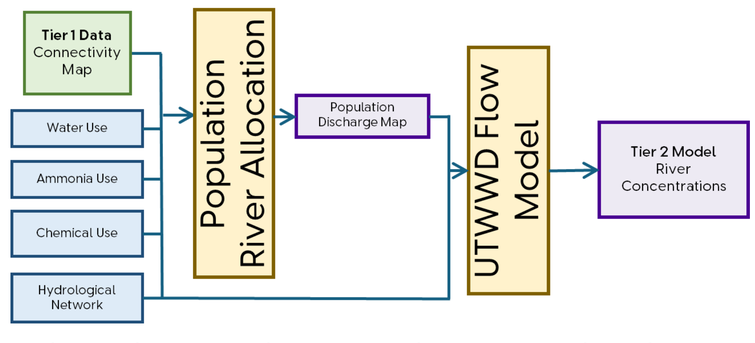
Figure 3: Connectivity of population to Sewage Treatment Plants (STPs) in China using the sewersheds approach. Connectivity map where coloured regions indicate population connected to STPs–pale orange for low population density and deep red for high. Grey areas represent populated regions without STP connectivity, and white areas are unpopulated. The province of Hubei is highlighted for detailed illustration.

Example 3

Tier 2 Modelling:

Point Source Routed Modelling

To represent emissions from populations **discharging wastewater directly to rivers**, grid cells are assigned to their nearest river segments, defining spatially explicit discharge points. The population associated with each discharge point is aggregated and combined with per-capita emission factors to define **untreated wastewater discharges (UTWWD)**. Emissions are then **routed through the river network** using segment-specific hydrology [4], accounting for flow direction, residence time, and in-river degradation until a steady-state distribution is reached. This produces **spatially resolved concentrations for every river segment**, enabling exposure (and subsequent risk) to be assessed at the **individual river-reach level**.



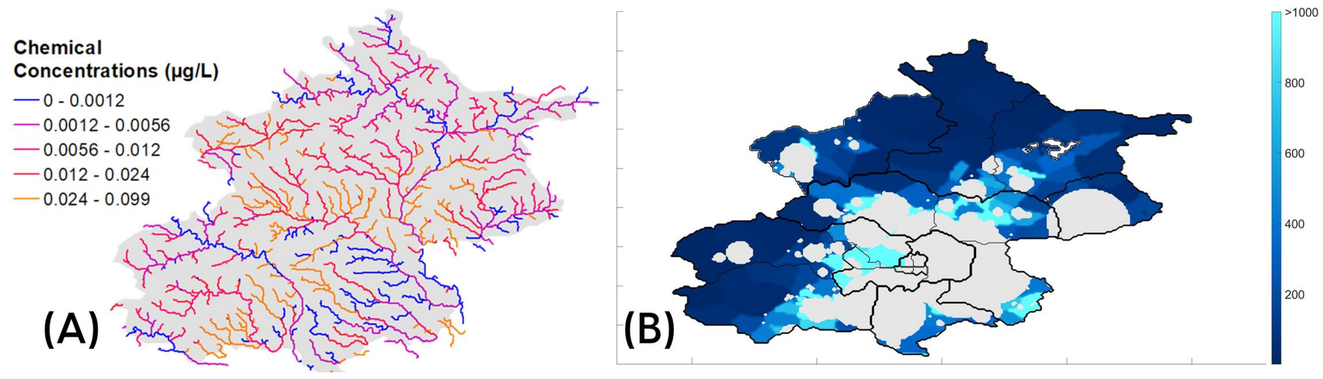


Figure 4: Outputs from the routed wastewater dispersion workflow. (A) Steady-state river-segment concentrations (µg L⁻¹) from routed untreated inputs. (B) Population unconnectivity map identifying non-STP-connected areas used to generate discharge points.
This approach represents a high-tier, fully routed exposure model, extending the tiered framework beyond area-averaged screening to geographically explicit exposure assessment across the entire river network.

This work demonstrates how increasing spatial resolution can be applied meaningfully within NGRA, providing geographically explicit exposure insights while maintaining the clarity, traceability, and confidence needed for regulatory decision-making.

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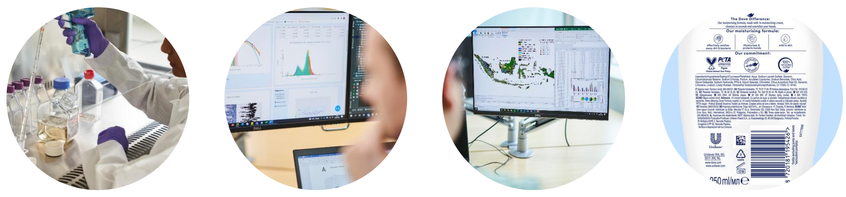

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[4] Ehalt Macedo, H., Lehner, B., Nicell, J., Grill, G., Li, J., Limtong, A., & Shakya, R. (2022).Distribution and characteristics of wastewater treatment plants within the global river network.Earth System Science Data, 14(2), 559–577.https://doi.org/10.5194/essd-14-559-2022

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