

# Modelling the Fate of Chemicals from Untreated Wastewater Discharges (UTWWD):

## A Routed and Spatially refined Model

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### Introduction

Populations without sewage treatment discharge wastewater **directly to freshwater systems**. These untreated discharges contain **human waste** and **down-the-drain chemicals**, posing potential risks to river and marine ecosystems.

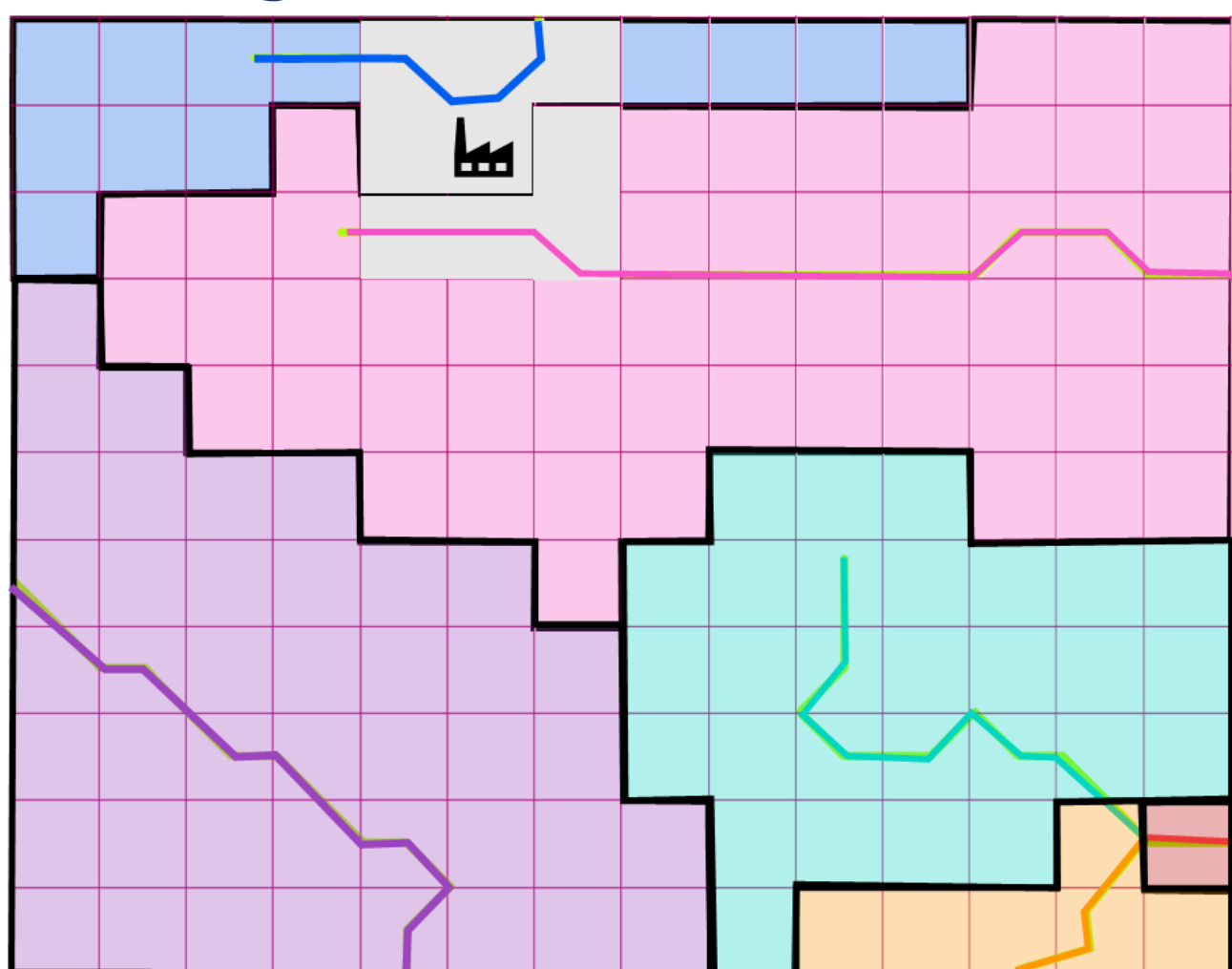
We present a **spatially refined, routed river-network model** that predicts chemical concentrations across river segments relevant for environmental exposure assessment.

### Population River Allocation

**Step 1:** Sewersheds methodology [2, 3] identify **populations not connected to wastewater treatment** at a 1km grid resolution

**Step 2:** Each grid cell is matched to its **nearest river segment** within a detailed hydrological network [4]

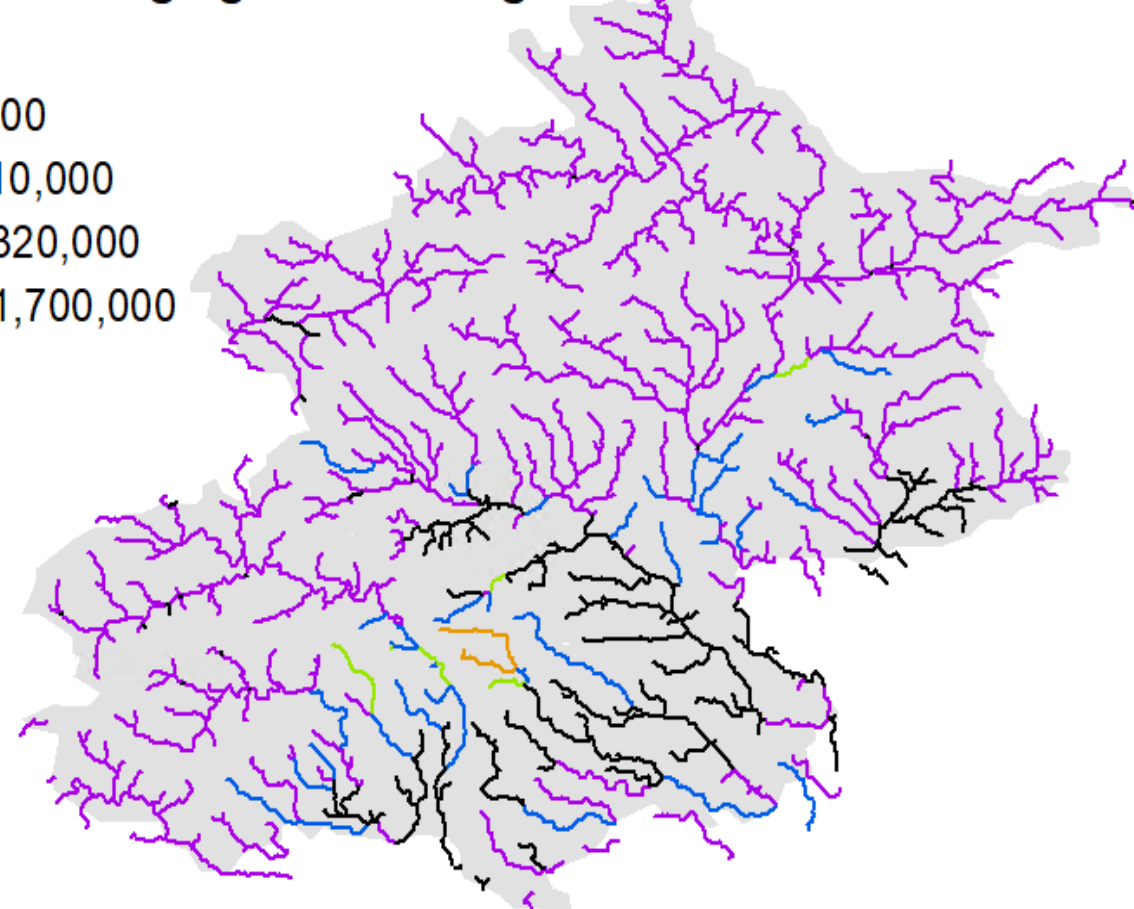
**Figure 3. Allocation of population and UTWWD to river segments**  
Illustrative example of how population grid cells are matched to their nearest river segment, based on a Euclidean distance approach.



**Step 3:** Populations are aggregated per segment to estimate **wastewater volume, ammonia, and chemical discharge loads**

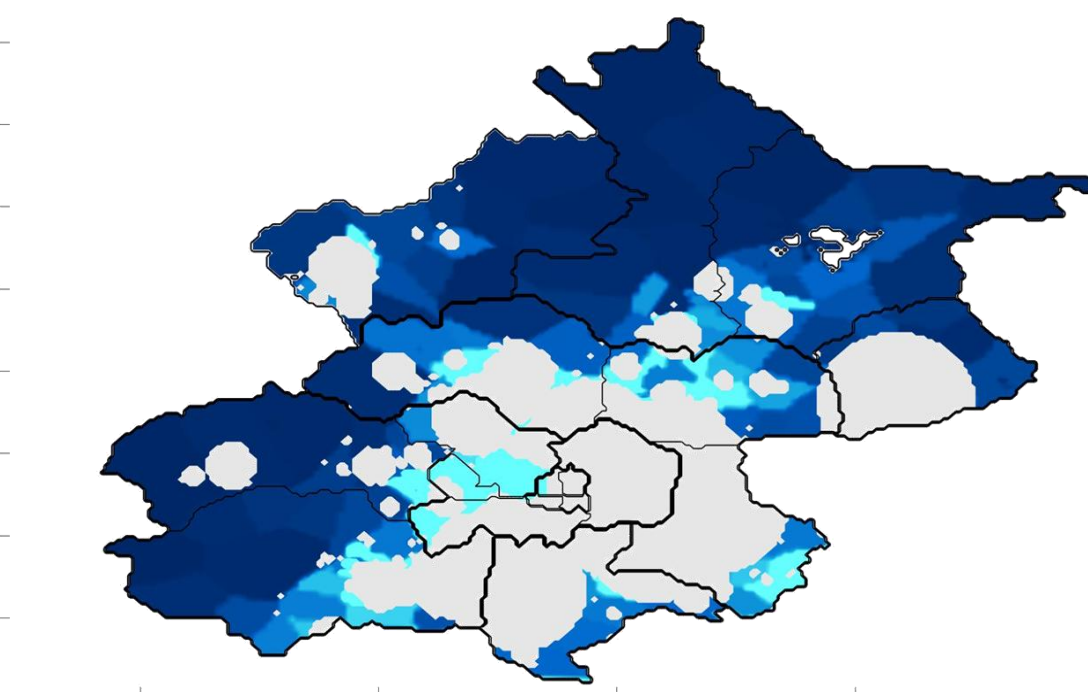
Population Discharging to River Segment

- 0
- 0.01 - 25,000
- 26,000 - 110,000
- 120,000 - 320,000
- 330,000 - 1,700,000

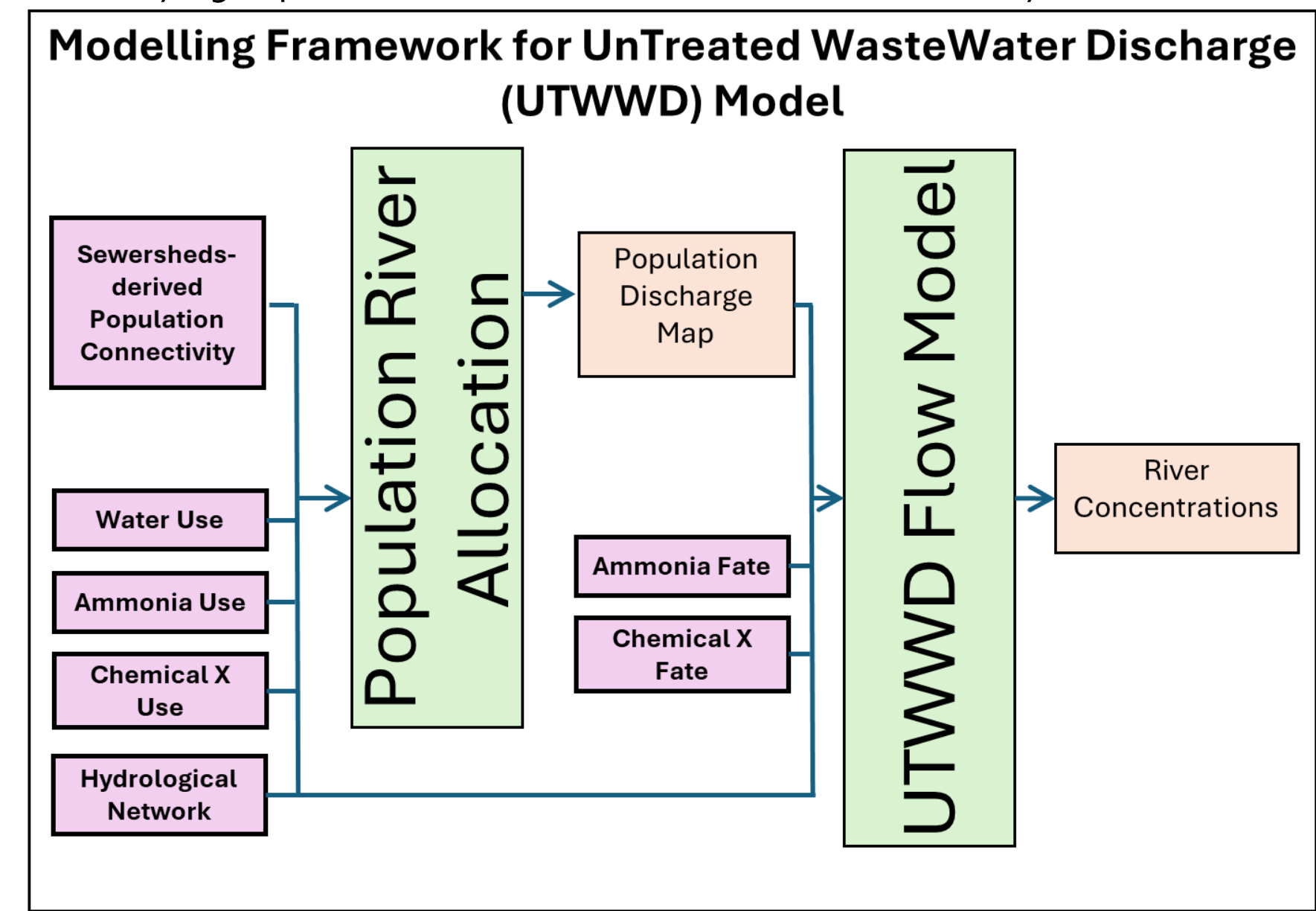


**Figure 4. Aggregation of Pollutant Loads**  
Following allocation of grid cells to their closest river segments, populations are aggregated to estimate the chemical, ammonia and water use discharges for each individual segment.

**Figure 2. Treatment Connectivity**  
Identification of populations, at a 1km grid resolution, not connected to sewage treatment derived from a sewersheds methodology.



**Figure 1. UTWWD modelling framework**  
Overview of the UTWWD model linking populations to rivers, routing untreated wastewater through the hydrological network, and deriving river-segment concentrations of down-the-drain chemicals while identifying impact zones for which human waste is the key driver of risk.



### Impact Zone

The **impact zone** [1] is a stretch of river downstream of UTWWD where elements of **untreated human waste**, elevates stress on freshwater organisms, while also enhancing biodegradation processes, resulting in **faster chemical decay**.

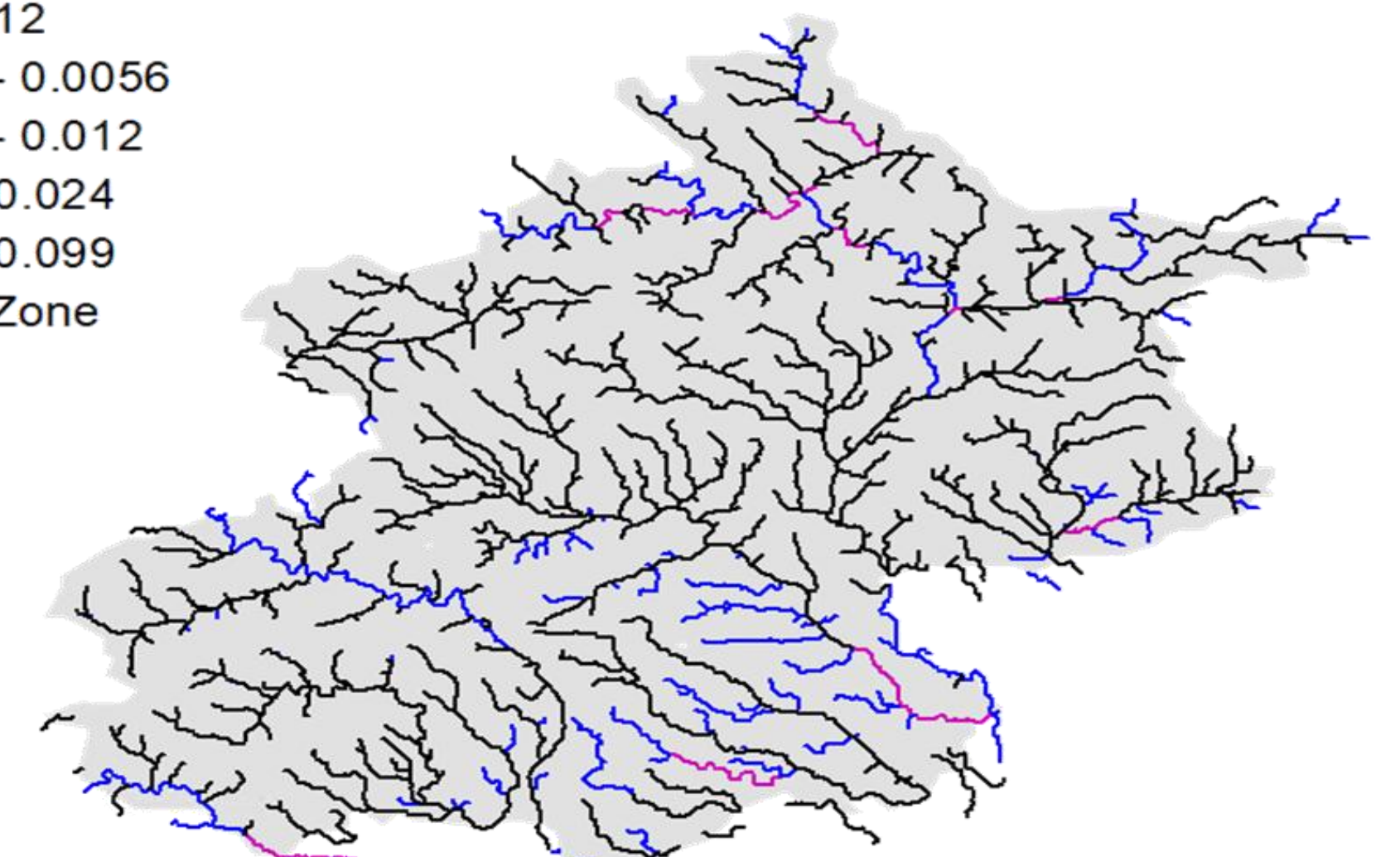
Outside these impact zones, where unionised ammonia is below its hazard threshold, the chemical concentrations should be considered.

### Routed Flow, Dilution and Fate

- Mass is **routed downstream** through the hydrological river network
- For each river segment, **flow and residence time determine degradation rates**, with chemical fate depending on river state:
  - **Within the impact zone:** enhanced decay (shorter half-life)
  - **Outside the impact zone:** biodegradation follows background freshwater condition (longer half life)
- **River flow and wastewater volume determine dilution** to derive concentrations
- The model reaches a **steady state**, identifying impact zones and providing **river-segment-specific concentrations** of chemicals for use in exposure and risk assessment.

**Chemical Concentrations (µg/L)**

- 0 - 0.0012
- 0.0012 - 0.0056
- 0.0056 - 0.012
- 0.012 - 0.024
- 0.024 - 0.099
- Impact Zone



**Figure 3. Predicted chemical concentrations per river segment**  
River segment concentrations of a representative down-the-drain chemical predicted by the UTWWD model, shown alongside identified impact zones. Approximately 77% of river segments are identified as impact zones in the Beijing case study, illustrating how routing, dilution, and zone-dependent fate shape downstream chemical exposure across the river network.

### Conclusions

- **UTWWD** from populations not connected to wastewater treatment can be spatially allocated and **routed through river networks**
- The model identifies **impact zones** where unionised ammonia is higher than its toxic threshold and applies **zone-dependent half-lives** to represent different biodegradation dependent on river conditions and quality
- This **spatially refined, routed approach** can be used to support **higher-tier exposure modelling and NGRA**

