



From Sparse Data to Risk-Informed Decisions: Bayesian Monitoring and Risk Assessment



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Advanced **QUALITY MONITORING** system of water in urba**N** areas | <https://www.aquamon-project.eu/>

The challenge

Urban water-quality management often relies on sparse and irregular monitoring. Short-lived microbial contamination may be missed, while variable chemical hazards can remain poorly characterised when observations are limited.

The AQUAMON approach

AQUAMON combines advanced sensors, automated monitoring, data-driven models and digital tools to turn heterogeneous observations into actionable information for timely, risk-informed water management across five pilot use cases.

KWB contribution

As part of its broader contribution to AQUAMON, KWB develops Bayesian decision-support approaches for limited and uncertain data, applied to bathing-water quality prediction and risk assessment for water reuse.

Bayesian integration and updating

Both applications use probabilistic and Bayesian methods to quantify uncertainty and incorporate new observations. As evidence accumulates, estimates can be refined, uncertainty tracked and informative monitoring needs identified.

Adaptive bathing-water prediction

- In the Paris pilot, SWIM:AI² will combine rainfall, river-flow and *E. coli* observations to predict short-term microbial water quality and its predictive uncertainty.
- High predictive uncertainty from the Gaussian process flags conditions poorly represented by previous observations
- Sufficient confidence: support the bathing-water management decision.
- Novel or uncertain conditions: trigger an on-demand *E. coli* measurement with the ALERT system developed by Fluidion.
- New observations are incorporated into the model, creating an adaptive prediction-measurement-update cycle (Figure 1).

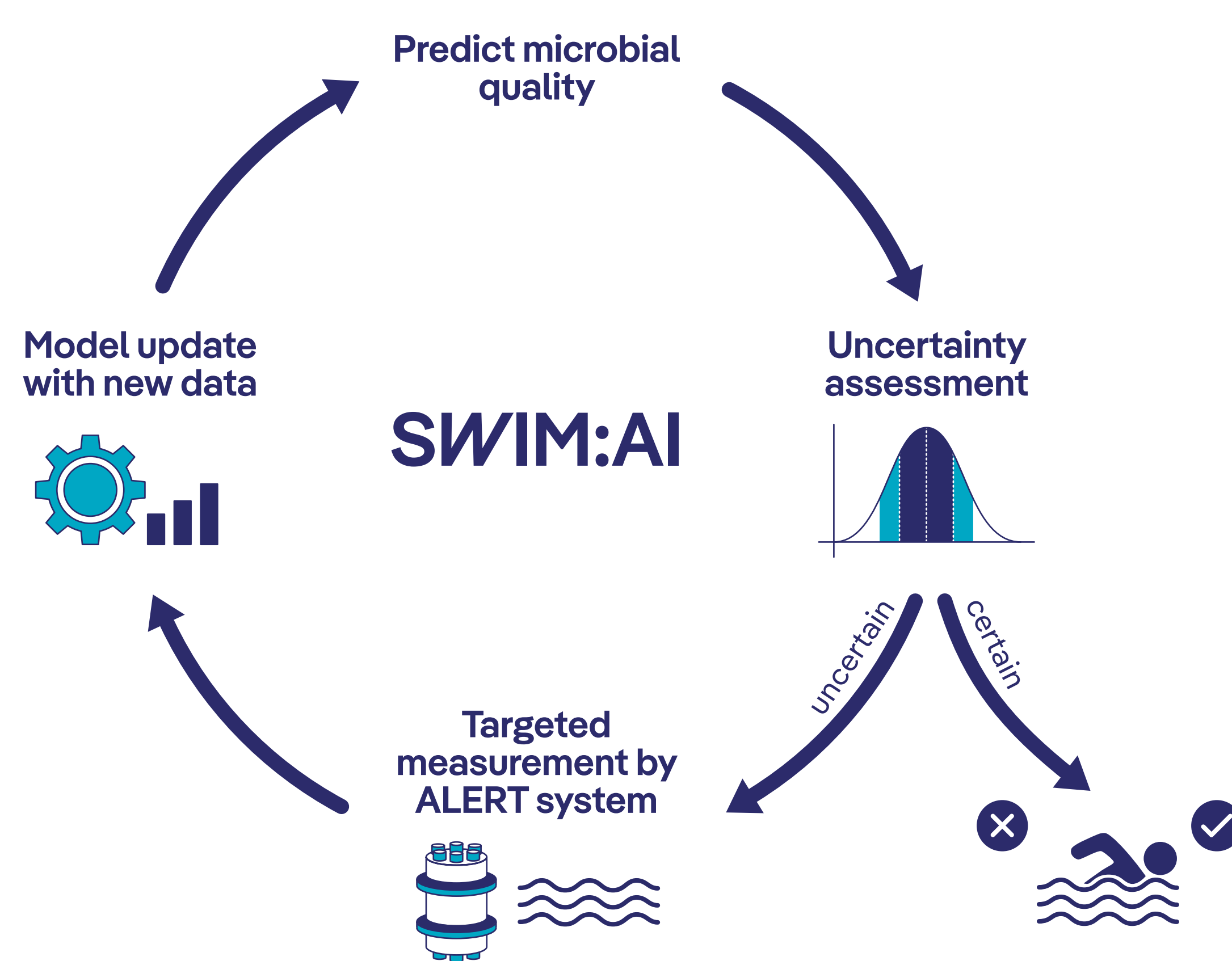


Figure 1: Adaptive SWIM:AI² prediction-measurement-update cycle for uncertainty-aware bathing-water monitoring.

Key advantage

Focus monitoring effort in near real time on uncertain or unusual conditions and collect additional data when they are most useful for a robust bathing-water decision

Chemical risk assessment for water reuse

- In the Turin pilot, KWB will develop a Quantitative Chemical Risk Assessment (QCRA) by coupling the Early Warning Exposure Assessment Framework (EWEX¹) with the fertiliser chemical risk model (FCR³) to assess risks along the water-reuse chain (Figure 2).
- Substance- and treatment-specific removal distributions propagate variability and uncertainty to predicted concentrations in reclaimed water (Figure 3).
 - These concentrations feed the irrigation fate model to estimate environmental concentrations and human- and environmental-health risks.
 - Site-specific monitoring data can update treatment-removal estimates using Bayesian methods.
 - The probabilistic analysis identifies the substances, treatment steps and knowledge gaps contributing most to risk and uncertainty.

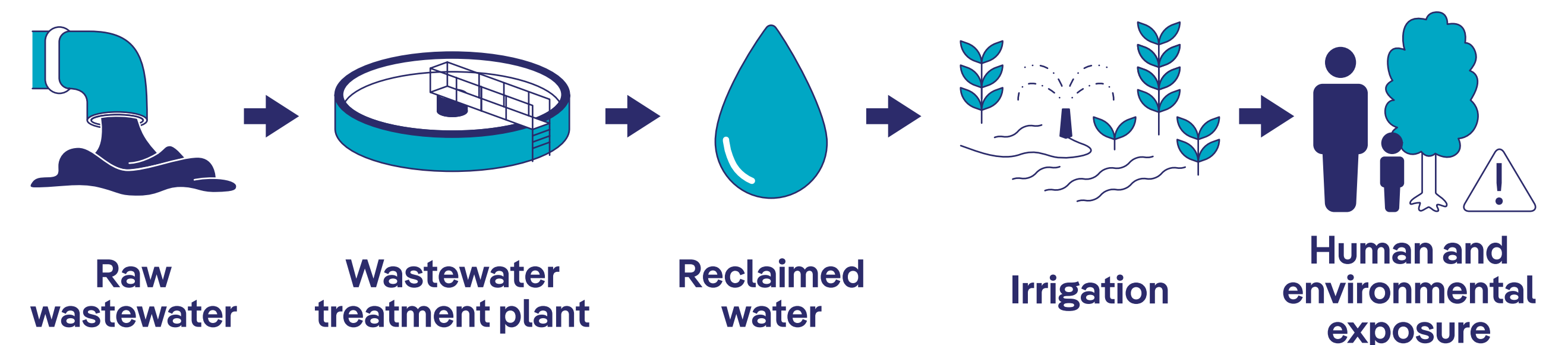


Figure 2: Conceptual water-reuse pathway considered in the QCRA, from raw wastewater treatment and reclaimed-water production to irrigation and human and environmental exposure.

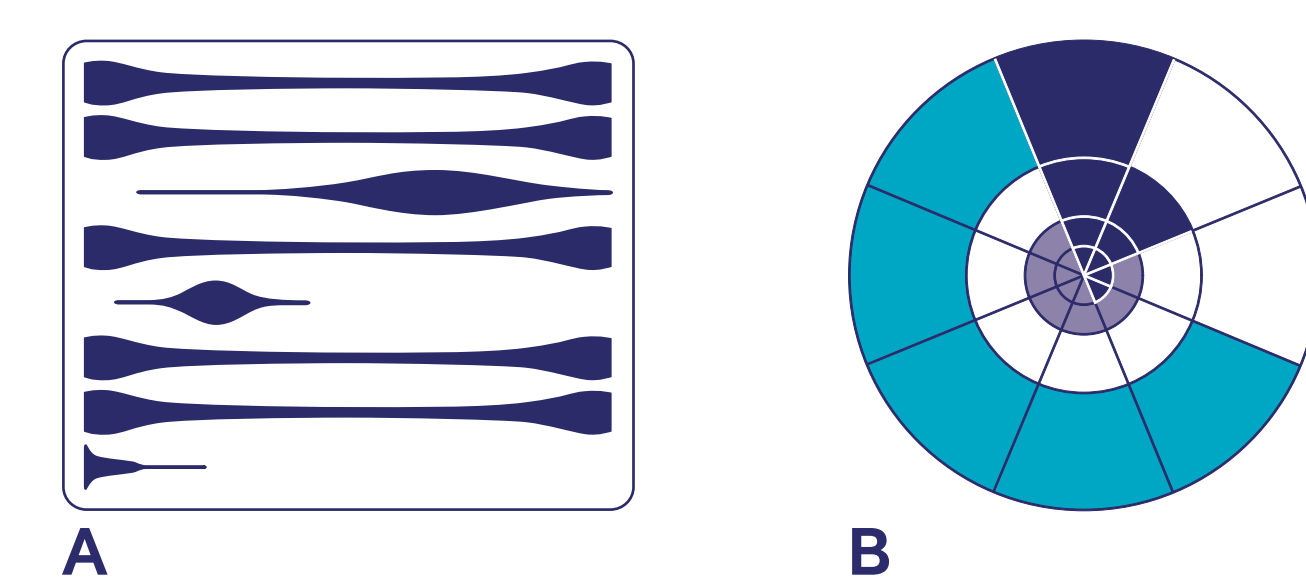


Figure 3: Schematic illustration of posterior removal-factor distributions (A) and resulting risk-quotient percentiles (B) along the treatment train, as implemented in the EWEX¹ tool.

Key advantage

Quantify uncertainty, identify influential knowledge gaps, and assess where additional information could most effectively reduce uncertainty and support risk-informed decision-making

AQUAMON digital platform – integrated monitoring and decision support

The AQUAMON platform will bring together data from advanced sensors and autonomous robotic monitoring with AI-based analytics, a 4D Digital Twin and decision-support tools, providing an integrated view of urban water quality.

- Combines real-time and historical observations from heterogeneous monitoring sources.
- Integrates predictions, risk estimates and their associated uncertainties, including outputs from SWIM:AI² and QCRA.
- Makes the information accessible through an interactive dashboard to support interpretation and risk-informed water management.

Key advantage

Connects monitoring → analysis → interpretation → decision support within one integrated framework.



Figure 4: AQUAMON digital platform and dashboard for integrated decision support.