Effective Monitoring and Modelling solution of data driven holistic management of urban water quality

Urban M2O
Smart Monitoring and Modelling for Water Wise Cities

Funded by the European Union

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Why measuring?

Our vision: *a sustainable urban water management, in harmony with the environment around cities*

This requires measurements!

https://iwa-network.org/publications/the-iwa-princip...ter-wise-cities/

Monitoring for managing water quality in cities

We need monitoring to:

- Assess the current situation in urban water matrices

  How bad the situation is?
- Plan actions to reduce pollution and improve water quality

  What should we do to fix the problem
- Continous surveillance of our efforts

  Are our efforts working?

We need to monitor:

- Many water matrices (wastewater, drinking water, stormwater, natural waters, etc.)
- Many pollutants and water quality indicators (bacteria, nutrients, pesticides, metals, etc…)

A lot of challenges!

Our solution

Challenges

We need data to plan pollution reduction actions and to evaluate them

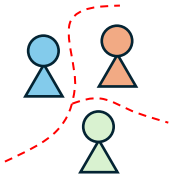
New threats to water resources

We need an integrated perspective

Current Limitations

Best Available Monitoring Methods (BAMM) are costly, difficult to use, limited spatial and temporal limitations

We could use models, but they are uncertain and do not easily integrate monitoring data



Available data are stored across multiple system and stakeholders

Our solution

AI-enhanced Monitoring technologies

*validated, cost-effective and market-ready **sensors** that allow targeting **multiple pollution** threats in **various water matrices***

Holistic data management system

*smooth **information transfer** across stakeholders and administrative entities, fostering a **new digital economy***

Fit-for-purpose Modelling tools

*flexible Digital Urban Water Twin (DUWT) to **track pollutants**, allowing the **planning and evaluation** of current and future pollution reduction strategies*

Our solution

hOlistic

Monitoring

Modelling

AI-enhanced Monitoring technologies

*validated, cost-effective and market-ready **sensors** that allow targeting **multiple pollution** threats in **various water matrices***

Holistic data management system

*smooth **information transfer** across stakeholders and administrative entities, fostering a **new digital economy***

Fit-for-purpose Modelling tools

*flexible Digital Urban Water Twin (DUWT) to **track pollutants**, allowing the **planning and evaluation** of current and future pollution reduction strategies*

How are we going to do that?

Developing over 5 different Monitoring technologies

1. Real-time biomonitoring for online alerting
2. Online sensors based on spectrophotometry
3. Real-time remote water quality learning micro-sensors
4. Ultrasound multi-frequency backscattering for online particle (TSS_{eq}) measurement
5. Passive pollutant flux sampling

+ Other commercially available methods

Benchmarking against Best Available Monitoring Methods (BAMM)

Official methods currently acknowledged by environmental authorities

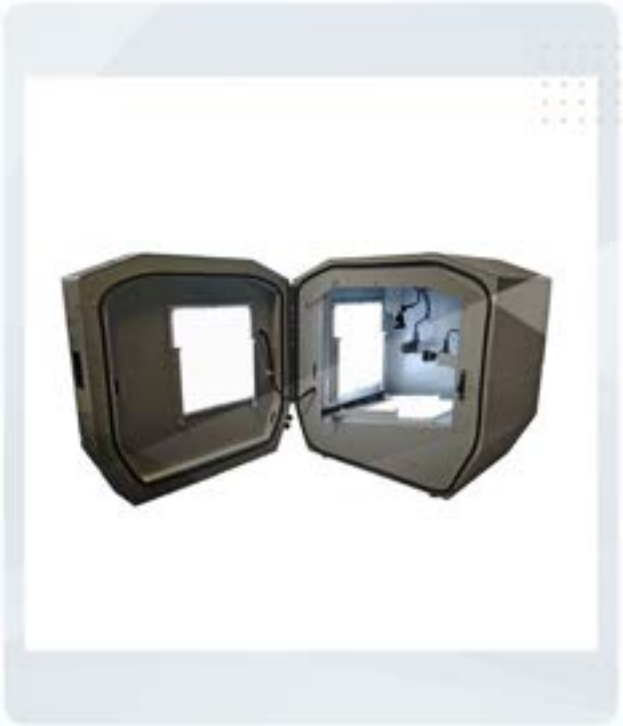
Are we measuring the same environmental risk?
Are we losing information?
Are we getting worse accuracy and precision? If so, how much worse?
What is the required investments (OPEX and CAPEX?)

Which sensors are we developing

1

Real-time biomonitoring for online alerting (episodic pollution) in various water matrices

real-time locomotion behaviour of non-invasive invertebrate organisms



High throughput analysis, controlled environment:

ToxmateLab is composed of three independent panels, lighted with infrared, each containing 16 animals, offering up to 48 animals analyzed simultaneously. It can accept different sizing from 5 mm to 5 cm. The ToxmateLab chamber allows you to fully control the experiment conditions such as light intensity, temperature, and noise. A homogeneous circulation of liquids oxygenates the organisms for long-term experimentation through a consistent water flow. Different experimental designs can be set up thanks to the 3 independent panels. All subjects can be under the same condition or rather, different ones to evaluate the locomotor activity with different scenarios: species/contaminants/concentrations.

estimates

3

A multi-species tool

Every living organism sized from 0.3 cm can be analysed by Toxmate. Here are a couple of examples:

Aquatic

- macroinvertebrates: Arthropods (Gammarus), Daphnia Magna, Gastropods (Lymnea), Annelids (Oligochaeta), aquatic larvae's insects (Ephemera, Chironomidae)

Terrestrial

- Arachnids (Spiders), Annelids (Earthworms), Molluscs (Snails), insects (Beetles)

Airborne

- Honeybees, Mosquitoes, Drosophila

Monitoring groundwater fluxes

ıer commercially available methods

ater assessment kits

ventional and non-conventional microbiological contaminants

fect-based assessment tools

toxicology

Passive sampling (Chemcatcher SDB-RPS disks)

polar organic chemicals

Urban M2O
Smart Monitoring and Modelling for Water Wise Cities

Which sensors are we developing

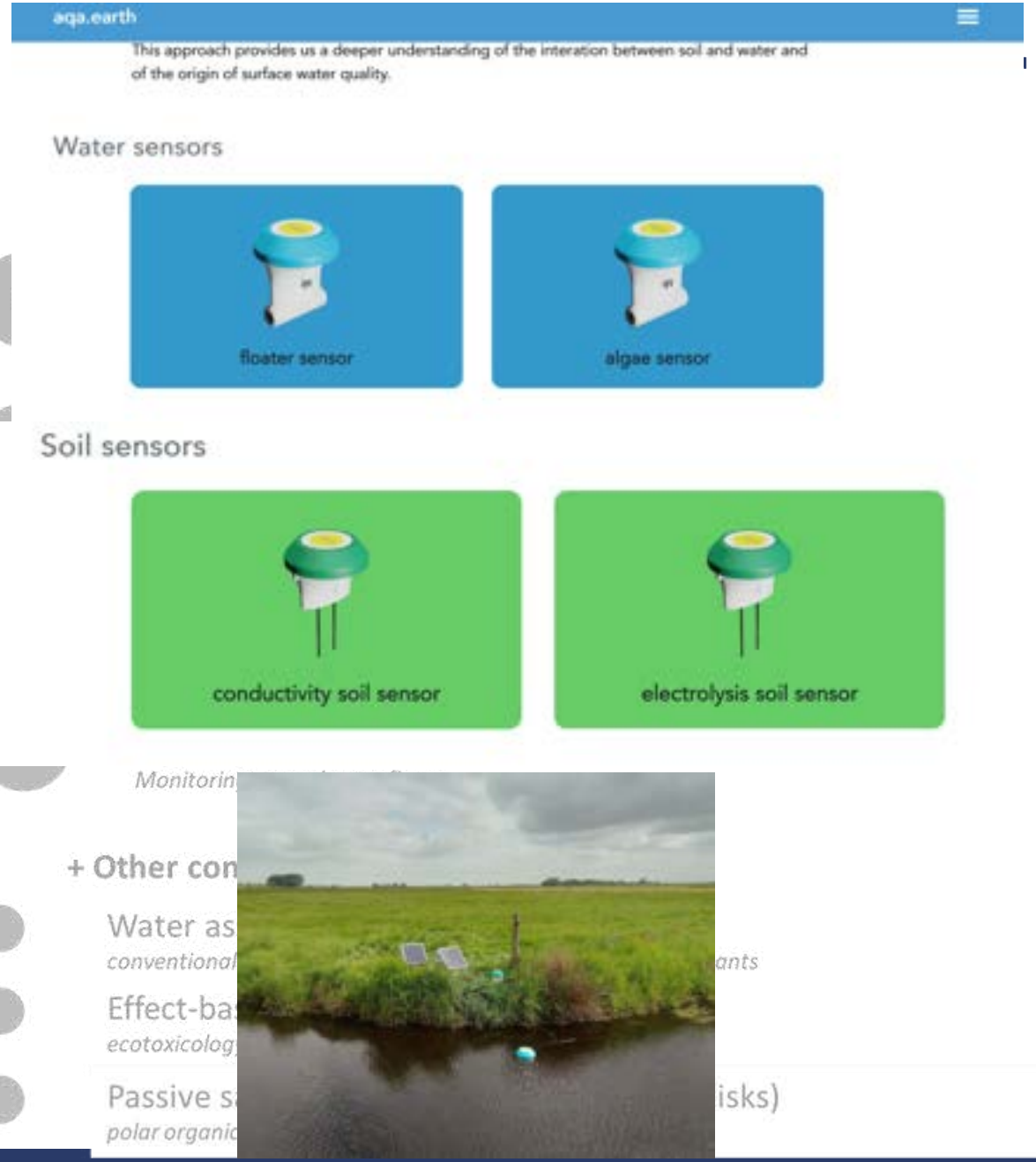
1 Real-time biomonitoring for online alerting (episodic pollution) in various water matrices
real-time locomotion behaviour of non-invasive invertebrate organisms

2a Online, real-time, remote (surface-)water quality sensor (uvc/uva/RGB type)
measuring conductivity, temperature, UV280 (280 nm), UV400, VIS461, VIS520, VIS640, TOC, tot N, tot P, humic acids, turbidity, DO, micropollutants, biofouling trends

2b Online, real-time, remote soil and air quality sensor
Topsoil and subsoil moisture content, organic matter content, nutrient saturation degree, drought sensitivity, topsoil biological activity, washout risk

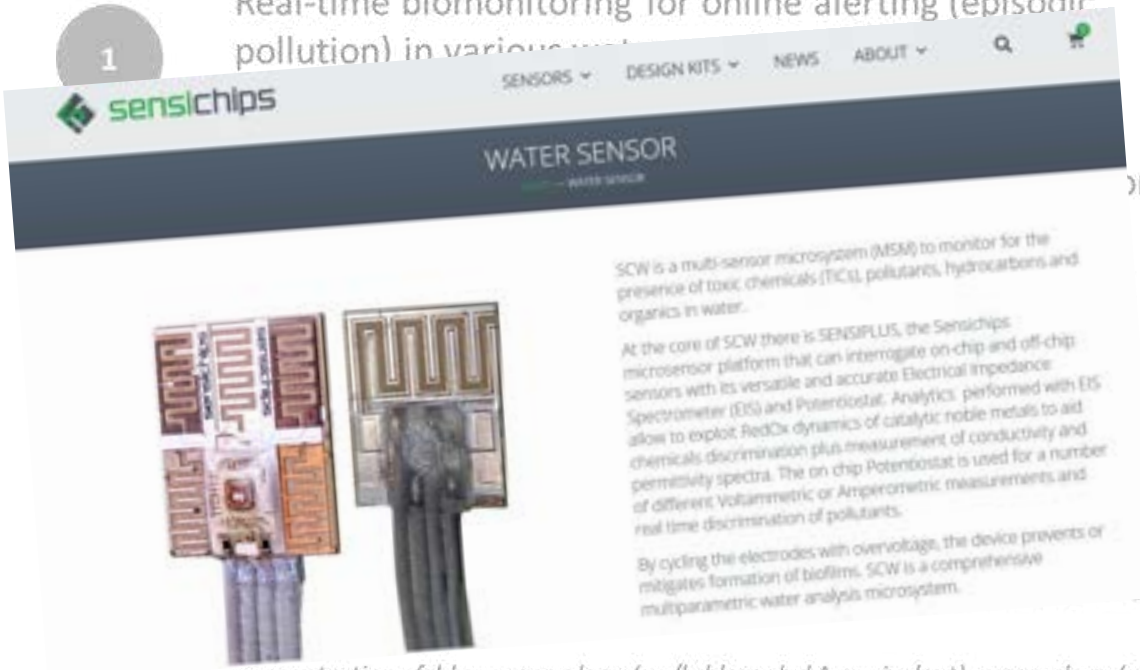
2c Online, real-time, remote (blue-)green algae surface water quality sensor
concentration of: blue-green algae (ug/l chlorophyl A equivalent), green algae (ug/l Chlorophyl A), dissolved oxygen; Measurements of turbidity, humic acids, biodiversity, micropollutants

2d Antimicrobial resistance (surface-) water quality sensor
Future: detection of antibiotic-resistant bacteria in samples, exponential growth rate estimates



Which sensors are we developing

1 Real-time biomonitoring for online alerting (episodic pollution) in various



concentration of: blue-green algae (ug/l chlorophyl A equivalent), green algae (ug/l Chlorophyl A), dissolved oxygen; Measurements of turbidity, humic acids, biodiversity, micropollutants

2d Antimicrobial resistance (surface-) water quality sensor

Future: detection of antibiotic-resistant bacteria in samples, exponential growth rate estimates

3 Real-time remote water quality learning micro-sensors

classification of multiple contaminants (heavy metals)

4 Ultrasound multi-frequency backscattering for online particle (TSS_{eq}) measurement

measure Particle Size Distribution (PSD)

5a Passive pollutant flux sampling

Sampling of groundwater for nutrients, heavy metals, organic micropollutants (incl. PFAS)

5b Digital groundwater flux sensors

Monitoring groundwater fluxes

+ Other commercially available methods

Water assessment kits

conventional and non-conventional microbiological contaminants

Effect-based assessment tools

ecotoxicology

Passive sampling (Chemcatcher SDB-RPS disks)

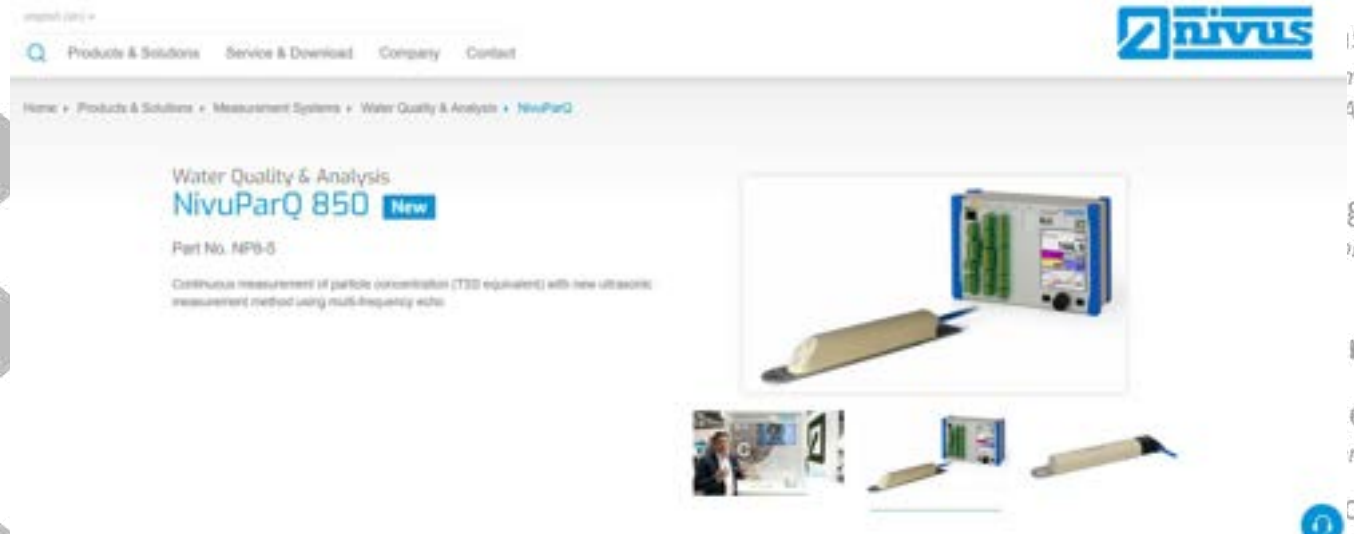
polar organic chemicals

Which sensors are we developing

1 Real-time biomonitoring for online alerting (episodic pollution) in various water matrices
real-time locomotion behaviour of non-invasive invertebrate organisms

2a Online, real-time, remote (surface-)water quality sensor (uvc/uva/RGB type)
measuring conductivity, temperature, UV280 (280 nm), UV400, VIS461, VIS520

2b



2c

2d *Future: detection of antibiotic-resistant bacteria in samples, exponential growth rate estimates*

3 Real-time remote water quality learning micro-sensors
classification of multiple contaminants (heavy metals)

4 Ultrasound multi-frequency backscattering for online particle (TSS_{eq}) measurement
measure Particle Size Distribution (PSD)

nivus

ssive pollutant flux sampling
npling of groundwater for nutrients, heavy metals, organic micropollutants (incl. AS)

gital groundwater flux sensors
nitoring groundwater fluxes

r commercially available methods

er assessment kits
ntional and non-conventional microbiological contaminants

ct-based assessment tools
xicology

Passive sampling (Chemcatcher SDB-RPS disks)
polar organic chemicals

Which sensors are we developing

Unique patented technology

Current monitoring relies on water levels and snap shot concentrations while flow and pollution fluxes are the missing link, responsible for the highest uncertainties in modelling predictions and future scenarios. That is why iFLUX developed their own **patented technologies** for measuring groundwater fluxes.

Our flux sensor technology is the newly developed groundwater sensing probe which monitors in low-flow conditions. The data from this sensor is then combined with water level data, infiltration rates and/or pollution measurements to give valuable insights to customers. The ability to detect in real-time groundwater fluxes in a range of 1-500 cm/day to depths of +50m, multidirectional, makes it unique in the market.

2b

Onli… real-time remote soil and air quality sensor

Tops… …uration

degr…

2c

Onl… …e water

qua…

conc… …gae (ug/l

Chlor… …biodiversity,

micr…

2d

Ant… …nsor

Futur… …rowth rate

estim…

3

Real-time remote water quality learning micro-sensors

classification of multiple contaminants (heavy metals)

4

Ultrasound multi-frequency backscattering for online particle (TSS_{eq}) measurement

measure Particle Size Distribution (PSD)

5a

Passive pollutant flux sampling

Sampling of groundwater for nutrients, heavy metals, organic micropollutants (incl. PFAS)

5b

Digital groundwater flux sensors

Monitoring groundwater fluxes

+ Other commercially available methods

Water assessment kits

conventional and non-conventional microbiological contaminants

Effect-based assessment tools

ecotoxicology

Passive sampling (Chemcatcher SDB-RPS disks)

polar organic chemicals

Which sensors are we developing

AI-enhanced Monitoring technologies

What do we mean?

NO new sensing principles

Some sensors are already available in the market

Elaboration/combination of (multiple) signals from existing sensors

1 Real-time biomonitoring for online pollution) in various water matrices
real-time locomotion behaviour of non-invasive inv

2a Online, real-time, remote (surface-) (uvc/uva/RGB type)
measuring conductivity, temperature, UV280 (280 nm), UV400, VIS461, VIS520, VIS640, TOC, tot N, tot P, humic acids, turbidity, DO, micropollutants, biofouling trends

2c Online, real-time, remote (blue-)green algae surface water quality sensor

sensor

estimates

vater quality learning micro-sensors
ntaminants (heavy metals)

equency backscattering for online
asurement
ution (PSD)

5a Passive pollutant flux sampling
Sampling of groundwater for nutrients, heavy metals, organic micropollutants (incl. PFAS)

5b

Effect-based assessment tools
ecotoxicology

Passive sampling (Chemcatcher SDB-RPS disks)
polar organic chemicals

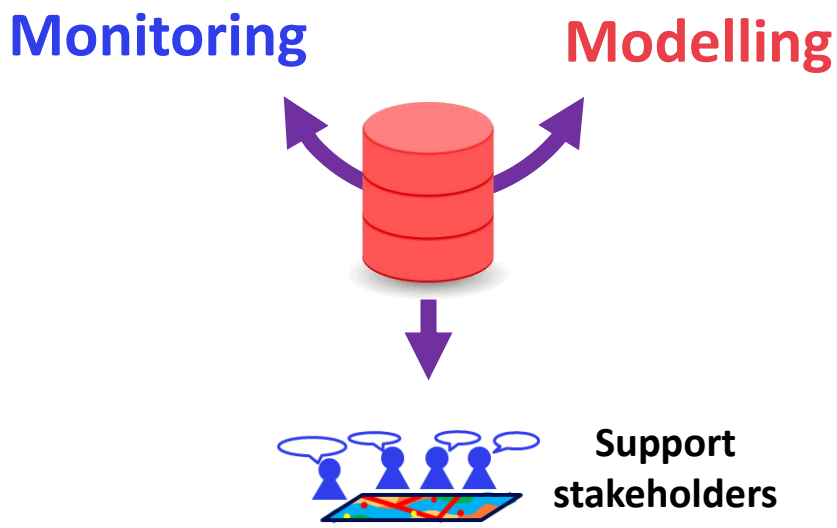
How are we going to do that?

Fit for purpose Digital Urban Water Twins

1. Identification of pollutant sources in the urban catchment
2. Source-flux-fate modelling (using as little data as possible)
3. Simulation of future management scenarios
4. Supplying additional information to monitoring activities (software sensors)
5. Supporting planning of monitoring (*where to sample? When?*)

Holistic Data Management System

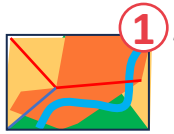
Ensure exchange of data across monitoring activities and stakeholders



The steps towards Digital Urban Water Twins

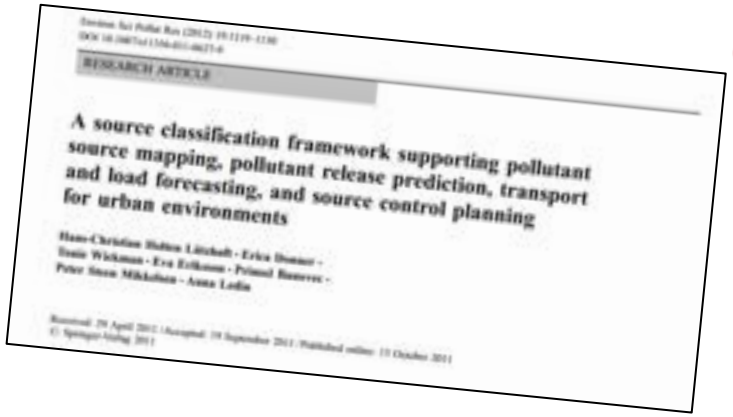
ScorePP

ScorePP is a Specific Targeted Research Project (STREP) funded by the European Commission under the Sixth Framework Programme



1 *Source identification*

- *Point sources*
- *Diffuse sources*



RESEARCH ARTICLE

A source classification framework supporting pollutant source mapping, pollutant release prediction, transport and load forecasting, and source control planning for urban environments

(combined)

waterun CleanCityCover tool **(separate)**

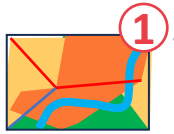
Urban M2O
Smart Monitoring and Modelling for Water Wise Cities

www.urbanm2o.eu

ScorePP

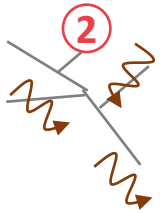
ScorePP is a Specific Targeted Research Project (STREP) funded by the European Commission under the Sixth Framework Programme

The steps towards Digital Urban Water Twins



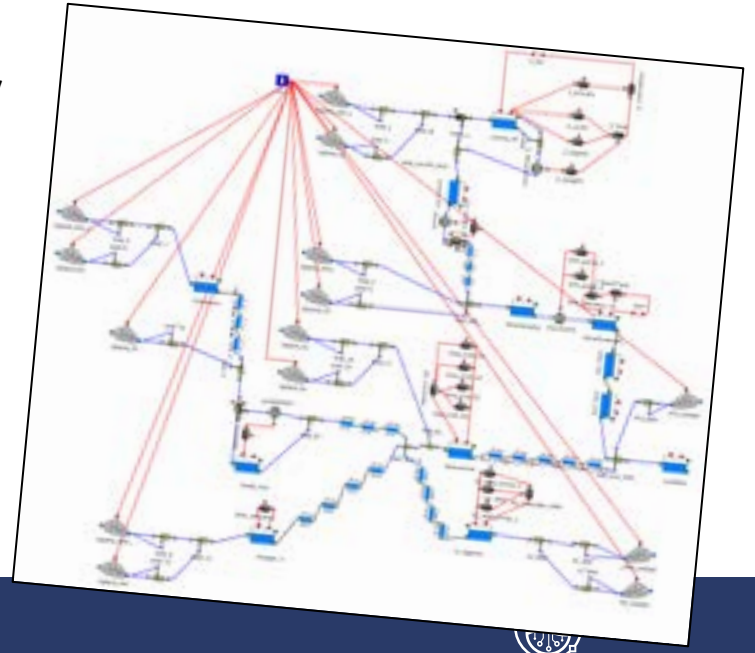
Source identification
- *Point sources*
- *Diffuse sources*

Inputs



Conceptual models
- *Mass fluxes tracking*
- *Literature parameters*

IUWS_MP library available in WEST already 10 yrs ago…



CITY DRAIN II
INTEGRATED URBAN DRAINAGE

Will also be available in open-source software

Urban M2O
Smart Monitoring and Modelling for Water Wise Cities

www.urbanm2o.eu

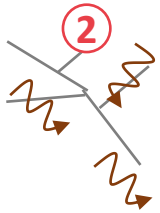
ScorePP

ScorePP is a Specific Targeted Research Project (STREP) funded by the European Commission under the Sixth Framework Programme

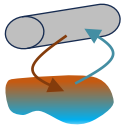
The steps towards Digital Urban Water Twins

1 *Source identification*
- *Point sources*
- *Diffuse sources*

Inputs →



2 *Conceptual models*
- *Mass fluxes tracking*
- *Literature parameters*



3 *Inter-compartment fluxes*

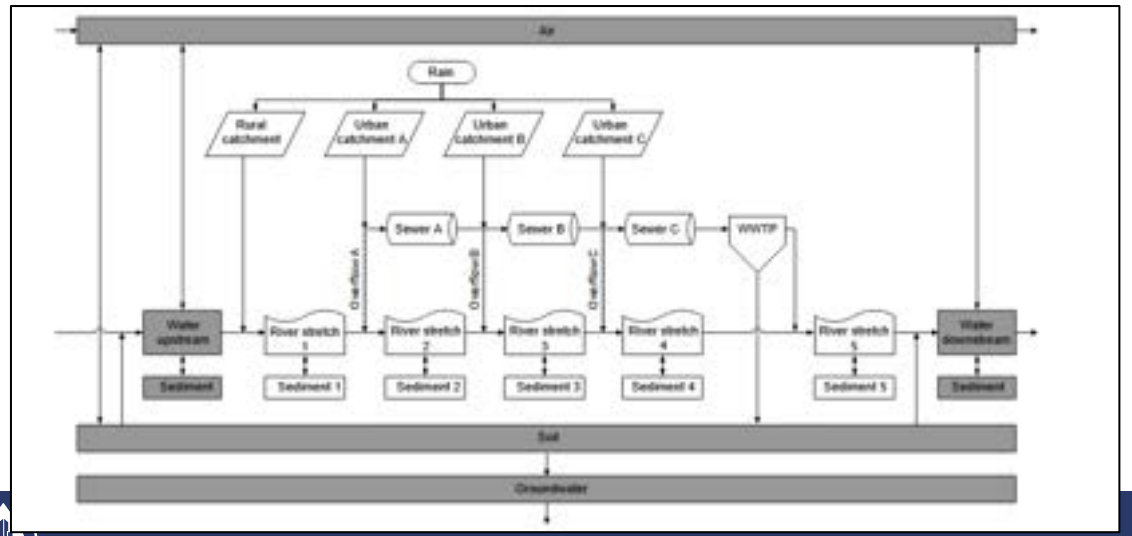
Water Science & Technology—WST | 62.3 | 2010

Combining multimedia models with integrated urban water system models for micropollutants

W. De Keyser, V. Gevaert, F. Verdonck, I. Nopens, B. De Baets, P. A. Vanrolleghem, P. S. Mikkelsen and L. Benedetti

ABSTRACT

Integrated urban water system (IUWS) modeling aims at assessing the quality of the surface water receiving the urban emissions through sewage treatment plants, combined sewer overflows (CSOs) and stormwater drainage systems. However, some micropollutants tend to appear in more than one environmental medium (air, water, sediment, soil, groundwater, etc.). In this work, a multimedia fate and transport model (MFTM) is "wrapped around" a dynamic IUWS model for organic micropollutants to enable integrated environmental assessment. The combined model was tested on a hypothetical catchment using two scenarios: on the one hand a reference scenario with a combined sewerage system and on the other hand a stormwater infiltration pond scenario, as an example of a sustainable urban drainage system (SUDS). A case for

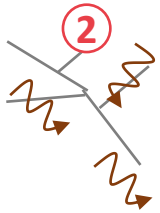


The steps towards Digital Urban Water Twins

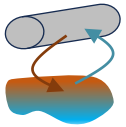
Digital Urban Water Twin (DUWT)

1 *Source identification*
- *Point sources*
- *Diffuse sources*

Inputs



2 *Conceptual models*
- *Mass fluxes tracking*
- *Literature parameters*



3 *Inter-compartment fluxes*

5 Data integration
- *Parameter estimation*
- *Uncertainty quantification*

Outputs

4 Holistic Data Management System (DMS)

Holistic water system

New sensor technologies

6 **Support stakeholders**

- *Evaluation current situation*
  How bad is it?
- *Planning monitoring activities and control strategies*

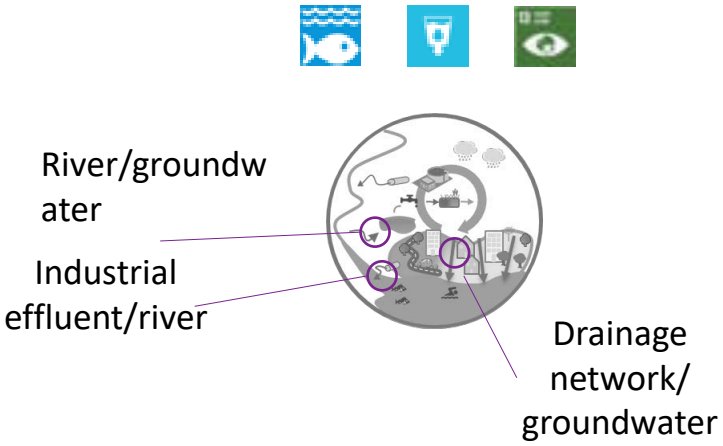
Where to measure?

Which solution to implement?

Where are working? – Urban M_2O case studies

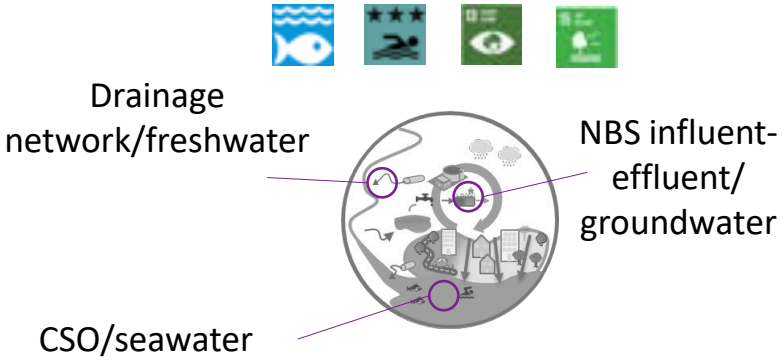
Barcelona/Sant Adria de Besos (BCN)

the water scarce city



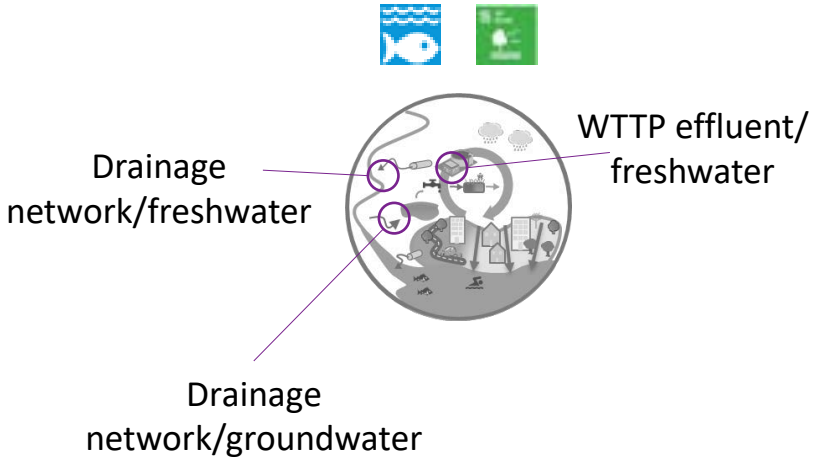
Copenhagen (CPH)

the blue-green climate city



Zurich (ZRH)

the urban water test lab



What we will measure

- Microbial contaminants
- Heavy metals
- Nutrients (N, P), TSS, Major ions, TOC, DOC
- Organic micropollutants
- Bioassays

How will we do it? - The 3 phases of Urban M_2O

4 years duration (June 25 – May 29)

Phase 1
Co-Design / Set the frame

End Users/Stakeholders (water utilities, regulators)

Define current and future monitoring needs (User Stories)

Phase 2 - Develop and demonstrate

Industrial partners

- Develop AI-enhanced sensors
- Develop Flexible modelling tools
- Develop Data sharing systems

Research partners

- Demonstrate data integration
- Benchmarking technologies

Phase 3 - Synthetize

End Users/Stakeholders (water utilities, regulators)

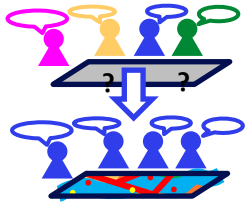
- Identify Lesson learnt
- Co-create flexible guidance to develop monitoring and management plans
- Build transition capacity

Exploitation Group (EG)

External Technology Developers (ETD)

This is where are now

End-Users and stakeholders - Involvement and roles

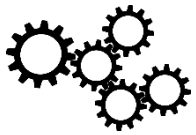


Phase 1 - Co-Design / Set the frame

”User Stories” = requirements for the solutions

What do you need to monitor?

How do you need the data to be shown?



Follow the development of solutions

What do you think about our developments?

Phase 3 - Synthetize

Co-design guidance material

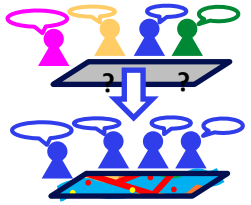
Create transition capacity in their organization

How should the guide look like?

Let’s make sure your staff can use our results

Source: www.lego.com

End-Users and stakeholders - Involvement and roles

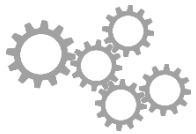


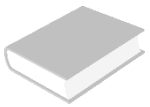
Phase 1 - Co-Design / Set the frame

”User Stories” = requirements for the solutions

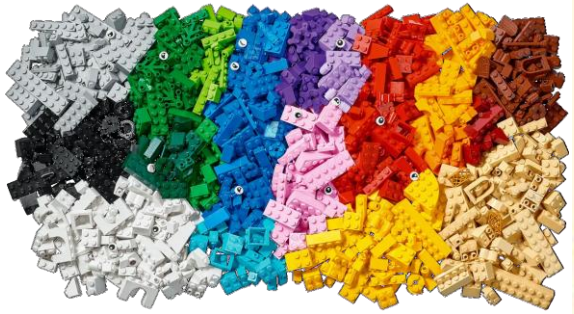
What do you need to monitor?

How do you need the data to be shown?





Lots of options

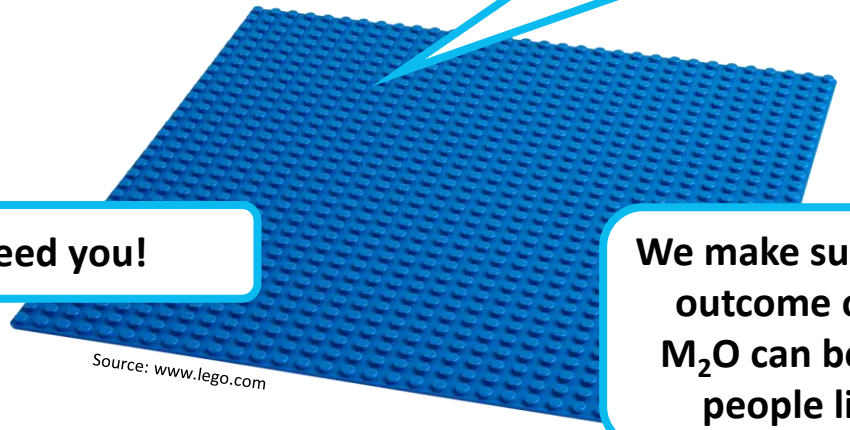


How should the guide look like?

Let’s make sure your staff can use our results

Source: www.lego.com

Urban M_2O project



Source: www.lego.com

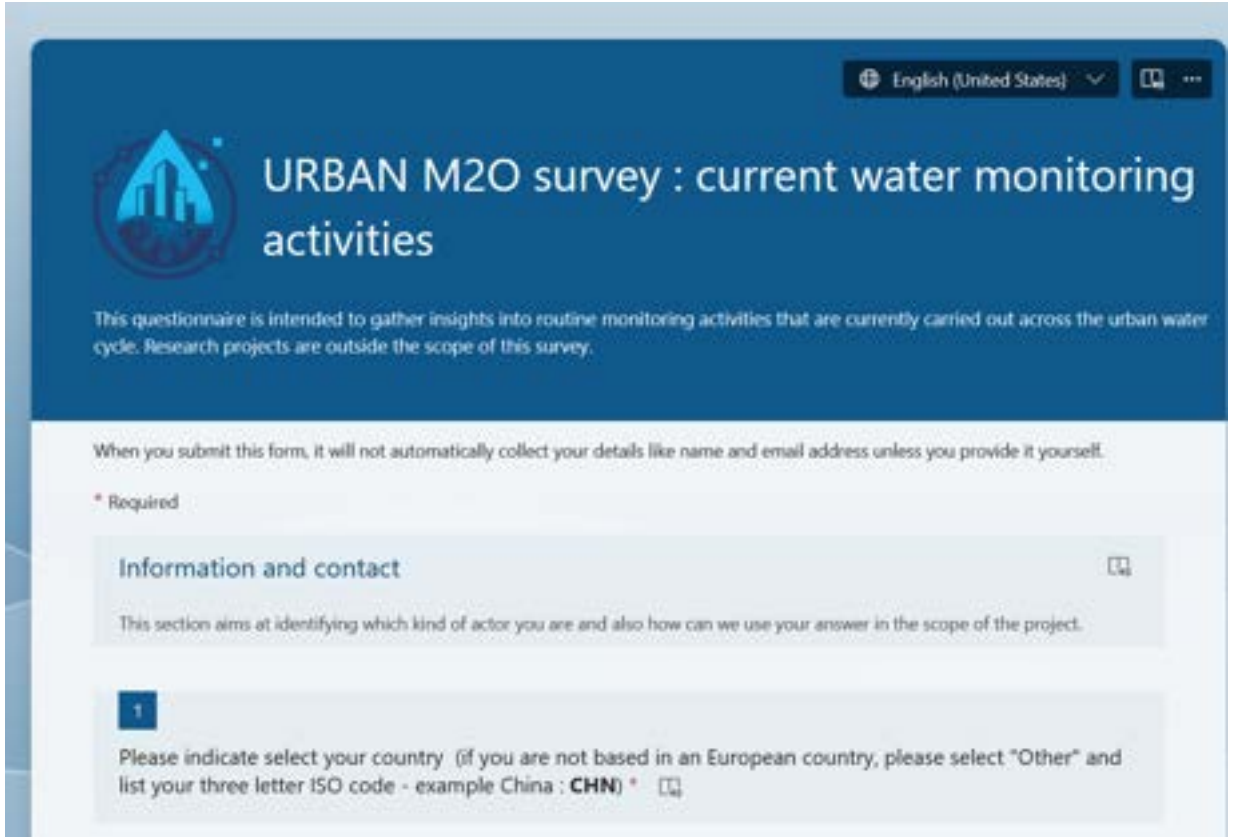
We need you!

We make sure that the outcome of Urban M_2O can be used by people like you

Source: www.lego.com

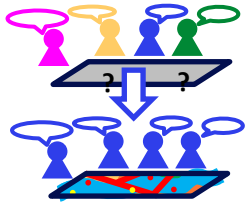
Source: www.lego.com

WHAT ARE PEOPLE MEASURING?



You can still give us your input

End-Users and stakeholders - Involvement and roles

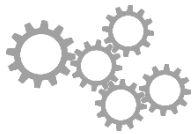


Phase 1 - Co-Design / Set the frame

”User Stories” = requirements for the solutions

What do you need to monitor?

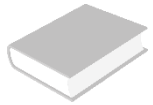
How do you need the data to be shown?



Follow the development of solutions

What do you think about our developments?

Phase 3 - Synthetize



Co-design guidance material

Create transition capacity in their organization

How should the guide look like?

Let’s make sure your staff can use our results

From Wikipedia: “*user story is an informal, natural language description of features of a **MONITORING** system.*
They are written from the perspective of an end user or user of a system”

Typical user of water quality data

What is needed

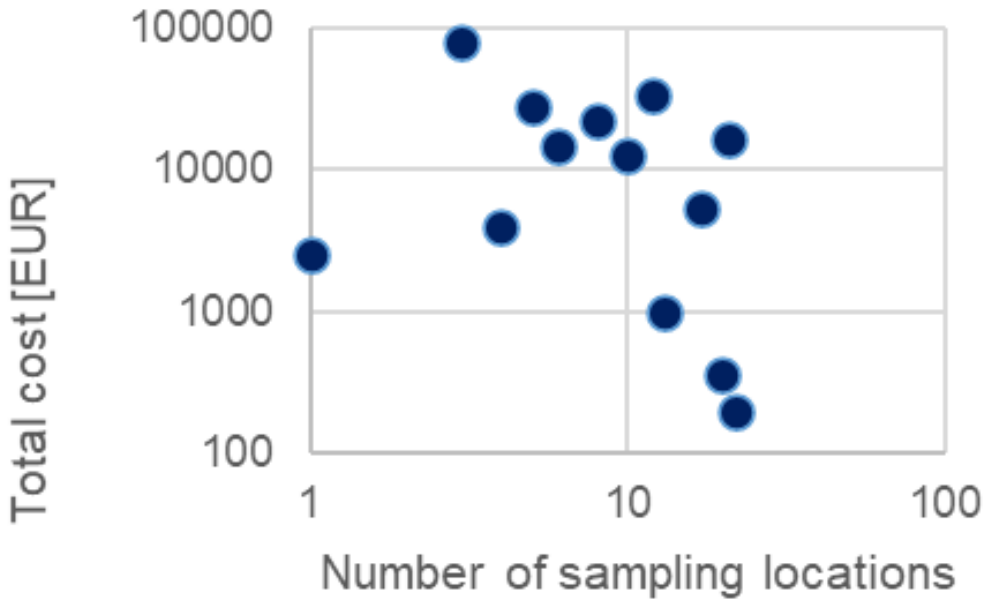
At which resolution

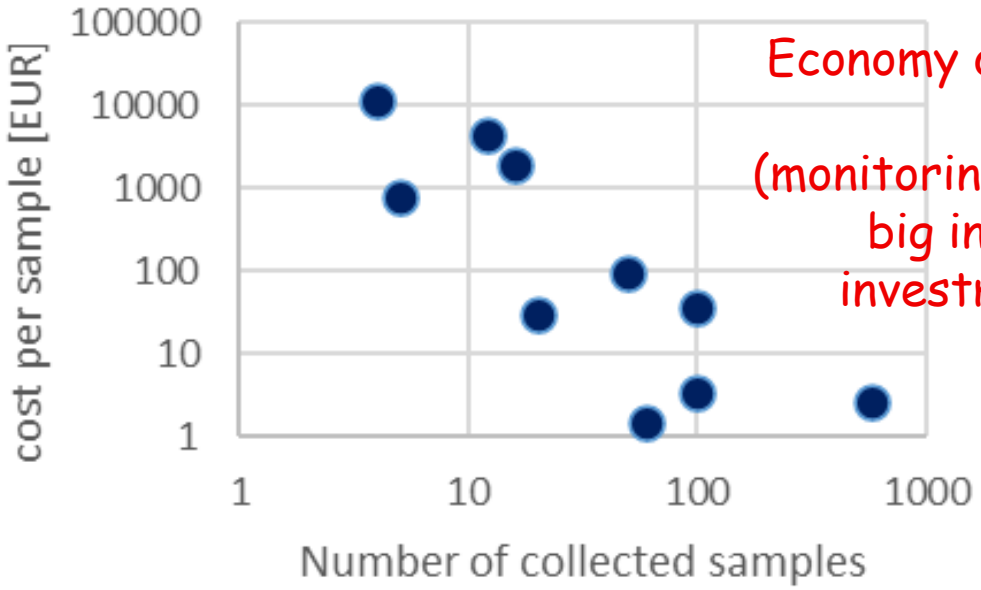
Where should be shown

Etc…

T1.1 Mapping current and future requirements and transition trends

As before Christmas





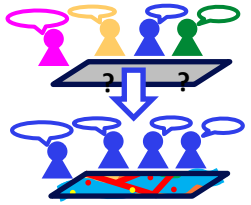
Economy of scale?

(monitoring needs a big initial investment)

Results constantly updated (until we close the questionnaire)

Challenge (= what takes time): open questions/translation

End-Users and stakeholders - Involvement and roles

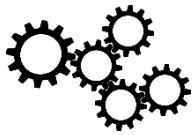


Phase 1 - Co-Design / Set the frame

”User Stories” = requirements for the solutions

What do you need to monitor?

How do you need the data to be shown?



Follow the development of solutions

What do you think about our developments?

Phase 3 - Synthetize

Co-design guidance material

Create transition capacity in their organization

How should the guide look like?

Let’s make sure your staff can use our results

Project Partners

Active part in the Urban M2O activities

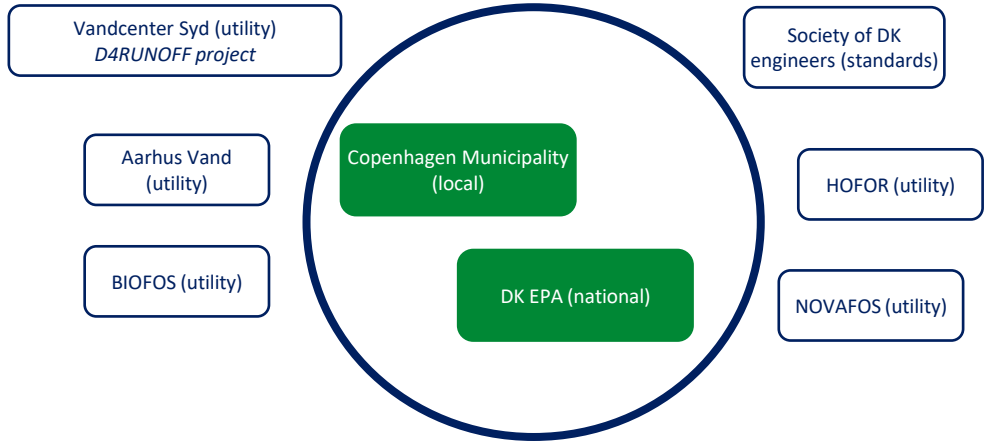
Exploitation Group (EG)

Participate to project on voluntary basis

Workshops/online meetings and webinars.

Organized at local level/around case studies

Example for Copenhagen



USER STORIES – WET WEATHER DISCHARGES

(V1.0)

ALEX

User ID: U01

Organization: Water Utility

Area of responsibility: Planning of urban drainage infrastructure

Alex works in the local water utility, and he is responsible for adapting the drainage network of the city to climate change. As part of this process, existing and new Urban Wet Weather Discharges (UWWD) need to be authorized. The utility has both combined and separate systems. Alex must ensure that UWWD discharges do not pose a threat to the ecological status of the freshwaters in the city. Since Alex is also planning the future infrastructure, he needs to use mathematical models to evaluate future scenarios.

Water Challenge

- Good status of surface waters
- Climate adaptation

Type of water

- Combined Sewer Overflows
- Separate Stormwater Systems
- Natural freshwater

Water Quality Indicators of Concern

Alex is primarily interested in chemical and physical parameters (measured both in the laboratory and by using online sensors); nutrients. Also, he needs to measure emerging contaminants; (eco)toxicity, heavy metals, plant protection products and biocides, and other organic compounds.

Temporal and Spatial resolution

Alex prefers to have continuous data or on an event basis. He can also rely on monthly data.

Alex needs data only from representative locations in the system.

Data Visualization

- Time series
- Reports

Data End-Users

Alex needs to send the data to the municipal environmental authority.

Alex wants to make the data publicly available, but he wants to make sure that data are validated before publishing them.

Other important aspects

The utility where Alex works has limited resources allocated for water quality monitoring.

BERTHA

User ID: C01

Organization: Consultant

Area of responsibility: Operation, Field work

Bertha works in a consultant company providing services to the local water utility such as maintenance of treatment facilities, maintenance of Nature Based Solutions, and compliance assessment for reporting to the environmental authority (Monitoring As A Service). The utility for which Bertha works has both combined and separate systems. When a treatment facility/NBS does not perform as intended, Bertha needs to alert the utility and perform extraordinary maintenance.

Water Challenge

- Good status of surface waters

Type of water

- Combined Sewer Overflows
- Separate Stormwater Systems
- Effluent of NBS/treatment facilities

Water Quality Indicators of Concern

Bertha is primarily interested in chemical and physical parameters (measured both in the laboratory and by using online sensors); nutrients. Also, he needs to measure emerging contaminants; (eco)toxicity, heavy metals, plant protection products and biocides, and other organic compounds.

Temporal and Spatial resolution

Bertha prefers to have continuous data or on an event basis. He can also rely on monthly data.

Bertha needs data from all the locations in the system that she has to monitor.

Data Visualization

- Time series
- Reports
- Alerts

Data End-Users

Bertha needs to send the data to the water utility and to the municipal environmental authority.

Other important aspects

Alex is interested to look at the data from Bertha, as he can use them to better plan the future infrastructure for climate adaptation.

CHRIS

User ID: A01

Organization: Municipality

Area of responsibility: Environmental Department

Chris is responsible for discharge permits at the local municipality. Chris need to ensure that discharges from the local water utility do not pose a threat to the chemical and ecological status of the natural waters. He evaluates requests for new discharges, and he evaluates compliance with regulations for existing discharge points. The municipality where Chris lives has both combined and separate drainage systems.

Water Challenge

- Good status of surface waters

Type of water

- Combined Sewer Overflows
- Separate Stormwater Systems
- Natural freshwater and saltwater

Water Quality Indicators of Concern

Chris is primarily focused on chemical and physical parameters (measured online) and heavy metals. He is also interested in nutrients, plant protection products & biocides and other organic compounds.

Temporal and Spatial resolution

Chris prefers to have data monthly, but he can also work with event-based data.

Chris needs data from representative locations in the network.

Data Visualization

- Time series
- Reports

Data End-Users

Chris needs to make the data available for anyone, but only after a quality check.

Other important aspects

Chris has an issue with the insufficient data sharing and lack of standardized (reporting) systems.

Urban M2O

info@urbanm2o.eu www. urbanm2o.eu urban-m2o-project

Luca Vezzaro

luve@dtu.dk

45251579

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Funded by the European Union