

# SAFEWATER

**Innovative tools for the detection and mitigation  
of CBRN related contamination events  
of drinking water**

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water**



**Water security is compromised by  
deliberate or accidental contamination**

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# Accidental Contaminations



# Accidental Contaminations

In Germany / Switzerland 2014-2015

## Bakterien im Trinkwasser rund um Meikirch

Februar 2015

Das Trinkwasser der Gemeinde Meikirch ist offenbar verunreinigt. Betroffen sind auch Bütschwil, Schüpbühl, Uetligen sowie einzelne Bauernhöfe von Kirchbühl und Diemerswil. Ursache ist der Jauche-Unfall in Schüpbühl vom letzten Montag.

Städtische Werke: Keine akute Gesundheitsgefahr

## E-Coli-Keim entdeckt: Trinkwasser in Kassel abkochen

März 2015

10.03.15 - 16.52  
Kassel. Da bei einer Kontrolle ein E-Coli-Keim an einem Wasserhochbehälter am Brasseberg entdeckt worden ist, muss das Trinkwasser ab sofort in mehreren Kasseler Stadtteilen abgekocht werden.

Autor

## In Le Locle hat jeder Zehnte eine Magen-Darm-Infektion

Juli 2015

Das Trinkwasser des Ortes im Neuchâtel Jura ist mit Kolibakterien verseucht. Rund 1000 Menschen sind betroffen. Noch gibt es keine Entwarnung.

Gesundheitsgefahr gering

## Trinkwasser in Adliswil verschmutzt

tri. Die Bevölkerung der Gemeinde Adliswil muss aus Sicherheitsgründen bis auf weiteres ihr Trinkwasser abkochen. Grund des Übels ist eine Verschmutzung des Leitungswassers. Wie die Kantonspolizei in der Nacht auf Donnerstag mitteilte, war es am späten Mittwochnachmittag im Zuge von

8.2.2008

Februar 2008

November 2014

## Trinkwasser wegen Technik-Defekt verseucht

Eine defekte Verschlussklappe sorgte am Sonntag dafür, dass das Trinkwasser in Gredlingen verunreinigt wurde. Die Gemeinde wartet nun gespannt auf Entwarnung.

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**Information we need when a CBRN event contaminates the drinking water supply...**



- Location of contamination?
- Impact of contamination?
- Which action?

- Toxicity sensors
- Hydraulic and quality sensors
- Hydraulic stations (tanks, pumps, valves)
- ★ Contamination source

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**At project start ...**

**No end to end holistic solution available  
for the detection and management of a  
CBRN water safety event**

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## At project start ...

- ▶ No online sensors for microbial or radiological detection
- ▶ Only a few sensors for specific chemicals' detection
- ▶ No reliable tools for real time detection/online simulation

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## SAFEWATER Objectives

**Global generic solution for detection and mitigation of drinking water event resulting from CBRN contamination**

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## SAFEWATER Objectives

- ▶ New CBRN water quality sensors
- ▶ Improved contamination alert systems
- ▶ Simulators to determine source and spread
- ▶ Management system to provide decision support
- ▶ Testing the system in three water utilities in six use cases

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## SAFEWATER at a glance

- EU funded FP7 – security project, 10/2013 – 12/2016
- 9 partners from 5 countries:
  - ▶ **Sensor development** (CEA, ACREO, biomonitech)
  - ▶ **Event management system** (Fraunhofer IOSB)
  - ▶ **Event detection systems** (Decision Makers)
  - ▶ **Simulators** (3S Consult, Fraunhofer IOSB)
  - ▶ **Management of Drinking Water Networks** (Hagihon, AdA, Zürich)

coordinator



scientific coordinator

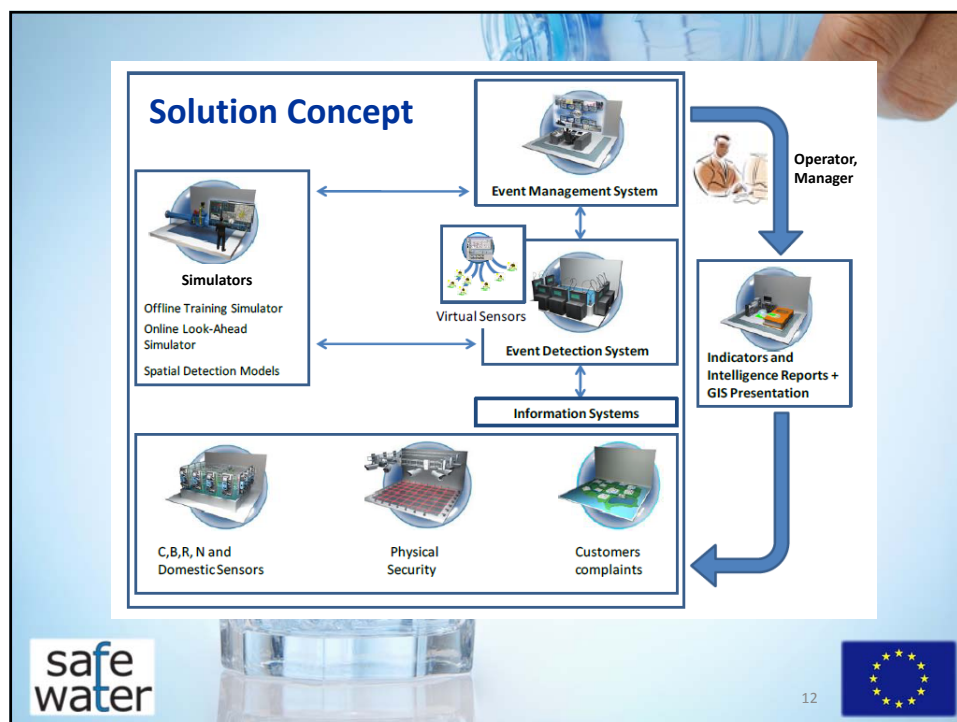
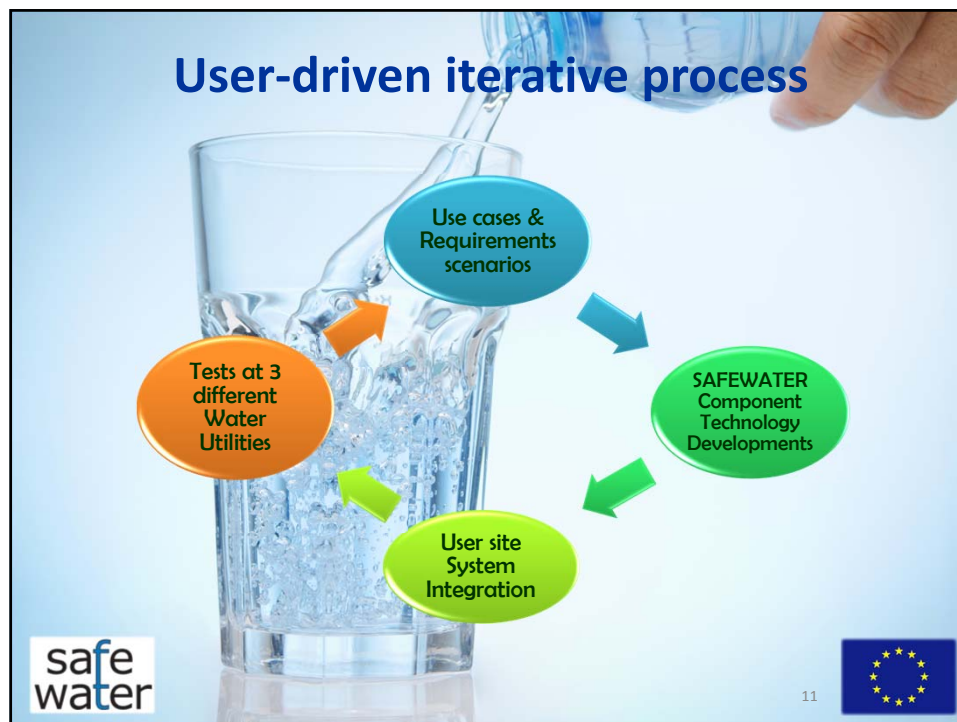


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## New CBRN Sensors

- 1) Rapid detection of *E. coli* (ACREO, Sweden)
- 2) Chemical toxicity detection (biomonitech, Israel)
- 3) Radioactivity detection ( $\alpha$ ,  $\beta$ ) (CEA, France)

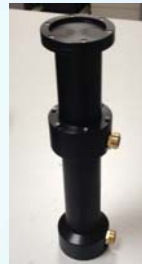


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Rapid detection of  
*E. coli* (ACREO)



Chemical toxicity detection  
(biomonitech)



Radioactivity  
sensor (CEA)



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## Rapid detection of *E. coli*

*E. coli* bacteria are labeled with fluorescent nanoparticles via specific antibodies



Antibody stained *E. coli* bacteria



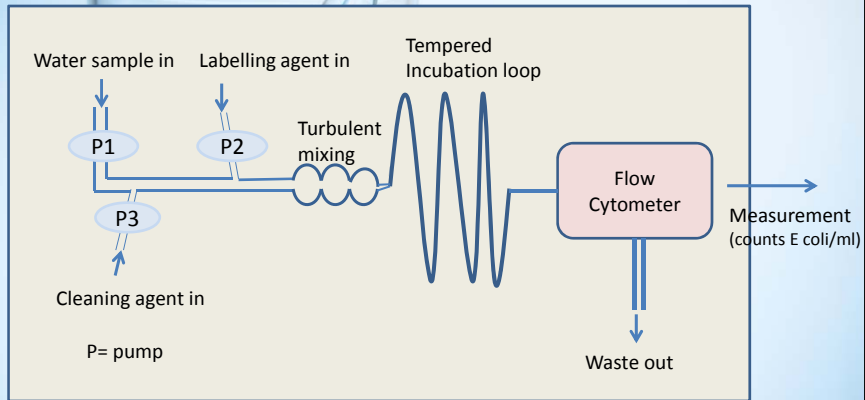
Clusters of *E. coli* bacteria in sewage water

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## Rapid detection of *E. coli*

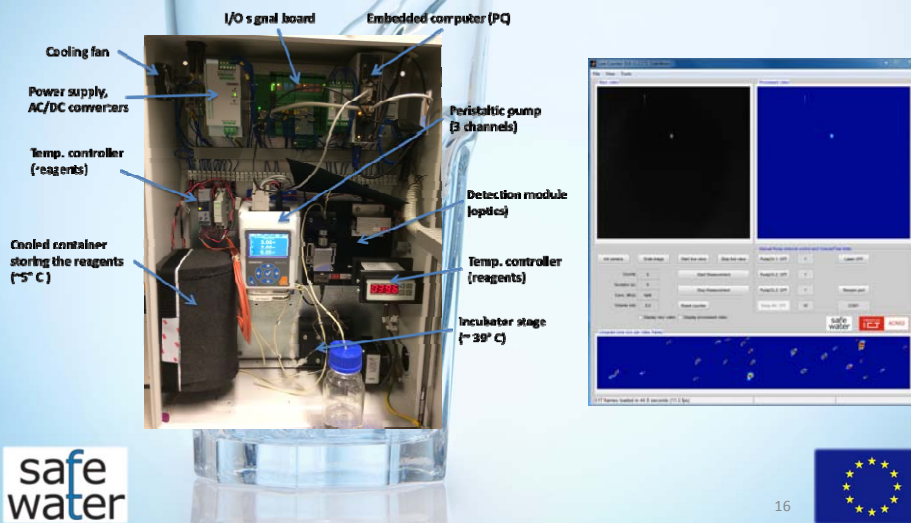


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## Rapid detection of *E. coli*

**Sensor Prototype – tested at Hagihon (Jerusalem) and WVZ (Zurich)**

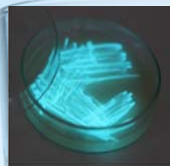


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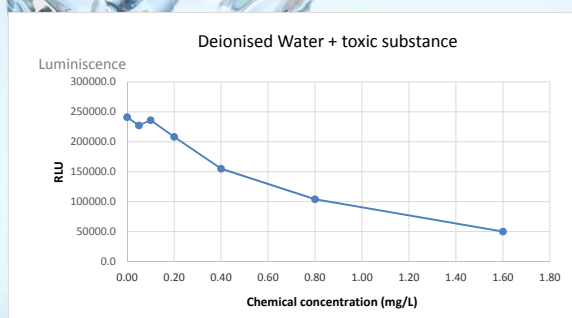




## Chemical Toxicity Detection



Chemical toxicity detection  
by luminescent marine bacteria  
(e.g. pesticides, herbicides, heavy metals)



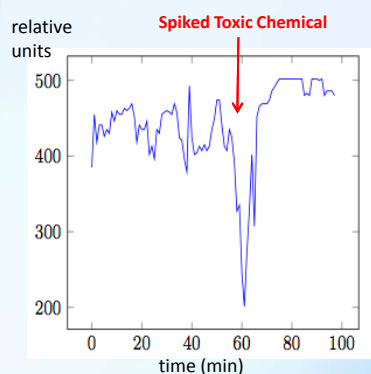
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## Chemical Toxicity Detection

Sensor Prototype – tested at Hagihon (Jerusalem) and AdA (Portugal)



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Chemical toxicity detection  
by luminescent marine bacteria  
(e.g. pesticides, herbicides, heavy metals)

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## Radioactivity Detection

**Detection of  $\alpha$ - and  $\beta$ -radiation**

- Based on a scintillating optical fibers bundle
- Miniaturised Photomultiplier Tube (PMT)






Photonmultiplier

First prototype

Scintillating optical fibers bundle

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## Radioactivity Detection

**Sensor Prototype – tested at Hagihon (Jerusalem)**




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## Sensors with wireless Data Transmission

- Aim: Obtain more water quality data from the network
- Data transmission via GSM; secure cloud based data storage



Hagihon, Jerusalem



Wasserversorgung Zürich

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## Test-sites at Water Utilities

### Test Sites at Water Utilities HaGihon (Jerusalem) and AdA (Portugal)

- Test of the Safewater Software modules (EDS, EMS, Simulators)
- Test of Safewater CBRN sensors & commercial sensors



HaGihon (Jerusalem)



AdA (Portugal)

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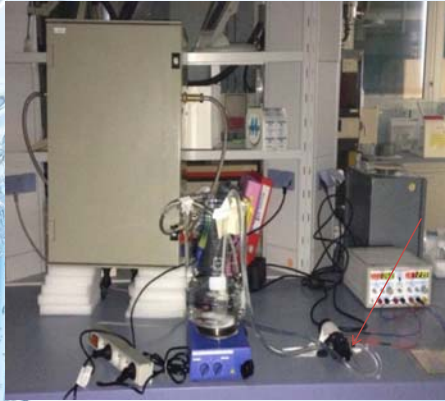
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## Test site at CEA (France)

Experiments:  $\alpha$ ,  $\beta$  radiation material mixed with water



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## Test Network in Zurich

- Test of all SAFEWATER software modules
- Test of *E. coli* sensor & commercial sensors



Test network Zurich: 150 m pipe length, 5 m width



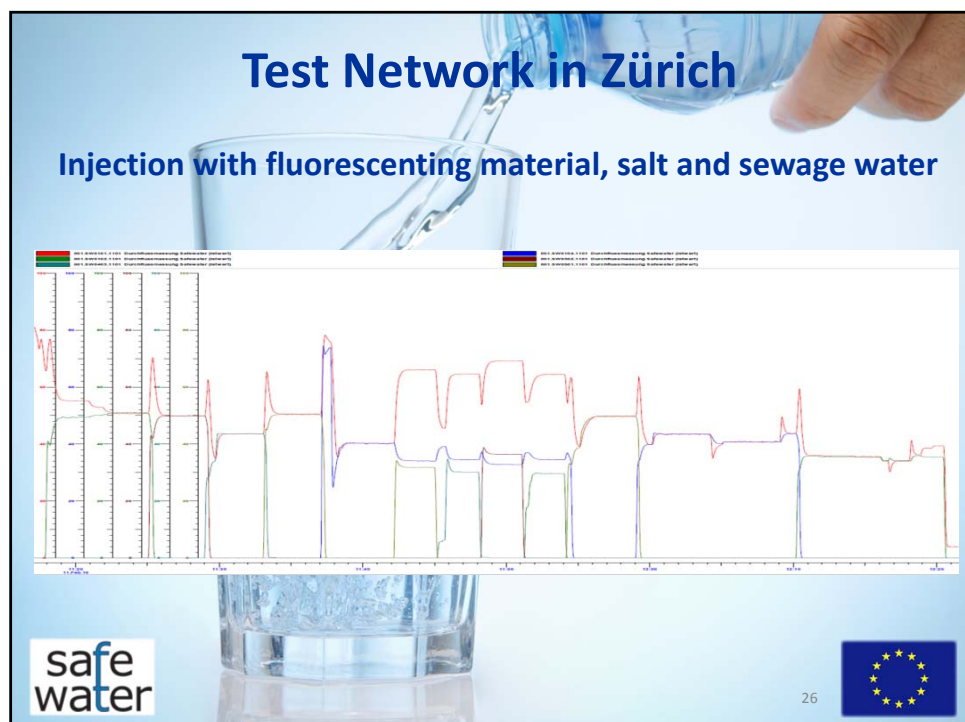
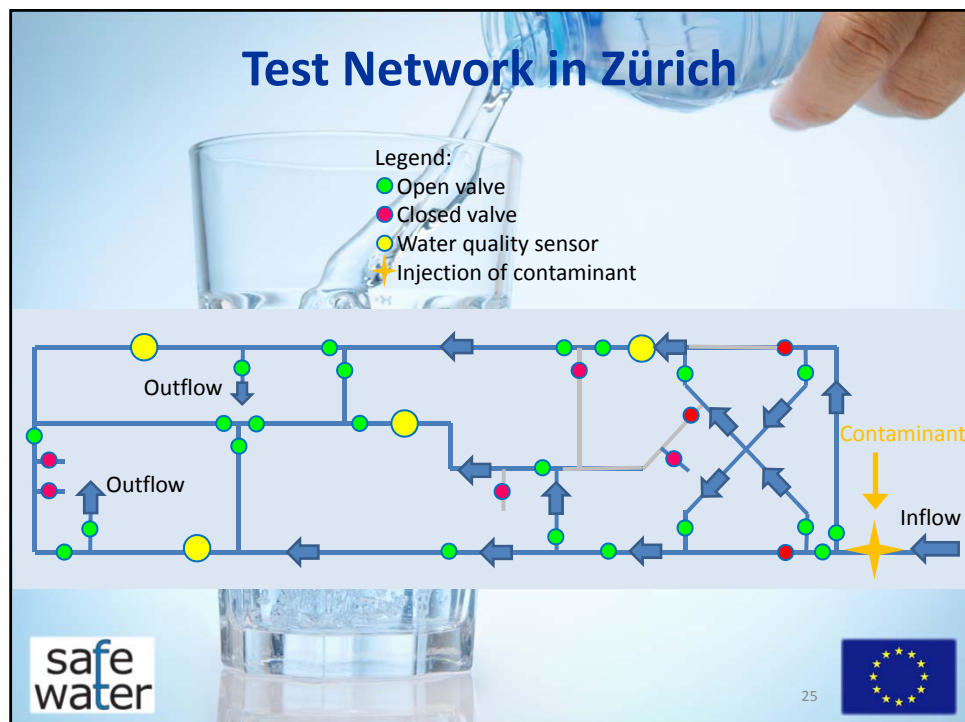
Injection pump

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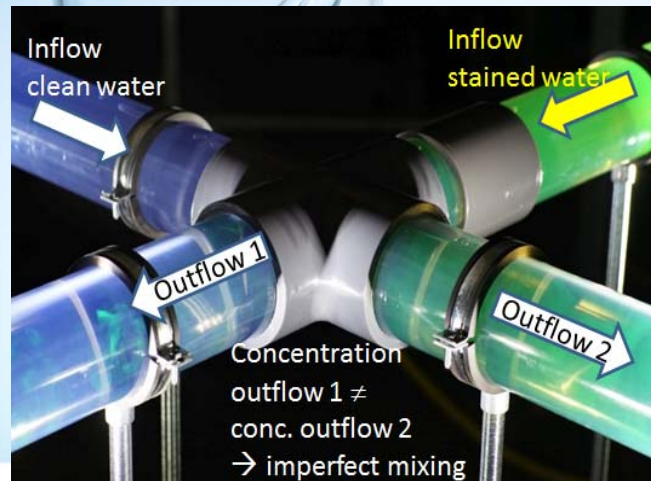






# Incomplete Mixing at Crossing

Investigation of mixing at crossing under various flow conditions



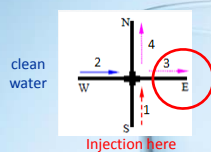
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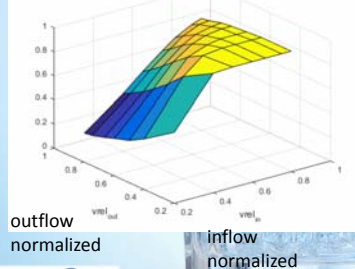


# Incomplete Mixing at Crossing

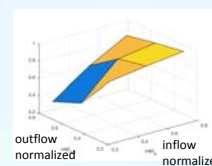
Results from the test-network with different Reynolds numbers



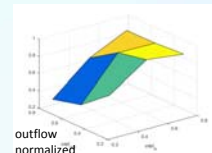
Results from Literature  
AZRED model,  $Re = 52.000$



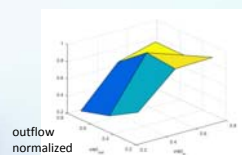
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Results with  
 $Re = 1.000$



Results with  
 $Re = 3.000$



Results with  
 $Re = 10.000$

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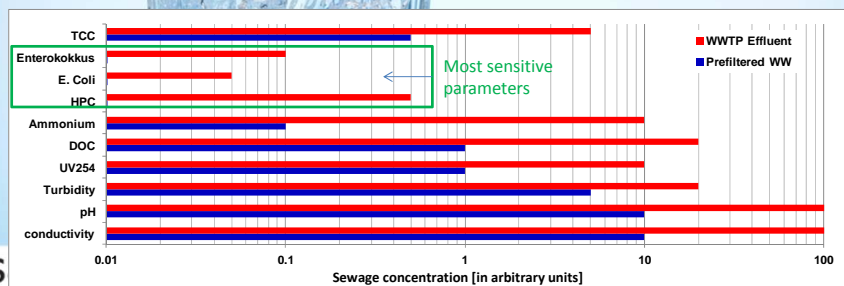


# Detection of sewage intrusion

Lab tests at Wasserversorgung Zürich

- Dilution experiments with waste water to determine the sensitivity of different parameters for the detection of faecal contamination in tap water
- Most promising parameters to detect faecal contamination in drinking water are the biological parameters:

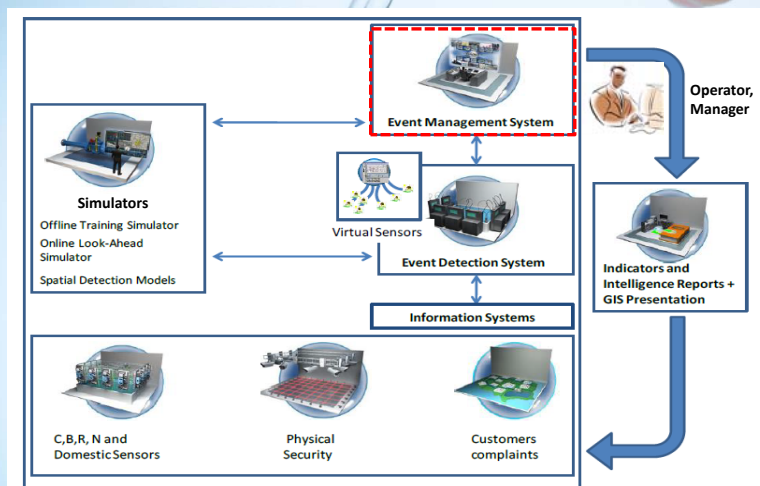
**Enterococcus, *E. coli* and Heterotrophic Plate Count (HPC)**



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# Event Management System (EMS)



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# Event Management System

Web based, user friendly platform that handles events reported by the Event Detection System (EDS)

The screenshot shows the 'safe water' web interface for managing alarms. It features a navigation bar with 'Water Network', 'Alarms', 'Events', 'Addresses', and 'Simulation (Quality)'. The 'Alarms' section is active, displaying a table of events. The table has columns for Type, Severity, Title, Creation, Ack status, Latitude, and Longitude. The events listed include 'Test Durscher Tor', 'no water', 'Strange smell', 'Maintenance reminder', 'biobal', 'Something happened', and 'ausfaad'. To the right of the table are buttons for 'Add', 'Edit', and 'Delete'. Below the table are buttons for 'Maps' (Water Network) and 'Other' (Ack Alarm, Discard Alarm). At the bottom, there are links for 'Top', 'Print', 'Imprint', and 'Privacy policy'.

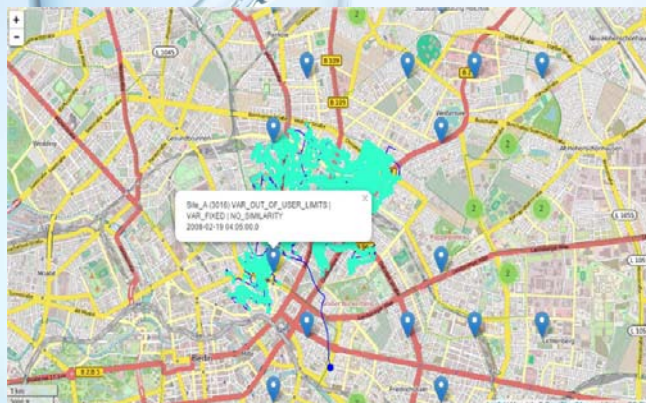
Type	Severity	Title	Creation	Ack status	Latitude	Longitude
EDS	HIGH	Test Durscher Tor	01.06.2015 14:27:00	✓		
Other	MEDIUM	no water	01.09.2014 11:46:12	⚠	52.529996779207	13.47
Complaint	LOW	Strange smell	18.08.2014 14:26:27	⚠	52.540000915527	13.48
Maintenance	INFO	Maintenance reminder	02.06.2015 17:00:00	✓	52.580001831055	13.43
Other	INFO	biobal	01.06.2015 13:36:17	✗		
Other	INFO	Something happened	01.06.2015 10:48:00	✓		
Maintenance	INFO	ausfaad	01.06.2015 09:22:55	⚠		

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# Event Management System

Interface to offline & online simulators with GIS-based visualisation of results



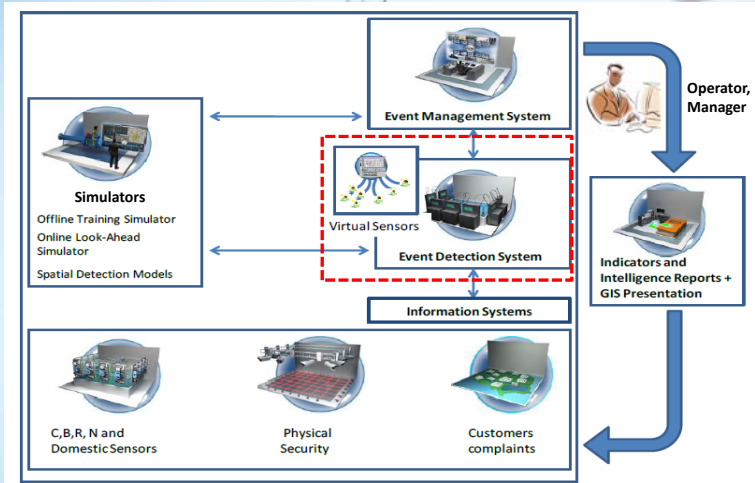
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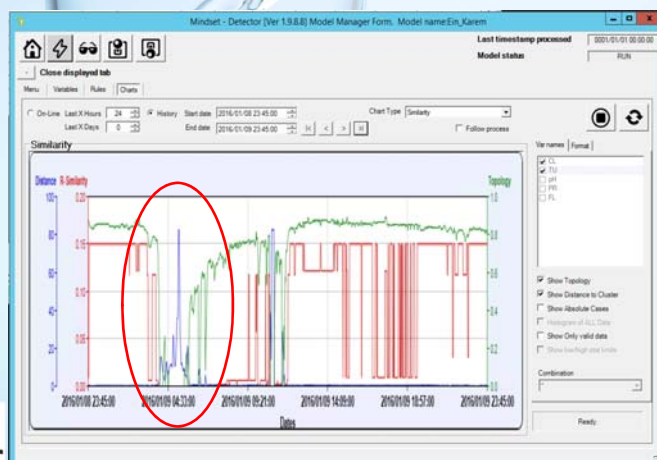


# Event Detection System (EDS)



# Event Detection System

Combines information from multiple sensors in order to detect anomalies in water quality measurements



## Event Detection System

**Spatial Model:** Computes water flow time using water quality measurements

→ understand relations between stations



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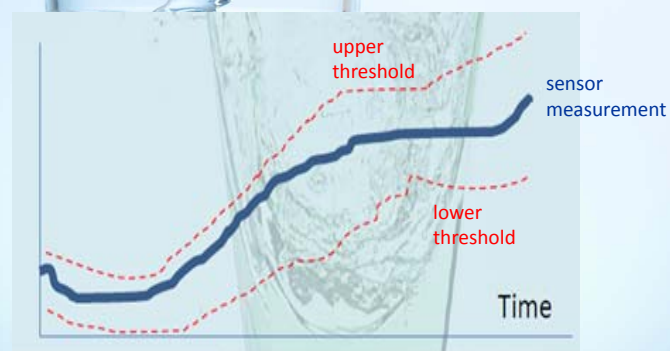
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## Event Detection System

**Calculates adaptive thresholds for low energy sensors**

Benefit: Sensors send data out frequently only when threshold is exceeded



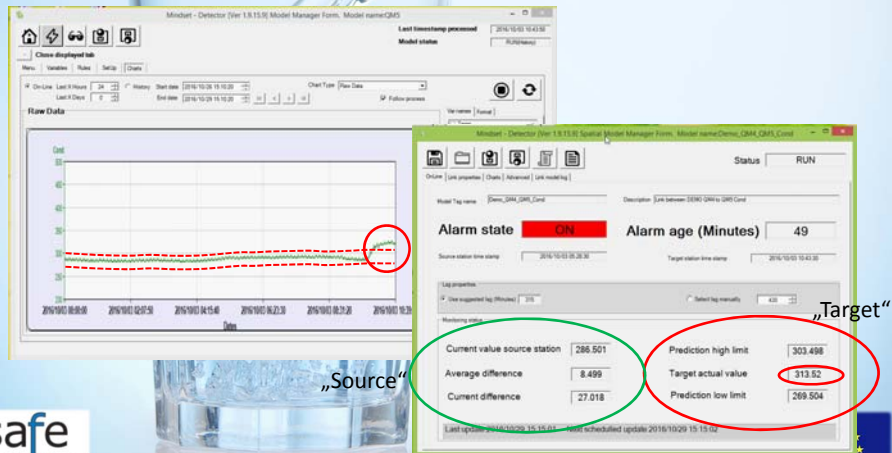
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# Event Detection System

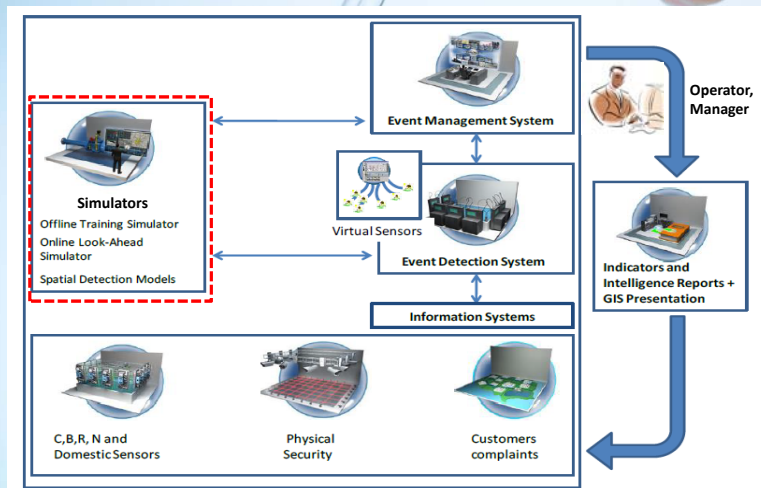
Spatial Model: Detecting anomalies by comparing stations



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## Simulators (Offline & Online)



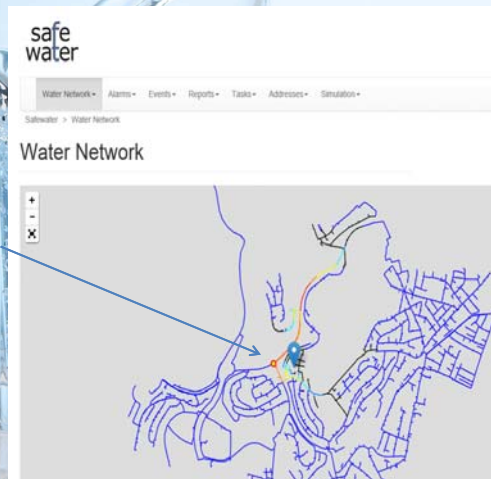
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## Offline Simulator

- Understand the hydraulic and water quality behavior
- Simulations of reactions and decay of substances
- Generate training data for the Event Detection system

Simulation of spread of contamination



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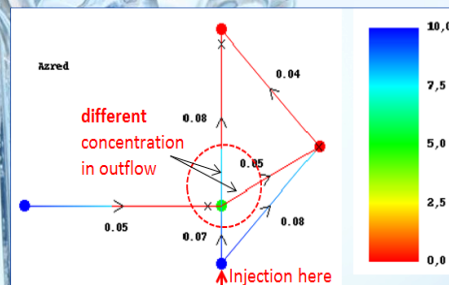
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## Offline Simulator

### Consideration of incomplete mixing at junctions

Enhanced EPANET-MSX simulation software



Exemplary simulation:  
Incomplete mixing at junctions

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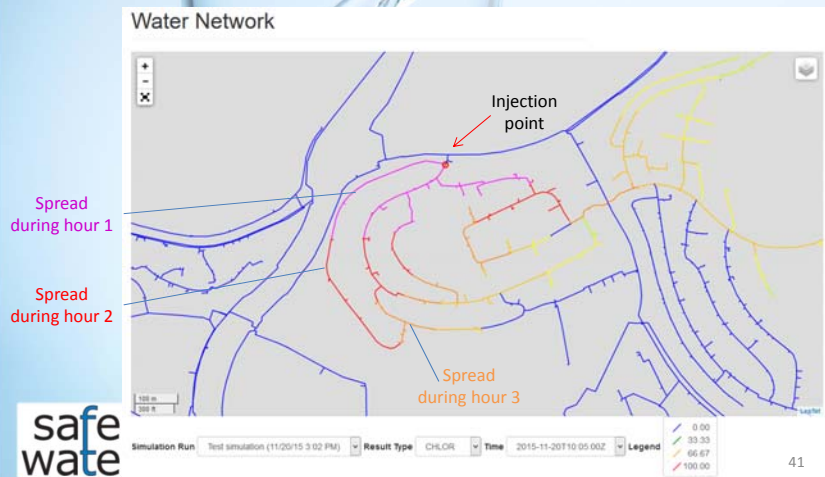




## GIS-based Display of Simulation Results

### Display options for water quality simulation results:

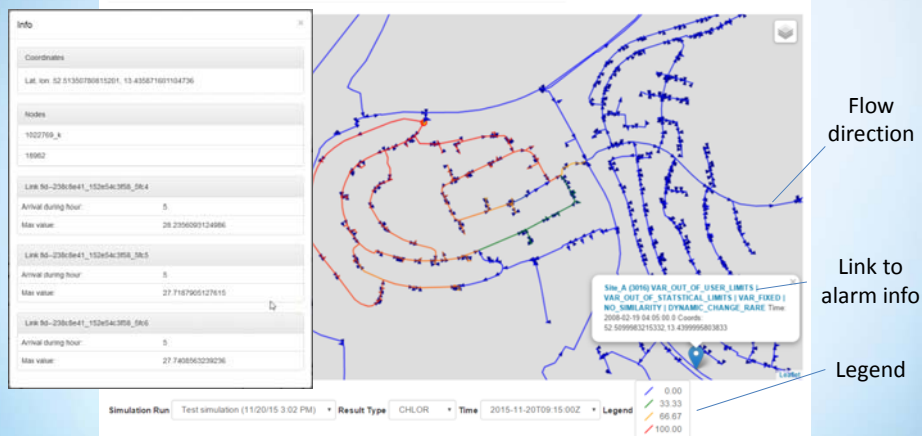
- (1) concentrations or
- (2) time for spread of contamination



## GIS-based Display of Simulation Results

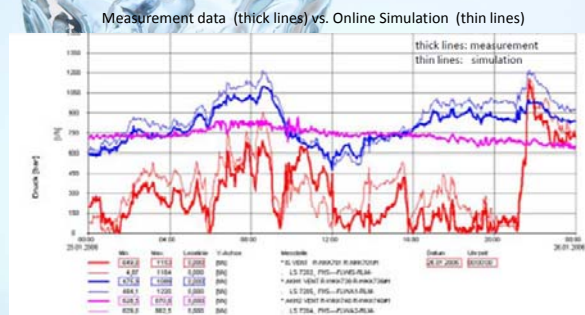
### Display of flow and flow directions

#### Water Network



## Online Simulator & Response Tools

- **Online Hydraulic Simulator:** Overview about current hydraulic state (pressure, velocity) of the drinking water distribution system
- **Needs online measurements**, e.g. inflow, flow of main pipes, pressure
- Update of the results e.g. every minute



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## Online Simulator & Response Tools

- **Identification of contaminant sources** by backtracking algorithm
- **Look-ahead calculations:** Estimated spread of the contamination
- **Isolation valves:** Identification of valves which have to be closed

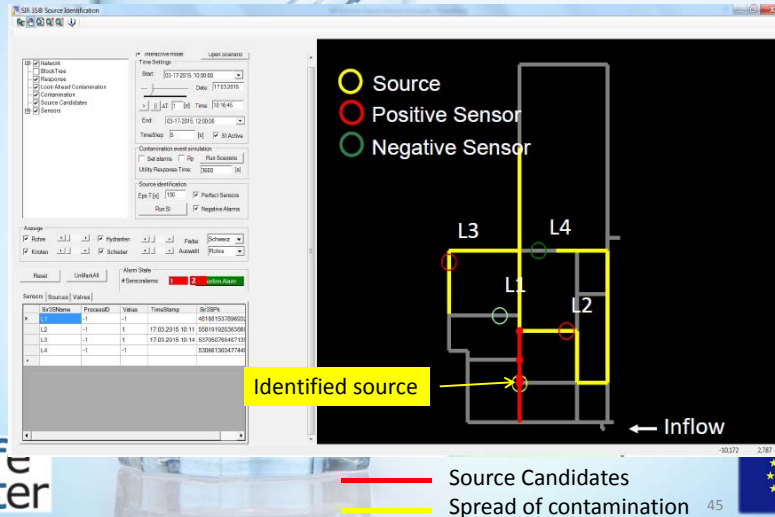
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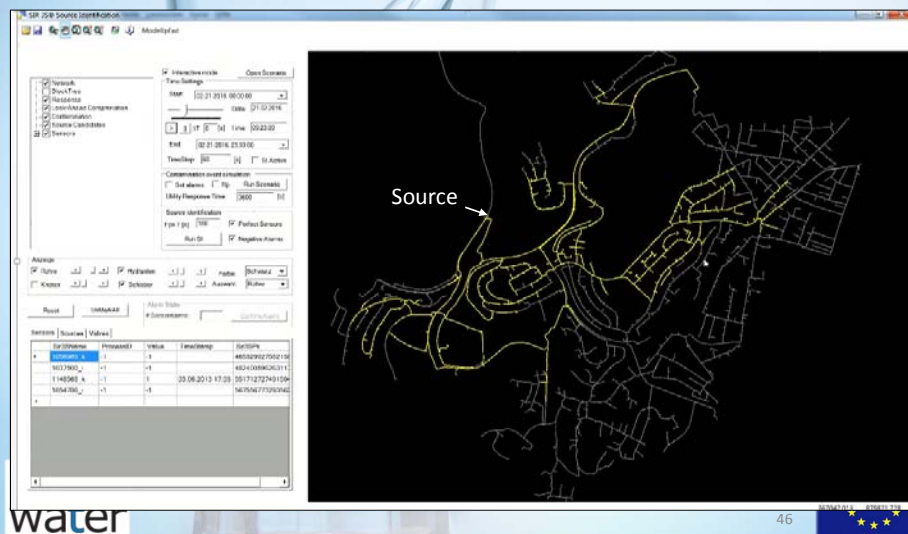
## Source Identification

Potential intrusion points are calculated based on “positive” / “negative” water quality sensor measurements (positive -> contamination detected)



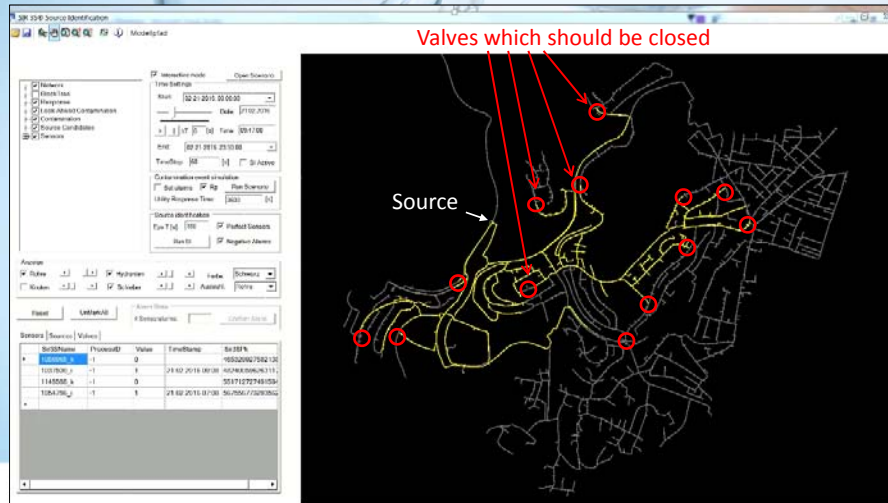
## Look-Ahead Simulator

Online prediction of spread of contamination based on online hydraulic data



# Valve Closing Recommendation

based on response time of water utilities for closing the valves (e.g. 1 hour)



## SAFewater Summary



- Location of contamination?
  - Impact of contamination?
  - Which action?
- Toxicity sensors
  - Hydraulic and quality sensors
  - Hydraulic stations (tanks, pumps, valves)
  - Contamination source

- **New CBRN sensors** for real-time detection of CBRN contaminants in water
- **Event Detection System** for detection of abnormal water quality behaviour
- **Event Management System** to provide decision support
- **Offline and Online Simulators** to determine the contamination's source, the spread and identification of isolation valves

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## SAFEWATER Summary



- Location of contamination?  
- Impact of contamination?  
- Which action?

- Toxicity sensors
- Hydraulic and quality sensors
- Hydraulic stations (tanks, pumps, valves)
- ★ Contamination source

**Step towards a holistic solution for water safety,  
from detection to event management**

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## Thank you!

SAFEWATER Website [www.safewater-project.eu](http://www.safewater-project.eu)

SAFEWATER project movie: <https://youtu.be/Bs5SljKUxgE>

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 312764.



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