Improved safety for drinking water distribution

Adrian Rieder, dipl. Ing. NDS-U, Head of water distribution,

Water Supply Zurich, 8023 Zurich, Switzerland

Management Summary

To guarantee the safety of drinking water is increasingly recognized as an important challenge for municipalities and water utilities. The safety of drinking water can be threatened by natural disasters, accidents or malevolent attacks.
The goal of the project SAFEWATER was to develop a global generic solution for the detection and management of drinking water crises resulting from CBRN-related contaminations.
The monitoring of the water quality in a distribution network is not a simple task. When the project started, online sensors applicable in the field for the detection of microbiological or radiological contaminations were not available. Furthermore, only few sensors for specific detection of individual chemical substances in drinking water were known. Finally, online models to simulate the behavior of water networks and to calculate the spread of contaminants were still under development.
The Water Supply Zurich is interested in more detailed information on its network based on hydraulic models and data of online sensor. Therefore, Zurich Water Supply was involved in the SAFEWATER project as a subcontractor. WVZ's contributions to the project comprised internal practical knowledge, laboratory analytics and the use of the water infrastructure.

The SAFEWATER project

The three-year research collaboration in the project has been funded by the European Commission within the Framework Program FP7-Security. Nine partners from Europe and Israel constituted the research consortium, including the water utilities Hagihon (water supply and sanitation of Jerusalem), Águas do Algarve (AdA, Portugal) and Zurich Water Supply as a subcontractor.

Motivation

The safety of drinking water is compromised by various threats, i.e. by deliberate or accidental contaminations. A real-time detection of these contaminations is essential to reduce their impact on water safety. At the beginning of the project, no practical online sensors neither for microbial detection nor for radiological detection were available. Only a few sensors for the detection of specific chemicals were at hand for the usage in water distribution

network. Moreover, no reliable tools for the real-time detection of events and online simulation were available for the end user.
The aim of the project SAFEWATER was to develop a comprehensive platform to manage the safety of drinking water. Clearly, such a solution has to integrate all elements of the process from the detection of an event compromising water safety to the management of the situation.

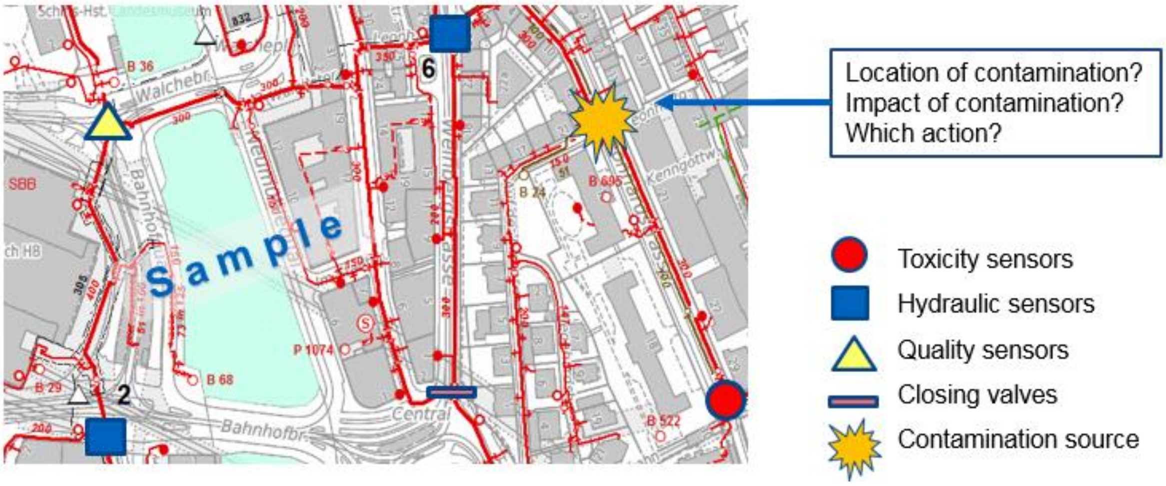

Fig. 1: Princip of a network monitoring. Using different sensors to detect a contamination event, starting actions to manage the event (example).

Figure 2 gives an overview on the structure of the SAFEWATER system. The key element is the Event Management System (EMS), a web-based platform serving as the central point for collecting information and tracking the evolution of an incident as well as supporting decision taking. With the help of another innovative platform, the Event Detection System (EDS), anomalies in water quality are detected, which would otherwise go unnoticed. Such anomalies may indicate a contamination of the drinking water network. In the SAFEWATER system, the hydraulic and water quality state of the network is simulated in “real-time”. In case of an event, the “online look ahaed simulator” predicts the spread of the contamination. Eventually, new CBRN sensors were developed in the SAFEWATER project in order to enable the early detection of contaminants.

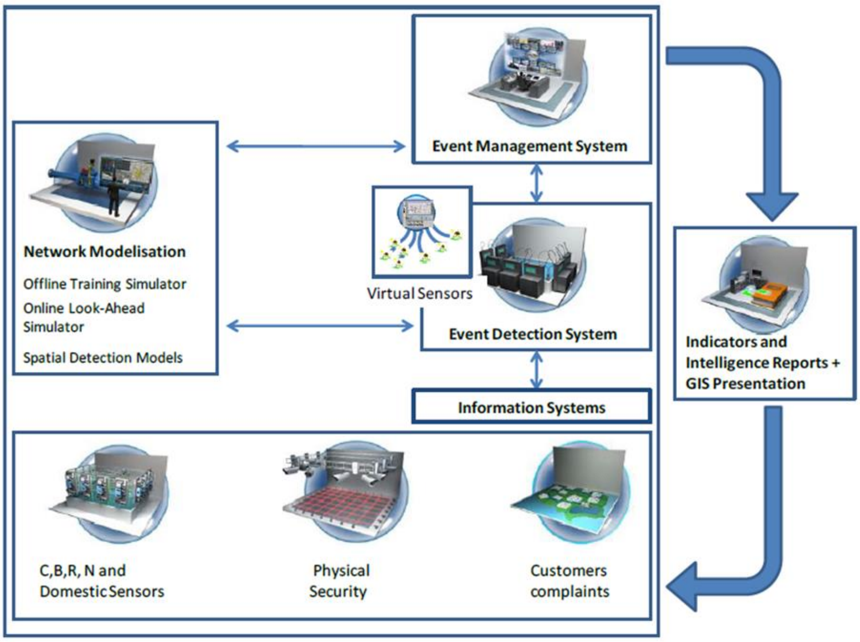

Fig. 2: Concept of the SAFEWATER project. The aim of the project was to develope new sensors and software tools for the online monitoring, quality control and detection of CBRN-related contaminations

The tools developped in the course of the SAFEWATER project were tested in test facilities, where several scenarios, e.g. contamination of a water reservoir, contamination of a water main pipe or contamination in the distribution network, were simulated.Various types of contaminants such as organic compounds, toxic waste and radioactive material were studied. For these investigations, hydraulic test networks were constructed at the three water utilities involved in the project.

Main goals of the project

To summarize, the main goals of the project were:

- to develop an “Event Management System, EMS” for water suppliers
- to develop an improved contamination alert system for the detection of abnormal situations in large drinking water systems
- to develop, implement and integrate offline and online hydraulic simulation model
- to develop new water quality sensors
- to test the system developped at three water utilities in six use cases.

In the following paper, I will mainly present the contributions of Zurich Water Supply as well as some of the experiments carried out.

New CBRN Sensors

During the project, three new sensors were developed reaching a Technology Readiness Level (TRL) of 5 respectively 7. A TRL of 9 indicates a completely revised and tested product.

C**hemical sensor** for virtually continuous detection of chemical contaminants (e.g. pesticides, herbicides, heavy metals; fig. 3): BioMonitech refined its sensor system which is based on luminescent bacteria used as living probes. The sensor was integrated into an autonomous stand-alone system for detection of chemical toxicity in water.

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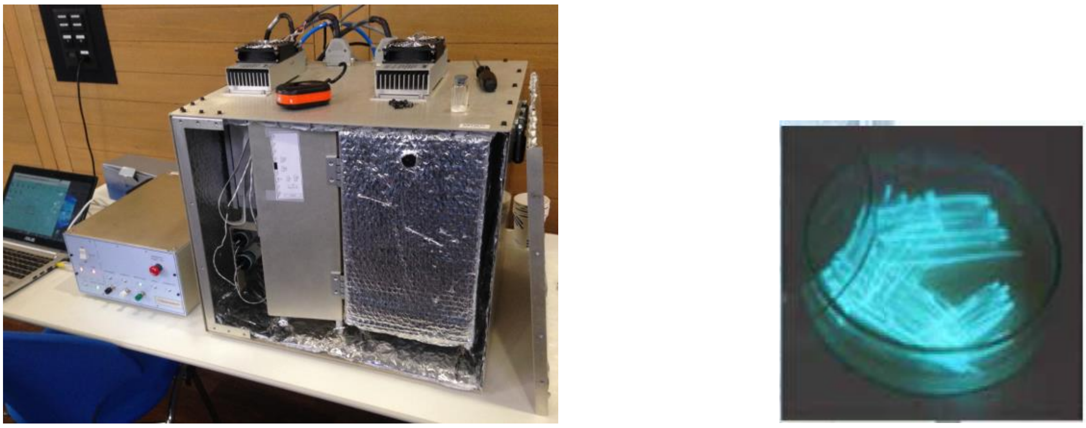
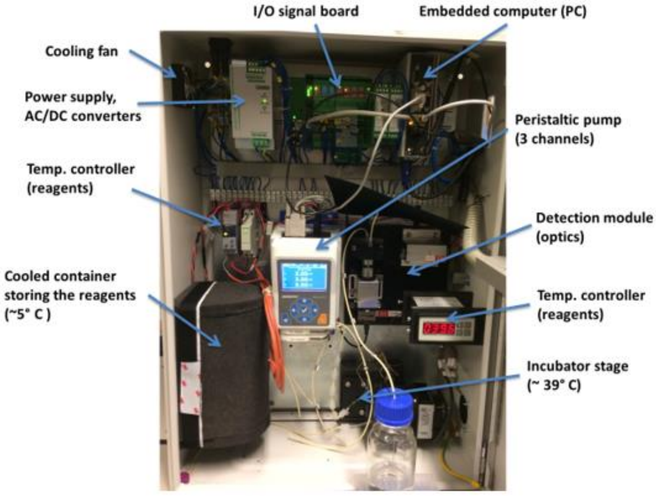


Fig. 3: Chemical toxicity detection by luminescent marine bacteria (BioMonitech, Israel)

B**iological sensor (fig. 4)**: The sensor system has been developed by Acreo. It is an integrated system to detect fecal bacteria such as *E. coli* in drinking water. In a first step, the water sample is first mixed with a fluorescent labelling agent that specifically binds to *E. coli* bacteria. In a second step, the fluorescent bacteria are detected and counted in an optical device (flow cytometer).



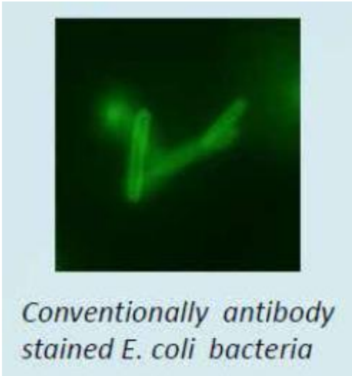


Fig. 4: For the biological sensor Acreo developed a flow cytometer which was integrated into an autonomous unit that can perform measurements at pre-set intervals (ACREO, Sweden).

R**adiological sensor (fig. 5):** CEA refined a radiological sensor for the detection of alpha- and beta-(**α, β**)-radiation in water. The second version of the system was tested in-house at CEA with radioactive alpha-emitting samples. Thereafter it was sent to Hagihon water utilities for integration in the SCADA system and nonradioactive tests.

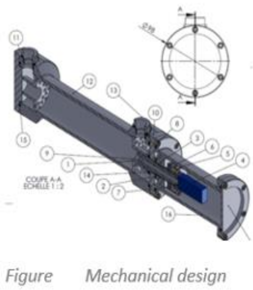


Fig. 5: Radiological sensor (release version B). The integrated system is constituted of the detector part and a box containing the electronic board, Raspberry board and, LCD touch display (CEA, France).

Offline and Online Simulators

The development of simulation models was an important element of the SAFEWATER Project. As a result, several powerful simulation tools that enable decision makers to simulate the dynamic behavior of hydraulic and water quality parameters in distribution networks are now available. These tools can be used either offline (based on historical measurements) or online (based on current sensor measurements and operational data which are provided by a SCADA system). Online response tools support decision makers in case of a contamination event by providing predictions on the spread of a contamination or recommendations concerning the closing of valves.

Test installation at Zurich Water Supply (WVZ)

The WVZ has built a test installation (fig. 6), which is completely separated from the existing SCADA system and the daily operation. The test installation represents a simple hydraulic drinking water distribution network (length 140 m) and contains T-pieces and a pipe crossing section. In addition, it is equipped with various devices for measurement and analytics. At selected points, flow meters (MID) are installed. It is connected to a local SCADA system.They members of the project had access to the local network (VPN-access). Every 10 minutes, measurement data were transmitted to the secured FTPS server hosted by Fraunhofer IOSB. The test installation was designed to answer the following main questions:

- What are the hydraulic mixing conditions in junctions?
- Are the sensors developed in the project able to detect faecal contamination?
- Can the event detection system detect a faecal contamination?
- Can the hydraulic models be validated?

Normally, five *Intellitec* multi parameter sensors are installed in the test network. These sensors can measure up to seven parameters (pressure, conductivity, redox potential, dissolved oxygen, turbidity, temperature and concentration of ammonium and free chlorine). In addition, one S::can spectro::lyser probe and external particle counter were installed in a bypass at the test network. With a dosing pump, salt solutions or diluted waste water could be introduced into the test network to simulate local contamination.

Fig. 6 The test installation at Zürich Water Supply, in the foreground a pipe junction with MID installation, dosing station (Zurich Water Supply)

Outlook

During the SAFEWATER Project, a system has been developed which allows to detect contamination events in a drinking water network in "real time". The self-learning alert system (EDS) can help to reduce the number of false alarms and the EMS supports the management of a water contamination incident. Thereby, the management of events is more reliable and faster. The evaluation of the localization and propagation of the contamination supports the decision makers in their response and management of the event.
As a water operator and partner in a R&D project, we had to show the limits of the different tools. Even with the new sensors at hand, it is not possible to survey a whole distribution network. There are too many unknown factors influencing the water quality. Moreover, the hydraulic models and measurements have to be trusted. Still, it is the only way to represent the real situation found in a network as precisely as possible. This has to be taken into account when the results are analyzed. With an optimal placement of the sensors in the network, a better understanding of the hydraulic processes will be reached prohabilitly. In addition, more research is needed concerning reliability, sensor operation and a safe data transmission.
The test installation was a good opportunity for testing sensors and simulating different water contamination scenarios. The internal laboratory supported us in calibrating the sensors to be tested and in determining their reliability. As a next step, we will continue to installe sensors in the real network of WVZ in order to implement our integrated concept for water safety, i.e. from the detection to the event management.

Adrian Rieder c/o Water Supply Zurich
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