Event Detection in Crisis Management Systems

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Event detection in crisis management systems

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Abstract

The EVENT project concerns drinking water surveillance and includes sensors and algorithms that detect anomalies in the drinking water properties, communication of the evaluated sensor data to a crises management system and presentation of information that is relevant for the end users of the crises management system. We have chosen to focus on a sensor technique based on an "electronic tongue", since this robust type of non-selective sensor, can detect a plurality of anomalies without the need of a specific sensor for each type of event. Measurements of natural variations and contamination events are presented and discussed.

Keywords: Electronic tongue; voltammetry; drinking water; surveillance; crises management; critical infrastructure

1. Introduction

The EVENT project is a national Swedish collaborative project that aims at strengthening and developing existing crisis management systems by incorporating a detector for unexpected events due to biological and chemical substances, leading to faster actions in case of an emergency. The municipal drinking water system is used as a test bed for the development of such an event detector. In the project the whole chain from the sensor to the end user is taken into account. Therefore both *sensors* that detect changes in the water properties, *algorithms* that distinguish between normal variations of the drinking water properties and anomalies, *communication* of the evaluated sensor data to a *crises management system* and *presentation* of information that is relevant for the end users of the crises management system are considered, see Fig. 1. Several technologies can be used for local event (anomaly) detection but in this project we have chosen to focus on a technique based on an "electronic tongue".[1,2] By utilizing this type of non-selective sensor, we will be able to detect a plurality of anomalies without the need of a specific sensor for each type of event. This property combined with the robustness of the voltammetric electronic tongue and the possibility to operate it without the use of a common reference electrode makes it a potential candidate for drinking water surveillance. The normal variations of the drinking water properties include variations of temperature, flow velocity, pH, chlorine compound concentration and turbidity. The anomalies of the drinking water properties can e.g. be due to terrorist attacks, sabotage or accidents. One aim of the project is to supply an early warning to the crises management system, in order to provide a common picture of the current situation to all

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relevant authorities expected to act in an emergency situation. This will facilitate fast initial decisions which can be followed up with careful investigations leading to optimized actions. In order to achieve this goal a project consortium with complementary competences has been formed. It consists of the S-SENCE group (the Swedish Sensor Centre) at Linköping University, the municipality of Linköping, in particular their security group, who serves as an end user, the drinking water supplier Tekniska Verken i Linköping AB, Saab Security, supplier of the crisis management system ISAK and a spin-off company in the chemical sensor field, Adixen Scandinavia AB. The municipality of Linköping and Tekniska Verken also act as important specifiers of technical requirements.

2. Experimental details

The sensor is a so called electronic tongue which is schematically illustrated in Fig. 2. It contains an electrode array of 4 working electrodes and a counter electrode. We have used an electronic tongue supplied by Senset AB that features working electrodes of Rh, PtIr (two identical electrodes) and Ir and a large area counter electrode of stainless steel. The diameter of the working electrodes is 1 mm. The measurement principle is based on pulsed voltammetry where the voltage between the working electrode and the counter electrode is first set to 0 V for a certain time and is then switched to a certain voltage and the corresponding current response is measured. This is repeated for a series of increasing or decreasing voltages in the range -0.4 V to +1.2 V. The size and the shape of the current response depend on the conductivity, the concentration of redox active components, of the diffusion coefficients of the charged components in the water, on the applied voltage and on the working electrode material. Different substances and different concentrations added to the water will give rise to different current responses and can often be distinguished by applying multivariate evaluation techniques. The water temperature has been measured with a Pt-100 temperature sensor in parallel with the electronic tongue measurements.

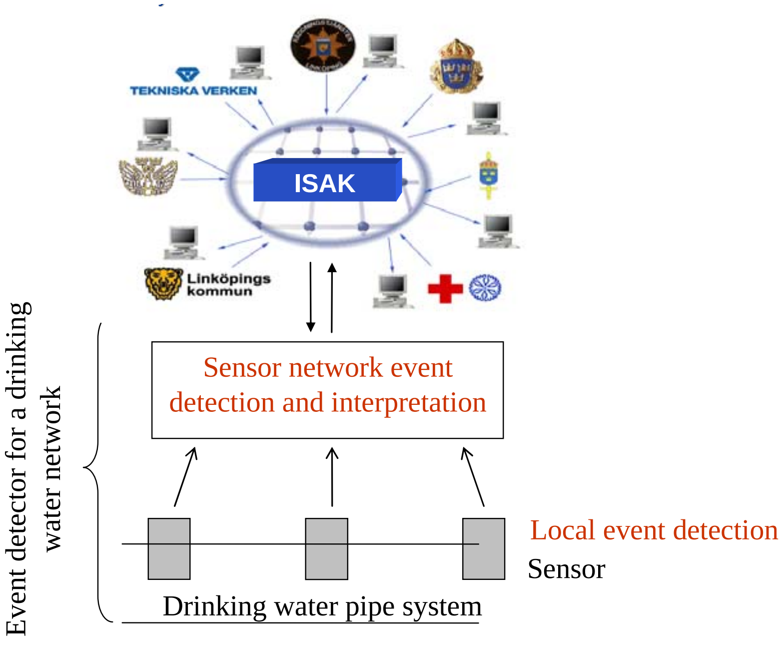

Fig. 1. Schematic view of the EVENT project. Sensors ("electronic tongues") are placed in a small network along a drinking water test system. An algorithm evaluates the sensor data and provides a local event (or anomaly) detection. The local information from all sensors is collected in a network detector where a network algorithm interprets the collective information. From this data the network algorithm provides input to a crises management system, which in turn provides a common picture of the situation to all relevant emergency actors.

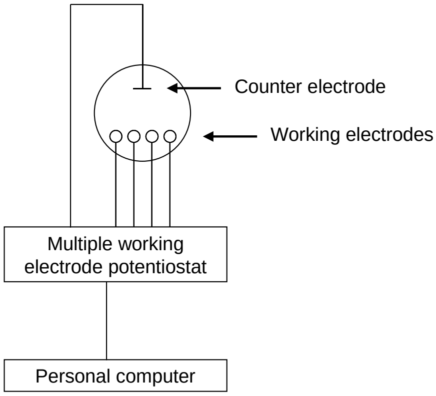

Fig. 2. Schematic illustration of the electronic tongue measurement setup. The sensing probe contains four working electrodes and a counter electrode. A "multiple working electrode potentiostat" and a personal computer are used to supply voltage pulses and to measure the corresponding current transients.

Initial measurements have been performed on the outgoing water at the water plant of Tekniska Verken i Linköping AB, where the natural variations have been followed for several months with the electronic tongue and with reference measurements of temperature, chlorine compound concentration, pH, turbidity and flow velocity. Also lab measurements have been performed where different substances have been added to the water and the response has been measured with the electronic tongue.

Results and discussion

Fig. 3 gives an example of the results obtained so far. The electronic tongue has been exposed to different substances, such as arsenic, cyanide, heavy metals (Cd, Hg), sewage water and diesel, at different concentrations in a laboratory setup. As illustrated in this PCA plot some substances give rise to different directions in the PCA plot and the sewage water response shows a strong variation with concentration.

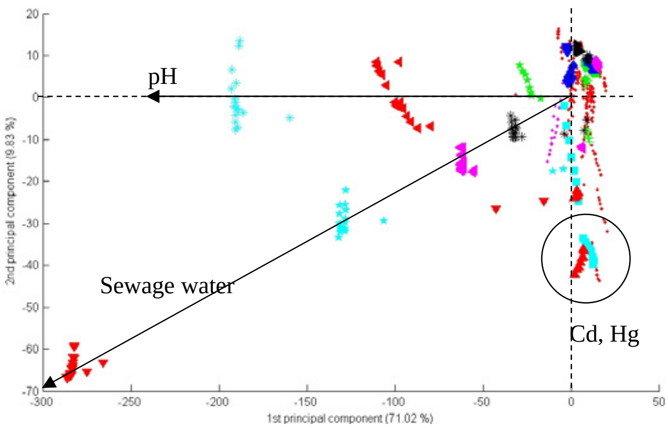

Fig. 3: Data from laboratory measurements showing, in the first two principal components of a PCA plot, that different types of substances in the drinking water may give rise to deviations in different directions of the PCA plot. There are four different concentrations of sewage water along the "sewage water axis" and two different pH values along the "pH axis".

Measurements with natural variations of the water properties have been running for several months and have revealed that temperature variations and flow velocity variations have the strongest impact on the response of the electronic tongue. The natural variations of pH, chlorine compound concentrations and turbidity have been too small to give an appreciable influence on the electronic tongue signals.

The temperature influence on the electronic tongue signals is somewhat intriguing when the measurements are performed close to the water production site. There is typically an oscillation in the temperature and in the electronic tongue signals with a period of 24 h. There is, however, a delay of 3-4 h of the electronic tongue signal compared to the temperature change. A control experiment was therefore performed where the water temperature was intentionally pulsed with an amplitude of about 3 °C with a heating source placed close to the electronic tongue. In this case there was no delay in the electronic tongue signal compared to the temperature variations. Also measurements far from the water production plant indicate no delay. We therefore suspect that there is another (or several other) process(es) occurring in the water filter basins that also has a period of 24 h but with a delay compared to the temperature changes. This could for example be due to bioprocesses in the filter basins that are influenced by the sunlight intensity which of course also varies during the day. This hypothesis agrees with measurements during late fall where the amplitude of the temperature oscillations became very small while significant daily oscillations in the electronic tongue signals could still be observed.

The tests with different substances added to the water, performed in the laboratory measurements mentioned above (Fig. 3), will now be continued at a pilot test site. Here the flow velocities, water pressure and temperature variations are more typical for the situation in the real drinking water distribution system. A small network of sensors will be utilized, algorithms for the single sensors and for the sensor network will be developed and communication with the crises management system will be established. Other working electrode materials than those tested so far will also be investigated. In the algorithm development special attention will be paid to natural variations of temperature and water flow velocity in order to avoid false alarms.

Conclusions

The EVENT project will demonstrate drinking water surveillance in a test version of a distribution system. The whole chain, from a small sensor network in water pipes via anomaly algorithms and a crises management system and finally presentation of the situation to the end users, will be developed in the project. Thus far we have seen that a large number of potential threats to the drinking water can be detected. We have also identified water temperature and water flow velocity as two parameters whose natural variations must be handled without giving rise to false alarms.

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