275201

Multi Sensor Fusion for Real-time Monitoring of Waste Water Quality (Water-Spotcheck)

Publishable Summary

The water industry is one of the major industrial sectors in the EU, threatened by erosion of world markets and slowing growth. Major problems affecting water in urban management comprise increased demand or obsolete distribution networks. Water distribution systems are vulnerable to intentional and inadvertent contamination. Wastewater treatment involves removal of nutrients, such as phosphorous, ammonia and volatile fatty acids before water can be discharged for further use. The measurements of water contaminants are mostly based on off-line monitoring and the current approaches include optical, acoustic, mechanical, electrical and bio sensors. However, they often suffer from low reliability, sensitivity and accuracy, combined with infrequent measurements and high cost, all of which hinder their industrial application. The implementation of The European Water Framework Directive has triggered the need for new methods and systems which enable the monitoring of chemical and biological pollutants in water in real time, on the spot.

Thus, the primary focus of the Water-Spotcheck project was to develop and adapt a number of sensors individually and then fuse them into novel prototype system, which will accurately qualify/quantify various wastewater contaminants in real time. The distinctive feature of the approach is that it deploys the latest achievements in the areas of the microelectronics, biology, sensor technology, physics and materials science.

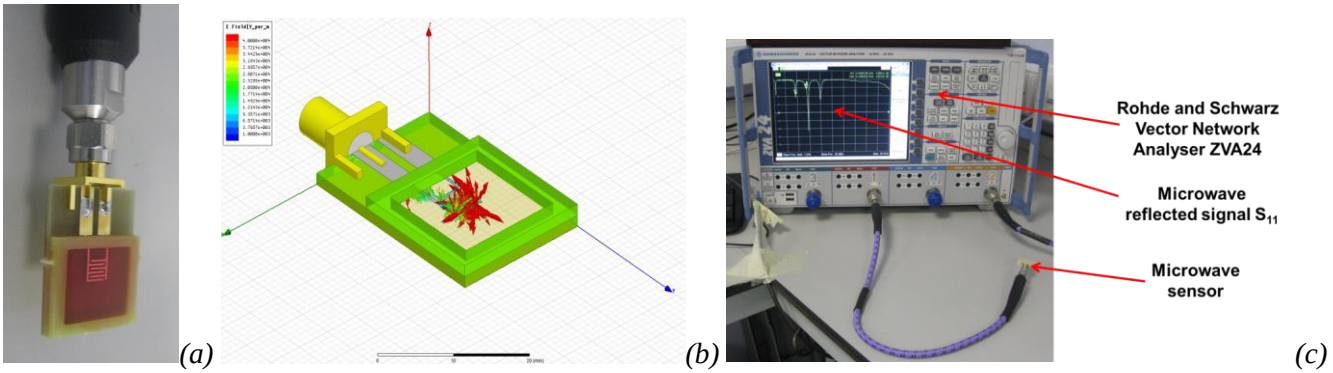
In light of the above, the Water-Spotcheck project, funded by the FP7-PEOPLE-2010-IEF Marie-Curie Action, has pioneered a novel on-line monitoring system with high resolution and repeatability to improve the daily water supply process management. It potentially facilitates the real-time detection of abnormal situations and the implementation of new control strategies. **The success of this project** has already led to further research and development contract negotiation with the waters industries including Untied Utilities (UK), Balfour Beatty (International), Manros (France), CICAP (Spain) and Animalia (Norway).

The success of the project, has led to the **publications of 2 patents, 6 book chapters, 17 scientific journal papers, 22 scientific refereed conference papers and 10 key note speak** in various national and international conferences, workshops and seminars at national and international.

Benefiting from the unique expertise of the host researcher, namely Prof. Ahmed Al-Shamma'a at Liverpool John Moores University in UK, and previous experience of the Marie Curie Fellow, Dr. O. Korostynska, in semiconductor based sensors, the laboratory scale multi sensor fusion prototype system for real-time monitoring of wastewater quality was invented. A comprehensive range of bespoke electromagnetic wave sensors that differ in size, sensing pattern layout and material and in substrate type, including flexible polymer sensors, were designed, manufactured and tested. Known amount of water was placed in direct contact with the printed antenna and the response to microwave signal fed to it was governed by the composition of tested water. Also, for continuous monitoring option, a number of specially designed flow cells with build-in microwave sensors were developed to suit various industries including water, healthcare and oil and gas.

Each sensor provides enhanced sensitivity to a particular water contaminant, and a sensor array option would be a possible choice for the water quality monitoring system with the stringent customer requirements. As an example, Fig. 1 (a) depicts a microwave sensor on FR4 substrate with gold pattern as an antenna. An object under test, i.e. water sample, when placed into vicinity or in direct contact with microwave sensor, interacts with the electromagnetic waves (Fig. 1 (b)) in a unique manner, which can be specifically correlated with the properties of this material. The developed novel electromagnetic wave sensors system prototype (Fig. 1 (c)) operating at various frequencies in 1 kHz - 24 GHz range fosters new and unique form of real time water composition monitoring.

Complete experimental validation of the novel proof-of-concept system was performed on a selected range of possible water pollutants, such as phosphates, nitrates, chlorides, pesticides and bacteria. The choice of tested contaminants types and their concentrations was dictated by the water industry needs and direct requests from the companies' representatives, who potentially would be interested in employing the system in their operational units. To benchmark the performance of the developed prototype system against the standard laboratory based methods of water quality control employed by the water industry, the facilities of local wastewater treatment plant, operated by the United Utilities Ltd, were used. In particular, wastewater from the same well was simultaneously tested using UK industry standard method in the lab and novel microwave sensing method, and the latter one has demonstrated its ability to identify the presence of bromate and bromide compounds at sub microgram concentrations in real time, as opposed to typical 2-weeks results processing time. The outcomes of this interdisciplinary project would serve as a basis for the flexible portable real-time water quality monitoring platform that would potentially improve the safety and quality of water. Prof. Son Le from United Utilities said: "*The developed sensors by LJMU have certainly helped us in determining the quality of water with consistency and high repeatability in real time without the need for the biological and chemical laboratory testing*."



(a) *(b)* *(c)*

Fig. 1. (a) A microwave sensor on FR4 substrate with gold pattern as an antenna, (b) Distribution of the electromagnetic waves from the sensor surface, (c) Sensors system prototype, connected to VNA.

The Water-Spotcheck[1] project has successfully achieved its aims at developing a unique real time monitoring sensing platform for the water industry via the accomplishment of its key objectives. The outcomes of the Water-Spotcheck project were disseminated to the academics, researchers, industries and to the public via meetings, public talks and scientific presentations at international conferences (Fig. 2 (a) and (b)). To date, the project has resulted in publication of 6 book chapters, 17 journal and 21 conference papers, with further 3 journal papers under review and 2 UK patents pending (GB1219016.1 and GB1219929.4) and 2 US patents being filed.

(a) *(b)*

Fig. 2. Dr. O. Korostynska presenting the outcomes of the Water-Spotcheck project at: (a) IOP Sensors and Their Applications (2013) and (b) 6th International Conference on Sensing Technology (2012).

[1] http://www.ljmu.ac.uk/BLT/BEST/RFM/121778.htm