Homeland Security

Chelsea Technologies Group Ltd

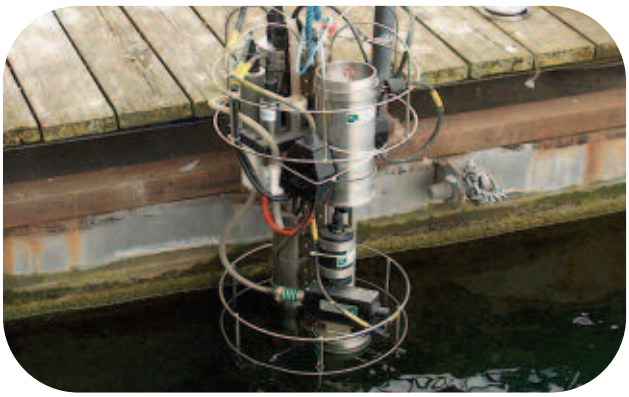
Water Contamination Monitoring

Chelsea Technologies Group (CTG) is working with UK and US Government Departments and Agencies on developing novel sensor systems for environmental monitoring and protection. The systems are specifically designed to measure a wide range of physical, chemical, biological and optical properties. These enable the natural biological and physical background levels in rivers, reservoirs and abstraction points to be characterised.

Understanding the Environment

Water abstraction points are vulnerable to spills from farms or factories, and deliberate contamination through terrorism. Early warning monitoring systems are required to alert operators to these contaminants and to changes in key water quality parameters. A timely response is necessary to prevent contamination and disruption of the public water supply. A long-term baseline of water quality data is required to reduce the occurrence of false alarms and understand typical parameter ranges. CTG is developing systems to observe the natural trends in water quality parameters and rapidly detect anomalies. When a value is outside expected ranges warning signals can be transmitted, increased sampling and testing can be conducted, and the system operation adjusted appropriately.

Portable Instrumentation



Profiling System

Novel Systems for Rapid Contaminant Detection

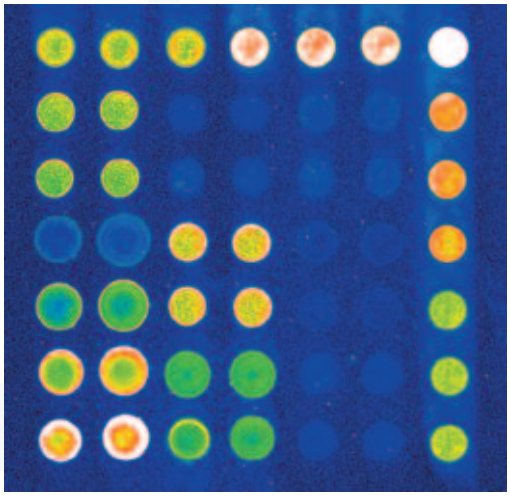
CTG is conducting a development programme to assess the suitability of the Fast Repetition Rate Fluorescence (FRRF) technology for detecting the effects of hostile contaminants. It is a prime candidate for the real-time monitoring of potable water reservoirs. Studies in the USA have found that the ability of water borne algae to photosynthesize, and hence fluoresce, is significantly affected by toxic chemicals. Initial chemicals investigated include methylparathion (an insecticide that is structurally and functionally similar to the nerve gas sarin), potassium cyanide (which can result in nervous system and respiratory failure), diuron and paraquat.

Fast Repetition Rate Fluorescence (FRRF)

The fluorescence signal from algae in chemically polluted water is impaired compared to signals from algae in clean water. In a monitoring situation algorithms determine the rate of change of fluorescence signal that are independent of algae concentration and changes in ambient light levels. The FRRF measures a time dependent fluorescence signal that arises solely from chlorophyll that is active in photosynthesis - a parameter that can be related directly to the physiology of the algae. The FRRF is therefore capable of discriminating between chlorophyll that is free in the water column, present in dead algae and present in physiologically active organisms.

The response time for the FRRF to detect a deliberate contamination event is a matter of seconds. When combined with historic time series, and other water quality parameters the likelihood of a false alarm is minimised and the threat promptly reported and assessed. This makes it ideally suited for deployments at critical points in water distribution systems to detect contamination of water pre- and post-treatment.

On-Site Rapid Diagnostic Screening



Typical microarray image using conventional laser scanner

Background

Microarrays are becoming an increasingly significant format for multi-analyte testing. The technique has found many applications in gene expression studies and is now being adapted for protein applications including immunodiagnostics.

In a typical configuration, an array of immunoreagent 'spots', typically 300µm in diameter, is immobilised on a microscope slide. The assay is performed by introducing a fixed volume of sample to the slide followed by a fluorescently labelled conjugate reagent to reveal the quantity of the target analyte bound to its complimentary immobilised reagent. One of the attractions of the format is that the large number of spots deposited enables internal controls to be run in parallel with the test panel. Thus, any sample factors affecting the fluorescence signal will influence both the test and control spots equally. Further, false positives and/or negative test results can be avoided by providing replicate spots within the array.

Limitations of Current Technology

The widespread commercial exploitation of the technique for routine diagnostics applications has been hampered by the cost of the equipment required to read the fluorescent signals from the arrays. This has arisen because the main driver for the development of the format has been DNA analysis, which typically requires the use of high-density arrays, comprising 10,000 spots or more. This has necessitated the use of sophisticated and thus expensive optical techniques capable of resolving the smaller spots used in these arrays.

New Approach

Over the past few years CTG has been working with Microtest Matrices Ltd, a commercial spin out from the Department of Biology at Imperial College London, one of the world leaders in the immunoassay applications of protein arrays, to develop a cost effective detection technique for this important new format.

Commercial systems currently generate high-resolution images of the microarray, as illustrated opposite. Sophisticated image analysis software is then required to identify the spot positions and integrate the signal from the pixels making up each spot image. CTG has developed an optical system that fully illuminates a single spot in the array and collects its fluorescence emission to produce an integrated signal value from the spot. This significantly reduces the amount of data generated and the processing power required for analysis. Feasibility studies have demonstrated that it is possible to achieve better performance with this approach than is currently possible using a commercial scanning system and at a fraction of the cost.

Portable Microarray System For CBRN Countermeasure Applications

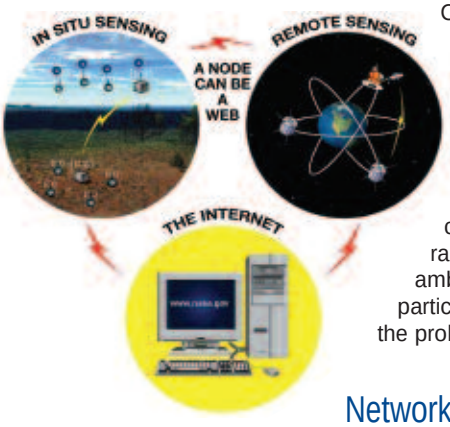
Following on from the work described above, CTG is now leading a consortium developing a flexible, robust and portable microarray platform for the detection of micro-organisms. The proposed platform is designed to be rapidly deployed in the event of unexplained clusters of acute febrile illness or fatality, to screen for the presence of a comprehensive panel of micro-organisms that might be associated with a deliberate terrorist attack, allowing these to be ruled out as a potential threat early in any investigation. The microarray format is readily adapted to other applications, including the detection of potentially harmful chemicals in water supplies.

On-site diagnostics screening

Operational Monitoring Systems

Recent terrorist attacks have lead to an increased emphasis on Homeland Security and the protection of key infrastructure. Unintentional pollution events have already resulted in increased monitoring and the establishment of many of the measures necessary to safeguard our water supply. An early-warning monitoring network can help to ensure abstraction point and water storage protection.

The sensors must perform reliably when unattended for extended periods of time, typically many months. Any contamination events must be detected promptly and information passed efficiently to the monitoring station that may be many miles away. Incorrect reporting of events, and false positives, are unacceptable.



CTG is addressing the new challenges of the Homeland Security threat with our proven capability in sensors and system design for operations in hostile environments. As the design authority for the UK Sonar 2081 and Sonar 2115 oceanographic systems, we understand the demands of operational systems and provide sensors with significantly extended calibration intervals, built in test circuitry and redundancy. Our sensors operate in a range of environments from clear waters with high ambient daylight to extremely turbid conditions. CTG has participated in several European programmes addressing the problem of biofouling on long-term systems.

Networked Systems for Threat Detection

The infrastructure system for abstraction and distribution of potable waters is spread over wide geographical areas. Any monitoring system will consist of a number of distributed sensors integrated into a robust network. Accurate data should be passed in real-time and enable a rapid determination of position and spread of any contamination event.

CTG is working with SensorWare Systems Inc to fuse their respective technologies into an innovative system to protect water supplies. SensorWare Systems will provide the Sensor Web, a new class of Geographical Information System originally developed at NASA. The Sensor Web is a collection of sensor platforms, or pods, that wirelessly communicate with each other. It provides a dynamic infrastructure for sensors for embedded monitoring and control and will enable a powerful in-field synthesis of data collected by the CTG sensors over large spatial areas.

Unlike configurations where information from all pods is passed directly to a central collection point, information in the Sensor Web is spread throughout the system by wirelessly hopping the data pod-to-pod so that each pod knows what is going on at every other pod. This architecture allows the Sensor Web to interpret and react to the entire environment as a collective whole, providing for identification of false positives or plume shapes and directions. This new class of instrument will transform the way we explore, monitor, and control environments and will impact many fields including homeland security as well as agriculture and remediation.

In view of our continual improvement, the designs and specifications of our products may vary from those described.

Photographs courtesy of SensorWare Systems Inc

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