RAPID MICROBIOLOGY FIELD INSTRUMENTATION: SOURCE TRACKING IN SENSITIVE AREAS

The UK Environment Agency is pioneering the use of the latest E.coli field quantification technology for pollution monitoring and source identification in sensitive areas.

By Matthew Loewenthal, Andrew D. Newton (Environment Agency, National Laboratory Service); Steve Wright, Claire Campbell (Environment Agency, Yorkshire); Andy Crossley (Scarborough Borough Council); Andreas Hausot, Dan E. Angelescu (Fluidion SAS)

Surface water quality has a direct impact on the safety of water supply for drinking, agriculture and aquaculture applications, and also to ensure the safety of recreational water users. At sensitive areas such as drinking water catchments, bathing and aquaculture sites, in addition to standard water quality parameters (temperature, turbidity, conductivity, pH, dissolved oxygen and nutrient concentrations), frequent monitoring of faecal indicator bacteria (FIB: Escherichia Coli and/or enterococci) is also required. FIB can be naturally present in waterways through presence of birds and other warm-blooded animals, but most commonly large contaminations can be traced down to contaminated effluent from wastewater plants, to untreated sewage infiltrating from failing infrastructure or poor sewage connections, to agricultural run-off in rural areas, and, in certain cases, to sewage from boating activities.During heavy rain episodes faecal contamination can be greatly amplified by sewer and sanitary overflow phenomena. Through high-resolution time series monitoring of FIB it is possible to provide an early warning in the case of contamination events, or to map out the bacterial concentration distribution to identify its sources.

Traditionally, FIB concentrations have been measured using spot sampling and culture-based laboratory techniques, such as membrane filtration (MF) and plating, or most-probable-number (MPN) techniques, which both involve significant logistics and manpower: manual spot sampling, rapid transportation to a lab in refrigerated conditions, running the measurement protocol, and reporting results. These constraints result in remote locations being very difficult and costly to monitor. Furthermore, results are generally only available 24 to 72 hours after the moment of sampling, often too late to enable effective preventive or curative actions.

[**Figure 1**: Environment Agency agent Karen Irwin using a Fluidion ALERT LAB for E.coli field measurements.]

A number of rapid measurement techniques and instruments have been developed in recent years for quantifying bacteria online[1], ranging from simple fluorescence measurements, to enzymatic activity assays, to complex DNA or RNA-based techniques. Many of the reported instruments are unfortunately poorly adapted to fieldwork, being either too complex, too fragile, or having specific infrastructure requirements (power, communication, weather protection). More importantly, they are often not sufficiently specific to viable and culturable target organisms, which are the focus of water quality regulations. Very recently, a new generation of ultra-portable instruments has become available from French instrument manufacturer Fluidion. The Fluidion ALERT analysers implement a novel quantification method based on real-time defined substrate technology, which is highly specific to viable and culturable E.coli bacteria and can be applied to both fresh water and seawater samples to provide full quantification results in less than 12 hours. The method has been thoroughly validated scientifically, with results showing good accuracy and excellent correlation (r=0.90) against laboratory MPN measurements over multiple orders of magnitude in concentration[2,3]. More importantly, the ALERT analysers are highly adapted to field use through rugged waterproof construction, fully autonomous battery operation, remote configuration and data transmission capability. Data are transmitted in real time to Fluidion's secure web-based platform, allowing visualisation, reporting, archival and automatic alert generation.

[**Figure 2**: Environment Agency water quality monitor deployed at Scarborough Harbour. The Fluidion ALERT System is visible at the bottom right.]

The analysers are available in portable version (ALERT LAB – a shoe-box size instrument, with capability to measure up to six samples concurrently) or in situ version (ALERT System – integrating vacuum sampling and capability to perform 7 analyses). The UK Environment Agency performed a thorough evaluation of Fluidion's ALERT technology over several months in 2017. Following successful trials, multiple systems (both portable and in situ units) have been operationally deployed since early 2018 to equip fixed monitoring stations, or be used at various remote locations which were prone to contamination.

A good example of using such instruments in the field comes from the Scarborough area. Scarborough South Bay Bathing Water was classified as having poor water quality in both 2016 and 2017. The Environment Agency carried out a large monitoring program within South and North Bay during 2016, which identified a number of possible sources of FIB including sea birds, dogs, sewage and industrial effluent. However, traditional spot-sampling monitoring

programs proved limited in both spatial and temporal resolution, and often did not provide enough evidence to determine precise sources of contamination. The availability of the new ALERT System and ALERT LAB instruments enabled the Environment Agency to develop a complete monitoring platform combining high-resolution real-time water quality with fast FIB concentration results. It comprises of a lightweight transportable aluminium kiosk housing a peristaltic pump delivery system and flow-through cell. Hourly measurements of conductivity, dissolved oxygen, ammonium and turbidity are made by a YSI EXO multi parameter sonde fitted within the flow-through cell. The Fluidion ALERT System is mounted directly above the cell, and FIB measurements are triggered as needed. Real-time data from the sonde were fed to the Agencies' web-based viewer. Communication with the Fluidion ALERT devices was performed wirelessly using the GSM network, with all data transmitted for viewing in real-time on the Fluidion web-based platform.

The monitor was initially deployed at Scarborough Harbour to investigate potential sources of contamination with respect to rainfall, tidal cycle and working practices. The results confirmed that the harbour was not a contributor to bathing water failures and by process of elimination allowed the Agency to quickly focus its investigation elsewhere. The unit was subsequently deployed at a freshwater location near North Bay called Scalby Beck. The river drains an agricultural area, so deployment at this site had significant interest, with the primary purpose being to investigate the relationship between ammoniacal nitrogen and FIB concentrations. Previous investigations had been inconclusive at this site, with low reported values of ammoniacal nitrogen and high FIB counts. In addition, there was also some evidence suggesting that on high tides organic pollutants were entering this freshwater watercourse, most probably from the sea. The monitor was deployed into Scalby Beck in such a position as to allow monitoring of both fresh and seawater depending on tidal cycle. Data from the site confirmed that no FIB contamination was in evidence in the freshwater phase at the site, and indeed water quality with respect to the physical and chemical parameters was also good. However, measurements from the real-time monitor combined with additional FIB concentration data acquired using the portable Fluidion ALERT LAB did indicate significant water quality issues in the seawater phases at certain points within the bay. On-going investigations are taking place to further narrow down the pollution source.

The operational deployment of a combination of ALERT System and ALERT LAB instruments at this and other sites has allowed the Environment Agency to clearly identify locations where sources of FIB resulted in water quality problems, and to better focus recourses on those areas. The results demonstrate that Fluidion ALERT technology can provide rapid and reliable bacterial measurements in operational field conditions, greatly improving contamination source tracking in sensitive areas and enabling improved protection for all water users.

References

1. Lopez-Roldan, R. et al. (2013) On-line bacteriological detection in water. Trends Analyt. Chem. 44, 46–57.
2. Angelescu, D.E. et al. (2018) Autonomous system for rapid field quantification of E. coli in surface waters, J. Appl. Microbiol. doi: 10.1111/jam.14066.
3. Huynh, V. et al. (2016) An autonomous field sensor for Total Coliform and E. coli monitoring at remote sites.IEEE Oceans Conference Proceedings.

[**Figure 3:** Map of monitoring locations around Scarborough that are described in the article]