IS COASTAL MONITORING JUST A DROP IN THE OCEAN?

As the old adage goes 'you can only control what you understand', so how well do we understand the pressures and impacts we have on the coastal zone? How do we monitor and regulate the waters immediately adjacent to the coast, particularly in Europe? And what developments are on the horizon in terms of monitoring and better understanding the coastal zone?

Pressures and issues affecting the coastal zone include nutrient run-off from agriculture, wastewater discharges from wastewater treatment plant and combined sewer overflows (CSOs), animal waste, and harmful organisms such as toxic phytoplankton and jellyfish. Some of these are interlinked as nutrient pollution may lead to algal (phytoplankton) blooms, and jellyfish consume phytoplankton. Certain species of phytoplankton produce biotoxins (which cause food poisoning) and are therefore problematic to the shellfish industry. Jellyfish can cause damage to fish gills and also lead to an inferior product for sale; as well as posing a problem for bathing waters. Coastal monitoring is therefore needed for purposes as diverse as aquaculture, recreation, coastal engineering, ports and harbours, the water industry, research and academia.

In terms of bathing water quality at least, standards have generally improved across Europe since the introduction of the Bathing Water Directive in 1976. In 2014, 95% of bathing waters met the minimum standards for bathing and of those 83% met the more stringent standards of 'excellent' according to the European Environment Agency. Other legislation playing a part in controlling pollution from harmful substances and organisms and improving coastal water quality includes the Shellfish Directive, Marine Strategy Framework Directive, the Urban Wastewater

Key aspects of EC legislation in the coastal zone

Bathing Water Directive (BWD) (76/160/EEC) has been replaced by (2006/7/EC):
- Focuses on E.coli and Intestinal Enterococci now;
- 4-year assessment cycle;
- lower thresholds set to prevent disease outbreaks.

Marine Strategy Framework Directive (MSFD) (2008/56/EC)
- Aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020;
- Aims to protect the resource base upon which marine-related economic and social activities depend;
- Applies an ecosystem approach to the management of human activities impacting on the marine environment, integrating the concepts of environmental protection and sustainable use;
- 6 yearly reviews.

Shellfish Directive (SD) (79/923/EEC) has been replaced by (2006/113/EC):
- Monitoring and reporting of water quality where shellfish for human consumption are being farmed;
- Shellfish waters are selected by each country;
- Limit values must be met for certain parameters e.g. pesticides, metals.

Urban Wastewater Treatment Directive (UWWTD) (98/15/EC) – replacing (91/271/EEC)
- Control of discharges from wastewater treatment plant into nutrient and biologically sensitive areas;
- Collection and treatment of waste water for all settlements of more than 2,000 population equivalent (which relates to the biodegradable load of the wastewater);
- Requirement for secondary treatment of wastewater from agglomerations of more than 2,000 population equivalent;
- Phasing out and control of harmful substances, for example heavy metals;
- Monitoring and reporting.

Water Framework Directive (WFD) (2000/60/EC)
- Applies an ecosystem approach to managing water quality, and integrating the above EC water policy legislation;
- Aimed to achieve Good Ecological Status of all water bodies by 2015 but some exceptions and extensions were allowed;
- Covers biological, chemical and hydro-morphological status of waters;
- Waters include rivers, lakes, groundwater and coastal water (up to one mile from the shoreline);
- Requires the reduction and elimination of harmful substance from the aquatic environment;
- 6 yearly cycle of monitoring, reporting, management plans.

Treatment Directive and the Water Framework Directive (see box).

Although bathing water quality is fairly good across Europe, ongoing monitoring is of course required to check for one-off pollution events and longer term trends. The public must be warned if bathing water quality is temporarily not fit for swimming due to the presence of faecal bacteria for example. Regulatory agencies need to identify sources of pollution and monitor pollution. Coastal planners also make use of monitoring data. Monitoring means that measures can be taken to control pollution in order that long term targets for water quality can be met for the various legislation in place. So which methods and technologies are currently used for monitoring coastal waters and what is on the horizon for new technology?

Water quality parameters can be monitored using various sensors. Nitrate can be monitored using a sensor which utilises an inbuilt fluorimeter to detect peaks in absorption due to nitrate (e.g. the Sea-Bird Coastal SUNA/ISUS Nitrate Sensor). Phosphate is more difficult to monitor, but methods do exist such as the Cycle-P in-situ phosphate sensor. This phosphate sensor again uses a fluorimeter, this time using a wet chemistry reaction. If phosphate is present a 'heteropoly molybdenum blue complex' is formed by mixing reagents with the water sample and this complex will affect absorption which can be measured (e.g. the Sea-Bird Coastal Cycle-P sensor). The reagents must of course be replenished regularly. Optical sensors can also be used to measure parameters such as chlorophyll, free dissolved organic matter (FDOM), turbidity and blue-green algae (e.g. the Sea-Bird Coastal ECO sensor). A separate sensor such as the Sea-Bird Coastal Water Quality Monitor (WQM) can monitor salinity, temperature, dissolved oxygen and pressure. Such sensors will need to be serviced every six to twelve weeks to check for and remove any fouling and calibrate the sensors to ensure the readings are accurate and reliable. A suite of sensors can be mounted in a multiparameter 'sonde' (or multiple sondes) and

TechWorks Marine buoy, deployed in Smart Bay, Galway, Ireland

fixed to a buoy in order to measure a range of parameters simultaneously at a reliable depth in the coastal zone. Data can even be transmitted in real time if telemetry is incorporated into the design (e.g. the TechWorks Marine buoys deployed in Smart Bay, Galway, Ireland – see image).

Hourly measurements of nitrate and phosphate fluctuations can be taken by a multiparameter sonde, and by applying the Redfield ratio (C:N:P in a ratio of 106:16:1), algal blooms can be predicted. Hach undertook a 3 year study (2009-2012) in Yaquina Bay (Oregon, US); a river estuary affected by seasonal upwellings of nutrients which result in algal blooms. By applying the above method, algal blooms were successfully predicted. Hach found that nitrate was exported from the catchment into the estuary particularly during wet winters. However the levels of nitrate exported into the bay varied greatly and corresponded with the length of time between

Phytoplankton bloom © Joe Silke, Marine Institute

Sample of a bivalve mollusc being taken © Joe Silke, Marine Institute

storms (and presumably the nutrients which had built up on land between rainfall events).

Currently, methods for monitoring toxic and harmful phytoplankton are largely limited to laboratory testing (high performance liquid chromatography, immunoassays, functional assays etc) which take 1 or more days.

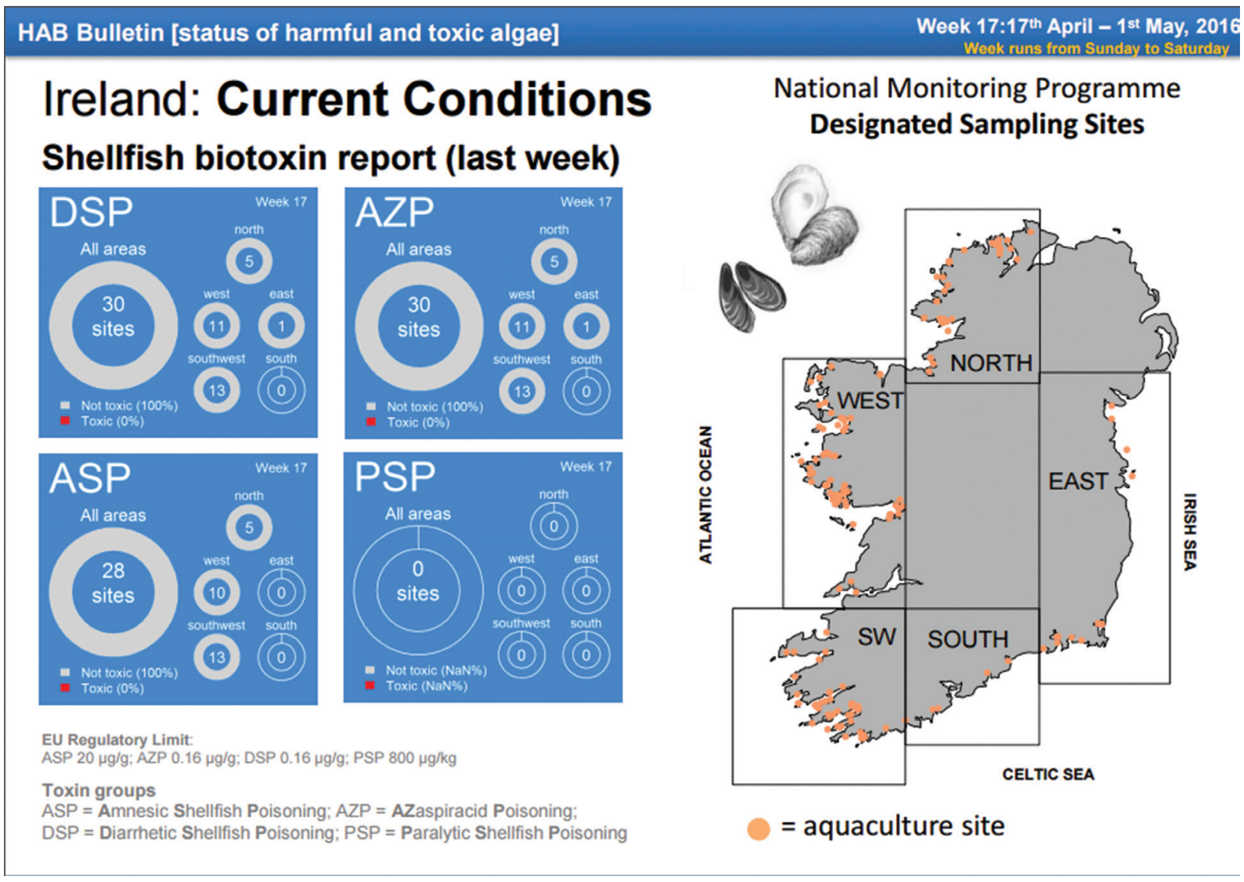
Such phytoplankton must be monitored (as prescribed in the EC Shellfish Directive) because these plankton produce

present but they are currently too expensive at around $500,000. Micro arrays coupled with microfluidic platforms are another technology under development which can detect the presence of multiple species of phytoplankton concurrently.

The ATALANTA (autonomous analytical algal toxin) lab on a disc platform which is being developed at Dublin City University is one such platform which shows great potential for detecting phytoplankton. A fluorescent labelled antibody is added to the water sample, before running a reverse assay 6 times in a circular array, applying a centrifugal force (by spinning the disc) to create radial fluid flow, and measuring the fluorescence in the final chambers using a low cost LED laser and photodiode to detect the presence of the molecule in question e.g. microcystein compared with a control.

ATALANTA has been used to successfully detect the cyanobacteria which produces microcystin. Currently the limit of detection (8 ng ml-1) is less sensitive than other laboratory methods (1 ng ml-1), but some of the advantages of ATALANTA over laboratory methods are that it is portable and could be used out in the field (in situ), it is easy to use and cost effective - it is said to be 'the first step towards a fully autonomous in situ toxin detection system'.

There is a desire for faster, real-time measurement of toxic species by the regulators:



HAB (Hazardous Algal Bloom) Bulletin © Marine Institute

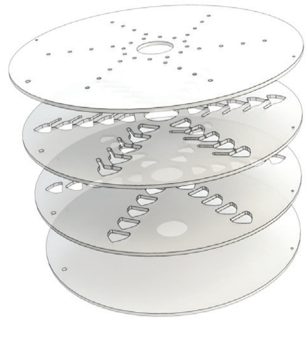
biotoxins in live bivalve molluscs which can cause food poisoning in humans amongst other effects. A toxic event will have economic consequences to the local shellfish industry which must be closed temporarily. The Marine Institute in Ireland for example produce a weekly HAB (Harmful Algal Bloom) Bulletin to provide a forecast for the shellfish industry.

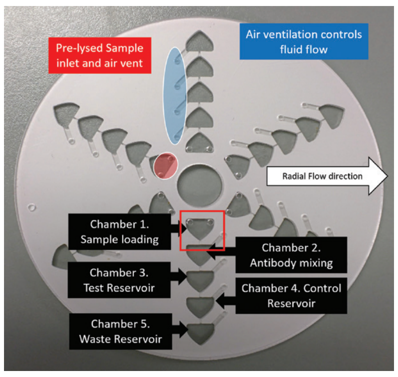
Even a small presence of toxic phytoplankton represents a real threat to human health. At such low levels only very sensitive technology could be used to replace laboratory testing. DNA sensors could be used to analyse the species of phytoplankton

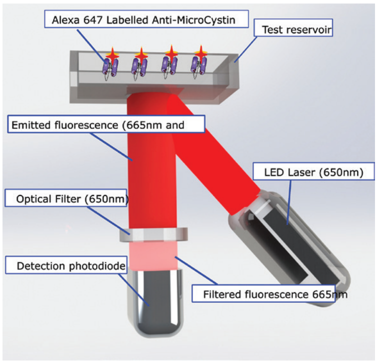
"Our current forecasting of the location and likelihood of harmful algal blooms and biotoxins 1-2 weeks ahead is adequate. However, forecasting would be better if offshore autonomous real-time measurement of toxic species were possible."

Explained Joe Silke, Section Manager of Shellfish Safety Programmes, Marine Institute.

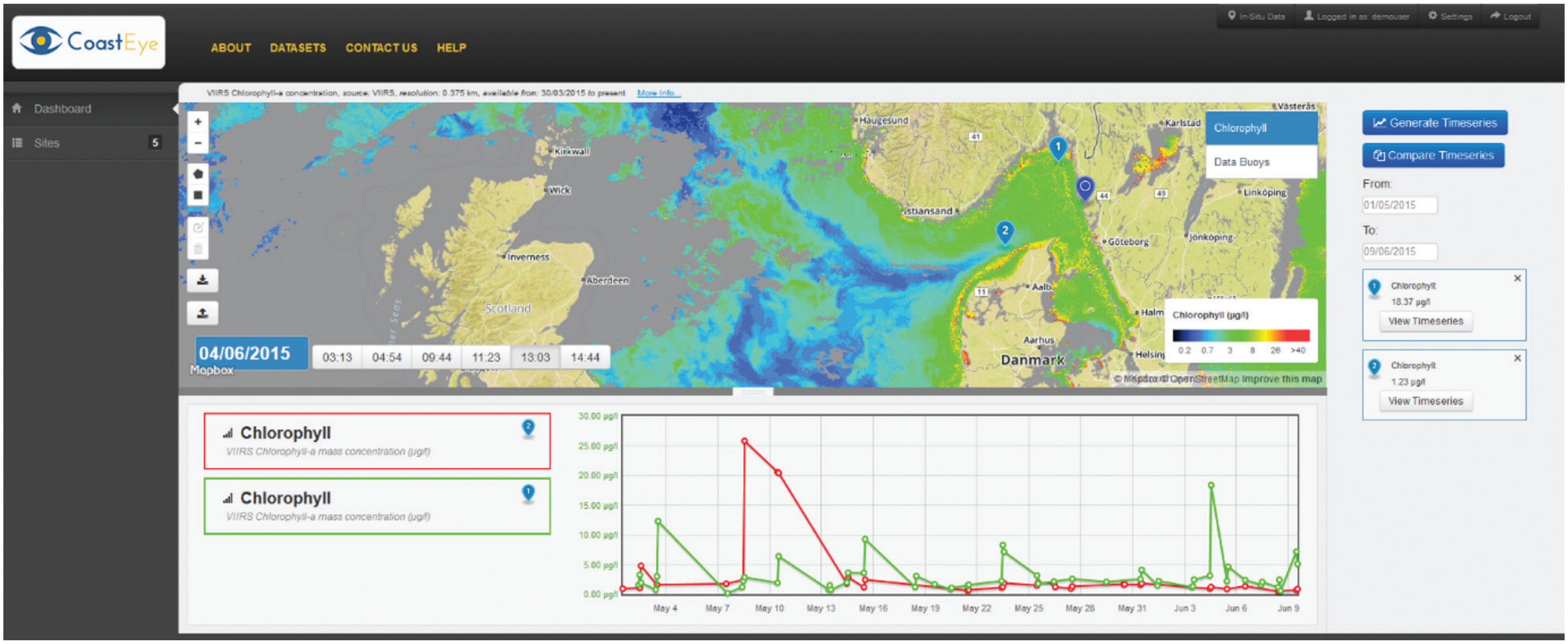
"So far this has not been feasible due to technical and cost considerations. Personally I believe that microarrays capable of detecting many species simultaneously coupled with cheap microfluidic platforms could provide promising cost







ATALANTA lab on a disc platform © Dublin City University, MARIA BOX FP7 Project



CoastEye Data Portal screen shot © TechWorks Marine

effective technology for the future. These could potentially be incorporated into passive monitoring equipment floating around in the sea - for low maintenance monitoring."

High level water quality parameters parameters can already be monitored in real time using recent advances in technology. Earth Observation (EO) (satellite image technology) can be used to monitor parameters such as chlorophyll, turbidity and total suspended matter. EO data can be combined with and validated by real time monitoring in the sea and with local knowledge to reliably predict water quality issues. TechWorks Marine have developed an online data portal for modelling and visualising this data in real time which can be used for a variety of coastal planning purposes [see image]. For example, TechWorks worked closely with Marine Harvest Ireland at Inver, Co Donegal to help them forecast the direction algal blooms will travel in (by using data on surface water currents) and temperature changes in seawater, both of which impact upon salmon fisheries. The same software can be used to find the best sites for monitoring water quality and aid in locating the most minimal impact site for a new wastewater outfall into the sea as it can take account of topography and currents (eddies) and turbidity more accurately than older, cruder modelling methods. The portal is also being used in predicting turbidity plumes for dredging licences. The portal could be used in future to incorporate data from other technologies under development to monitor the presence of zooplankton (small jellyfish) or toxic phytoplankton for example, once the sensors are cost effective, to improve forecasting capabilities for the salmon fisheries and shellfish industries for example.

What with winds, waves and currents to contend with (not to mention saltwater and biofouling), the coastal zone can be an extremely challenging environment to monitor. This article has been a whistle stop tour of the current monitoring technologies deployed in this environment and a couple of exciting new technologies for the future. Current understanding of coastal water quality is usually sufficient for the purposes set out, but there is room for improvement. Incorporation of new datasets (e.g. from sensors detecting harmful algae) into real-time modelling software will be possible using data portals which already exist. In future there might be a choice and a trade-off between cost and sensitivity; either deploying a few expensive sonde platforms on buoys, or numerous low cost but less sensitive optical environmental sensors (using LED technology) which are currently under development - these could be deployed more extensively to cover a greater spatial area. Or more likely both of these extremes may be used for different purposes – the latter as a simple present/absent detection of whether there is a problem and the former to investigate the problem more thoroughly.

Different end users will have specific requirements that may be worth bearing in mind for developers of new sensor technology. I will end this article with some food for thought from the Marine Institute which undertakes monitoring for regulatory purposes in Ireland; and some useful resources:

"When making a decision on purchasing new monitoring technology environmental laboratories are looking for instrumentation that provides solid, reliable data that is reproducible, precise, robust, free from the effects of fouling and that is complementary to results of their current methodologies.

In the case of monitoring or research programmes, we need to have demonstrated confidence in the measured monitoring data, particularly where very low levels of detection may be required. As a starting point, sensor manufacturers who can demonstrate such comparability of results to conventional techniques, but in real time monitoring setting would clearly be at an advantage to other technologies."

Dr Brendan McHugh, Marine Environmental Chemist, Marine Institute

A good starting point for technology developers to meet these requirements and for end users to obtain assurance of performance would be to consider the UK Environment Agency Monitoring Certification Scheme and/or the European Environmental Technology Verification (ETV) Scheme (see 'Resources' below).

Resources

MCERTS guidance to approve instrumentation for monitoring water in particular:

MCERTS: performance standard for organisations undertaking sampling and chemical testing of water

MCERTS: performance standards and test procedures for continuous water monitoring equipment - part 1 automatic sampling equipment

MCERTS: performance standards and test procedures for continuous water monitoring equipment - part 2 on-line monitors

MCERTS: Performance standards and test procedures for portable water monitoring equipment

https://www.gov.uk/government/collections/monitoring-emissions-to-air-land-and-water-mcerts#water-monitoring

For more info about the European ETV Scheme: http://iet.jrc.ec.europa.eu/etv/about-etv

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