THE EVOLUTION OF MONITORING UNDER THE EUROPEAN WATER FRAMEWORK DIRECTIVE

The European Water Framework Directive (WFD) has driven a wide variety of environmental improvements over the last 20 years, but by its own measures it has failed to meet ambitious targets.

In its report on the state of EU water, the European Environment Agency (EEA) said that the main aim of EU water policy is to ensure that a sufficient quantity of good quality water is available for people's needs and for the environment. However, the report showed just 70% of groundwater with good chemical status, and for surface water only 40% of water bodies had good ecological status. So, this article will examine the Directive and highlight the vital role of monitoring.

In December 2019, the EU conducted a 'Fitness Check' of the WFD, the Environmental Quality Standards Directive (EQSD), the Groundwater Directive (GWD) and the Floods Directive (FD). Despite the shortcomings mentioned above, this assessment concluded that the Directives were largely fit for purpose. Factors that have contributed to the effectiveness of the Directives in "progressing towards their objectives" were listed as follows:

- the list of priority substances
- the (binding) cross-references to the WFD's objectives in other EU policies
- EU funding
- the widely applicable non-deterioration principle
- the Directives' monitoring requirements

The Water Framework Directive 2000/60/EC

The WFD was published in December 2000 in the Official Journal of the European Communities and thereby entered into force; establishing a framework for the assessment, management, protection and improvement of the quality of water resources across the EU. The overall objective of the WFD was to achieve good water status for all waters by 2015, and that there should be no deterioration of water bodies. It also set longer term deadlines (2021 and 2027) through two further implementation cycles, as well as mechanisms for derogations and exemptions.

The WFD established what has become known as the 'one out all out' rule, under which rivers fail to meet the required status if they fail on any of the four WFD categories for achieving good water status:

1. Biological (phytoplankton, macroalgae, fish, invertebrates, etc.)
2. Physical-chemical (temperature, pH, dissolved oxygen, ammonia, etc.)
3. Chemical (concentrations of pollutants such as arsenic and iron)
4. Hydromorphological

The Directive establishes a framework for the protection of all waters (including inland surface waters, transitional waters, coastal waters and groundwater) which:

- Prevents further deterioration of, protects and enhances the status of water resources
- Promotes sustainable water use based on long-term protection of water resources
- Aims at enhancing protection and improvement of the aquatic environment through specific measures relating to discharges, emissions and priority substances
- Ensures the progressive reduction of pollution of groundwater and prevents its further pollution
- Contributes to mitigating the effects of floods and droughts.

EU Member States publish river basin management plans (RBMPs) for achieving the environmental objectives of the WFD. One might assume that a comparison of data from different Member States would provide useful insights for future initiatives. However, the EEA website advises: "Caution is advised when comparing Member States and when comparing the first and second RBMPs, as the results are affected by the methods Member States have used to collect data and often cannot be compared directly."

The EEA's 2018 report showed that the quantity and quality of the available evidence on status and pressures has grown significantly. Many Member States and river basin districts (RBDs) have invested in new or better ecological and chemical monitoring programmes, with a greater number of monitoring sites and the inclusion of more chemical parameters and quality elements. In Europe, surface waters and groundwater have been monitored at more than 130,000 monitoring sites over the past six years.

The key findings of the 2018 report were as follows:

- Groundwaters generally have the best status. Nitrates are the main pollutant, affecting over 18% of the area of groundwater bodies. In total, 160 pollutants resulted in failure to achieve good chemical status. Most of these were reported in only a few Member States, and only 15 pollutants were reported by five or more Member States.
- Around 40% of surface waters are in good ecological status or potential, and only 38% are in good chemical status.
- In most Member States, a few priority substances account for poor chemical status, the most common being mercury. Improvements for individual substances show that Member States are making progress in tackling the sources of contamination.
- Overall, the second RBMPs show limited change in status. The proportion of water bodies with unknown status has decreased and confidence in status assessment has grown.
- Improvements are usually visible at the level of individual quality elements or pollutants but often do not translate into improved status overall.
- The main significant pressures on surface water bodies are hydromorphological pressures (40%), diffuse sources (38%), particularly from agriculture, and atmospheric deposition (38%), particularly of mercury, followed by point sources (18%) and water abstraction (7%).
- Member States have made marked efforts to improve water quality or reduce pressure on hydromorphology. Some of the measures have had an immediate effect; others will result in improvements in the longer term.
- It can be expected that, by the time the third RBMPs are drafted (2019-2021), some of the several thousand individual measures undertaken in the first and second RBMPs should have had a positive effect in terms of achieving good status.

Monitoring requirements

With good ecological status as its main objective, the WFD obviously relies heavily on effective monitoring, but requires a different strategy to the largely end-of-pipe approach that previously existed. Under the WFD, Member States are required to develop an improved understanding of catchments, taking a holistic approach that considers human activities as a source of disturbance and water quality degradation.

WFD Monitoring Guidance Document No. 7 requires Member States to ensure that the following key criteria are incorporated into their programmes:

- Assessment of the deviation of observed conditions to those that would normally be found under reference conditions
- Provision for natural and artificial physical habitat variation

• Accommodation of the range of natural and anthropogenic variability in all water-body types
• Interactions between surface and groundwaters
• Detection of the full range of potential impacts to enable a robust classification of ecological status.

Incorporation of the above key criteria into the assessment systems of each Member State has been designed to ensure that ecological quality is reported to the Commission using a unit-less classification scale based on ratios or fractions of reference values. In theory, this enables Member States to continue using existing national assessment systems (where they exist), whilst reporting ecological status to the Commission on a common European scale.

Monitoring programmes are required to cover three modes:

1. Surveillance monitoring to:

a. supplement and validate impact-assessments

b. enable the adequate preparation of future monitoring

c. assess long-term changes in natural conditions or as a result of anthropogenic activity

This data provides the basis for RBMPs.

2. Operational monitoring provides information for classifying the status of water bodies identified as being at risk of failing their environmental objectives. Operational monitoring may also be used to assess any changes resulting from remedial actions.

3. Investigative monitoring may be undertaken where surveillance monitoring shows that environmental objectives for a particular water body are not likely to be met, and to understand the causes of such failure. In addition, investigative monitoring is also designed to assess the extent of the impact of pollution events.

Whilst monitoring is required to cover a number of 'quality elements,' including chemical, biological and ecological parameters, the WFD does not specify the techniques and the methods to be used.

Water Quality Monitoring

Directive 2009/90/EC provides technical specifications for chemical analysis and monitoring of water status under the WFD. It says the quality and comparability of analytical results generated by laboratories appointed by competent authorities of the Member States to perform water chemical monitoring pursuant to Article 8 of the WFD should be compliant with EN 17025.

In order to fulfil validation requirements, all methods of analysis applied by Member States for the purposes of chemical monitoring programmes of water status should meet certain minimum performance criteria, including rules on the uncertainty of measurements and on the limit of quantification of the methods.

In the early years of the WFD, much of the physical/chemical monitoring would have been undertaken by spot sampling – taking a reading from a portable instrument or collecting a water sample for laboratory analysis. The manual collection of samples is labour intensive and therefore costly, but it enables the analysis of a wide variety of parameters. Manual sampling also results in samples mainly being taken during normal working hours, although this has been partly alleviated by the use of automatic water samplers which are able to collect samples

This is Levelogger 5 LTC (Water Level, Water Temperature, Water Conductivity) datalogger installed in a stream.

24/7. Nevertheless, there is an inevitable delay between sample collection and the delivery of a laboratory result.

In recent years, rapidly deployable remote water quality monitoring systems have been developed that operate on low power without the need for a mains supply. These systems are able to measure a small number of key parameters (pH, temperature, dissolved oxygen, turbidity, conductivity, ammonium, chlorophyll etc.) continuously.

The interval between sensor service and calibration has been extended considerably, and in addition to taking measurements, smart sensors are also able to provide 'health status' which helps reduce the number of site visits required. Dataloggers have become more flexible and 'intelligent' with capabilities such as dial-out on alarm (email, text etc.) and automatic changes to logging speed when pre-set conditions arise. The latest developments include simple scripting for more complex applications, plug and play modems for switching between telemetry methods, and greater data redundancy such as dual transmission of data, to avoid the potential for gaps in data streams.

Advances in telemetry and internet based communications have meant that it is now possible to collect data from almost anywhere and deliver it in real-time to almost anywhere else. Cellular communications are now much lower in cost with wider coverage, and the cost of satellite communication has also lowered dramatically. Consequently, the remoteness of sites is no longer a barrier to real-time monitoring.

All of the developments highlighted above combine to reduce the cost per measurement, whilst increasing the intensity of monitoring. This reduces the levels of uncertainty in data and improves the value of models. However, the volume of data is increasing rapidly, so there is a growing demand for software to manage the data and deliver useful insights; avoiding the danger of becoming data rich and information poor.

Priority Substances

This first list of Priority Substances was replaced in the Directive on Environmental Quality Standards (Directive 2008/105/EC) (EQSD), also known as the Priority Substances Directive, which also set environmental quality standards (EQS) for the substances in surface waters. The list was replaced again in 2013 by Directive 2013/39/EU, which included 12 additional priority substances (45 in total), 6 of them designated as priority hazardous substances.

The monitoring frequencies given in WFD, Annex V 1.3.4 are once-a-month for priority substances and once-per-three-months for other pollutants. Monitoring Guidance Document No. 19 suggests that more frequent sampling may be necessary e.g., to detect long-term changes, to estimate pollution loads and to achieve acceptable levels of confidence and precision in assessing the status of water bodies.

For priority pollutants, measurements are compared with annual average and maximum acceptable concentration quality standards (AA-QS and MAC-QS, respectively) for compliance purposes. However, in order for such comparisons to be worthwhile, it is vitally important that samples are truly representative of the water body. To achieve this, it is necessary to take a number of factors into account, such as spatial and temporal variability of the water body; the number of monitoring sites; tidal influence; discharges from industry, municipal or storm sewers; the monitoring frequency, and the sampling/analysis technology employed. Professor Graham Mills from the University of Portsmouth explains: "It is unlikely that spot sampling once a month would provide a reasonable estimate of the true maximum and/or mean concentration for a particular chemical in a water body with marked temporal and spatial variability. For example, where pesticide occurrence spans over 4 months, an average of 12 equally spaced samples will not give a representative estimate of the maximum concentration, and the mean value obtained will be misleading if used in a risk assessment. When persistent fluctuations occur, the use of passive samplers may be appropriate. However, on-line continuous measurements (albeit more expensive) would be necessary for detecting sporadic peaks of concentration."

Direct comparisons cannot be drawn between data from passive samplers and 'whole' samples unless the particulate fraction is also analysed to determine the total concentration for a pollutant. An important consideration is the water solubility of the compound being measured. For example, the herbicide Diuron is predominantly present in the soluble phase, so passive samplers may be appropriate for regulatory compliance, but the EC would need to formally amend the WFD/EQSD to allow this.

There is a strong argument that it would be better to measure bioavailable concentrations and that EQS should be the bioavailable concentration, however, it would still be necessary to also measure the particulate phase because this is an important fraction containing many hydrophobic compounds which may be consumed by lower organisms and passed up the food chain.

The assessment of compliance with EQS is complicated by the levels of uncertainty in different measurements, particularly when non-compliance for trace substances is marginal. In 2008, the UK Technical Advisory Group (UKTAG) of the WFD published EQS proposals including: In many cases the assessment of compliance involves using data from monitoring to make the appropriate comparison with the standard. In other cases it might involve

Water Quality Monitoring Station

calculations using models. These data or models will always be associated with levels of error and uncertainty, and these translate into statements of the degree of confidence that a standard has been met, or has been failed.

The approach adopted by UKTAG was designed to minimise levels of uncertainty that may give rise to unnecessarily stringent standards. However, levels of uncertainty can be reduced by the collection of more data.

Watch List Substances

The WFD surface water Watch List provides a mechanism for obtaining high-quality monitoring data on emerging pollutants and substances that may pose a significant risk to or via the aquatic environment, but for which available monitoring data are insufficient to draw conclusions on the actual risk posed. The first Watch List was established in 2015 and updated in 2018 whereby the substances diclofenac, oxadiazon, 2,6-di-tert-butyl-4-methylphenol, tri-allate and 2-ethylhexyl-4-methoxycinnamate were removed from the list, while the insecticide metaflumizone and the antibiotics amoxicillin and ciprofloxacin were included. A list of candidate substances for the third Watch List was published in August 2020.

The analysis of trace substances

One of the dilemmas facing those responsible for compliance with the WFD is that risk assessments indicate which substances present a threat to good ecological status, but it has not always been possible to easily analyse them with sufficient sensitivity, or without requiring very large samples, and/or without incurring excessive cost. Furthermore, even where it has been possible to analyse at the very low concentrations required, questions have been raised as to whether affordable mitigation measures are available. So, for example, analysis of a priority substance might indicate a need for a specific wastewater treatment technology, but the cost of doing so might be preclusive. Nevertheless, it is important to remember that EQS are set to protect the environment, without consideration of the current analytical capability or cost. This, however, has helped to drive innovation in laboratory technology. For example, when the WFD first came into force, the sensitivity of lab instrumentation for tributyl tin was around 10 ng/L whereas 0.1 ng/L or less is now routinely possible. Sensitivity improvements of 10x to 100x have not been uncommon for many parameters over the last 20 years. This has been made possible through developments in atomic spectroscopy, chromatography, electrochemistry and mass spectrometry. Advances in hyphenated techniques and instruments such as LC-MS and ICP-MS with multiple quadrupoles have delivered sub-ppt detection level capability.

Sample preparation methods have also improved significantly, with automation increasing speed, consistency and lab capacity. Generally, less solvent is required which saves costs, reduces staff exposure risk and is good for the environment. Smaller samples are also necessary, but analysts need to ensure that samples are representative.

The combination of chemical and physical analysis is useful for attribution purposes. For example, EQS exceedances for PCBs and PAHs may be due to elevated levels of suspended solids. However, the determination of this correlation requires more than just the monitoring capability; it also requires investment in data analysis.

UK Chemicals Investigation Programme

To address the challenge of meeting the Environmental Quality Standards, the 10 water and wastewater companies in England and Wales funded a 10+ year programme of work to improve understanding of how effective treatment processes are at removing trace chemicals. The Chemical Investigations Programme (CIP) analysed final effluent data from 600 wastewater treatment works in England and Wales over the last five years, with corresponding river quality data from upstream and downstream of where these works are located.

The samples taken were analysed for 46 regulated trace substances, 26 substances of emerging concern and 12 supporting measures of wastewater quality. Crucially it also provides the evidence needed to help inform future policy decisions about how to regulate these trace chemicals – including metals, fire retardants and biocides, hydrocarbons, pharmaceuticals, hormones and personal care products – and what can be done to reduce concentrations, if needed, so that rivers and streams can be protected.

CIP has been organised in three phases, with the third phase due for completion in 2022. In the meantime, the CIP data is freely available online. CIP Programme Lead Howard Brett says: "CIP is probably the best dataset of its kind anywhere in the world. It will provide greater transparency about the contribution of wastewater treatment works to river water quality, as well as the role other sectors play, and what action they also need to take."

In general, the CIP has highlighted the enormous potential costs of complying with the priority substances EQS, so informed policy decisions will be needed to determine the cost/benefit of doing so.

UK – a pilot study for Europe?

Following BREXIT, the UK seems likely to make changes to its version of the WFD, so this may provide a pilot study for the EU; creating insights for possible future amendments to the WFD.

In England, the chief executive of the Environment Agency Sir James Bevan, has said that the WFD is "a candidate for thoughtful reform to deliver even better outcomes." He confirmed that the WFD had set high standards and demanding deadlines for improving water quality in rivers, lakes, estuaries and groundwater, and that it has driven much of the work that the Agency and others have done over the last twenty years to secure those improvements. However, he also said that the WFD is not perfect; referencing the 'one out all out' rule, under which rivers fail to meet the required status if they fail on any of the four categories.

He said that there are two problems with this approach. "The first is that it can underplay where rivers are in a good state or where improvements have been made to those that aren't. Right now only 14% of rivers in England qualify for good status under the WFD, because most of them fail on one or other of the criteria. But many of those rivers are actually in a much better state than that, because most of them now meet most of the criteria: across England, 79% of the individual WFD indicators are at good status.

"The second problem with the one out all out rule is that it can force regulators and others to focus time and resources on indicators that may not make much difference to the actual water quality, or where we realistically cannot achieve one of the criteria – some of England's heavily engineered rivers in urban centres, for example, will never be restored to their natural state."

Summary

The WFD is making progress towards its objectives, but it may be necessary to redefine these objectives if success is to be more demonstrable. At the same time, it may be necessary to refine the Directive to ensure that sufficient focus is given to the substances posing the greatest ecological risks, whilst giving consideration to the mitigation measures that are realistically affordable. However, there are two potential problems with such changes. Firstly, if ecological objectives that are currently difficult or impossible to achieve, are removed, the potential for innovation may be harmed. Secondly, if financial cost becomes a major consideration in the creation of ecological objectives, there is a danger that these objectives may be lost or diminished – after a costly pandemic for example.

Climate change and urbanisation will increase pressure on water resources. Flooding, extreme weather and water scarcity are likely to become more frequent, so water catchments will need to be more resilient, and water managers must have the capability to respond quickly and effectively.

The good news is that monitoring technology has dramatically improved since 2000. Laboratory analysis is faster and more sensitive, and continuous monitoring with remote access to real-time data creates a better picture of water quality and enables faster, more effective response measures.

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