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Innovation in the water sector: ecosystem services, Net Zero and nature-based solutions

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In this article, we examine how innovation is being explored by the water sector. Here, innovation needs to be understood as new methods, ideas, products, or solutions for adoption by environmental practitioners.

We look at three different domains within which innovation has played a significant role: ecosystem services, nature-based solutions (NbS) and greenhouse gas emissions quantification (although we acknowledge that there are many other domains within the water sector where innovation is an important factor).

Recent regulatory ambitions and investments have provided an opportunity to innovate in the way the sector actively engages in the protection, conservation, restoration, sustainable use and management of ecosystem services through NbS. Innovation can lead to more effective NbS when systems approaches, multiple capital approaches, multifunctionality, hybridised solutions and standardised approaches are considered. We describe these key principles in the next sections, and then focus on how technological innovation helps quantify methane

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emissions, improving understanding of carbon sequestration contributing to the ecosystem service of climate regulation.

Innovation and ecosystem services

What do ecosystem services mean to the UK water sector, and what is their link with innovative nature-based solutions? UK water companies have recently published their business plans for 2025-2030, and this provides a timely opportunity to review and understand their individual proposals for ecosystem services. Using word frequency analysis for “Ecosystem Services”, UK water companies’ current and future Asset Management Plans (AMP) (AMP7, 2020-2025, and AMP8, 2025-2030) were explored. In both AMP7 and AMP8, “Ecosystem Services” was mentioned infrequently (0.03 and 0.01 per 1,000 words respectively). Does this mean that UK water companies are not committing to protecting and maintaining ecosystem services? Not quite.

Ecosystem services can include provision of clean drinking water, wetland habitat provision, and recreation. UK water companies typically use NbS as the mechanism to deliver ecosystem services, and if we look at the word frequency analysis for “Nature-based Solutions” there is a significant increase in the average mentions within business plans from AMP7 to AMP8 (0.0004 to 0.27 per 1,000 words). NbS are clearly a future focus for UK water companies, driven in the most part by Ofwat’s ambition for AMP8 to deliver greater environmental and social value through an expansion of NbS schemes and opportunities.

With increased focus comes greater potential for innovation, which is already being capitalised upon by the funding of a multi-partner, water company-led ‘Mainstreaming nature-based solutions to deliver greater value’ project, which was awarded over £8 million through the Ofwat Innovation Fund.[1] Looking through a flood resilience lens, UK water companies are involved in eight projects delivering NbS as part of the Defra-funded, EA-managed Flood and Coastal Resilience Innovation Programme.[2]

Small site-level scale innovations for NbS include a nature-based treatment technology combining microbial electrochemical technology and constructed wetlands, an algae-based wastewater treatment technology, and an eco-friendly digital tool to measure, report and verify carbon emission and sequestration at an ecosystem level. In the pipeline we can expect to see digital twins for ecosystems (a virtual representation or model of a system), which will facilitate the optioneering of NbS. Innovation within financial mechanisms could enable economic ecosystem service value to be generated from and for NbS. The Wyre Catchment Natural Flood Management project is the first UK example of private investment enabling the delivery of natural flood management.[3]

People are always the greatest concern when considering innovation options. Water

companies are all at different stages of innovation maturity with respect to nature-based solutions and ecosystem services. A reoccurring theme in conversations within the sector is the requirement and desire to learn from each other. Collaboration between water companies combined with innovative approaches will be the most important factors if the sector is to successfully deliver NbS at the economies of scale and pace required in AMP8 and beyond.

Innovation and nature-based solutions

The water environment is facing ever-growing pressures ranging from quantity (too little or too much) to hygiene and quality (water that is too dirty). These are exacerbated by climate change, biodiversity crises, socio-political factors, economic challenges, and ageing assets. It is clear that there are too many problems to be solved separately, as these pressures are all interconnected. Addressing these effectively will require the water sector to work in innovative, collaborative and adaptive ways. The solutions to these problems cannot be provided by traditional approaches alone. NbS can play a critical role in addressing multiple challenges, creating future resilience, adding socio-economic value, connecting the landscape, and in supporting sustainable development.

There are a number of innovative ways in which NbS can deliver more value for water, people and the environment:

- NbS should be designed for multifunctionality, whereby one solution can deliver multiple improvements at the same time and therefore provide social, environmental and economic benefits.
- NbS should hybridise, and be integrated within, engineered solutions and the built environment in order to optimise synergies and trade-offs with traditional infrastructure. This includes reducing impacts associated with carbon-intensive methods, and providing more resilience to current and future risks.
- With relevance to scale and aggregation, the value of NbS can be maximised when taking a systems-based approach to how they are planned, designed, and delivered across the landscape. The benefits of working in this way can drive the aggregation of ecosystem services and wider value, and it can attract multiple funding and investment opportunities. A key example is the use of innovative market approaches, such as in the Wyre NFM project.[4]
- A multiple capitals approach should be used in assessing value for NbS by considering the impact across the landscape. By calculating the value

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of the many ecosystem services that NbS can provide (including reflecting the significance of ecosystem services that are inherently not monetizable or quantifiable, but that matter to local people and ecosystem functioning), solutions can be designed to achieve much more added value for customers, society, and the environment beyond cost savings.

However, this requires new ways of working and more collaborative approaches, with much more joined-up and coordinated planning and delivery, at a greater scale than what has been observed to date.

This is one of the main goals that the 'Mainstreaming NbS' project is hoping to deliver.[5] An innovative five-year programme of work funded through the OFWAT Innovation Fund, 'Mainstreaming NbS' involves a partnership of over 22 multi-sectoral organisations that have experience within and outside of the water sector. The project aims to bring fresh perspectives that will maximise uptake and benefits arising from NbS by addressing the numerous challenges within the water sector and moving away from siloed working. The project will form a coalition of unlikely allies from different disciplines and cultures (including policymakers and regulators) to reframe existing problems, identify obstacles of change, to learn and co-create new solutions, and to drive the transition to transformational change within AMP8 and beyond.

The project proposes using policy and regulation, tools, processes and knowledge resources to facilitate the dissemination, expertise and standardisation of best practice. It thereby accelerates the transition of NbS from a solely innovative approach into a standard practice, resulting in multi-million-pound investment to be delivered across the UK in novel ways.

Innovation and Net Zero

The UK water industry has made a pledge to achieve Net Zero carbon emissions by 2030. The accelerated pace at which the impending deadline is approaching is driving the industry to take up new technologies, especially those that can provide accurate and rapid quantification of gas concentrations, enhancements and fluxes. In the last few years, the water sector has significantly invested in the uptake of technological solutions that enable the estimation of total CH_4, CO_2 and N_2O emissions, amongst other greenhouse gases. An excellent example is the application of using Unmanned Aerial Vehicles (UAVs also known as drones) for measuring CH_4 concentrations in wastewater treatment plants. Within the context of CH_4 emissions, drone technology deployment has been curtailed in the past decade by sensor weight and size. Until recently, the minimization of commercial sensors had not been achieved sufficiently for them to be installed and used on drones. Tunable Diode Laser Absorption Spectroscopy (TDLAS) sensors have now been successfully miniaturized to enable their integration in rotary drones, and wastewater treatment plants are pioneers in the use of this newly marketed emerging technology.

Drones with embedded TDLAS sensors can be easily deployed when they are required, enabling rapid collection of crucial environmental data. They have been proven extremely useful when it comes to collecting path integrated CH_4 concentrations at an unprecedented spatial resolution over target assets. Their ability to record measurements at pre-determined way points, and their "hovering in one spot" function, offers a wide range of possibilities to characterise fugitive emissions from diffuse and point sources. Drones also enable the integration of a wide range of bespoke sensors, such as thermal and infrared cameras, and Light Detection and Ranging (LiDAR) sensors.

Current technology does have its limits and constraints. Operational constraints need to be carefully considered before making any capital commitments to the technology. There are limitations around drone deployment under windy and rainy conditions, and frequent software and technological upgrades are also necessary to ensure capability is fit for purpose. Other limitations, such as battery endurance and payload, may constrain the range of variables that can be measured. There is often resistance to the uptake of new technologies, even when they are not innovative or disruptive approaches. Sometimes this is because alternative methodologies have been used for decades to comply with policy and regulations, and these are primarily reliant on the outputs from an existing technique. There is also the time and cost associated with learning the new technology. Social perception also plays a key role. The identification of solutions for overcoming such challenges is required to maximise the benefits of innovation within the water sector.

From an in-situ deployment perspective, there is uncertainty as to how the sampling programmes should be executed. Such uncertainty is not specific to greenhouse gas emission monitoring, but also applies to other applications of drones within the water sector. Surface water flood management is another well-known example where the combined use of artificial intelligence and high-resolution drone imagery has informed management decisions. The flight plan, the location of waypoints, the type of sensors and their orientation all have a role with respect to the assessment of the current environmental challenges. The need for data collection, processing and visualisation standards is clear, and the water sector could lead on this development.

Final thoughts

The use of NbS to deliver multiple ecosystem services is emerging as a key mechanism in the water sector. Innovation within this context spans multiple domains, from new ways of working, to the development of treatment technologies, and the use of digital technologies for greenhouse gas emissions quantification and reporting. Technology has played a key role, empowering organisations in both the private and public sector to collect data for the estimation of total emissions. Environmental monitoring technologies have advanced significantly in the last few years, enhancing our surveying capabilities through the provision of enhanced data sets with improved quantity and quality. The water sector is a pioneer in the uptake of such technologies and should continue to be a sector of reference for innovation in the future. This great potential for innovation in different domains and scales offers a unique opportunity to engage in the development of multi and cross-disciplinary solutions that tackle many of the pressing environmental issues facing the water sector. Interconnected environmental challenges require interconnected innovative solutions, and the success of such solutions will ultimately depend on how the sector empowers individuals to collaborate.

The Institution for Environmental Sciences offers multiple platforms for environmental practitioners to identify subject-specific experts and initiate collaboration, such as the Land Condition Early Careers Network.[6] Similarly, the UK Government offers multiple funding mechanisms available to initiate multidisciplinary cross-sector collaborations. Enterprises can access Innovate UK-driven initiatives, and UK Research Councils (such as the Natural Environment Research Council, NERC) will fund scientific research collaborative programmes between research institutions, and the public and private sector. Separate to the source of funding, successful multidisciplinary collaborations will always require individuals to step up and embrace inclusive, diverse, flexible, and adaptive approaches that depart from siloed working.

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The rise of sewer network monitoring

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Before 2015, the wastewater collection network was typically very poorly monitored, with the exception of monitors that controlled wastewater pumping stations and floats on emergency overflows.

However, the Event Duration Monitoring programme, proposed by Richard Benyon in his letter to the Water Companies in 2013,[1] saw the vast majority of combined storm overflows monitored over the next seven years. The monitoring of these overflows has since led to public outcry, as evidence has been openly shared with the public on how many times overflows were "storming" into the river environment.

Figure 1 shows the number of monitors installed (in blue) versus the number of spills reported (the orange line).

2016 was the first time that the industry had seen actual data on the number of overflows to the environment. The problem was that there was no quality control of the data, as the monitoring was not put under the Environment Agency quality control scheme MCERTS (Monitoring Certification Scheme) in real terms. The installations were rushed, and the quality of the data (and thus the number of overflows) is likely overestimated at the current time. The quality of the monitoring data has not yet been ascertained, as the Monitoring Certification scheme is retrospectively being applied to all network event duration monitors. This network monitoring is currently being expanded to wastewater treatment works, and in the next investment period, to all emergency overflows on pumping stations within the pumped wastewater collection network.

This is only part of the story though: water companies themselves are also installing level monitoring (the same technology, but with a different purpose) in wastewater collection networks, as part of a medium-term strategy to limit overflows to the environment. Members of the public will be well aware of the menace of wet wipes and fatbergs in sewers, and the blockages they cause. The most recent published cost for sewer blockages was £100 million, which was released by Water UK in 2017.[2] Not included in this figure, however, is the environmental cost of sewer blockages and how this impacts the environment.

To combat this, water companies have been installing sewer monitors within the wastewater network, to inform machine learning systems developed by technology companies to help identify the precise locations of sewer blockages. This is much needed, as there are approximately 220,000 miles of sewers in the UK, and understanding where sewage blockages are at any one time is a momentous task.

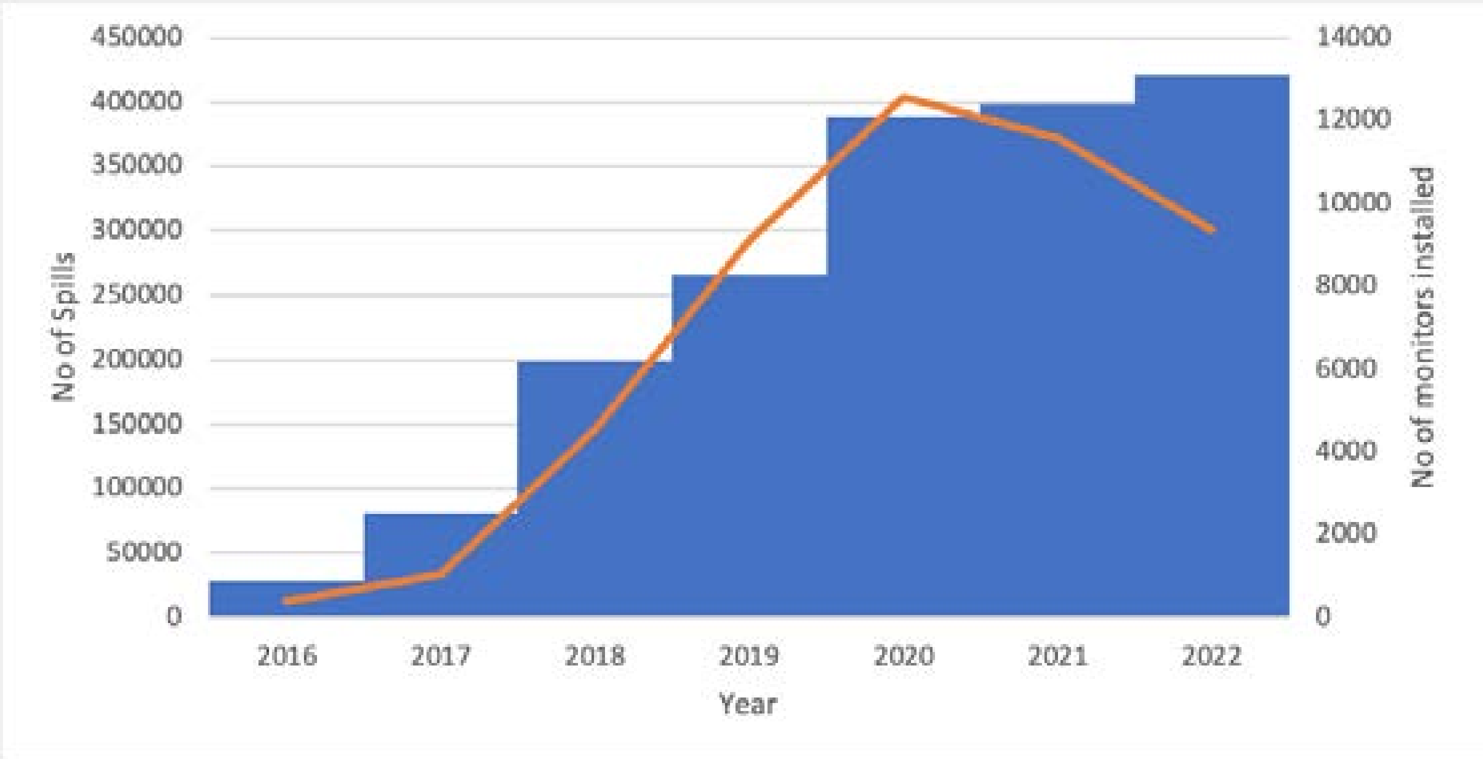

Figure 1. *Number of Storm Overflows Monitored versus the number of spills reported (from data reported to the EA)*

The rise of tools that help water companies identify where blockages are developing has allowed them to identify exactly where to target their resources, to reduce the risk of sewage backing up into people's homes or into the environment. There are approximately 90,000 monitors already installed across the UK that monitor sewer levels, and some of the best machine learning systems are showing a 92% accuracy in identifying early-forming blockages.[3] This allows water companies to take a proactive approach, limiting the risk of storm overflows happening due to sewer blockages. This is a great example of water companies using technology to limit environmental risk.

The monitoring of the wastewater network and its receiving rivers is only set to increase. The Environment Act 2021 saw water quality monitoring of rivers become enshrined in law. Section 82 of the Act stated:

> A sewerage undertaker whose area is wholly or mainly in England must continuously monitor the quality of water upstream and downstream of an asset within subsection for the purpose of obtaining the information referred to in subsection.[4]

This will see monitoring installed across storm overflows and sewage discharge points across England and Wales over the next ten years. The challenge that the water industry faces in putting this into action cannot be understated. The question is: what will be done with the data, and how it can be used to improve the water environment? The necessary investment has been estimated in the billions of pounds just for the initial installation of monitoring systems, let alone the ongoing cost of maintaining the monitoring points. However, to get the true value of the data, there must be a wider vision shared by government, regulators and water companies that clarifies what will be achieved by undertaking the monitoring.

In real terms, the monitoring under Section 82 is short sighted, as we really need to be monitoring the full river environment. This could in turn be used, as part of the National Digital Twin strategy, to complete a digital twin of river basins and their environmental quality, giving a much more accurate outcome, which could inform the overall health of our river environments. It would also allow us to understand, in almost real-time, the level of pollution being contributed by each polluter, and ultimately where to target the Environment Agency's limited resources in its policing of environmental quality.

It is evident that the amount of monitoring has increased exponentially over the past decade and is set to increase even further over the next decade. This will hopefully enable regulators, water companies and other polluters to restore our precious river environments.

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Making a splash: new and innovative approaches to the monitoring of bathing waters

Dr Vera Jones, Global Technical Authority for Water Quality & Associate Director at AtkinsRéalis

Bathing waters are defined as 'surface waters […] other than excluded pools and waters, at which the Secretary of State expects a large number of people to bathe […]'.[1]

There are many more coastal locations than inland sites designated as bathing waters, but there is a growing movement to designate more river locations as such. Bathing water bodies are regulated in England under the Bathing Water Regulations,[1] with similar pieces of legislation in other UK nations, all stemming from the European Commission Bathing Water Directive.[2] The Directive and subsequent Regulations stipulate a number of limits and commitments relating to water quality. Bathing waters are assessed on an annual basis by regulators, using standards that focus on microbiological quality. These standards have been derived from public health guidance, and relate to the potential public health risk of gastrointestinal illness arising from swimming in natural waters.[3]

In England, the latest classifications (2022) showed that 72.1% of bathing waters are at 'Excellent' status, as defined in the Regulations, while 2.9% are at 'Poor' status (intermediate categories are 'Good' and 'Sufficient').[4] The percentage of 'Excellent' water bodies across England is lower than the same metric across the EU, which stands at 85.6%,[5] but it also represents an improvement compared to the results five years ago (2017) when only 65.6% of designated waterbodies in England achieved 'Excellent' status.[4]

Notwithstanding the above, there is a lot more to be done to ameliorate bathing water quality: to both improve more water bodies, and also go beyond the requirements of an 'Excellent' classification. Significant numbers of people enjoy bathing waters as an important amenity, whether this is a beach walk and paddling in the water or swimming and water sports. The rising popularity of "wild swimming", in combination with increased awareness of pollution from sewer overflows, means that there is an enormous amount of public attention on this topic, which has become the focus of intense media scrutiny. There are also a number of campaigning and stakeholder organisations who are very active in this area and strive to make a positive difference, such as, for example, Surfers Against Sewage, the Outdoor Swimming Society and the Ilkley Clean River Group. The public now has an expectation that as many water bodies as possible – irrespective of whether they are formally designated – should be accessible and safe for swimming, from a water quality point of view. Given the increased interest in this field, it is pertinent to examine innovation and new technologies that will provide the public with as much information as possible on bathing water quality.

It is important to note that the central goal should be for as little pollution as possible to reach our watercourses at any time. But the causes of pollution in the water environment, whether this is a river, lake or the coast, are highly complex. They involve a multitude of sources, such as intermittent and continuous wastewater discharges,

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agriculture and farming, road and other surface water runoff and private discharges. So, in parallel to the huge ongoing efforts to decrease the amount of pollution going into our water bodies, we should be looking at technologies to keep people informed on water quality. We should also be mindful that bathing water standards focus on public health, and hence microbial water quality only, but pollution impacts on the environment arise from a range of different parameters beyond the microbial elements, including nutrients and trace chemicals.

Historically, information on bathing water quality has been provided on boards situated by the designated bathing water body, which are updated by the environmental regulators. However, this information is usually either generic, refers to the previous classification year, or is at least one week out of date, due to the time it takes to collect a sample, transfer it to the lab and for the lab to report back results. Modern technologies mean that we can now start moving towards providing more detailed and near real-time information to bathing water users. So which new innovative technologies may help us better protect public health and the environment in bathing water sites? Let's look at two technologies, which may bring significant transformation to the sector.

Firstly, molecular biology techniques: primarily Polymerase Chain Reaction (PCR) applications. At the moment, culture-based techniques are used for bathing water quality monitoring (as prescribed by the Bathing Water Directive). These focus on two parameters which act as very useful indicators of sewage pollution or animal waste – E.coli and Intestinal Enterococci – but provide a limited window into the microbial pathogen picture in a particular location. PCR would allow for testing of a much wider range of organisms, and would therefore provide a significantly more comprehensive picture of microbiological water quality. For example, people who become unwell after swimming in open waters often present with Norovirus-type symptoms. PCR would allow us to test for such viruses, as well as for a much wider range of pathogenic bacteria, therefore providing a much clearer link between public health and bathing water use. Additionally, molecular biology techniques could explore new risks that we are becoming aware of; for example the risk of exposure to antimicrobial resistance (AMR). Research has shown that surfers are three times more likely to harbour antimicrobial-resistant E.coli in their guts,[6] highlighting the potential for exposure to AMR through the use of bathing waters. Molecular biology techniques could check for AMR markers, providing a different and more specialised angle to bathing water quality information. Such techniques are becoming cheaper and faster all the time, meaning that a very comprehensive picture of bathing water quality could be provided in the future on a near-real-time basis to the public.

The second promising technology in this field is artificial intelligence (AI), which is gradually becoming a part of so many different aspects of our lives. A number of AI trials are ongoing in the sector, such as a pilot project in Devon[7] that has combined datasets from local rivers, rainfall and soil with satellite images of local land use, in order to yield water pollution predictions. Wessex Water has also been developing an app for Warleigh Weir to provide information to bathing water users, based on algorithms that give half-hourly predictions of bacterial levels on the River Avon.[8] The app is thought to be 90% accurate compared to lab samples, with the main advantage being that it provides predictions in near real-time. With all AI technology, it is worth bearing in mind that large volumes of good input data are required for it to learn from. An evaluation of the performance of machine learning approaches to predict the microbial quality of surface waters has highlighted the significance of optimising water quality motoring data that feed into machine learning.[9] AI technology to predict bathing water quality is in its initial stages, but it provides a promising new avenue for research and development in this sector.

Technological innovation is great, but results also need to be presented in an easy-to-understand manner so that they are useful not just to the specialists, but to the wider public. The requirement for a focus on public information has been included in the European Commission Bathing Water Directive, and is becoming more and more important as environmental awareness rises and the public rightly expects accurate and accessible information. Therefore, a key element of either of the above technologies should be the clear presentation of results. In an era of data openness, bathing water quality information must be transparent and presented in a manner which is accessible and informative to a broad audience, reaching different communities and social groups. This may be in the form of apps, online maps, phone alerts, but should also continue to include physical signage.

An amalgamation of the above innovative technologies – molecular biology and AI – could provide the ideal, unique combination of a comprehensive bathing water quality picture with near-real-time public information; allowing a range of bathing water users to make informed decisions on whether to visit a specific water body on a particular day. At the same time as exploring new technologies to monitor the bathing water environment, we all need to continue working towards reducing pollution to all of our water bodies at both the individual and community level.

Let's enjoy and appreciate our coastal and inland bathing waters, and the huge benefits they provide to our wellbeing; while also investing in innovation to better protect the environment and provide accurate and useful information on water quality to all.

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