ELGA VEOLIA

Going Green

Discover 6 case studies
on monitoring, understanding and managing environmental water pollutants

MONITORING

You have to keep a sharp eye on pollutants if you want to detect change

UNDERSTANDING

To overcome environmental pressures you need to understand them

MANAGEMENT

Innovative methods can be implemented to fight environmental water pollution

Dedicated to Discovery

Inside

Intro

The situation for life on our blue planet is critical. Find out more about some of the exciting research projects that are helping us to understand and reduce the effects of environmental water pollution.

We have now entered the anthropocene – the current geological age when human activity is the dominant influence on the climate and the environment. Threats to our world are in the news daily, from rising sea levels and the climate crisis, to the extinction of species and the contamination of water, soil and air. Global icons such as Sir David Attenborough inform us about the wonders of the natural world, but also the pervasiveness of microplastics and the collapse of ecosystems.

We must act, and act wisely based on facts revealed by collaborative interdisciplinary research that progresses environmental science. The insights gained into threats such as pharmaceuticals in wastewater, hormone pollution and heavy metal pollutants in water systems, and the development of water treatment methods such as activated carbon wastewater treatment and bioremediation will help us to secure sustainable water supplies now and for future generations.

To understand our environmental impact, it is imperative that we quickly implement robust and accurate monitoring systems that establish baselines to help measure the effect of interventions and guide pollution control.

The next step is to get a better understanding of what these changes could mean – for both the environment and its inhabitants. This often pulls in a variety of technical expertise, from low-level chemical detection and biochemical assays, to cell-based analysis, and ecological modelling. The better we understand a change, the better equipped we are to deal with it.

Which brings us to the final aspect: managing the situation. With an already sizable amount of data from both initial monitoring studies and subsequent investigations, evidence-based initiatives can then be implemented to manage, avoid or even completely remove these environmental impacts.

Environmental science builds on innovative analytical methods based on ultra-pure lab water

The worldwide effort to monitor, understand and manage water pollution ultimately relies on developing innovative methods that can deliver accurate data on pollutants and technologies for their removal. Confidence in the data that drives this process depends on the ability to reliably measure low pollutant levels, and this is only possible with pure lab water.

Here we explore some of the exciting research projects that help us understand and protect our environment. Forewarned is forearmed, and more scientific knowledge will increase our ability to manage and maintain a healthy environment.

If you have a comment, or would like us to feature your work in a future edition you can contact us today at elgalabwaterglobal@veolia.com

ELGA EDITORIAL TEAM

Monitoring

DO YOU KNOW WHAT LURKS IN YOUR ENVIRONMENT?

From the soil to the river to the sea, we put enormous pressure on the environment. Fortunately, our awareness of environmental water pollution is increasing and there are many dedicated researchers working tirelessly to develop new ways of detecting and monitoring the plethora of pollutants lurking all around us.

THE LAST BASTION OF DEFENCE — PROTECTING OUR WATER

Every day, industries across the world release vast amounts of compounds into our surroundings that invariably find their way into the aquatic environment. These sources of water contaminants can take many forms, including industrial effluent, rainfall run-off, agricultural drainage, and even human waste.

The constituents of wastewater vary considerably depending on their origin, and can include pathogens, pharmaceuticals, pesticides and organic or inorganic material, including toxic heavy metals. Fighting the good fight against contamination such as hormone pollution and heavy metals in water, wastewater treatment (WWT) facilities are in place around the world, serving as our last line of defence!

However, when many contaminants such as pharmaceuticals in wastewater exert their effects at extremely low concentrations, how can we be sure that WWT is effectively removing them?

To get things started, we need to be able to identify the often-tiny amounts of wastewater contaminants in order to monitor them with confidence. This can be challenging as low-level detection itself poses a significant technological hurdle. The myriad components of wastewater are also capable of multiple interactions with both the environment and other constituents of the wastewater itself.

Keeping an eye on this complex chemistry can keep even the most diligent scientist working at their limit.

Monitoring these contaminants in the natural environment and in the wastewater laboratory is therefore critical in the fight against environmental degradation.

CASE STUDY

Sludge sampling to optimise wastewater treatment

AstraZeneca and the University of Portsmouth
Portsmouth, UK

The accumulation of solids from wastewater at WWT plants falls under the collective (and unappealing!) name of 'sludge'. Whilst detection of wastewater contaminants is typically very robust, active pharmaceutical ingredients (APIs) and other contaminants can potentially sneak through WWT detection systems if they are adsorbed onto sludge components. They can then be released at a later date to cause all manner of environmental problems. Some of the models employed to predict the impact of this process can lack accuracy, occasionally failing to predict real-world effects and consequences, especially when it comes to the indirect metabolites and derivatives of pharmaceuticals in wastewater.

Thankfully, researchers are working to protect against this potential chemical calamity and this has included devising a method of identifying API adsorption behaviour. A team from AstraZeneca and the University of Portsmouth developed a solid-phase extraction (SPE) method to rapidly determine API-sludge interactions from just a half-gram sample (Berthod et al. 2014). Existing models of API-sludge interactions tended to emphasise hydrophobic interactions. While these are important when dealing with neutral organic compounds, when it comes to ionisable compounds (such as many APIs) this model fails to give reliable predictions. Using an SPE method, the researchers demonstrated that additional interactions, such as ion exchange, π–π and H-bonding, are just as important as hydrophobic interactions when examining API adsorption mechanics during WWT.

The same SPE method was used in a later study to supply data aimed at quantifying structure-property relationships to predict pharmaceutical sorption to sludge (Berthod et al. 2017). Modelling such interactions will greatly improve the understanding of the environmental fate of APIs and in risk assessments.

INFOGRAPHIC

What will be the perfectly green lab of the future?

CASE STUDY

Heavy metal pollution data

University of Sindh
Pakistan

Heavy metal water pollution is a global threat to the environment, human health and food security, and is the result of the rapid pace of urbanization, land use changes, and industrialization, especially in countries with extremely high populations. Monitoring heavy metal pollutants such as silver, cobalt or nickel, has therefore become an important part of water pollution testing. In countries that are implementing or optimising their WWT plants, the contamination of surface waters with these potentially toxic metals is a concern, and detecting multiple metals – often in the parts-per-billion (ppb) range – can be challenging and time consuming.

A team from the University of Sindh in Pakistan were the first to provide evidence on the influence of industrial effluent on silver and heavy metal concentrations in the freshwaters of Pakistan (Naeemullah et al. 2014). They used single-step cloud point extraction coupled with flame atomic absorption spectrometry (FAAS), along with micelles made of Triton-X to entrap and isolate the metal chelates that had been reacted with ammonium pyrrolidinedithiocarbamate (APDC). The researchers were able to detect silver, cadmium, nickel, cobalt and lead simultaneously down to µg/L levels. Their research also highlighted the spatial variation of metal concentrations and the dilution by other abiotic factors such as canal run-off and sediment erosion.
A similar method, which combined solid-phase extraction of APDC-reacted metals surrounded by Triton X micelles, was used to measure chromium, cadmium, and lead in urine samples of welding workers in Iran (Sadat et al. 2018).

These monitoring methods will be invaluable in rapidly identifying and monitoring heavy metal pollutants in the environment and in humans, and guide the development of effective management strategies.

INFOGRAPHIC

What will be the perfectly green lab of the future?

Understanding

BEHAVIOUR AND BASELINES

The nature of pollution is both complex and dynamic. Understanding baselines, effects and fates within a system is an important area of investigation. As a result, researchers are employing a range of methods to assess not only the effects compounds such as herbicides can have on organisms, but also how they behave within their environment.

OF PLANT PESTS AND POLLUTION

Using a non-radioactive isotope of nitrogen (^{15}N) is one approach that can bring insight into how a harmful substance affects the metabolism of amino acids and proteins. This approach was effectively validated in a microorganism system nearly twenty years ago (Arndt et al. 1998) and was used to investigate interactions between cultivated rapeseed plants and the parasitic weed, broomrape (Gaudin et al. 2014).

This is something that could have important impacts on managing agricultural concerns such as pests. For example, while there is some amino acid transport from the host to the parasite it has since been shown that the herbicide glyphosate controls broomrapes by directly inhibiting enzymes of the parasite that are involved in amino acid synthesis (Dor et al. 2017).

Being able to understand the metabolism of nitrogen, and thus proteins, is a very powerful tool to have at your disposal, since the disruption of protein synthesis can have severe consequences to an organism. In addition to looking at how metabolism may be disrupted, this approach also provides a deeper insight into how an organism utilises, transports and stores nitrogen under normal conditions.

Such an approach opens up the possibility of developing more detailed baseline measurements, as well as offering a means of quantifying metabolic disruption.

CASE STUDY

Understanding seasonal variations

Urban sewage plant
Tunisia

Some compounds can have subtle effects on an organism and this is where understanding how they behave is especially important. Predictive modelling of environmental behaviour is especially important if you consider that there are seasonal variations in the efficiency of removal of certain pharmaceutical compounds, specifically estrogenic compounds, by wastewater treatment.

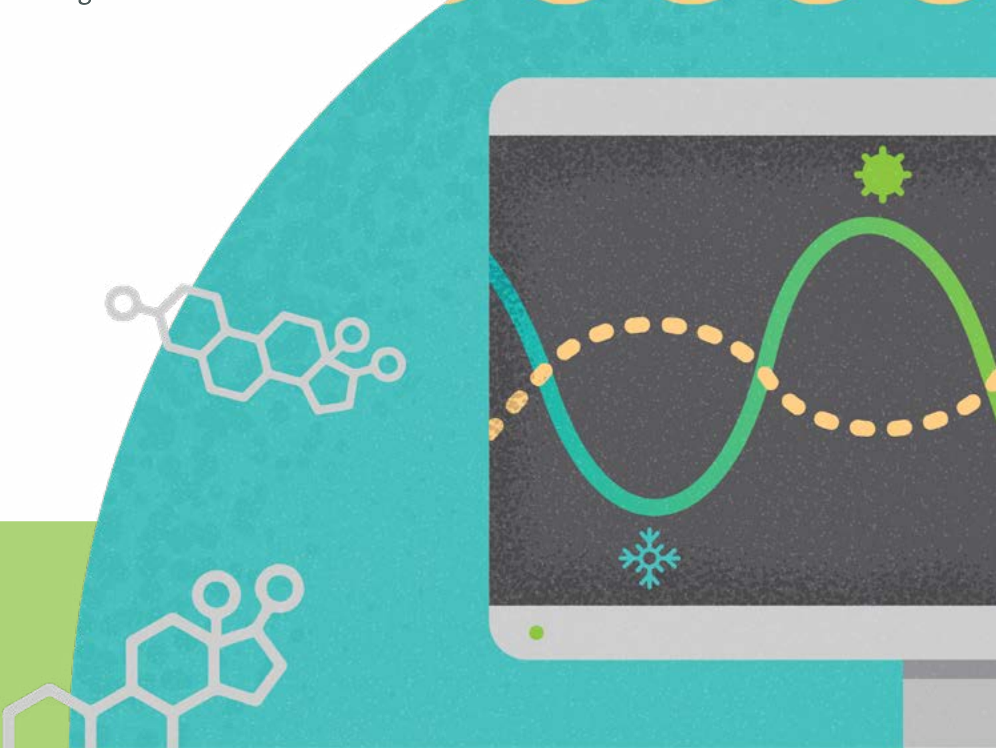
Endocrine-disrupting chemicals (EDCs) that mimic, block, or alter the actions of normal hormones have been studied in depth over the past 30 years due to their ability to affect both humans and wildlife at low concentrations. Hundreds of EDCs, from phthalates and bisphenol A to pesticides and the contraceptive 17-alpha ethinylestradiol, cause a range of problems including feminization, reduced reproduction, cancer and birth defects. Since sewage treatment plants are exposed to EDCs, understanding how these chemicals behave and vary is important for protecting the environment.

Research conducted at an urban sewage treatment plant in Tunisia set out to understand the aquatic hormonal fluctuations caused by EDCs in more detail (Belhaj et al. 2015). With the aid of an extensive sampling regimen followed by analysis using gas chromatography coupled with mass spectrometry (GC-MS), the researchers were able to detect EDCs down to just a few parts per trillion. Even more interestingly, their results showed that there were seasonal variations in the efficiency of treatment: certain EDCs were removed from water more effectively during the summer months. This was thought to be a combination of biodegradation and fluctuating microbial activity throughout the year.

The value of exploiting such biological processes to fight EDC pollution has been highlighted in a recent review of methods to remove EDCs from wastewater in the United Kingdom (Gadupudi et al. 2019). While 70–90% of EDCs can be removed using chemical and physical methods, biofilms were regarded as very promising alternatives.

LEARN MORE...

About how labs around the world can become more sustainable



CASE STUDY

Aquatic acid and Antarctic air

University Ca' Foscari
Venice

The physicochemical effects of atmospheric pollution moving into surface water are significant. Ocean acidification, for example, results from the uptake of high levels of atmospheric carbon dioxide and can spell disaster for the pH-sensitive construction of calcium carbonate shells by crustaceans, molluscs and corals. Another example is the formation of sea spray, which is the largest source of atmospheric aerosol on Earth, playing a significant, but poorly defined role in cloud formation and the global climate.

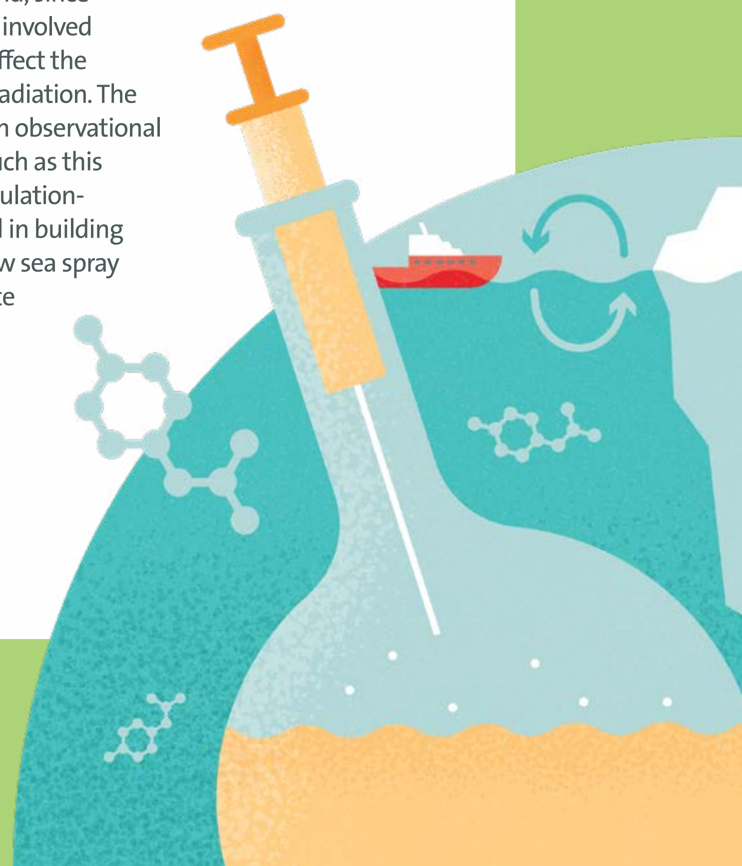
Establishing baseline atmospheric measurements of marine aerosols can be difficult near inhabited continents due to anthropogenic interferences. This is why some scientists make use of the Polar Regions to serve as 'natural laboratories' for such studies. Understanding how aerosols, particularly marine aerosols, behave (where they came from and where they end up) is important to understanding how they affect atmospheric chemistry, climate change and a host of organisms. The production of naturally occurring marine organic aerosols, for example, is complex, driven by physical (wind), biological (phytoplankton) and chemical (sunlight-stimulated) processes.

Amino acids in the atmosphere are attracting attention due to the theory that they contribute to new particle formation, as well as their crucial role as nutrients. Aboard their vessel in the Antarctic, a team of Italian scientists investigated how amino acids produced at the sea surface become distributed as aerosols across Antarctica (Barbaro et al. 2014). These types of studies help to define the changes in amino acid composition that take place as marine aerosols move inland. To preserve sample integrity and ensure a lack of contamination, the researchers used a unique procedure that involved meticulous aliquoting and extraction by ultrasonication in ultra-pure water.

The valuable samples were analysed using triple quadrupole mass spectrometry (TQMS) and chromatography. Their results showed that hydrophilic amino acids were the predominant marine aerosol released into the atmosphere, and that there was a low abundance of hydrophobic amino acids in coastal areas. This is important to understand, since amino acids can become involved in cloud formation and affect the balance of atmospheric radiation. The combination of data from observational and laboratory studies such as this with computational (simulation-based) methods is crucial in building our understanding of how sea spray aerosols affect the climate (Schiffer et al. 2018).

READ MORE...

Digest the full Barbaro et al case study here



Managing

TAKING INNOVATIVE ACTION ON IMPACTS

The dangers posed by environmental pollutants are considerable, as are the challenges in detecting, monitoring and understanding them. Despite this, the future for the environment looks brighter thanks to the devotion of time and energy in many labs around the world to the development of pollution management and 'clean-up' technologies designed to protect our environment and ourselves.

CASE STUDY

More than just BBQ fuel

Technische Universität
Berlin

Organic micropollutants (OMPs) such as drugs, cosmetic products, and some insecticides, are generally regarded as a risk to both aquatic ecosystems and public health. One way to remove these from water is with activated carbon (AC) in either a granular (GAC), or a powdered (PAC) form.

This form of carbon is a little more sophisticated than the standard briquettes you'll use in your barbecue, and works by adsorbing compounds from the water onto its surface. AC is incredibly porous, meaning it has a very large total surface area: just one gram can have a surface area of up to 1000 square meters (Karmakar 2010)! This massive surface area is the secret to its success.

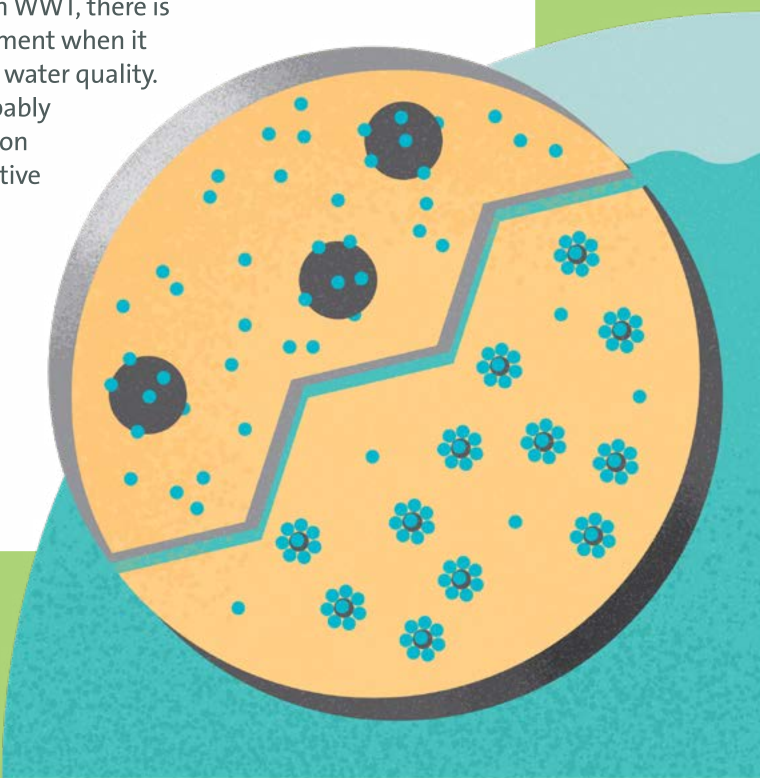
Carbon, in one form or another, is widely used in filtration systems and is a part of most drinking water and WWT plants. Dissolved natural organic matter (NOM) is typically already present in these water sources and can effectively 'use up' the capacity of the AC, blocking its pores and reducing its effectiveness. A team from Technische Universität Berlin went a step beyond lab bench experiments and applied their findings in a WWT pilot plant (Meinel et al. 2014).

Running both lab bench- and pilot plant filtration studies, the researchers looked at the effectiveness of PAC and GAC at removing OMPs. They employed liquid chromatography–mass spectrometry (LC-MS) to analyse the OMPs post-filtration and indicated distinct benefits of PAC over GAC. The lower performance of GAC was attributed to two main factors: direct site competition between contaminants, and pore blockage. However, even after 240 days of GAC filtration, adsorption sites were still available if the carbon was first ground up before being reused. Ultimately though, PAC in the pilot plant was significantly more effective at removing OMPs than GAC, due to its smaller particle size and a longer contact time, which increased the amount of time for adsorption. A later study at the same lab showed that the adsorption efficiency of PAC can be further increased by recycling back into the adsorption stage, enabling large amounts of OMP to be eliminated using only small dosages of PAC (Meinel et al. 2016).

This work shows that while filtration using both GAC and PAC is useful for removing pollutants in WWT, there is still room for improvement when it comes to maintaining water quality. This research will probably continue to capitalise on the impressive adsorptive potential of activated carbon in the effort to improve wastewater treatment.

DOWNLOAD

The PureLab Water Guide, an essential overview of lab water purification



CASE STUDY

Bio clean-up

University of Sheffield
UK

When it comes to large-scale pollution events such as oil spills, the clean-up efforts need to be ramped up. The devices and chemicals that offer an immediate solution to a spill have several limitations. Chemical dispersants, for example, have been the agent of choice at various major oil spills, such as the Exxon Valdez spill in 1998 and the Deepwater Horizon spill in 2010. However, dispersants have had only limited effect and are known to be toxic and alternatives have been slow to materialise.

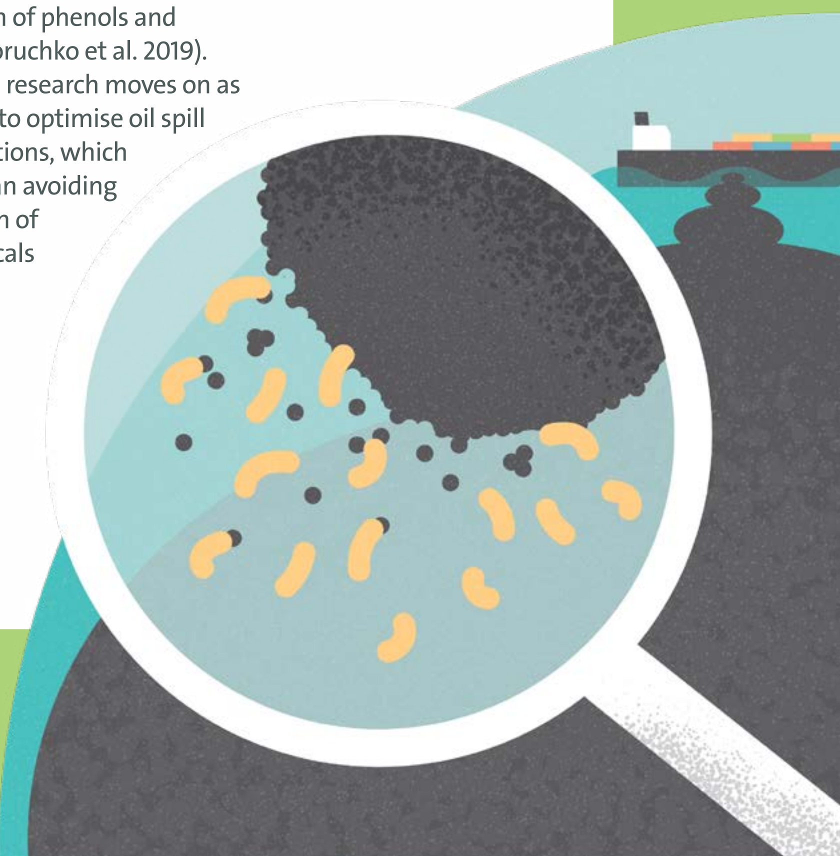
Fortunately, a promising solution lies in the form of bioremediation: a cost-effective, non-destructive process that makes use of the microorganisms already present in the water that feed upon the oil droplets. Selective nutrients can also be added in a controlled manner to encourage their growth and aid oil degradation. Hardy bacteria such as *Rhodococcus* have previously been deemed very suitable for the bioremediation of difficult contaminants, such as petroleum hydrocarbons (Kuyukina & Ivshina 2010).

More recent work has set out to understand and characterize the mechanical properties of *Rhodococcus*, such as cell-cell adhesion and the interactions between the cell and mineral surfaces – important parameters if you're trying to understand and improve its bioremediation potential (Pen et al. 2015). With an interdisciplinary approach involving bacterial culture, atomic force microscopy (AFM) and modelling using scale theory, the researchers explored this bacterium's biomechanical properties in detail. *Rhodococcus* was found to have greater adhesive properties during its early growth stages due to the presence of more extracellular polymeric substances (EPS), which are responsible for binding contaminants. In addition, the study showed that changing the pH of the surrounding water also affects the conformation of EPS, which could influence the efficiency of bioremediation.

Insights such as these have paved the way to developing advanced stress-tolerant *Rhodococcus* biocatalysts for wastewater treatment and bioremediation, including the degradation of phenols and crude oils (Krivoruchko et al. 2019). Bioremediation research moves on as labs work hard to optimise oil spill clean-up operations, which could even mean avoiding the introduction of harmful chemicals altogether.

INFOGRAPHIC

What will be the perfectly green lab of the future?



The solution to pollution...

Innovation

Contrary to popular belief – and a genuine approach to pollution management for several years – the solution to pollution is not dilution.

It turns out that many of the contaminants and pollutants that we initially thought were either absent or unable to exert toxic effects at the concentrations seen in the environment, are in fact both present and causing problems. The power of dilution at the lab level may very well mitigate the impact of hazardous materials, but when it comes to managing environmental pollution, the solution to pollution is actually innovation.

Recent research has resulted in numerous techniques and processes that are now being developed or deployed to monitor, understand and manage a broad spectrum of environmental contaminants.

Innovative solutions are being sought to detect single particles or molecules amongst billions of others, to provide early indicators of environmental change, and to find new ways of fighting existing problems.

Work like this depends heavily upon detailed and robust protocols and methodologies that require the highest quality reagents to maximize the control of every parameter. This might mean dissolving atmospheric samples from the Antarctic, or eluting volatile organic compounds from a biologically active sludge prior to analysis.

The researchers who authored the scientific articles presented here were aware of the need for accuracy and precision in their work, which is why they made use of ultra-pure water when the situation called for it. If the right equipment, the right reagents and the right applications are selected early on, you can minimise the risk of unforeseen experimental problems and ensure your data is as trustworthy as possible, giving you confidence in the insights you make.

These are exciting times for environmental research. With the right tools, and fuelled by the rapid growth in public awareness together with an explosion in interdisciplinary research, we still have the possibility to do great environmental science for a better future.

Learn more by visiting:
www.elgalabwater.com

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