Position Statement

Tackling Contaminants of Emerging Concern (CECs) in water

October 2024

Pollution in water is driving an unprecedented global crisis. Water bodies – including lakes, rivers, groundwaters, coastal waters and oceans – make up 71% of the Earth's surface, yet they are widely contaminated with cocktails of toxic chemicals and plastics. Contaminants of Emerging Concern (CECs) represent a troubling subset of pollutants, which are often unregulated and poorly understood. However, what is well-evidenced is that they are impacting our environment, resulting in adverse consequences for ecosystems and human health. We urgently need a comprehensive approach to CECs that complements remediation strategies and combines monitoring, regulation, interdisciplinary research and collaboration. The Royal Society of Chemistry (RSC) is therefore calling on our governments and regulators for ambitious and urgent action in tackling CECs.

Our asks in brief:

1. **Implement effective, comprehensive and resilient monitoring strategies to identify and monitor trends in CEC occurrence in water, and also in humans, wildlife, air, sediments, and soil.** Monitoring should begin now and continue over the years ahead to establish long-term trends and to provide information on the evolving fate of CECs.
2. **Ensure monitoring programmes are adequately resourced and transparent, and there is a harmonised approach within the UK.** Whilst water policy is devolved in the UK, where possible some degree of harmonisation in monitoring (e.g., standardised methods, CECs in scope) should be done to avoid loss of long-term spatial data sets.
3. **Implement improved risk assessments that assess the biological impact that chemical mixtures can have on ecosystems and human health.** Such methods could include effect-based methods, e.g. techniques that can measure the effects of chemical mixtures on organisms and/or cells and importantly also including New Approach Methodologies (NAMs).
4. **Implement a stronger 'polluter pays' principle by making additional treatment to remove CECs from urban wastewater mandatory.** This could be funded via extended producer responsibility of major polluters of CECs (e.g. industries that produce or use problematic CECs) that consequently end up in wastewater streams.
5. **Commit to identifying and tackling the other major diffuse sources of CECs in waterbodies, such as pollution from road run-off, waste emissions and agriculture.** These sources must be held to the same level of scrutiny as water companies.
6. **Promote responsible innovation and use in industry to ensure clean and sustainable water**. This includes incorporating safe and sustainable-by-design principles and extended producer responsibility, in the development of chemicals, products and processes.
7. **Promote non-technological solutions and raise awareness in the public to achieve clean and sustainable water.** This includes increasing consumer awareness and promoting behavioural changes (e.g., promotion of correct disposal practices of medicines).
8. **Commit funding to ambitious programmes to enhance global collaboration and to enable the UK to provide support for surveillance programmes of CECs.** By actively engaging in international collaboration, the UK can share global expertise and data.

Contaminants of Emerging Concern – an invisible threat?

Contaminants of emerging concern (CECs) refer to substances that are often not controlled or monitored in the environment, and even at low concentrations may be harmful to human health or the environment.[1] A diverse and large number of CECs have been detected in the aquatic environment globally, including in surface waters, ground waters, drinking water, and wastewater influent and effluents.[2,3]

Despite what their name suggests, many CECs may have been present in the environment for a long time.[4] However, the advancement of analytical techniques has enabled the detection of thousands of chemicals, enhancing the capacity to analyse a wide range of CECs in environmental samples, even at low concentrations, which can still cause adverse effects.[5]

The term CECs covers a diverse range of both synthetic and natural contaminants with wide-ranging properties, including per- and polyfluoroalkyl substances (PFAS) or 'forever chemicals'; brominated and organo-phosphate flame retardants; polycyclic aromatic hydrocarbons (PAHs); pesticides, fungicides and herbicides; pharmaceuticals (which include antimicrobials) and antimicrobial resistant genes (carried by bacteria, fungi and parasites); UV filters in sunscreens and other chemicals in personal care products; micro- and nano- plastics and harmful additives in plastics.

The presence of CECs in the environment raises concerns due to their potential toxicity, persistence, bioaccumulation, mobility, or other adverse effects.[6,7] For instance, some CECs can mimic naturally occurring hormones, thereby disrupting finely tuned endocrine systems in a range of organisms, which in turn can lead to neurological, developmental and reproductive defects (for example, ecosystem effects have included feminisation of male fish).[8,9] Other CECs have exhibited high toxicity on non-target organisms, such as the veterinary pharmaceutical diclofenac that causes toxicity and therefore population crashes of vultures.[10]

Furthermore, antimicrobials and antibiotic-resistant genes in the environment have also been identified as potential drivers for antimicrobial resistance (AMR), recognised by the World Health Organisation (WHO) as one of the top global public health threats[11,12,13,14]

Humans can be exposed to CECs contained in water via a number of routes, for example during recreational activities such as swimming and bathing, and in drinking water (for example, widespread PFAS contamination in drinking water[15]). While individual exposure events might involve low levels of contaminants, the long-term effects of exposure to these CECs are not well understood.

Sources of CECs

CECs can enter the aquatic environment via diverse routes, which can be categorised as point sources of pollution or diffuse (non-point) sources of pollution (Figure 1). Pollution from point sources is discharged from discrete spots such as wastewater effluent from a wastewater treatment plant (WWTP). Traditional WWTP processes were not developed to remove CECs from water, resulting in CECs still often being present in the effluent or treated wastewater streams produced by WWTPs.[16] Whilst a range of treatment technologies exist to remove more CECs than traditional approaches, some can be expensive and energy-intensive, and there is a current lack of both guidelines and legislation to force action.

Diffuse sources of CEC pollution include agricultural run-off from fields, which can enter nearby water bodies. This run-off can contain agrochemicals[17] (including pesticides or herbicides), veterinary pharmaceuticals and CECs contained within sewage sludge derived from WWTPs and used as fertiliser[18]. Run-off from highly urbanised areas and roads is another major source of pollution in rivers, often containing mixtures of microplastics, tyre wear particles, PAHs and metals.[19,20] Other potential sources of chemical pollution include landfills, mines, atmospheric deposition, and industrial discharges. Compared to point sources, diffuse sources of pollution are harder to identify, manage and regulate, due to their high variability, both temporally and spatially, and the number of stakeholders that are involved. This has led to a fragmented policy landscape.[21]

That said, new, scalable laboratory and *in silico* modelling methods are already emerging that together can help with source apportionment (e.g. the process of identifying sources of pollution and their contributions to overall pollution levels), and to help unravel the complexity of mixtures present in water.[22,23] In addition, any approach aiming to tackle CEC sources needs to be resilient to cope with changing consumption practices or marketing strategies (e.g., 'greenwashing*', 'regrettable substitution'† or market repositioning‡), which may arise in response to chemicals policy, or demand for or introduction of new chemical products.

Figure 1. Sources and fates of CECs into the environment.

Regardless of the source, once CECs have entered waterbodies they can be challenging to remove. A substantial proportion of the contaminants introduced into freshwater eventually find their way into transitional waters and marine environments, such as estuaries, coastal waters and oceans. It has been estimated that 80% of the chemical pollution in our oceans has come from anthropogenic land-based activities.[24]

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* Greenwashing – Misleading the public to believe that a company or other entity is doing more to protect the environment then it is. https://www.un.org/en/climatechange/science/climate-issues/greenwashing

† Regrettable substitution – The process by which a known harmful or problematic chemical or product is replaced with a chemical or product with an unknown or unforeseen hazard.

‡ Market repositioning – A process by which a company can change the target market or the perception of a product or brand.

Despite this, our understanding of fate and impact of contaminants in the marine environment has had a limited focus to date, potentially due to historic misconceptions on the ability of the oceans to dilute chemical pollution. However, recent studies have demonstrated that contaminants finding their way into oceans are not gone forever. For example, one recent study estimated that more PFAS is released into the atmosphere via waves in coasts than industrial emissions.[25] The limited understanding of chemical pollution in marine environments, has resulted in a severe lack of knowledge and data to inform policy action.

Current water regulations in the UK

Following the UK's exit from the European Union (EU), two major EU water management policies were retained in the UK:

- The **Water Framework Directive (WFD)**[26] and its relevant daughter directives (Environmental Quality Standards Directive[§]/EQSD and the Groundwater Directive/GD[**]) aim to protect waterbodies and halt their deterioration in status, both in terms of the chemical and ecological water quality and in terms of water availability. The legislation covers surface waters (such as rivers and lakes), groundwaters, transitional bodies (such as estuaries) and coastal waters.
- The **Urban Wastewater Treatment Directive (UWWTD)**[27] sets standards for the collection, treatment and discharge of wastewater from urban sources and specific industries.

In the UK, water policy is devolved, and each nation is responsible for implementing and managing its own plans to deliver protection to the water environment under the UK WFD (Table 1). When the UK was part of the EU, the UK government and devolved nations were required to comply with EU law. This ensured coherence across different policy areas, establishing a broadly uniform approach across all four nations in the UK.

Table 1. How water policy is regulated across the UK.

Country	Key regulators	Ownership/responsibility	Relevant policies/strategies
England	Environment Agency Water Services Regulation Authority (Ofwat) Drinking Water Inspectorate	Privatised – water companies are responsible for water supply and treatment	Clean water is a key aim in the 25-Year Environment Plan (2023) Water is a priority area under the Environment Act (2021) Draft River Basin Management Plans (2021/22)
Wales	Natural Resources Wales Water Services Regulation Authority (Ofwat) Drinking Water Inspectorate	Not-for-profit company – Welsh Water is responsible for water supply and treatment	Water Strategy for Wales (2015) Well-being of Future Generations Act 2015 and the Environment (Wales) Act 2016
Scotland	Scottish Environment Protection Agency Drinking Water Quality Regulator (DWQR)	Public body – Scottish Water is responsible for water supply and treatment	Water is an element in the Environment Strategy to 2045 River Basin Management Plan for Scotland 2021-2027

[§] The EQSD sets Environmental Quality Standards (EQS) for priority substances in order to achieve good chemical status. EQS are limits on substances that present a risk to the aquatic environment.
[**] The GD provides detailed measures for meeting the WFD's objectives for groundwater quality.

Northern Ireland	Northern Ireland Environment Agency's Water Management Unit Drinking Water Inspectorate	Public body – Northern Ireland Water is responsible for water supply and treatment	Sustainable Water 2015-2040 Living With Water Programme Northern Ireland Water's Strategy 2021-2046

Whilst the WFD and UWWTD in their original form were retained in the UK following its exit from the EU, these two major water policies are currently undergoing review and potential reformation in 2024 in the EU.[28,29] Included in the suite of proposed changes are actions recognising that current legislation is not protective enough against CECs entering the environment. Suggested amendments have included greater monitoring of CECs in surface waters, groundwaters and in effluents and sludge, along with additional levels of treatment in WWTPs to remove a broad spectrum of micropollutants. As the UK is no longer within the EU, they are not required to implement these changes.

Furthermore, an EU Watch List was established in 2015[30] to improve information to highlight substances of concern, with EU Member States required to monitor substances annually and report results to the European Commission. This list is updated every two years, with the most recent update occurring in 2022.[31] The UK is required to monitor chemicals that are under the EU watchlist when they were a part of the EU, but do not need to monitor any new ones that get added to subsequent updates. Furthermore, as the EU Watch List process for setting environmental quality standards no longer applies in the UK, a new process for setting new standards is also required.

Each UK nation is now free to diverge from the WFD, yet the Windsor Framework[32] mandates that Northern Ireland also complies with the urban wastewater treatment amendments that apply to the Republic of Ireland. These new dynamics may lead to significant differences in scale, scope and frequency of CEC monitoring between UK nations and between the UK and the EU, making long-term trends in the dispersion of environmentally mobile contaminants much more challenging to capture and respond to in an evidence-informed way.

Looking forward

Water policy in the UK risks being too narrowly focused. Water companies are rightly receiving increasing scrutiny and significant public attention in the UK due to storm overflows, which do contribute to the deterioration of our water bodies. However, poor chemical quality of water bodies is due to multiple sources as previously touched upon, including agriculture, industrial emissions, waste emissions (e.g. landfill), wastewater, military activities, mining and transport.

The Office for Environmental Protection (OEP) recently highlighted insufficient investment in measures to address all major pressures influencing the water environment in England.[33] Whilst significant investment is expected to tackle sewage overflows, other sources of pollution (e.g. agriculture, manufacturing and road run-off) are not receiving the required amount of attention and resources.

The UK, with its world-leading expertise and research in aquatic pollution, should take opportunities to expand existing programmes to encompass a broader range of pollution sources. This could lead to innovation-led interventions and promotion of non-technological solutions, to support cleaner water in the UK. Tackling sewage overflows will not alone achieve clean water. Other pollution sources must be scrutinised and held accountable to the same extent as water companies. Much greater effort is needed to understand, and provide solutions to stop or at least significantly curb, CEC pollution before it reaches water bodies in the first place.

So what are the solutions?

The sources of CECs in waterbodies are diverse and complex, often covering multiple stakeholders. Once contaminants enter surface waters or groundwaters they are challenging to remove. Therefore, concerted action across four key areas is required to stem the tide of CECs before entering the environment.

1. Comprehensive and resilient monitoring strategies

Importance of monitoring strategies

Effective monitoring strategies that are well-established and standardised are essential for effective management of CECs. Monitoring must be both spatial and temporal to help us understand the scale of the problem and build up baselines. Such baselines play a pivotal role in determining trends of CECs and allow for any interventions to reduce environmental concentrations to be evaluated.

Monitoring is also key for identifying pressures on waterbodies and potential hotspots for prioritisation. Moreover, by providing accurate and comprehensive data on the presence and behaviour of CECs, monitoring data can contribute to a deeper understanding of environmental fate and transport mechanisms. This knowledge is critical for developing predictive models and risk assessment frameworks, which, in turn, inform the design of more effective water treatment technologies and pollution control measures.

Key features of monitoring strategies

Effective monitoring strategies, however, can be costly, so an efficient strategy is essential. This includes establishing sentinel sites (e.g., using sensors or passive samplers[34,35]) and developing scalable analytical methods that enable comprehensive chemical profiling.[36,37] Importantly, monitoring devices should be made from materials that avoid introducing CEC contamination into the environment they are designed to monitor.

Other complimentary approaches include knowledge, perspectives and measurements from citizen science projects.[††] However, for programmes that engage the general public to design and assist with monitoring environmental pollution, quality assurance is critical. It is recommended that scientific experts and regulators engage formally with such programmes to ensure two-way knowledge transfer and adequate training.

Additionally, key to resilient monitoring strategies is the ability to adapt methods to detect new and emerging contaminants of concern. Whilst high sensitivity can be achieved with targeted analytical methods, these methods will only allow for the identification of specific and predefined targets. Untargeted and suspect screening-type methods can allow a broader detection of compounds, for example, untargeted screening can be used to identify unknown compounds. Untargeted and suspect screening-type methods therefore can be used as an early-warning platform to inform targeted analysis for chemicals requiring prioritised action and to support their evolving scope.

Another benefit of untargeted and suspect screening methods is the ability to re-analyse the data retrospectively, allowing the analysis of new compounds/targets at a later date. In some countries, environmental samples biobanks such as Germany's Umweltprobenbank des Bundes[‡‡] (the Federal Environmental Specimen Bank) not only store samples but also facilitate retrospective analysis.[38]

This flexibility is particularly important when novel or 'replacement' chemicals are introduced to the market. Effective and adaptive monitoring can establish a strong evidence base, crucial for identifying

[††] For example, see recent work from the Great UK WaterBlitz (https://earthwatch.org.uk/greatukwaterblitz/)
[‡‡] https://www.umweltprobenbank.de/en

regrettable substitutions or potential 'greenwashing.' Such insights can inform both environmental and chemical policies, ensuring timely and effective interventions. It is virtually impossible to reliably assess water quality with targeted chemical analyses only.

Furthermore, ensuring transparent monitoring strategies that promote open data can foster accountability and trust, while also enabling collaboration and data sharing across different sectors. Advances in digital technologies, including a growth of artificial intelligence combined with robust sensors, can offer promising opportunities for water monitoring.[39]

Holistic approach to monitoring

Further expanding the scope of monitoring programmes to include analysis of other environmental samples (including sediments, soils, and air) can provide key information on the fate and pathways of CECs. Analysis of CECs in biota (such as in wildlife) or biomonitoring in humans (for example analysis in blood, body tissue, human milk) can provide information on exposure, persistence and bioaccumulation effects.

Other innovative approaches that can assess exposure to pollution is wastewater-based epidemiology (WBE). This technique analyses chemical and biological makers in wastewater to assess the health and exposure levels of populations to pollution and other environmental factors.[40] This technique is complimentary to human biomonitoring techniques, and can be used to assess exposure to pollution, including pesticides, flame retardants and plasticisers.[41,42]

Importantly, consistency, harmonisation and transparency in data collection are essential for drawing reliable conclusions, which can allow targeted policy formulation and implementation. Moreover, gathering monitoring data serves compliance purposes, and can be used to hold regulators accountable. Having comprehensive monitoring data can aid in ensuring that regulatory frameworks remain up-to-date and relevant in the face of evolving environmental challenges. A critical enabler of these monitoring strategies and ensuring transfer of information from academia and industry to policymakers, is the funding of infrastructure for the analysis and monitoring. Notably, the UK Government has recently provided significant funding of £49 million to strengthen mass spectrometry facilities in the UK.[43]

2. Risk assessment and management

As well as understanding the scale of CECs in the environment, it is critical to understand their impacts to both human and environmental health. This can be informed via risk assessments, which take into consideration of hazards and exposure assessment to determine the potential risks posed by chemical substances can be determined. A key feature of current risk assessments is the consideration of the vulnerabilities of certain sub-populations (such as infants and children, the elderly and those with pre-existing medical conditions).[44]

Understanding the fate and impact of CECs in the environment should underpin policy, through informing acceptable guideline limits or highlighting areas where regulatory restriction of chemicals might be required. Additionally, understanding the risk and hazards that certain CECs pose can help inform monitoring priorities

However, due to the broad and diverse variation in characteristics and physiochemical properties of CECs, it can be challenging to make general predictions about behaviour and impact in the environment.[45] Furthermore, CECs rarely exist in isolation in the environment, instead they occur in complex mixtures which could cause synergistic or cumulative effects. However, traditional risk assessments tend to focus on individual chemicals, with toxicity data generated from individual chemicals being used to predict overall mixture toxicity.[46]

To address the uncertainty on how mixtures can impact the environment and human health, improved risk assessments that can assess the hazards of mixtures and the total exposure of those mixtures are key research areas. This, however, is not without challenges due to the diversity of mixtures in the environment that can be constantly changing.

Furthermore, it is not just the parent chemicals themselves, but transformation products (including metabolites) that can cause adverse effects. In some cases, transformation products can be more persistent and have greater toxicity than the corresponding parent chemicals.[47] For example, transformation products of the anti-epileptic drug carbamazepine, have been found more toxic than carbamazepine itself.[48]

Risk assessment approaches may need to be improved to consider potential effects in both ecosystems and humans following inadvertent chronic exposure to low levels of CECs in water. This is particularly pertinent in the case of contaminants emerging as a particular threat. Having a strong link between the scientific community and policymakers can allow problems to be identified and early action to be taken.

The EU project PARC[49] (the Partnership for Assessment of Risks from Chemicals) in which the UK participates is one initiative aimed at developing next generation chemical risks assessments to protect human health and the environment. PARC's work can be split into four areas: risk assessment (including monitoring and hazard assessment), tools and resources, building capacities and science to policy.

Innovative approaches in toxicology

The likely presence of a complex mixture of CECs in water also emphasises the need for a bioanalytical health-related approach to evaluate water safety. Effect-Based Methods (EBMs) are currently used globally to monitor biological effects of chemical pollution in surface waters provide an example of one, or illustrate what a battery of such tests might look like or achieve. The EU-funded project Solution[50] provided a policy briefing in which it recommended estimating biological effects with EBMs complemented by chemical screening and/or impact modelling to identify the causes of impacted water quality. These methods were recommended for WFD monitoring to cover the major modes of action of chemicals to evaluate improvements of water quality. [51,52]

Regarding chemicals risk assessment, New Approach Methodologies (NAMs) are a promising and rapidly developing area that could enhance the prioritisation of contaminants of concern for environmental monitoring (Box 1).

Box 1 – New approach methodologies for next generation risk assessments of chemicals

New approach methodologies (NAMs) are defined as any technology, methodology, approach, or combination that can provide information on chemical hazard and risk assessment, and avoid the use of animals, and may include in silico, in chemico, in vitro, and ex vivo approaches.[53,54]

These methods could provide a number of benefits, including the ability to screen a large number of chemicals more efficiently than traditional approaches, provide evidence for assessing chemical risks of groups of substances, and they can also help tackle the 3Rs in animal testing (Replacement, Reduction and Refinement). Furthermore, NAMs could provide valuable insight in the prioritisation process of which CECs to monitor in the environment.

However, NAM's are an emerging area of applied science, and increased confidence in new tools is essential to transitioning to next generation chemical risk assessments.[55,56] Key to achieving this is multisectoral engagement and continued support from the scientific, industry and regulatory communities and decision-makers in government to provide R&D funding in these areas.[57,58] The EU's PARC project is an area of investment where these approaches are being further developed.[49]

3. Tackling sources of pollution

Preventing CECs entering waters at source is essential for safeguarding both environment and human health, proactively mitigating the risks of pollution. This can be driven through a combination of research and innovation and policy interventions. Embracing a preventative approach aligns with principles of sustainability and the precautionary principle[§§], promoting the long-term health and resilience of ecosystems while supporting global efforts towards sustainable development.

End-of-pipe solutions

Point sources of pollution, which by definition are limited to a discrete location, offer the opportunity to apply appropriate processes to prevent CECs from entering water bodies. For example, effluent streams from both industrial activity and WWTPs provide opportunities for further treatment (such as advanced oxidation processes and activated carbon approaches).[53]

Whilst additional layers of treatment can be expensive, extended producer responsibility can play a key role here. The proposed update to the EU UWWTD includes additional levels of wastewater treatment to remove the broadest spectrum of micropollutants from wastewater streams, with extended producer responsibility[***] playing a key role to fund extra treatment. As it has been estimated that 92% of the toxic pollutants in wastewater come from the cosmetics and pharmaceutical industry, both these sectors will contribute at least 80% of the cost for this additional treatment.[54]

An example of a country already moving towards additional wastewater treatment targeting wastewater treatment, the Water Protection Act in Switzerland was revised in 2016 and requires WWTPs to be upgraded over the next 20 years to remove micropollutants.[55] Whilst a smaller country in comparison to the UK with only around 100 WWTPs are to be upgraded, this could still provide valuable lessons in upgrading WWTPs and implementing additional treatment technologies.

Alongside treated effluent, sewage overflows also discharge storm runoff, which contains a high concentration of contaminants. Although much public attention has focused on sewage overflows, various engineering solutions are being explored to alleviate the pressure on sewage systems during extreme weather events. These projects, such as the Thames Tideway Tunnel[†††], include the addition of extra storage capacity. However, the effectiveness of these interventions is not yet fully understood, and further monitoring is needed to evaluate their success before additional investments or infrastructure changes are undertaken.

At-source solutions: responsible innovation and use

At-source solutions are strategies that promote more proactive prevention or reduction of pollution before it reaches the environment. This can include ensuring sustainable chemical regulation, such as through REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals).[56] This legislation aims to improve the protection of human health and the environment from the risks that can be posed by chemicals.

[§§] The precautionary principle is thereby defined as where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

[***] Extended producer responsibility is defined by the OECD as "*as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle*".

[†††] A 25 km combined sewer, aimed to capture the storm run-off and store before treating and being discharged (https://tideway.london/the-tunnel)

Similar to water legislation in the UK, UK REACH was established following the UK's exit from the EU and UK has been developing a wider UK Chemicals Strategy.[57] Due to uncertainties and delays around chemicals regulation in the UK, the RSC has called for a dedicated National Chemicals Agency (Box 2).

Box 2 – A case for a National Chemicals Agency

The RSC has been calling for the UK Government to establish a national Chemicals Agency following the UK's departure from the EU.[64] Such an agency could provide a coordinated, centralised and systems-thinking approach to the management of chemicals in the UK. A National Chemicals Agency could:

- Protect human health and the environment against both short- and longer-term risks across the life cycle of chemicals.
- Drive innovation and economic growth by giving businesses and researchers clarity over what is required of them, adapting promptly to new developments in testing and risk mitigation, and facilitating international trade agreements.
- Deliver taxpayer value for money by maximising coordination across government, with a well-resourced and skilled staff, to deliver a 'one substance, one assessment' approach.

This new agency would bring increased confidence in chemicals regulation for both industry and society, and it could impact positively on the ability to secure trade agreements and foster international collaborations. Furthermore, in the case of CECs, a Chemicals Agency could also aid in informing the prioritisation of which CECs to monitor in the environment.

Furthermore, at-source strategies include ensuring responsible innovation and use. Industries have a responsibility for ensuring sustainable innovation, and ensuring products are safe and sustainable by design (e.g. use of non-hazardous chemicals, materials and products). Additionally, industries should be accountable for the full lifecycle of their products, including effective waste management under extended producer responsibility.

By minimising or avoiding the use of hazardous chemicals in products, the release of CECs from both point sources and diffuse sources of pollution can be reduced. This is especially critical for diffuse pollution, such as run-off from land and atmospheric deposition of contaminants, where it can be challenging to pinpoint sources and there are limited opportunities for 'end-of-pipe' type treatment.

For example, although road run-off has been identified as a significant source of CECs into waters, it has historically received less attention than other sources of pollution (such as wastewater and agriculture) and as a result is often inadequately addressed. Currently, no regulation exists on the wear rate of tyres and reportedly there is little regulation on the chemicals these tyres can contain. Emerging research, however, is indicating alarming trends. For instance, the chemical 6PPD (a rubber preservative in tyres) is transformed to 6PPD-quinone in the environment, which has been linked to mass deaths of salmon in the US.[58] Additionally, tyre wear has been identified as one of the most significant sources of microplastics in coasts and oceans.[59]

Addressing the issue of CECs in diffuse pollution, including urban and agricultural run-off, is particularly challenging due to the diversity of both pollution sources and the chemicals involved. Identifying and addressing diffuse sources of contamination can be complex, and can be challenging to assign who is responsible. Therefore, collaboration among various stakeholders to develop effective strategies and multifaced policy actions to mitigate the impacts and to ensure the protection of water is required.

A comprehensive evidence base on the presence of these contaminants in the environment and the risks they pose is key to designing effective interventions and policies to tackle sources of CECs. Effective and adaptive monitoring strategies on catchments can aid in identifying the most significant sources of pollution, and to prioritise interventions where they are most needed. This targeted, evidence-led approach ensures that resources are allocated effectively by focusing on the most critical pollution sources. Whilst this is unlikely to stop all chemicals from entering the environment due to the nature and purpose of them, ensuring that CECs likely to end up in the environment cause only minimal harm is essential.

Non-technological solutions

There are also alternative non-technological at-source solutions to address both point and diffuse sources of pollution, such as interventions aimed to reduce chemical usage in everyday life. Responsible use can also be extended to the general public, as consumer demand and behaviour can drive chemical and product use, which in turn can influence the levels of CECs in the environment. Non-technological solutions could therefore include educational and public-facing campaigns to raise awareness of the environmental impacts.

For example, in the context of pharmaceuticals, desirable behaviours could include avoiding incorrect disposal of un-used medicines down the drain[60], promoting vaccines to prevent diseases where vaccines are available, thus reducing the need for certain medications, or could include practices, where appropriate, such as green or social prescribing[‡‡‡].

Additionally, targeted engagement efforts could play a key role in addressing issues related to market repositioning, where products banned in one sector find new markets, remaining in use despite their risks. A relevant example is the parasiticide imidacloprid, which, whilst banned for use in agriculture due to its high environmental toxicity, is still used routinely in flea and tick treatments in the UK. Extensive and preventative use of such treatments on pets (often all year round) has resulted in concerningly high levels of the parasiticide in UK waters.[61] This could provide opportunities for engagement and raising awareness with pet owners and the veterinary industry of the importance of moving from year-round over-the-counter or prescribed preventative treatment to risk-based or reactive treatment instead.

Due to the diversity of both pollution sources and the number of contaminants involved, it is essential to combine non-technological solutions with technological interventions. Non-technological approaches, such as public engagement and behaviour change campaigns, help prevent contaminants from entering the environment, which complements technological solutions (e.g. treatment and removal). Additionally, engaging the public enhances compliance with regulations, ensuring policies are more effective. By working in partnership and integrating these diverse approaches, a comprehensive, adaptive, and inclusive framework for protecting water quality and environmental health can be enabled.

4. Global collaboration

Pollution, including chemical pollution, is one of the largest environmental causes of disease and death in the world today, yet exposure to pollution is not equal, and disproportionately impacts lower socioeconomic groups in all countries.[62,63,64] Furthermore, of the 9 million premature deaths that occur globally from pollution, more than 90% of these occurred in low-income and middle-income countries.[41]

Once contaminants enter the environment, they can be mobile and travel far away from the original pollution source. Persistent contaminants can undergo long-range transboundary movement through air or water. This transboundary nature of pollution makes it a global issue, with contamination reported in

[‡‡‡] The NHS definition of green or social prescribing is "*the practice of supporting people to engage in nature-based interventions and activities to improve their mental and physical health*" https://www.england.nhs.uk/personalisedcare/social-prescribing/green-social-prescribing/

some of the more remote places on Earth, such as the polar regions.[65,66] Additionally, the interconnected nature of global health poses problems for AMR, as resistant pathogens can spread very quickly.

Whilst pollution is a global issue, data coverage on chemical pollution in low- and middle-income countries, however, is inadequate, with often a limited understanding of the severity and scope of the issue.[2] A lack of data and limited resources pose significant challenges in setting priorities for monitoring and regulation. Hence, fostering collaboration between international organisations, governments, and research institutions is critical to address transboundary issues related to CECs. This could include sharing expertise, best practices, data, and infrastructure to enhance global efforts to address emerging contaminant challenges.

Due to the threat posed by chemical pollution globally, a new independent science-policy panel is being established to provide policymakers with robust and evidence-based information on chemicals (Box 3).[67,68]

Box 3 – United Nations Science-Policy Panel on Chemicals, Waste and Pollution Prevention

Due to the severity of the threat that pollution poses risks to both human health and the environment, it has been identified as one of the triple planetary crises, alongside climate change and biodiversity loss.[76] In February 2022, the United Nations Environmental Assembly passed a resolution for the establishment of a science-policy panel to contribute to the sound management of chemicals and waste to prevent pollution.[77] This global panel puts chemical pollution on an equal footing with climate change and biodiversity and will join the UN intergovernmental panel for climate change (IPCC) and the intergovernmental panel for biodiversity loss (IPBES).

The RSC has played a key role in advocating for the establishment of this panel and has been working with global partners to participate in the UN processes to make it a reality, keeping this vital issue of chemical pollution and waste on the agenda at every step.[78]

The sound management of chemicals is key for reducing chemical pollution in the environment. Whilst scope and priorities are still being assessed, the activities of this panel can support the Sustainable Development Goals, of which two are key for protection of water sources, SDG 6: Clean Water and Sanitation and SDG 14: Life Below Water.[79]

Our asks to government in detail

Urgent and concerted action is required now to protect our water bodies, and by extension, the environment and human health from CECs. The challenge of CEC pollution is exacerbated by other global trends. For instance, higher demand for food due to continued population growth may prompt increased pesticide usage, while aging populations will lead to increased pharmaceutical use. Additionally, climate change will also continue to exacerbate the pressure from CECs, as extreme weather events like flooding and droughts have the potential to magnify these existing issues.[75]

Furthermore, we know from efforts to control the use of persistent chemicals that it can take many years for the impacts on the environment to reduce. For example, for legacy pollutants PCBs, studies have found frequent occurrence of PCBs in whales and dolphins found in UK waters.[69] One study found that, although these chemicals were banned decades ago, their concentrations still exceeded estimated toxic thresholds in most samples. Importantly, whilst this position covers contaminants that are ‘emerging’, any efforts to tackle CECs should complement efforts on legacy or established pollutants, and not come at their expense.

Our governments and regulators must:

1. **Implement effective, comprehensive and resilient monitoring strategies to identify and monitor trends in CEC occurrence in water, and also in humans, wildlife, air, sediments, and soil.** Monitoring should begin now and continue over the years ahead to determine long-term trends and to provide information on the evolving fate of CECs.

2. **Ensure monitoring programmes are adequately resourced and there is a harmonised approach within the UK.** Whilst water policy is devolved in the UK, where possible some degree of harmonisation in monitoring (e.g., standardised methods, CECs in scope) should be done to avoid loss of long-term spatial data sets.

3. **Implement improved risk assessments that assess the biological impact that chemical mixtures can have on ecosystems and human health.** Such methods could include effect-based methods, e.g. techniques that can measure the effects of chemical mixtures on organisms and/or cells and importantly also including New Approach Methodologies (NAMs).

4. **Implement a stronger 'polluter pays' principle by making additional treatment to remove CECs from urban wastewater mandatory.** This could follow similar proposed changes to the Urban Wastewater Treatment Directive at the EU level, and be funded via extended producer responsibility of major polluters of CECs (e.g. industries that produce or use problematic CECs) in wastewater streams.

5. **Commit to tackling the other major diffuse sources of CECs in waterbodies, such as pollution from road run-off, waste emissions and agriculture.** Whilst water companies in the UK are rightfully under increasing pressure due to sewage overflows, CECs enter waterways via many different sources. These sources must be held to the same level of scrutiny as water companies. Greater concerted action across all sectors is needed to provide solutions to stop or at least significantly curb, chemical pollution.

6. **Promote responsible innovation and use in industry to ensure clean and sustainable water, including**

    - Incorporating safe and sustainable-by-design principles and ensuring the development of less hazardous chemicals, products or processes.

    - Both novel technologies to remove CECs from water streams and nature-driven solutions (e.g. constructed wetlands and sustainable drainage schemes).

    - Development of sustainable, scalable and robust water samplers and sensors, including point-of-use technology which can be utilised for on-site data collection and analysis.

7. **Promote non-technological solutions and to raise awareness in the public to achieve clean and sustainable water. This includes:**

    - Promotion of 'at source' solutions, such as reduction of use of pharmaceuticals at community level (e.g. promotion of disease prevention initiatives) or raising awareness of the proper routes to medicine disposal.

8. **Commit resource to ambitious programmes to enhance global collaboration and to enable the UK to provide support for surveillance programmes of CECs**. By actively engaging in international collaboration, the UK can share global expertise and data. Exposure to pollution globally is not equal and disproportionately impacts lower socioeconomic groups. The support of global surveillance programmes can inform regulatory measures to mitigate pollution threats, especially for those most at risk of hazardous exposure.

Contact

The Royal Society of Chemistry would be happy to discuss any of the issues raised in this position statement in more detail. Any questions should be directed to **policy@rsc.org**.

About us

With over 60,000 members in over 100 countries and a knowledge business that spans the globe, the Royal Society of Chemistry (RSC) is the UK's professional body for chemical scientists, supporting and representing our members and bringing together chemical scientists from all over the world. Our members include those working in large multinational companies and small to medium enterprises, researchers and students in universities, teachers and regulators.

There are numerous ways in which chemical scientists are working towards a sustainable, clean and healthy planet, and this position statement is part of The Royal Society of Chemistry's contribution to do so. It was developed by Dr Natalie Sims (Policy Adviser, RSC) and draws on a broad range of evidence and inputs from chemical scientists working on the issues, including members of the RSC Water Science Forum. We are particularly grateful for the expert review provided by Professor Barbara Kasprzyk-Hordern (University of Bath), Professor Fiona Regan (Dublin City University), Dr Leon Barron (King's College London), Professor Tamara Galloway (University of Exeter), Professor Juliane Hollender (Swiss Federal Institute of Aquatic Science and Technology), Dr David Megson (Manchester Metropolitan University), Dr Sarah Bull (TARA Consulting), Dr Martin Rose (JFECS) and Dr Zoë Ayres (President of the RSC Analytical Community and The Open University).

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