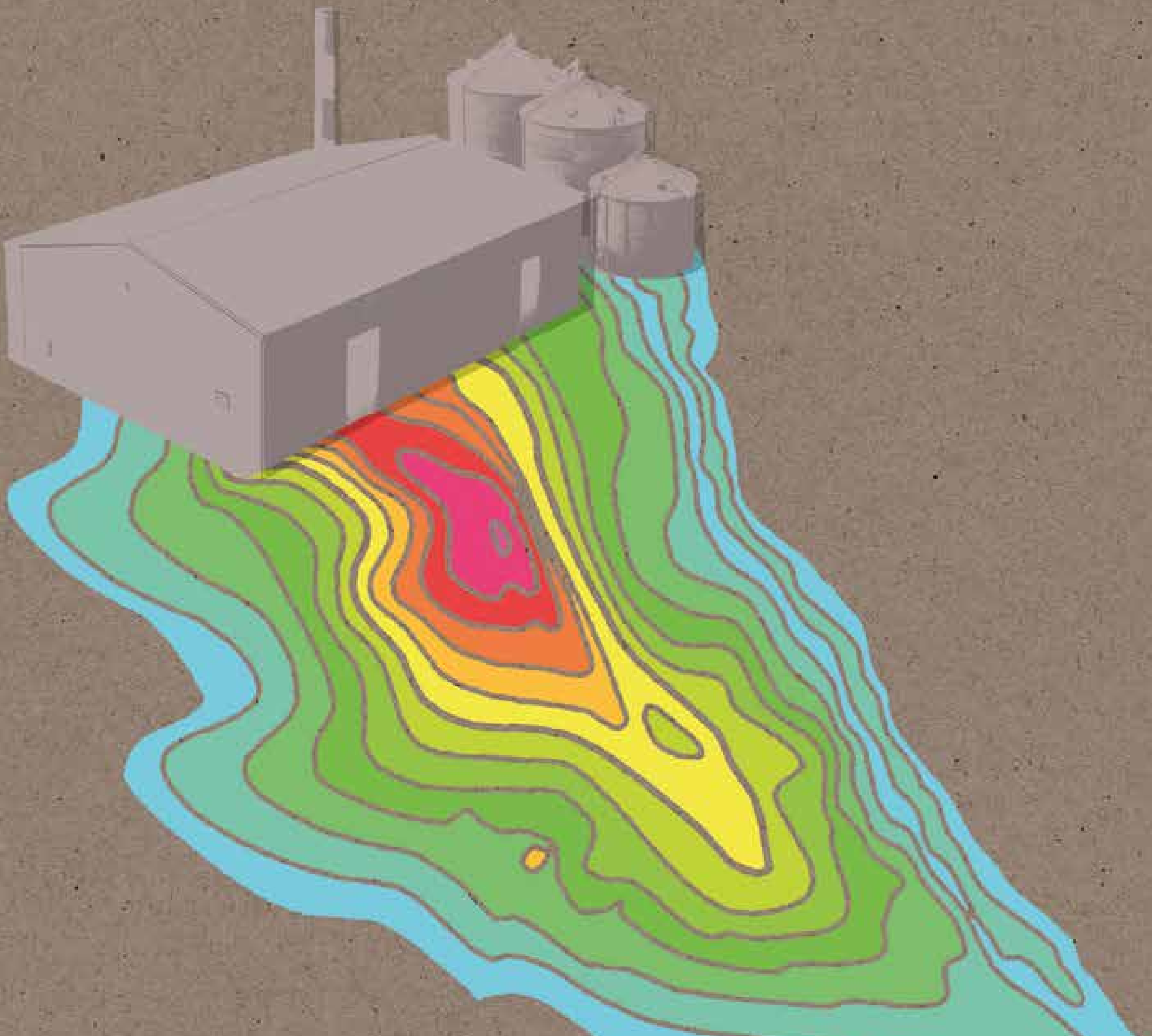
environmental SCIENTIST

June 2023
Journal of the Institution
of Environmental Sciences



Unearthing Global Megatrends in Land Condition

EDITORIAL

How global megatrends can make positive changes to the land condition community

No profession operates in a vacuum. The environmental sector has been and continues to be shaped by the world around it, and the same will be true in the future. It makes sense, then, that we pay attention to emerging trends and drivers for change. This edition of the environmental SCIENTIST explores how the global megatrends (GMTs), as identified by the European Environment Agency (EEA), influence the work of the land condition community and how we should be developing our approaches to accommodate the momentous changes that are happening around us.

The EEA defines GMTs as 'global, long-term trends that are slow to form but have a major impact once in place'.[1] Never before in our lifetime has the influence of external forces had such dominance on how we work and live, including in the UK. Economic isolation, political upheaval and resource scarcity have led to price increases that challenge the affordability of regenerating derelict and underused land, resulting in 'cheaper' greenfield land being sacrificed to address other economic needs such as housing and economic growth. Such short-term commercial activities run counter to the ethos of sustainable development.

GMTs are often interdependent social, economic, political, environmental or technological changes.[2] They require us to adapt our approach to incorporate systems thinking for a long-term strategic direction if we want to deliver the vision of the future we aspire to for all. We can no longer just assess ground conditions based on their geotechnical ability to bear foundations, or only characterise contamination sources. We also need to understand the whole picture if we are to ensure future soil health for flood alleviation, food security and carbon sequestration to combat climate change.

As a result of this edition, we hope that a discussion of GMTs can be viewed as a map of drivers that our community can use to adapt our practices to achieve a truly sustainable approach in which we learn to live within our planetary boundaries. It is evident from the wide range of articles that the land condition community has real capacity to deliver positive changes for human health and the built and natural environments. A key factor in how we achieve these outcomes will be driven by the competency of the community workforce.

To contribute meaningfully to sustainable development, the land condition sector must embrace new ways of working and thinking that include the GMT challenges. We hope this collection of articles highlights the impressive work currently being undertaken by our community and that it gently shifts our attention to embracing the challenges of the future.

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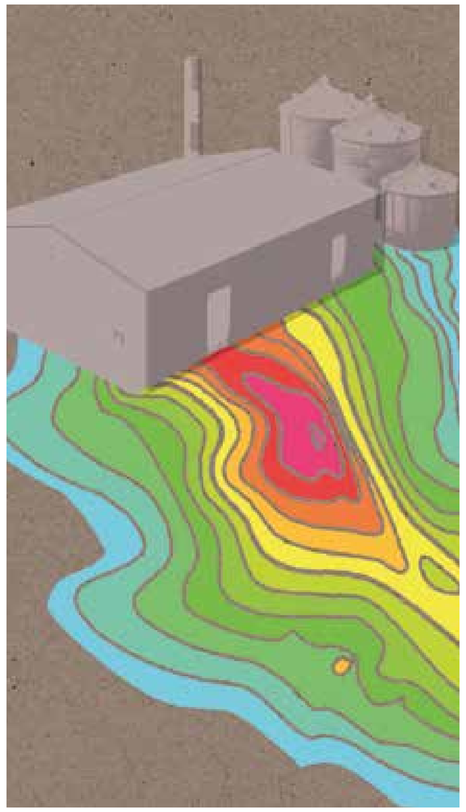

environmental SCIENTIST
The journal of the Institution of Environmental Sciences
Volume 33 No 2 | ISSN: 0966 8411

The environmental SCIENTIST provides a platform to discuss key issues within the environmental sciences, hosting original articles written by professionals, academics and experts working across the sector.

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INTRODUCTION


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Global drivers of change

Huw Williams offers a high-level review of these drivers and their implications for our world and way of life.

The future is inherently unknowable. Nonetheless, it is possible to identify several broad themes, or global megatrends (GMTs), that will have an impact in most possible futures. These drivers of change will interact in complex and unpredictable ways, so it is best to be flexible in our analysis of their implications for our daily lives.

Most futures consultancies and many public bodies maintain a list of what they consider the key drivers of change. The European Environment Agency's list consists of 11 GMTs (see **Figure 1**).[1] An alternative list of six global drivers has been prepared by SAMI Consulting (see **Figure 2**). Both are in use and continually monitored by the organisations.

POPULATION DYNAMICS

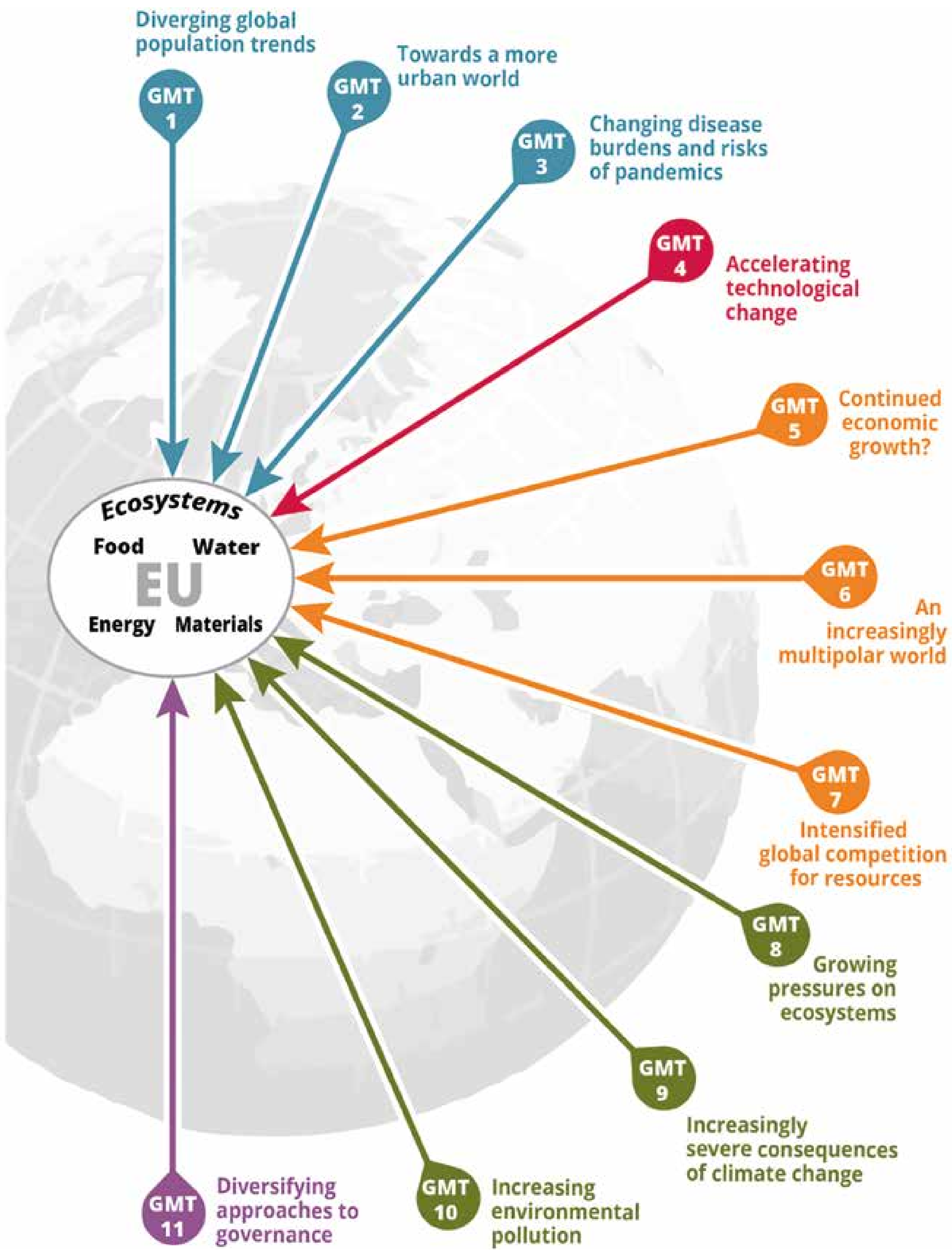
Historically, much concern has focused on population growth, although predictions are now more varied. A United Nations (UN) forecast in November 2022 put global population at 9.7 billion by 2050 and 10.4 billion by 2100.[3] Others, however, suggest the peak will come sooner:

- The Institute of Health Metrics and Evaluation suggests a peak in 2064 at around 9.7 billion people and a fall to 8.8 billion by 2100;[4] and
- The Club of Rome forecast lower growth, with a peak of 8.8 billion before 2050, declining rapidly to 7.3 billion by 2100.[5]

Diverging Global Population Trends (GMT1). This recognises that not all countries are affected in the same way. Low fertility rates in most advanced countries are falling below the replacement rate of 2.1: in South Korea it is just 0.9; in Hong Kong and Singapore it is 1.1; Spain is at 1.2; Italy is at 1.3; and the UK is at 1.57.[6,7] Population growth in India and China, meanwhile, is coming to an end. Dramatic declines in working-age populations are predicted in these countries, hampering economic growth and leading to shifts in global power. China's population peaked this year and India's is forecast to peak by 2070 (see **Figure 3**).[8] Only sub-Saharan Africa continues to show significant population growth by the end of the century.

The result is an ageing global population, with significant welfare and urban design and land-use implications. The challenges of a declining population are quite different from the growth patterns of recent years and we need to modify our social policies to respond to it. Populations in Western societies are only maintained by immigration: in the UK, for example, by 2040 deaths will outnumber births by over 90,000 per year, with a net immigration of 200,000.[6]

Towards a More Urban World (GMT2). Urbanisation is accelerating, and in 2007 the world passed the milestone of 50 per cent of the population living in urban areas.[9] Around 1 in 4 of those live in slums. By 2050, it is predicted that almost 70 per cent of people worldwide will live in cities. Most of that projected growth will occur in large cities, including new and existing megacities. Expanding cities not only have



▲ Figure 1. The European Environment Agency's 11 global megatrends. (© European Environment Agency[7])

problems of pollution, waste management, housing and transport, they also threaten to take over prime agricultural land worsening the impact on natural systems and biodiversity.[10]

The number of Africans living in urban areas keeps increasing and by 2050 that number could exceed 950 million.[11] In the UK, the urban population is now about 84 per cent. People are living longer, alone and in towns, so the built environment will need to adapt to provide for this urban population's changing needs.[12]

GEOPOLITICS

An Increasingly Multipolar World (GMT6). Demographic change also has implications for relative economic and political (and military) power, not to mention pressure on land. The USA's power is challenged by China's increasing economic strength, but the latter also faces internal pressures from its population dynamics and problems with the property market that could trigger a systemic collapse. The Ukraine war will have continued ramifications, and its impacts of rising energy prices and food scarcity have already been felt. Climate change is creating new opportunities for Russia with melting ice caps opening an Arctic route, and vast currently frozen tracts of land in Siberia are becoming agriculturally viable.

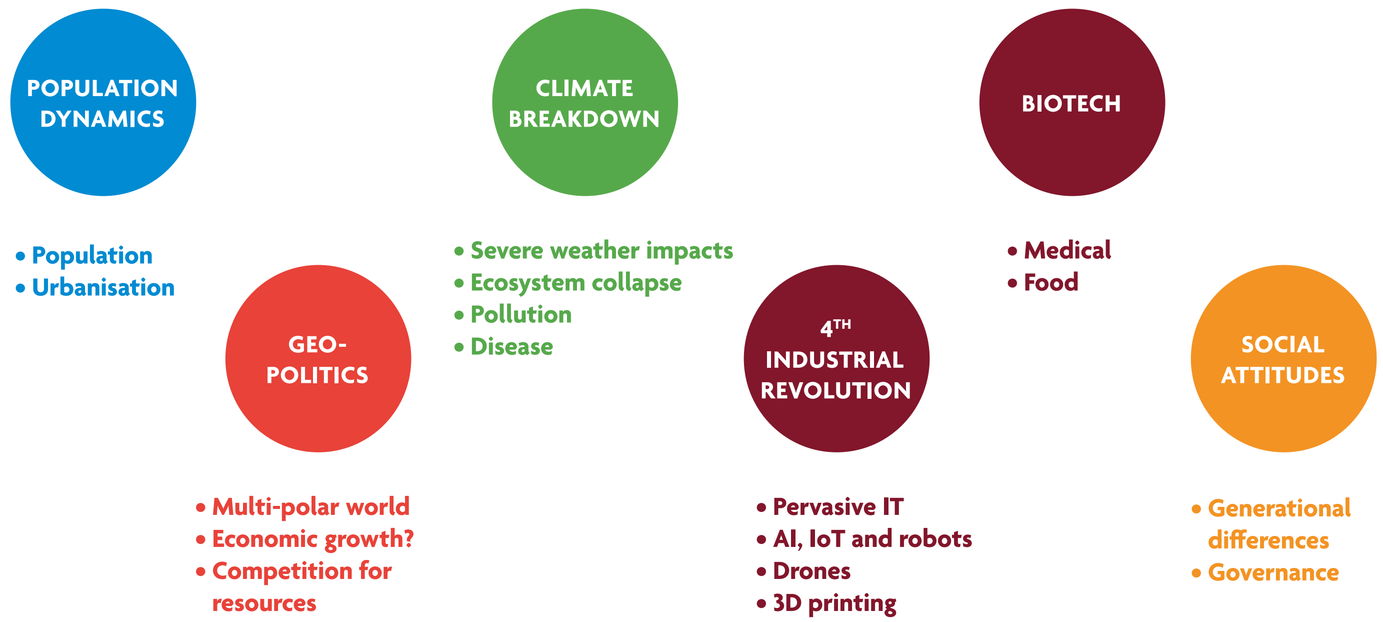
Diversifying Approaches to Governance (GMT11). In an increasingly multi-nodal world, the viability of global organisations like the World Health Organization (WHO) can be called into question. Challenges of global governance increase and new approaches are needed. The UK is not immune to changes in governance and legislative reform – Brexit is just one example, which could lead to divergent agricultural policies.

Continued Economic Growth? (GMT5) and Intensified Global Competition for Resources (GMT7). Rates of recovery in economic growth have varied around the world. Disruption to supply chains caused by geopolitical tensions and the Covid-19 pandemic is causing a rethink of resourcing and greater competition for resources. New technologies rely heavily on scarce metals and new mining activities have come under increasing criticism.

Inequality remains a major challenge. Although differences between countries are narrowing, we are seeing increasing inequality within countries. A recent Oxfam report demonstrates that the richest 1 per cent captured 63 per cent of all new wealth created between 2020 and 2021 (see **Figure 4**).[13]

CLIMATE AND OTHER ENVIRONMENTAL EMERGENCIES

Increasingly Severe Consequences of Climate Change (GMT9). There have been plenty of examples of extreme weather events in recent years, and their frequency and severity is increasing. In Wales, a coastal community is being abandoned to the sea, as the local council decides it can no longer defend it.[14]



▲ Figure 2. Six global drivers of change. (© SAMI Consulting)

No new 2030 climate targets have been announced since COP26 in Glasgow.[15] COP27 offered no further carbon emission commitments, focusing instead on an adaptation fund.[16] Analysis of emissions and expected warming indicates that keeping global warming to below the target of 1.5C is becoming highly unlikely (see **Figure 5**).[17]

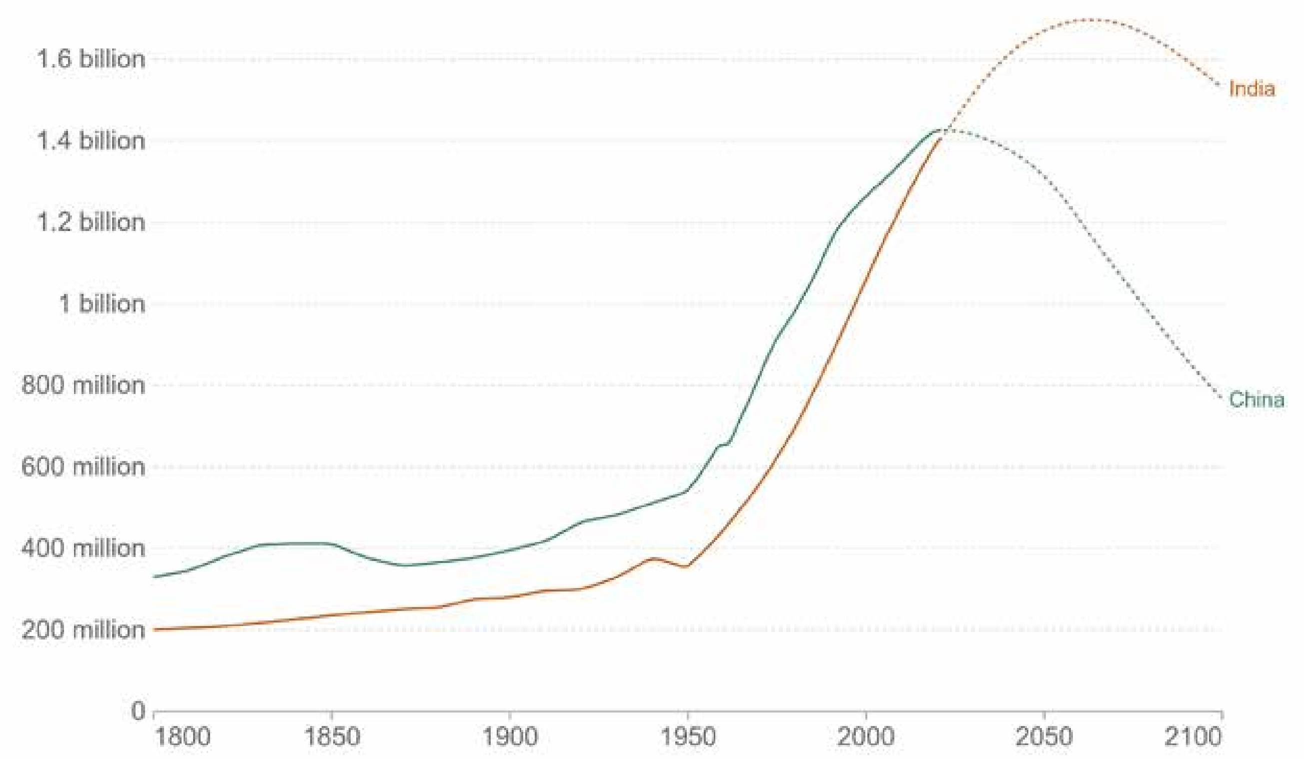
Accelerating Technological Change (GMT4). More positively, energy technology development is advancing rapidly. Solar is now the cheapest form of energy in most places;[18] wind power is also economic, so there should be market pressure towards phasing out fossil fuels. Battery technology and energy-storage initiatives are similarly improving, overcoming issues with intermittent power generation from renewables. However, there are still significant land-use implications associated with the development of these new technologies at scale.

Growing Pressures on Ecosystems (GMT8). Biodiversity is facing challenges on a global scale. The accelerating loss of species around the world is now referred to as the sixth mass extinction.[19] The Global Diversity Framework agreed at the UN Biodiversity Conference (COP15) in December 2022 aims for 30/30/30: 30 per cent of the planet and 30 per cent of degraded ecosystems coming under protection by 2030.[20]

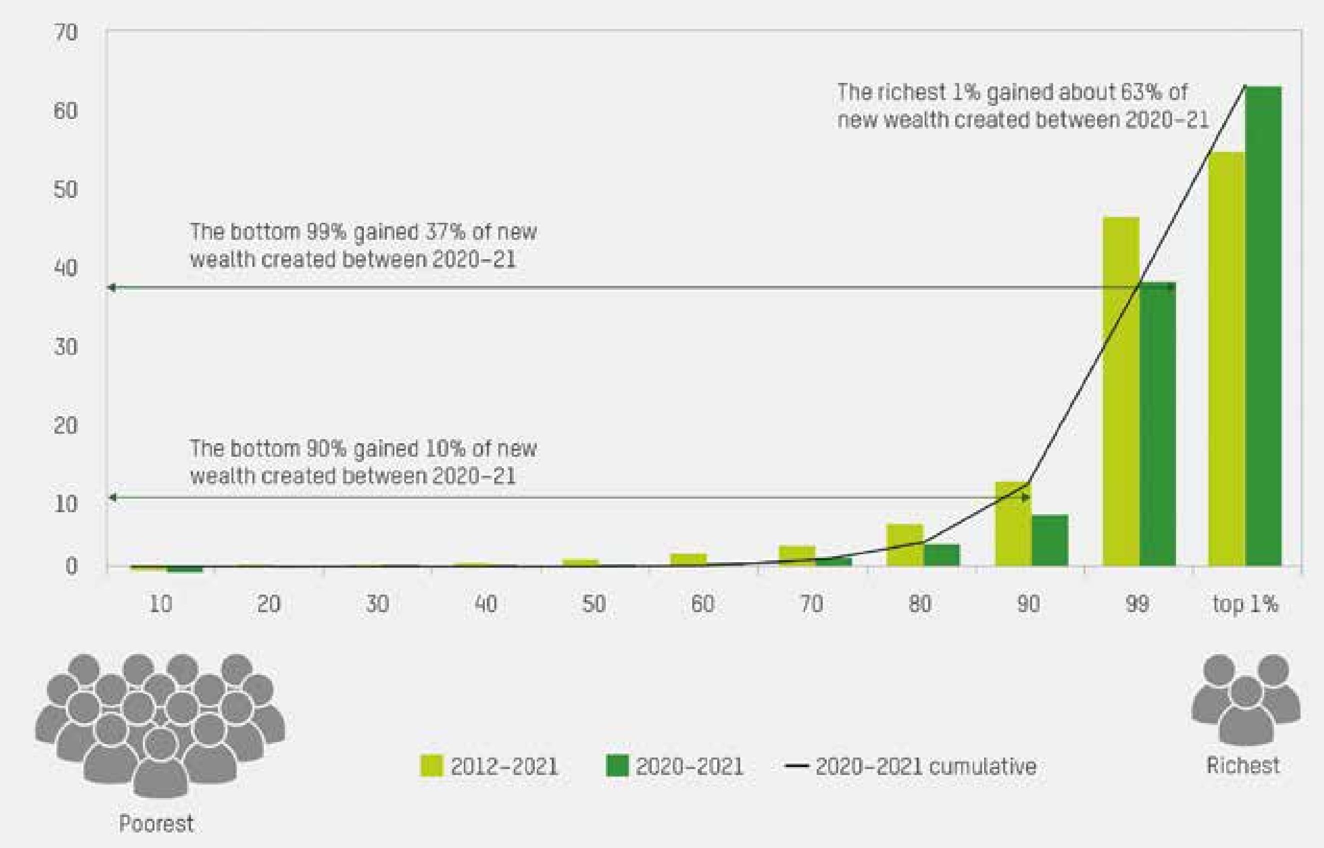
Increasing Environmental Pollution (GMT10). A related issue and another ecosystem challenge is global pollution, including:

- Air quality: In 2019, 99 per cent of the world's population was living in places where the WHO air quality guidelines were not met, causing 6.7 million premature deaths annually.[21]
- Rivers and seas: Nitrogen from agricultural runoff and phosphorus from households and industry are polluting rivers and seas. Around 99 per cent of the Baltic Sea and 53 per cent of the Black Sea are 'problem areas', though both are improving slowly due to recent efforts.[22]
- Soils: In Europe, 80 per cent of land pollution is attributed to agricultural activities; other causes are industrial activity, mining, urbanisation, waste disposal, construction and deforestation.[23]

Changing Disease Burdens and Risk of Pandemics (GMT3). Climate change and urbanisation are bringing humanity into contact with new pathogens.



▲ **Figure 3. Populations of India and China, including United Nations projections: 1800 to 2100. Future projections are based on the United Nations' medium-fertility scenario. (© Our World in Data[8])**



▲ **Figure 4. Share of wealth. (Source: Oxfam calculation based on Credit Suisse Global Wealth Report[13])**

Increasing antimicrobial resistance is becoming dangerous. Their effects are multiplied by ageing populations and inequality.

FOURTH INDUSTRIAL REVOLUTION

Accelerating Technological Change (GMT4). New technologies bring new opportunities and changing dynamics. There are two aspects to technological change that SAMI identify as important: a digital revolution and significant new biotechnology opportunities. The pandemic accelerated the trend towards pervasive information technology – online shopping, working from home, virtual meetings. Many changes in property use and transport systems are likely to continue. Advances in the fields of remote sensors (e.g. the Internet of Things), big-data analysis and machine learning reinforce each other.

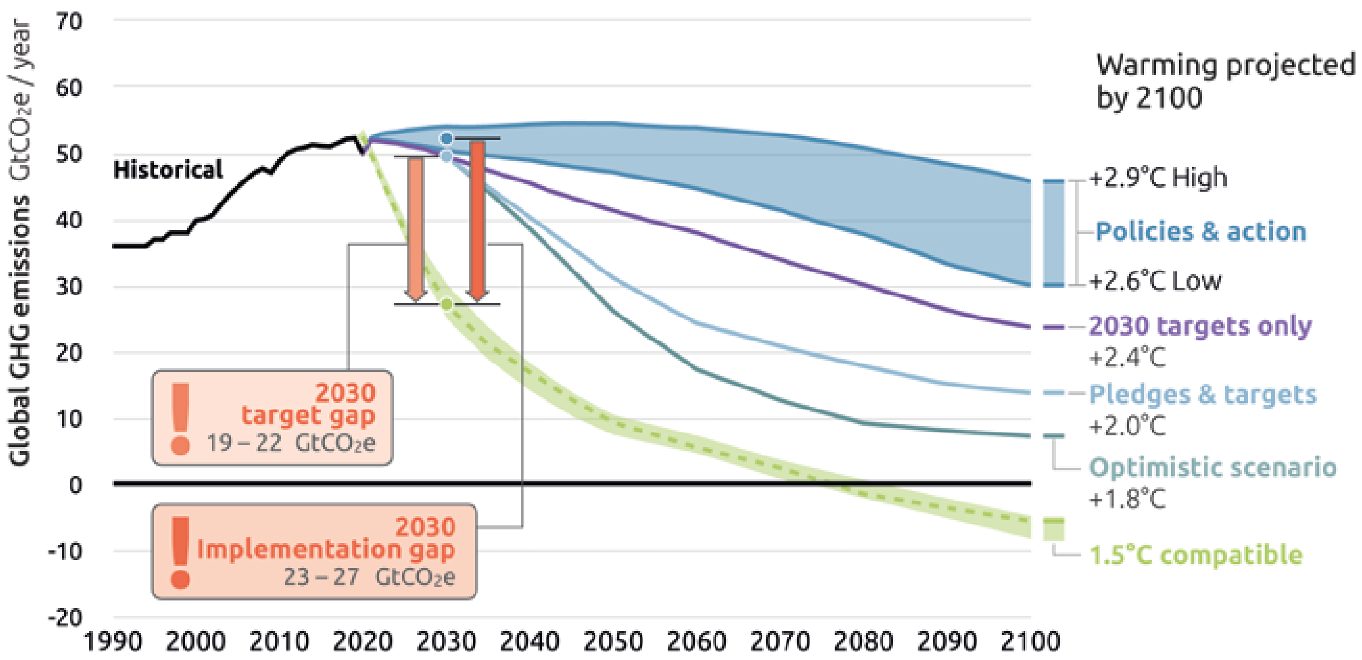
An example of this technological change in relation to land condition is precision agriculture, enabling more accurate irrigation and pesticide use. Other applications include survey drones, automated tractors, livestock equipped with sensors to track their movements and health, and above all more accurate data.[24] Scientists are working on automated weeding systems that can identify and eliminate a wider range of common weeds.[25] In Romania a 'smart forest' has been equipped with acoustic monitoring sensors and artificial intelligence technology to identify the sounds of chainsaws being used and send real-time alerts to rangers' mobile phones to prevent illegal logging.[26]

Agricultural applications of biotechnology are potentially huge. Many centre on improving resistance to drought, heat and pests – for example, making pigs resistant to African swine fever and sorghum resistant to the plant pest striga.[27]

SOCIAL ATTITUDES

Different generations bring changing views. Millennials value greater flexibility, appreciation, team collaboration, progression and career opportunities and, above all, a healthy work–life balance.[28] Climate change tops younger generations' list of vital challenges, with 41 per cent citing global warming as the most important issue facing the world.[29] Their idealism represents an opportunity for those campaigning for improved environmental conditions.

INTRODUCTION



▲ **Figure 5. Climate Action Tracker (November 2022) 2100 warming projections. Emissions and expected warming based on pledges and current policies. (© 2022 by Climate Analytics and NewClimate Institute. All rights reserved[17])**

IN CONCLUSION

Clearly, the many forces driving change in our world will have significant impacts on all our lives, on the environment, land use and societal motivation for action. The various threats and opportunities these changes present to the land condition community need to be thought through in some detail if the most positive outcomes are to be found for the:

- Different needs of an ageing population;
- Limitations to continued economic growth of a finite planet and the consequences of unequal distribution of wealth;
- Disruption caused by changing geopolitical dynamics;
- Threats emerging from the climate crisis;
- Opportunities created by new digital and biotechnologies; and
- The energy and commitment to ecological issues of younger generations.

The land condition community needs to develop its awareness and ways of responding to these changes. There are a number of futures-thinking tools and techniques, notably scenario analysis where the implications of alternative futures are systematically investigated, which can help explore the implications of an uncertain future. The GMTs provide a sound base from which to build new approaches. **ES**

Huw Williams is a Principal at SAMI Consulting, currently working on the Government Office for Science's Futures Toolkit. He has recently produced two major 'future of skills' reports for the North-East Local Enterprise Partnership and the Construction Industry Training Board. Huw's background is in mathematics and operational research, and for many years he worked in strategy roles at BT.

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ANALYSIS

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The effects of climate change and other megatrends on the land remediation industry

Steve Jackson and **Melinda Evans** offer a contractor's perspective into the industry's challenges and opportunities.

GLOBAL MEGATREND – 7

GLOBAL MEGATREND – 9

GLOBAL MEGATREND – 11

Of the eleven global megatrends, the key challenges faced by the UK land condition industry fall into Increasingly Severe Consequences of Climate Change (GMT9), Intensified Global Competition for Resources (GMT7) and Diversifying Approaches to Governance (GMT11).[1] These challenges are forcing land remediation contractors to adapt to a changing market that has, in part, clearly been driven by these global trends. However, in meeting these challenges, new opportunities exist for continued growth and evolution of this mature UK market.

REDUCING CARBON EMISSIONS

Fundamentally, the challenge of climate change for remediation contractors comes down to two issues. First, how do we reduce our greenhouse gas (GHG) emissions and, second, how do we adapt what we do on our sites to deal with the predicted changes? Our industry is only beginning to grapple with the first, but we are already seeing the impacts of the second.

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In 2019, the UK legislated a net-zero target to achieve a 100 per cent reduction in GHG emissions compared to 1990 levels by 2050.[2] In broader governance terms, the focus of UK climate change legislation to date has been on large companies, despite small and medium-sized enterprises (SMEs) accounting for around 60 per cent of total employment in the UK.[3]

On the first matter of reducing GHG emissions, there are standards and guidance available to help SMEs and the broader construction industry to find a path to net zero, but less so for remediation contractors. Soilfix's experience has been that it is challenging to, first, locate the most relevant and helpful guidance for remediation contractors and, second, to disentangle generic guidance to make it useful to our specific needs. Specialist third party advice was needed before embarking on this process to ensure robustness and credibility.

Straddling the construction and environmental industries, remediation contractors have been sluggish to tackle net zero, mostly because there are some significant barriers in the way. It does not appear this will change in the short to medium term without a shift in government policy. The remediation process is heavily dependent on large plant and equipment, which traditionally run on gas oil (diesel fuel). A lack of financial incentives to use green fuels or of increased government funding in green technologies (such as larger electric-powered plant) are two examples of such barriers.

EMISSIONS FROM COMBUSTIBLE FUELS

As part of Soilfix's net-zero journey, and as a first step to reducing our emissions, we calculated our baseline carbon footprint over a two-year period. Gas oil is by far the largest contributor to our Scope 1 emissions (direct emissions from combustible fuels – see **Box 1**), accounting for 36 per cent of our total carbon footprint. One way to significantly reduce Scope 1 emissions on a project, therefore, would be to switch to hydrotreated vegetable oil (HVO) or biodiesel.

HVO in particular is gaining popularity but, even with the cost differential with gas oil closing, larger 'plant heavy' projects become uncompetitive when this increased cost is applied. Encouragingly, Soilfix is beginning to see clients increasingly recognise the value of using green fuels and, in certain cases, even willing to cover the additional supply cost. Yet hydrogen-fuelled and heavy electric plant and equipment are still a long way off being both widely available and cost effective. The high cost of lower-emission fuels and the lack of replacement plant and equipment are the largest barriers to remediation contractors making significant gains in reducing their Scope 1 GHG emissions in the short to medium term.

Beyond the Scope 1 and 2 boundaries and into the broader supply chain, Scope 3 emissions are progressively in the spotlight. Scope 3 emissions arise indirectly from purchased goods and services. Taking ownership of Scope 3 emissions is increasingly critical to realising the step-change reductions needed to meet net zero; they must be addressed if they constitute more than 40 per cent of a company's total footprint.[4] In 2019 and 2020, Soilfix's Scope 3 emissions were around 60 per cent of total emissions, including large contributions from materials such as lime and cement used in stabilisation projects. As a result, Soilfix is now working in collaboration with suppliers to source lower-emission stabilisation additives. Working with clients and suppliers will be key to tackling these Scope 3 emissions and achieving science based net-zero targets.

CLIMATE CHANGE

The remediation industry can no longer ignore the changes to UK weather patterns associated with climate change. The past five years in particular have seen an increasing trend of hotter, drier summers and milder, wetter winters with increased frequency and intensity of flooding events. While certain remediation techniques such as ex situ bioremediation of soils may be enhanced by increasing temperatures, this trend affects the predictability and impacts of weather conditions, compromises the suitability of certain remediation techniques, restricts the calendar window for weather-dependent works, and influences contractual implications – after all, what is 'inclement weather' these days?

Hotter, drier summers, as evidenced during summer 2022, increase the challenge of controlling dust emissions and rapidly render soils too dry for re-engineering or possibly for the use of techniques such as bioremediation due to low moisture content. Greater dust suppression and soil hydration requirements increase the demand on already strained water supplies. Conversely, prolonged wet winters render effective processing and re-compaction of soils to be increasingly reliant upon additives such as quicklime and Portland cement, both having a high carbon footprint to produce and transport to site. It remains to be seen whether the commonly accepted UK 'earthworks season' of April to October is at risk of being shortened: was the onset of prolonged heavy rainfall from September 2022 merely an outlier or the new normal?

With trends of warmer weather, increased effective rainfall, and changing flood risk expected in the

UK, there is a foreseeable need to future-proof risk assessment and remediation projects. For example, in terms of non aqueous phase liquids and natural source zone depletion, fluctuations in the water table are likely to be the most significant change that will require planning ahead. For highly mobile contaminants such as PFAS (per- and polyfluoroalkyl substances, which are synthetic organic substances), volatile organic compounds, and pesticides, adjustments to remediation design may be necessary to accommodate increased infiltration and associated water-table fluctuations.

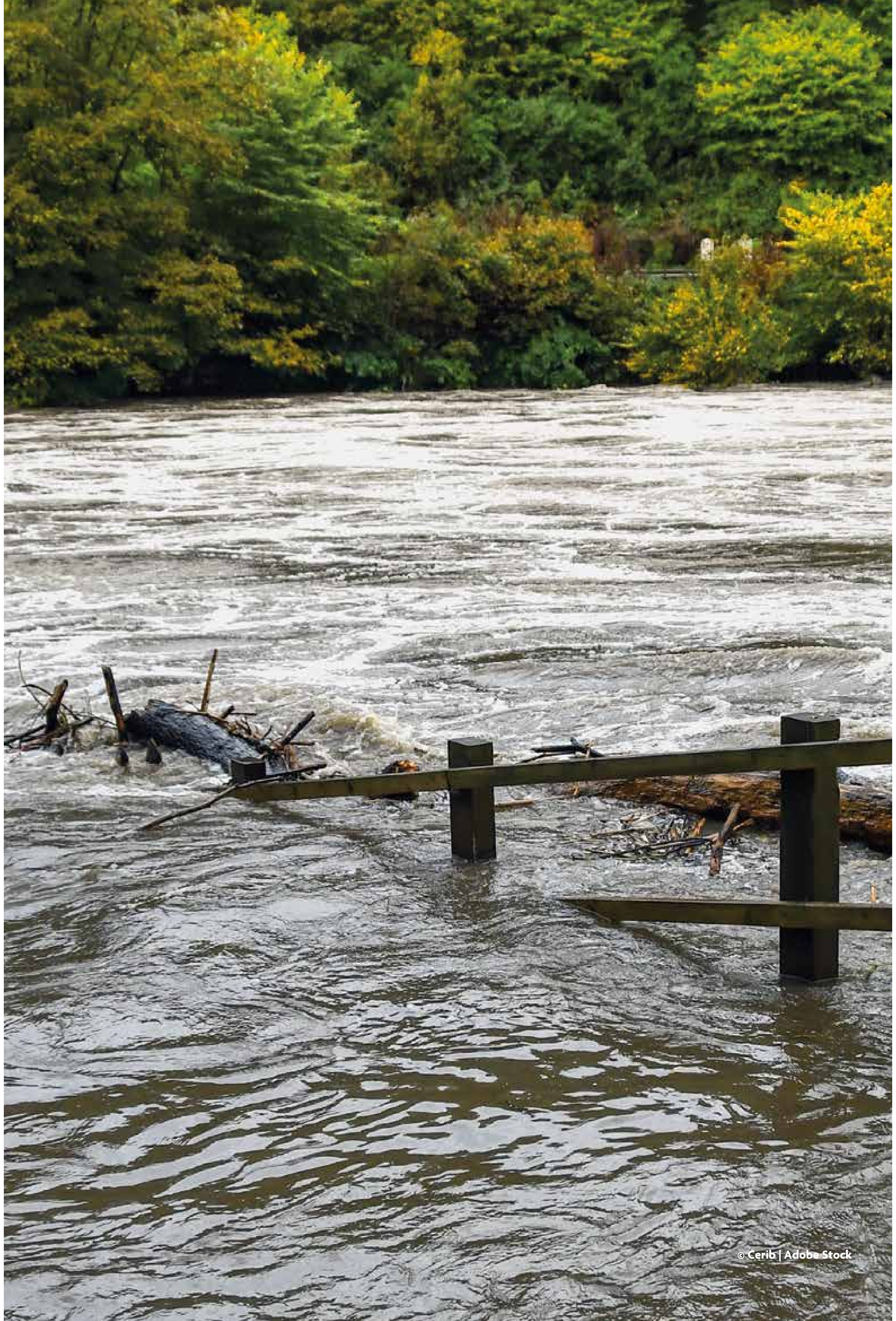
Complicating the picture, predicted changes will vary from site to site; thus, it will not be possible to use a one-size-fits-all approach in planning for these changes. Even harder to predict is whether the changes will be significant enough to require a review of previous risk-based remediation projects. The predicted warmer weather and increased rainfall and flood risk will likely be an increasing future consideration for the long-term robustness of treated soils both during project remediation and post completion.

Taken together, the challenges of climate change present many technical, commercial and practical tests for the remediation industry. Collaboration across businesses will be key to any measure of success. It is reasonable to expect that obligations placed on companies to tackle their emissions will increase, including the often-ignored or sidelined Scope 3 emissions. However, as recent reports from the Intergovernmental Panel on Climate Change have indicated, there is not a moment to waste.

INTENSIFIED GLOBAL COMPETITION FOR RESOURCES

The power shift towards increased global competition for resources has accelerated, particularly over the past three years due to post-Covid-19 economic growth, supply chain pressures and the Ukraine war. A marked increase in fuel and energy costs have driven up the cost of operating plant and equipment as well as procuring key materials for remediation works. As noted above, removal of the fuel duty exemption from the construction industry has only served to amplify this global megatrend.

In parallel with inflationary price increases, the spotlight has increasingly shone on the scarcity and pressure on our natural resources for continued redevelopment (including on brownfield land). This includes continued demand for quarried aggregates, naturally occurring subsoil and topsoil, timber and other building materials. We have only recently seen a shift towards circular economy obligations being a specific requirement in certain major schemes, where planning conditions specifically state targets for minimising waste and maximising reuse of materials arising from the construction and end-of-life phases of new developments.[5] This, however, presents an opportunity, as clients are encouraged to consider alternatives to using natural resources based on sustainable materials management.



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Examples of sustainable materials management (feeding into a circular economy) include:

- Processing recycled hardcore (e.g. crushed concrete) into graded aggregates for sustainable urban drainage systems or highway construction;
- Modification of poor-quality subsoils (including made ground, or human-made materials) into engineered fill; and
- Repurposing poor-quality, nutrient-deficient subsoil and topsoil for areas of open space or private gardens.

Understanding soil health is increasingly important to counter the adverse effects of climate change (e.g. increased flooding) but also to potentially offset carbon emissions (through sequestration of carbon dioxide in carbon-rich, healthy topsoil and subsoil). Initiatives such as the cross-channel ReconSoil project will greatly improve our understanding of using recycled materials (such as biochar, compost and wood chip) to render poor-quality soils into bespoke materials with a high, stable carbon content that can sequester (capture) carbon dioxide.[6] This approach could provide significant commercial benefit to the construction industry while significantly reducing the amount of waste soil sent to landfill.

DIVERSIFYING APPROACHES TO GOVERNANCE

When it comes to diversifying approaches to governance, there is no single direction of travel for land condition. Earlier gains from shifts towards greater self-regulation in key elements of remediation contracting seem to be faltering with direct consequences for project delivery. At the other end, mandatory annual reporting of environmental impacts for larger companies is now filtering down to SMEs, which is changing how projects are tendered and designed, for the better.

Probably the most marked shift towards self-regulation within the brownfield industry is not recent. The remediation licensing task force, established by the UK Government in 2004, ultimately resulted in the introduction of CL:AIRE's *Definition of Waste: Development Industry Code of Practice* (DoWCoP).[7] This was widely embraced by industry as a way to reduce red tape and uncertainty in applying for licences and permits to sustainably reuse materials generated on brownfield and greenfield sites considered suitable for use; the aim was that these materials would be managed in the same way as uncontaminated soils, provided there is no risk of environmental pollution.[8]

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This self-regulating code of practice was a game-changer for developers, consultants and contractors alike. It unlocked one of the most significant barriers to brownfield reclamation: obtaining a licence or permit for reuse of soils and hardcore arising from projects. Almost 20 years after establishing such a forward thinking task force, the industry awaits further news on an updated (and foreseeably more limited) version of DoWCoP, and an accelerated shift towards an Environment Agency permit-based regime for brownfield site reclamation, where landfill materials, mine wastes or material stockpiles (when deemed waste) are present on site or below the ground. Uncertainty on both these changes – the foreseeable shift away from self-regulation and the protracted timescale to secure an environmental permit – has left the industry less confident in how projects can move forward in the medium to long term.

The feared demise of the DoWCoP in the short to medium term seems to be both a reflection of the Environment Agency's loss of confidence in how it has been applied (or abused) by certain organisations, and of an increasing reliance on self-funding (including permitting fees) following government budget cuts. However, several targets and commitments set out by the Department for Environment, Food and Rural Affairs give cause for optimism that sustainable regeneration of brownfield sites can still be achieved without significant barriers.[9] Aligning with DoWCoP, this includes commitments to maximising resources, minimising waste and using natural resources more sustainably.

Corporate environmental and social governance (ESG) requirements within larger organisations are also filtering through to SMEs. For example, large companies are required to include an assessment of their environmental impact in annual statements, including streamlined energy and carbon reporting.[10] This is most noticeable through increased requirements in both pre qualifications and tenders for companies engaged in remediation contracting. Climate change has driven much of this shift change. Contractors are increasingly expected to monitor, manage and reduce their GHG emissions both operationally and on specific projects.

As part of its own net-zero journey, Soilfix has developed a bespoke remediation works carbon-calculator tool to estimate and confirm its project-specific GHG emissions. The tool has additional capability to select projects by determining the positive impacts of using alternatives to gas oil, quicklime, cement, landfill, incineration and other consumables or activities with high GHG emissions. This tool has been invaluable to Soilfix in helping clients achieve their ESG reporting requirements. It is also being used to nudge those clients and suppliers closer towards the transition to net zero.

CONCLUSION

The picture for the land remediation industry in relation to global megatrends is mixed. On the one hand the industry is facing increasingly cumbersome hurdles in getting remediation projects off the ground. There currently appears to be a perfect storm of under-resourced regulators that lack complete confidence in the industry to fully police itself. However, key to addressing the megatrends of climate change and resource scarcity and competition in the UK is to have a regulatory regime that encourages sustainable development of brownfield land rather than deterring it. In doing so, this will enable remediation practitioners to successfully evolve and future-proof themselves with greater certainty, in spite of the many challenges these global trends present.

However, there are green shoots appearing, with hopes that new environmental regulations and initiatives will revive the premise of a brownfield-first agenda. Elsewhere, progress is unmistakable: the requirement for larger companies to report on their broader environmental performance is in turn pushing remediation contractors to improve (and evolve) their practices. ES

BOX 1. SCOPE 1, 2 AND 3 EMISSIONS EXPLAINED

Scope 1. Direct emissions resulting from the primary combustion of fuels in organisation-controlled premises, vehicles and plant.

Scope 2. Indirect emissions resulting from the consumption of purchased electricity that has been generated off site and supplied by the national grid.

Scope 3. Indirect emissions associated with the consequences of the organisation's activities but controlled by another entity outside of the corporate structure.

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Tackling Scotland's legacy of vacant and derelict land

Hamish Trench examines how economic growth and governance offer viable solutions to this problem.

GLOBAL MEGATREND –5

GLOBAL MEGATREND – 11

CASE STUDY

The legacy of Scotland's industrial past means that almost a third of Scotland's population lives within 500 m of a derelict site. In deprived communities, that figure rises to over half the population (55 per cent).[1] This legacy has remained largely static for too long, causing harm to people in those places and creating missed opportunities for Scotland's communities and economy. How is Scotland tackling this legacy in the context of its wider land reform programme and the European Environment Agency (EEA) global megatrends (GMT) of Diversifying Approaches to Governance (GMT11) and Continued Economic Growth (GMT5)?

SCOTLAND'S VACANT AND DERELICT LAND TASKFORCE

In 2018, the Scottish Land Commission and Scottish Environment Protection Agency convened a national task force to challenge and transform the way Scotland approaches bringing vacant and derelict sites back into use. The task force brought together representatives from around 30 businesses, public bodies and third-sector organisations, and over two years took a deep dive into the nature of the sites and the systemic changes that could stimulate reuse.

The task force organised its recommendations into four strategic priorities:

1. Make better use of data to focus on persistent and problematic sites with productive potential;
2. Embed a joined-up approach to prioritising sites in policy and funding decisions;
3. Demonstrate effective delivery approaches and make the policy changes needed to support them; and
4. Embed a socially responsible approach to land reuse in corporate culture to prevent more sites being abandoned.[2]

No one organisation or sector can pull all these levers, so the cross-sector nature of the task force was a deliberate governance approach, with an awareness that an effort of this scale needs shared focus and alignment between the private, public and third sectors.

UNDERSTANDING THE PROBLEM

The task force took a wide scope in understanding the problem. Life expectancy in Scotland is lower than elsewhere in the UK and this cannot be explained by differences in socio-economic conditions. Even after adjusting for differences in poverty and deprivation (the main causes of poor health in any society) around 5,000 more people die in Scotland each year than should be the case. In 2016, a major research report on the causes of excess mortality found one of the factors is an 'adverse physical environment'.[3]

It is not hard to see the role regeneration can play in reducing health inequalities and improving wellbeing. Beyond individual impacts, the causal links between inequality and sub-optimal economic growth are well established.

A major piece of research undertaken for the task force investigated the consequences of long-term vacancy and dereliction on communities. It found that derelict sites can blight a community by affecting the wellbeing of the people living there, and negatively affect the local environment, economy and social cohesion. The report was used to develop a framework for decision-makers to gauge the impacts of a site on communities and to help identify and prioritise harmful sites. The research found that it is often smaller, particularly prominent sites within a local area that are the most harmful. The effect of clustering – where groups of neglected sites are concentrated in a geographic area – and physical condition (i.e. sites that are in a neglected state) were also factors that exacerbated the harmful effects of vacant and derelict land on communities.[4]

These findings have implications for both governance and looking beyond traditional economic appraisal. They point to the need for mechanisms that will enable communities to take a lead role in identifying and prioritising locally significant sites for action, particularly where these may not yet have been identified on the national register. They also point to a need to focus efforts on those areas where urban dereliction is most heavily concentrated.

BOX 1. EFFECTS OF DERELICT LAND

Health

- There is a spatial association between interaction with vacant and derelict land (VDL) and impacts on physical health with regard to poorer health outcomes, population health and life expectancy.
- VDL can negatively impact community wellbeing, with reported effects ranging from high anxiety levels, agitation and anger to increased incidence of crime and antisocial behaviours.

Environment

- Contaminated VDL sites can result in the pollution of watercourses, with potential for airborne contamination and impacts on human health and wildlife.
- Contaminants from VDL (typically former industrial uses) can present potential environmental hazards in the form of materials incorporated into structural fabrics.
- Contaminated VDL sites requiring costly remediation can act as a barrier to development and adversely affect perception.
- VDL sites that are not maintained can negatively influence area perceptions, locally and more widely.

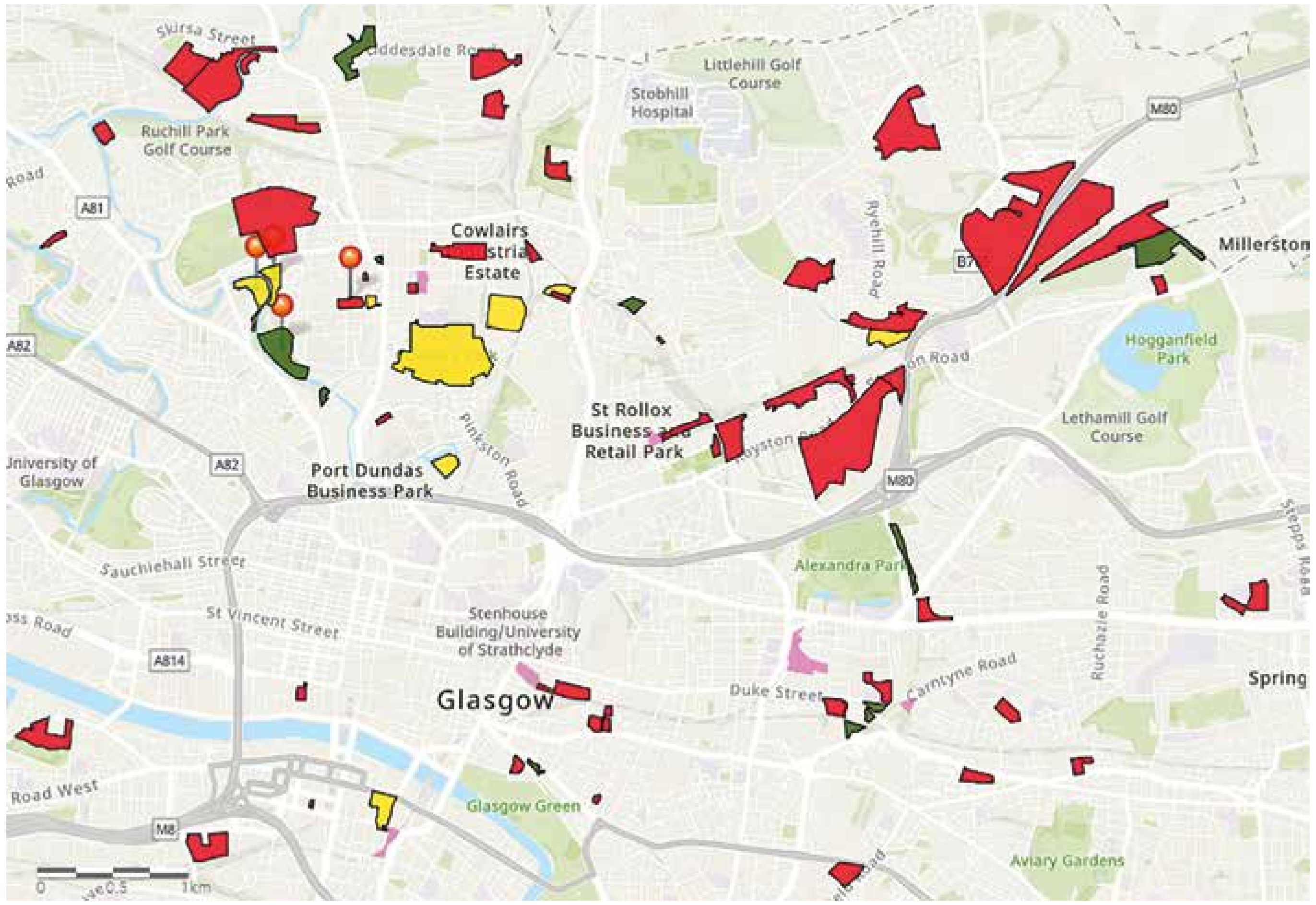
Economy

- The cost of remediating contaminated land, the means and timescales for recovery of infrastructure expenditure, and development risk due to economic factors beyond a developer's control reduce the likelihood of redevelopment on VDL sites.
- Proximity to VDL adversely affects developer perceptions and confidence.
- Substantial opportunity costs may be associated with continuing vacancy and dereliction.
- The level of maintenance of VDL sites can influence the value of neighbouring properties.

Community

- VDL can have a significant impact on community perceptions of the local area. Visibility and clustering of VDL can have a multiplier, exacerbating effect.
- VDL sites used as community green spaces can be lost following redevelopment, adversely affecting the community.
- More affluent communities may have greater resilience to cope with the effects of VDL.[4]

CASE STUDY



▲ **Figure 1. Map of long-term derelict urban sites. (© Scottish Land Commission[6])**

Red indicates that there is nothing happening on the site or it has limited planning activity (e.g. current or history of planning consents or applications).

Yellow indicates that some development or remediation activity is underway on the site but it has not been removed from the Vacant and Derelict Land Register.

Green indicates that the site has some greening or naturalisation underway (e.g. shrubs, grass or trees) and may be suited to a green end use. (NB: While a site may have potential, this would be subject to further assessment of specific site conditions [e.g. contamination] and appropriate measures, where required, to ensure the site is suitable for a green end use.)

Grey indicates that the site has been removed from the 2019 Vacant and Derelict Land Register or removal is anticipated due to completed development.

Pink indicates information not yet added to the map.

CASE STUDY

© Tom Manley. Courtesy Scottish Land Commission

© Tom Manley. Courtesy Scottish Land Commission

FULL ECONOMIC APPRAISAL

The potential for reusing vacant and derelict sites is huge. Such sites could provide new homes, grow food, generate renewable energy, and provide spaces to learn, play and connect. They could help us reduce carbon emissions, increase biodiversity and improve wellbeing. Addressing dereliction can also help to reduce crime and antisocial behaviour, making communities safer and more attractive for inward investment. This holistic approach to place-based intervention lies at the heart of the Place Principle, formally adopted by the Scottish Government in 2018.[5] Considerable progress has been made since then to embed the approach across Scotland's policy environment, but the continued presence of abandoned and neglected spaces within many Scottish communities is a reminder that more remains to be done.

The circular economy concept, in which reuse of resources is designed into the production process from the start, is increasingly becoming the expectation in many parts of our economy. However, we have yet to embrace this concept in relation to land reuse.

To support prioritisation, the Scottish Land Commission, Scottish Environment Protection Agency and the Green Action Trust published a map of over 500 long-term derelict urban sites (over 0.1 hectares). Essentially these are the 'stuck sites' that have remained derelict for over 20 years (see **Figure 1**).

With these highlighted as priorities, the Scottish Land Commission also published recommendations and guidance on a wider approach to economic appraisal beyond traditional financial considerations. This work by Biggar Economics noted that the wider economic benefits of land reuse are often not incorporated into economic appraisals. It recommended a new approach, consistent with the UK Treasury Green Book, which incorporates economic and wellbeing appraisals and the fiscal costs and benefits when looking at potential land reuse.[7]

GOVERNANCE CONSIDERATIONS

Following the task force's recommendations, the Scottish Land Commission worked with the Development Trusts Association Scotland to pilot support for community-led approaches to the reuse of derelict sites. This supported six community anchor organisations, via project officer support, to take forward regeneration plans. There is no question that community ownership and leadership are viable and effective means to bring some sites back into use.

During the project, four sites and three shop units were brought into meanwhile (i.e. temporary) uses, and permanent uses for ten sites were being explored. The collaboration demonstrated the need for early-stage feasibility support and the impact this could have – for example, securing a further £750,000 of funding support across the projects.

More widely, the task force emphasised the need to embed a responsible business approach in corporate culture to prevent the creation of a new legacy of vacant sites. With another major economic shift happening following the Covid-19 pandemic, the risks of a new generation of vacant sites, just as the 30-year legacy is tackled, are high. Environmental, social and governance responsibilities therefore need to make it unacceptable to let land become derelict or vacant indefinitely, something fiscal policy and taxation can reinforce.[2]

WIDER LAND REFORM CONTEXT

Scotland's approach to the reuse of vacant and derelict land is set in the wider land reform context that reflects the EEA's global megatrends, looking at both governance and beyond GDP in economic growth. The link between land and inequalities and productivity is one that drives Scotland's land reform programme, tackling the ownership and land value constraints to create opportunities.

Scotland's land reform programme puts significant emphasis on community ownership, with rights to buy – including a statutory right to buy abandoned, neglected and detrimental land. Alongside use of these rights, it will be equally important to support the capacity of communities to act through negotiated approaches to bringing sites back into productive use. In 2017, the Scottish Parliament agreed the Scottish Land Rights and Responsibilities Statement (revised in 2022), a set of principles underpinned by a human rights approach to the relationship between land and people.[8] Much of the Scottish Land Commission's work is helping people and organisations put these principles into practice in the ways in which land is owned and used.

The Statement and the approach taken by the Vacant and Derelict Land Taskforce offer some practical ways in which those global megatrends in governance and looking beyond GDP are shaping socially responsible approaches to the ways we own and use land in Scotland. ES

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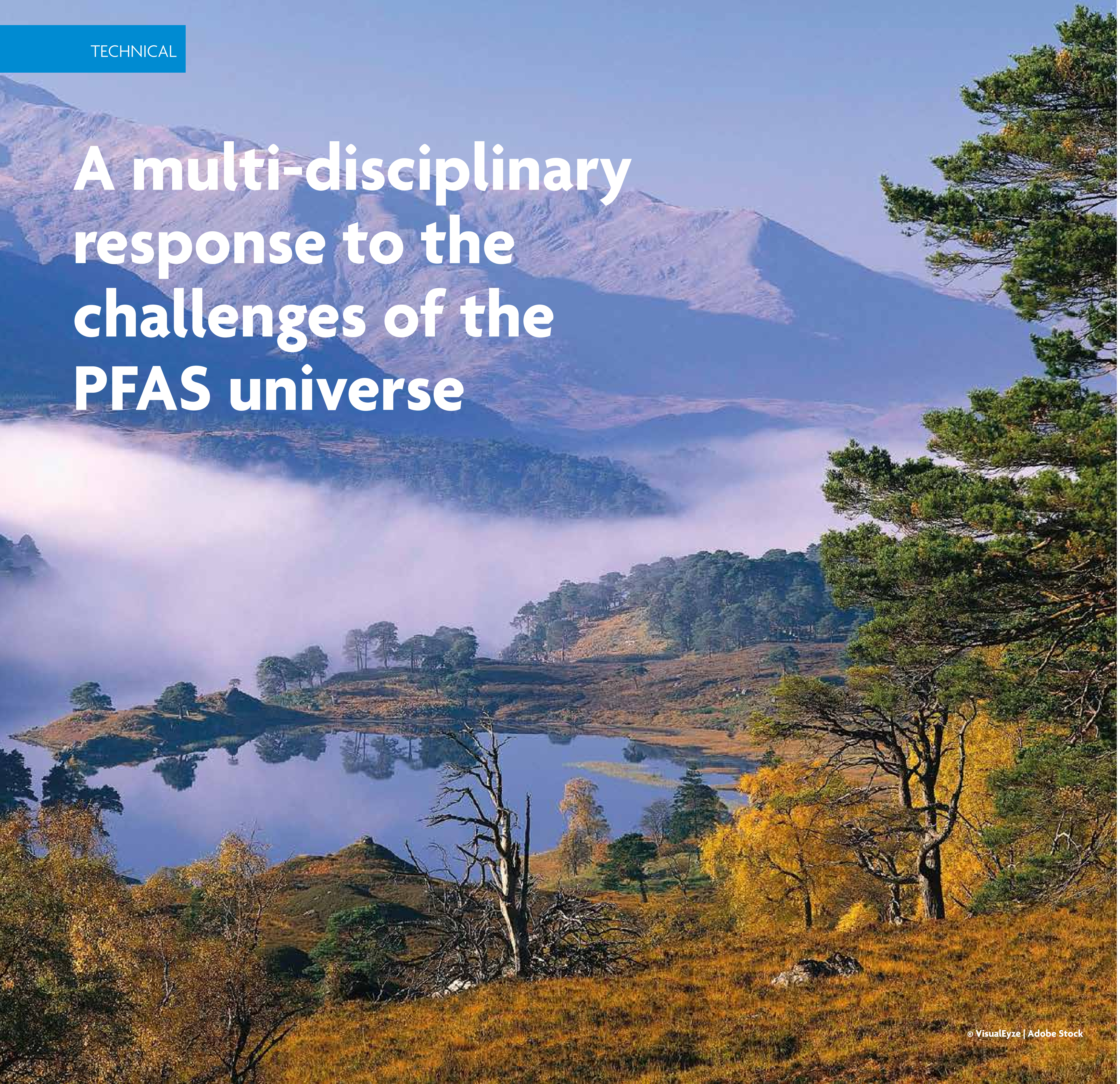

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TECHNICAL

A multi-disciplinary response to the challenges of the PFAS universe

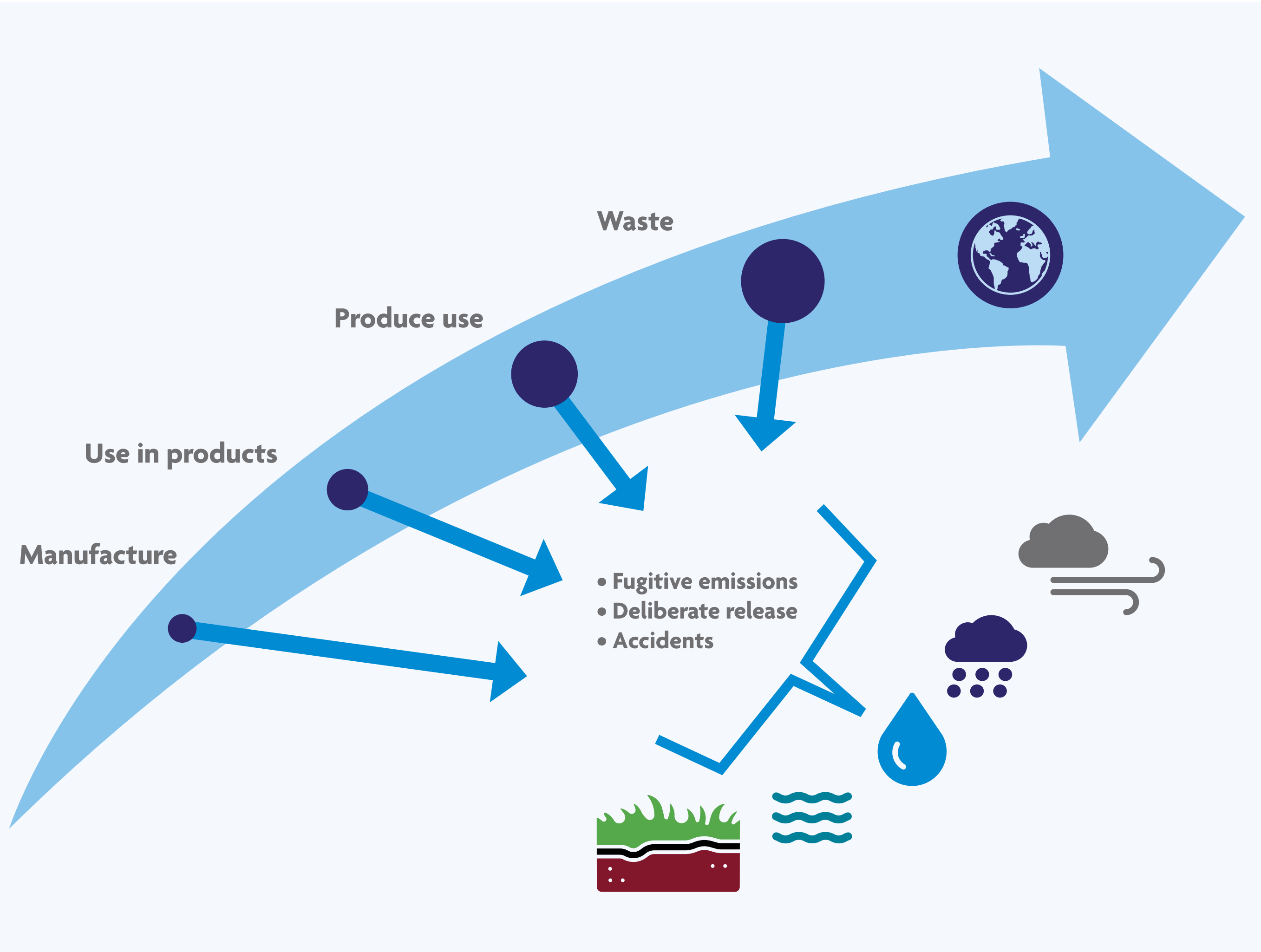
Paul Nathanail and **Shaun Grey** explain the difficulties of remediating sites affected by these complex chemicals.

GLOBAL MEGATREND – 10

INTRODUCTION

The European Environment Agency identified 11 global megatrends that will affect ecological and societal resilience and which have significant consequences for Europe.[1] One such megatrend, Increasing Environmental Pollution (GMT10), has been recognised as a global transboundary problem that affects air, water, soil and whole ecosystems. Three main human activities are linked to this pollution: fossil fuel combustion, the application of synthetic fertilisers, and the growing use and complexity of chemicals.

It is an increasing challenge to assess and manage the risk presented by a group of complex chemicals when released into the environment, and it poses a land contamination issue. Growing concerns over the level of risk of per- and polyfluorinated alkyl substances (PFAS) to human health and the environment have resulted in considerable regulatory, scientific and engineering developments. They have even been the subject of the 2019 Hollywood film *Dark Waters*.



▲ The PFAS life cycle. All PFAS were manufactured for use in products. During their use and upon disposal, many PFAS are released into the environment, and they have been found in some of the remotest parts of the planet. (© Land Quality Management)

WHAT ARE PFAS?

PFAS are a group of synthetic chemicals made over the past 80 years to serve many purposes. The basic building block of a PFAS is a chain of carbons – the alkyl part of the name. As a tetravalent atom, carbon needs to form four covalent bonds. In aliphatic hydrocarbons, a carbon does this by sharing electrons with another carbon or two and with hydrogens. In a PFAS some or all the hydrogens are replaced by fluorine – the fluoro part of the name. If all the hydrogen atoms bonded to a carbon are replaced by a fluorine atom, then the substance is a perfluoroalkyl substance – the same per- that we find in the chlorinated solvent named perchloroethene (PCE). If all the hydrogens on at least one – although not all – the carbons in the chain have been substituted with fluorines, then we have a polyfluorinated alkyl substance.

There are thousands of PFAS! The PFAS universe can be broken down into galaxies, many with different functional groups attached to one end of the carbon chain or with other atoms such as oxygen or sulphur acting as a bridge between two or more chains of carbons. Within each galaxy there will be substances with different numbers of carbons in the chain – from one (C1) to six (C6), eight (C8) and more… many more.

In an attempt to promote a consistent approach to the regulation and management of these chemicals, the Organisation for Economic Co-operation and Development (OECD) has provided a definition of PFAS (see **Box 1**).[2] However, the recent joint Health and Safety Executive Risk Management Options Analysis (RMOA) for PFAS has adopted a narrower definition.[3]

WHERE ARE PFAS USED AND FOUND?

PFAS have been detected worldwide and can be found on sites far away from point sources. Ambient levels in soil and concentrations in rainwater can exceed relevant screening levels.[4] However they were manufactured, stored and used, understanding a site's history is an important part of a preliminary risk assessment if PFAS land contamination is to be adequately considered.

BOX 1. THE OECD DEFINITION OF PFAS

'Any fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I[a] atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group (-CF3) or a perfluorinated methylene group (-CF2-) is a PFAS.'[2]

Note: [a] H = hydrogen; Cl = chorine; Br = bromine; I = iodine

Industrial sites with a history of using PFAS to fight certain types of fire, or to make clothing waterproof, food wrapping grease-proof, furniture fire resistant, and many more uses should require an intrusive investigation. Fighting fires of flammable liquids (Class B fires) has historically involved using PFAS-based aqueous film-forming foams (AFFF). Training to fight such fires and washing down appliances after a firefighting incident are likely to have resulted in AFFF PFAS getting into the ground – through soil, water courses and storm drains. The widespread use of PFAS in firefighting foams has seen pollution identified on civilian and military airfields and training areas. Fuel-storage sites have also been impacted during firefighting incidents and training activities, and from potential foam storage spills.[5]

In England, Environment Agency sampling programmes have identified PFAS in surface and ground water and in estuarine sediments.[6] Limited sampling of mammals and fish has also confirmed the presence of PFAS. Leachates from landfills where PFAS-containing wastes were disposed of – especially the more soluble ones – are likely to be contaminated and they are also found in discharge from wastewater treatment plants and on agricultural land where sewerage sludge has been spread.

TECHNICAL

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PFAS have been so widely used that they may be present in most media (soil, sediment, waste, wood, tarmac, bricks, concrete, glass, coatings and carpets).

HOW DO PFAS BEHAVE?

PFAS are very stable and resistant to chemical attack – largely because of the strength of the carbon–fluorine bonds. They can withstand high temperatures and resist chemical and biological degradation.

The PFAS of main environmental concern are those that are toxic, soluble, persistent and bioaccumulative – mainly the long-chain perfluoroalkyl carboxylic acids (PFCAs) and perfluoroalkane sulphonic acids (PFSAs). Perfluorooctane sulphonic acid (PFOS) is the best-known PFSA (used in firefighting foams) and perfluorooctanoic acid (PFOA) is the best-known PFCA (used in waterproofing fabric membranes) – but others are also common and hazardous. The structure of the most problematic PFAS gives them peculiar behaviours. Specifically, since the end of the carbon chain with a functional group is hydrophilic (attracting water) and the other end is hydrophobic (repelling water), they behave like surfactants – akin to washing-up detergents. This allows PFAS to foam and resist water and grease – the properties that make them useful.

PFAS behaviour depends on chain length. PFOA and PFOS are long-chain PFAS whose characteristics make them good surfactants, resulting in them accumulating at soil, water and air interfaces. Long-chain PFAS have also been observed on the surface of concrete at concentrations high enough to act as decades-long sources of pollution and potentially preventing the reuse of crushed concrete. Short-chain PFAS are more soluble and have a lower potential to bioaccumulate relative to long-chain PFAS.

Most PFAS do not readily partition to air and have a low to moderate sorption to soil. This, coupled with high solubility, results in groundwater plumes that can reach multiple kilometres – longer than either hydrocarbon or chlorinated solvent plumes.[4] Soil mineralogy and groundwater geochemistry, together with the individual type of PFAS, control mobility – for example, solubility decreases in brackish and saline conditions. Therefore, detailed, site-specific and chemical knowledge and understanding are required to comprehend and model PFAS mobility.

DISPOSAL AND RISKS

PFAS have been deposited into the environment through a multitude of waste activities, including controlled and uncontrolled discharge to water, incineration and open burning, landfilling, uncontrolled tipping and even littering. PFAS are very mobile when released into the environment and have been found in rivers, in lakes and in the human body. Many bioaccumulate and have been associated with adverse effects to human health and wildlife following exposure events.

Risks to human health. The toxicity of most PFAS remains poorly understood. However, those that have been relatively well studied have been associated with adverse effects on the liver, immune system and reproduction and are potentially carcinogenic in humans and animals. Unlike lipo-philic hydrocarbon or chlorinated solvent molecules, PFAS are protein-philic. Short-chain PFAS are also more likely to be excreted than long-chain PFAS. PFOS and PFOA can cross the placenta in humans and animals, and breast milk may transfer PFAS from mother to child.[7]

Risks to ecosystems. The ecotoxicity of PFAS varies across species. Most studies looked at exposure to PFOS and PFOA in only a few species (e.g. zebrafish, earthworms and chickens) and determined responses in growth, reproduction and mortality as well as biochemical effects and gene expression. PFOS specifically has been shown to increase bee mortality and affect colonies. UK ecological soil-screening levels are based on broad assumptions about secondary poisoning of birds through the food chain from PFOS and PFOA in soil that is consumed by earthworms. Studies of the effects of exposure to PFAS on survival, growth and reproduction indicate some level of toxicity, but the datasets are small and mainly for avian and mammalian wildlife species where other pollutants and stressors may prevent definitive associations of adverse effects with PFAS exposure.[4]

HOW CAN PFAS BE REMEDIATED IN SOIL?

Remediation involves managing unacceptable risk by demonstrably breaking the source–pathway–receptor linkage. The different chemical structures, including carbon chain length and functional group, mean that not all PFAS are amenable to the same remediation approaches. The persistence of the more problematic PFAS means in situ destruction is not yet a practical solution. Immobilisation and stabilisation can be achieved by mixing a sorbing agent, such as an activated clay.

Remediation of PFAS in soil involves in situ stabilisation or excavation, extraction and destruction. Several ex situ methods have also been applied. Excavation and disposal to landfill of PFAS-contaminated soils is only possible if levels do not exceed Stockholm Convention waste limits. Alternatively, high-temperature incineration (>1,100C) of soil can be used to destroy PFAS, but this requires very good process control so is expensive and costs may be prohibitive.

Soil washing may be considered to concentrate the PFAS if the soil has relatively low silt, clay and organic content (i.e. fines). The treatment and disposal of extracted water and fines may be complex and expensive. Various containment methods have also been used, such as capping soils in situ and engineering stockpiles to prevent infiltration and leaching of PFAS. Liability and continued management remain with the site owner, while restrictions may be placed on redevelopment of a site.

HOW CAN PFAS BE REMEDIATED IN GROUNDWATER?

Groundwater treatments revolve around immobilising PFAS in the ground or abstracting water and treating it. Immobilising agents can be injected that capture and remove PFAS. Above-ground treatments either use filters to remove PFAS or blast air through the water to create a PFAS-rich foam that is separated and dispatched for PFAS destruction. Different filter media are needed for short- and long-chain PFAS molecules. Treatment of PFAS-contaminated groundwater using abstraction and granular activated carbon to remove long-chain PFAS and ion exchange columns for short-chain PFAS are proven technologies, but life cycle and maintenance costs are high.[7]

Other techniques, such as reverse osmosis and nanofiltration, have been demonstrated to be effective. These methods are expensive and presently only suitable for large-scale drinking water treatment. Each method separates the PFAS, in some cases on to a solid medium (e.g. granular activated carbon). Both PFAS and the waste media require a suitable destruction, recovery or disposal route.

GUIDANCE AND COMPETENCIES

Across the UK, regulators point those responsible for managing the risks from land contamination to the generic Land Contamination Risk Management (LCRM) guidance.[8] LCRM adopts a three-stage framework of risk assessment, remediation options appraisal, and remediation implementation and verification. It sets out the standards expected in the investigation, sampling and assessment of soil and water contamination. There is also coverage of what constitutes a competent person to undertake assessment and management, and they are expected to have appropriate knowledge, skills, experience and qualifications in the specific area of work and, importantly, in the type of contamination being managed. Guidance due out later in 2023 from CIRIA will explore the PFAS-specific aspects of complying with LCRM.

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The investigation, assessment and remediation of PFAS needs a multi-disciplinary team – not least because of the rapid developments in our understanding of the fate, transport and toxicity of PFAS and of the technologies available to analyse samples and to treat soil and water. Specialists in Land Condition (SiLC) are well placed to bring together and marshal the necessary competencies in soil, groundwater, geochemistry, toxicology and process engineering. These are chartered professionals – for example, through the IES – who have then gone on to demonstrate the broader skills and knowledge needed to manage land condition.[9]

CURRENT INITIATIVES

The Environment Agency has an ongoing programme of work to understand the scale and nature of PFAS contamination. Phase 4 is currently underway with projects designed to understand ambient levels of PFAS in soil, develop internal guidance for regulators, explore how applying Part IIA of the Environmental Protection Act 1990 (as amended) works in practice for PFAS, and to characterise PFAS in landfill gas and leachates.

The RMOA for PFAS under UK REACH (which regulates chemical substances on the British market) examined information on the intrinsic hazards, uses and routes of exposure to PFAS. However, the RMOA excludes risks arising from historic or discontinued uses of PFAS.[2]

CIRIA is preparing technical guidance on the investigation, assessment and remediation of the short- and long-chain PFAS encountered most often in soil and groundwater. As well as the investigation, assessment and remediation of PFAS in soil and water, it also describes the range of targeted and non-targeted analytical techniques used to quantify PFAS.[4]

At a European level, both the EU Common Forum of policy-makers and regulators and the NICOLE network of industry, service providers and academia have working groups on PFAS seeking to create a shared understanding of the regulatory, analytical, remediation and risk assessment aspects of PFAS contamination. Australia has been at the forefront of efforts to deal with PFAS contamination in groundwater, at least in part because of high-profile pollution of drinking water supplies around defence sites. The USA has several large and well-funded research programmes. Efforts to reduce the potential magnitude of the US Department of Defense's PFAS liability have driven research on AFFF-impacted sites since 2011 to evaluate a range of potential treatment technologies, ecotoxicological effects and improved AFFF site characterisation. More recently the USA's Bipartisan Infrastructure Law has provided substantial funding to assess and tackle PFAS contamination – especially that affecting disadvantaged communities.[10]

TECHNICAL

CONCLUSION

Managing the risks this complex universe of chemicals poses in the environment is clearly a challenging conundrum. It requires a multi-disciplinary approach to maintain awareness of the developing science and to apply it in remediating the adverse effects. Such activities are a prime consideration under GMT10. Chemicals such as PFAS are also a factor intimately involved with other global megatrends, contributing to degrading and adding pressure on ecosystems (GMT8) and requiring transboundary management that demands a coherent international governance against a background of diversifying approaches (GMT11).[1] In the context of managing land contamination risks, the multi-disciplinary expertise of land contamination specialists is likely to become even more important. ES

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CASE STUDY

Embedding sustainability in remedial options appraisal

Peter Fitch introduces SURE by Ramboll, a free-to-use cloud-based digital tool designed to support the assessment of sustainable remediation options.

GLOBAL MEGATREND – 4

SURE by Ramboll (SURE) was launched in October 2021, and is an innovative tool for assessing the sustainability of pre-selected remedial options for contaminated sites. With the increasing need for action to tackle climate change, the international land condition community's members need such digital tools to help accelerate the application of sustainable remediation.

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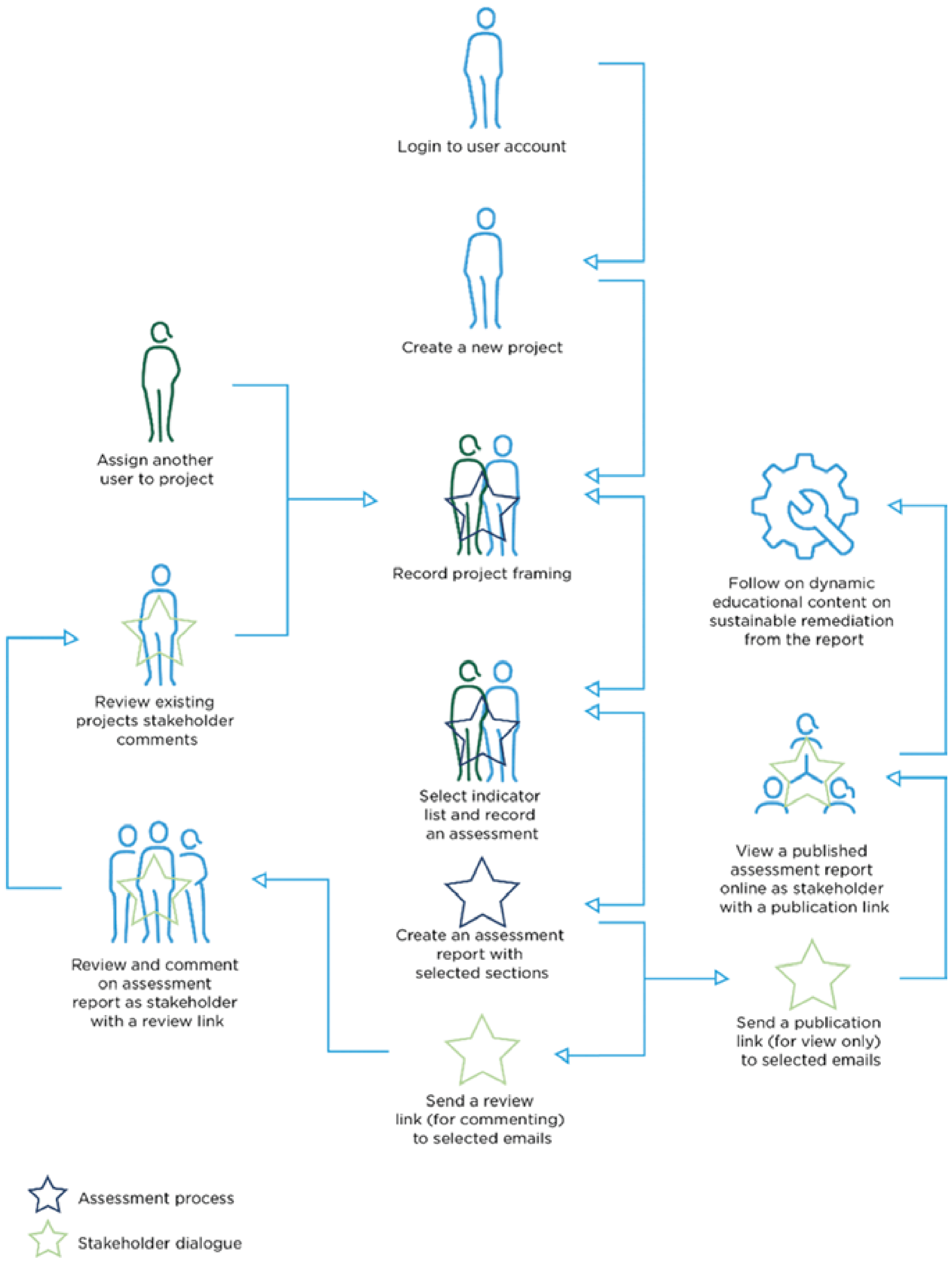
CASE STUDY



▲ **Figure 1. Schematic guide to using SURE. (© Ramboll)**

The European Environment Agency's 2015 report sets out 11 megatrends that are of key importance for Europe's long-term environmental outlook.[1] These megatrends are deeply concerning and show how there is now a greater urgency for sustainability to be embedded in risk assessment, remediation and use of brownfield land. To encourage more sustainable remediation decision-making, Ramboll developed SURE, which draws on over 70 sustainability indicators and their contribution to the United Nations Sustainable Development Goals (SDGs).

THE FUNCTIONALITY OF SURE

The functionality of SURE is based on three facets:

- Assessment of options for remediation according to procedures set out in BS ISO 18504:2017[2] and aligned with guidance from the NICOLE network and Sustainable Remediation Forum (SuRF), in particular the updated protocols issued by SuRF-UK;[3]
- Engagement with project stakeholders through an automated digital procedure to enable review and provide a record of decision-making; and
- Reporting based on a customisable format.

Assessment. Creating a new project is done by assigning a reference number and entering basic site and user information. Next is project framing, setting out the context, remedial objectives and potential constraints – for example, available time, space and budget, site features and decisions already taken that cannot be revisited.

Recognising that stakeholder involvement in sustainable remediation decision-making is important, stakeholder details and the level of engagement already undertaken can be recorded at an early stage in the assessment. Finally, in line with BS ISO 18504:2017, spatial, temporal and life-cycle boundaries of the sustainability assessment can be defined along with a statement on how uncertainties will be addressed. Relevant information such as site plans and technical documents can also be uploaded.

Once the project framing step is complete, the assessment can begin. The first stage is to select the sustainability indicators: the characteristics representing sustainability effects that will be used to compare the selected remedial options to evaluate their performance. These indicators are derived from the updated SuRF-UK listing, grouped into the five indicator categories within each of the three sustainability domains: environment, society and economy. Additional indicators can also be added by assessors, and all indicators are weighted according to their relevant importance on a scale of 1–5.
The second stage is to individually assess each remedial

▼ **Table 1: Reporting options available from SURE**

Section	Details
Introduction	Sets out the aim of the assessment and project objectives
Background	Sets out background to sustainable remediation, references ISO standard and SuRF-UK framework
Methodology	General description of SURE, description of assessment methodology and how results are calculated
Project framing	Description of project, remediation objectives, goals, decisions and actions to be supported by the assessment, constraints and opportunities, and stakeholders and their roles
Details of assessment	Summary of remedial options, methodology, boundary conditions, uncertainties
Results overview	Total sustainability scores for options, divided into environment, society and economy and weighted according to domain
Assessment details	Distribution of scores according to indicator category for each domain and results table providing assessors' comments and rationale for weighting and scores
Results for options	Sustainability scores and distribution of scores according to category and relative impact on the Sustainable Development Goals by option. Also reproduces option description
Stakeholder comments	Stakeholder name and associated comments
Revision history	Full history of changes made within document (i.e. changed from, changed to, changed by, changed when)

option against the selected indicators. To facilitate the assessment, a pop-up box is provided for each indicator to fully describe it (so its relevance to the project can be evaluated) as well as provide advice on how to compare the options against it, as aligned with SuRF-UK guidance. The description also identifies which of the 17 SDGs the indicator is linked to. In this way, SURE helps to disseminate SuRF-UK guidance and provides an educational facet to the assessment process.

Against each of the indicators, options are scored on a scale of 1–5, with a score of 5 representing the best contribution made to sustainability. Scoring should be proportional to the degree of sustainability benefits conferred; therefore, for instances where differences in contribution are marginal, the options are scored equally. For each option, the rationale for the scoring can be recorded.

Results. Once the assessment is complete, SURE calculates normalised scores for each remediation option as a percentage of the maximum weighted score achievable. Total scores for each domain are presented as histograms, with additional bar charts showing scores by indicator category for each domain. Overall weightings for each domain and by category are provided as pie charts. An option-by-option comparison is also available in pie chart form according to the relative contribution made to each of the 17 SDGs using the linkages established by SuRF-UK. Having reviewed these, the user can easily modify scoring and weighting or undertake a sensitivity analysis by returning to the assessment page and making the necessary amendments.

Stakeholder engagement. Once complete, the assessment can either proceed directly to the reporting stage, which is automatically generated, or the assessor can invite review and input from identified stakeholders. In the latter case, SURE automatically invites stakeholders by email to review the project. Stakeholders can create an account to access the project. While stakeholders are unable to directly change the scores in the assessment, they can enter comments within each section. Each stakeholder can then choose to approve the assessment or reject it if changes are required. The decision is automatically conveyed by email to the assessor so that the comments can be reviewed, updates made, and a revised version returned to the stakeholder for approval.

Reporting. SURE enables customisable reports to be generated as PDF documents by selecting up to 10 sections, together with a cover page and disclaimers (see **Table 1**). A schematic guide illustrates the full process (see **Figure 1**).

FORMER VEHICLE SHOWROOM ASSESSMENT EXAMPLE

A former vehicle showroom was to be redeveloped for mixed residential and educational use. Approximately 40 years of operations had resulted in significant contamination by diesel-range total petroleum hydrocarbons within both the made ground (artificial, human-made surface) and underlying sandy gravel aquifer. Light non-aqueous phase liquids and elevated dissolved phase concentrations were present, representing a potential risk to future occupants and off-site residents. Diffuse made-ground contaminants consisting of asbestos fibres and elevated concentrations of heavy metals and polycyclic aromatic hydrocarbons would also pose a risk if they remained exposed at the surface after redevelopment. Five potential remedial options for the project were identified (see **Table 2**) and SURE's outputs were graphically illustrated (see **Figure 2**, **Figure 3** and **Figure 4**).

The first output from SURE is at the domain level (see **Figure 2**). Remedial Option 2 incorporating ex situ and in situ bioremediation and capping demonstrated the best overall sustainability performance at the society domain level, although Option 4 (in situ bioremediation and capping) was marginally better for the environment domain. Excavation of the made-ground contaminants (instead of capping) substantially reduced the sustainability of both Option 3 compared to Option 2, and Option 5 compared to Option 4.

The options involving excavation and disposal (options 1, 3 and 5) attracted the lowest scores for environment, whereas the in situ ones (options 2 and 4) scored higher. For social indicators, Option 2 (on-site in situ and ex situ bioremediation treatment) scored higher than Option 1 (excavation and disposal with in situ bioremediation treatment), whereas options 4 and 5 performed less well due to low scores for uncertainty and evidence around the use of the alternative in situ bioremediation technique. For economic indicators, Option 1 (excavation and disposal with in situ bioremediation treatment) scored highest due to various factors including increased certainty, reduced duration and increase in land value.

The relative contribution of options 1, 2 and 5 to each of the 17 SDGs is presented as respectively representing the two best-performing and the worst-performing options (see **Figure 4**).

As an example of how the relative contribution to SDGs can be understood, the excavation-based Option 1 made greater positive contributions to the following SDGs than either of options 2 or 5, primarily due to the certainty of removing contamination from the site:

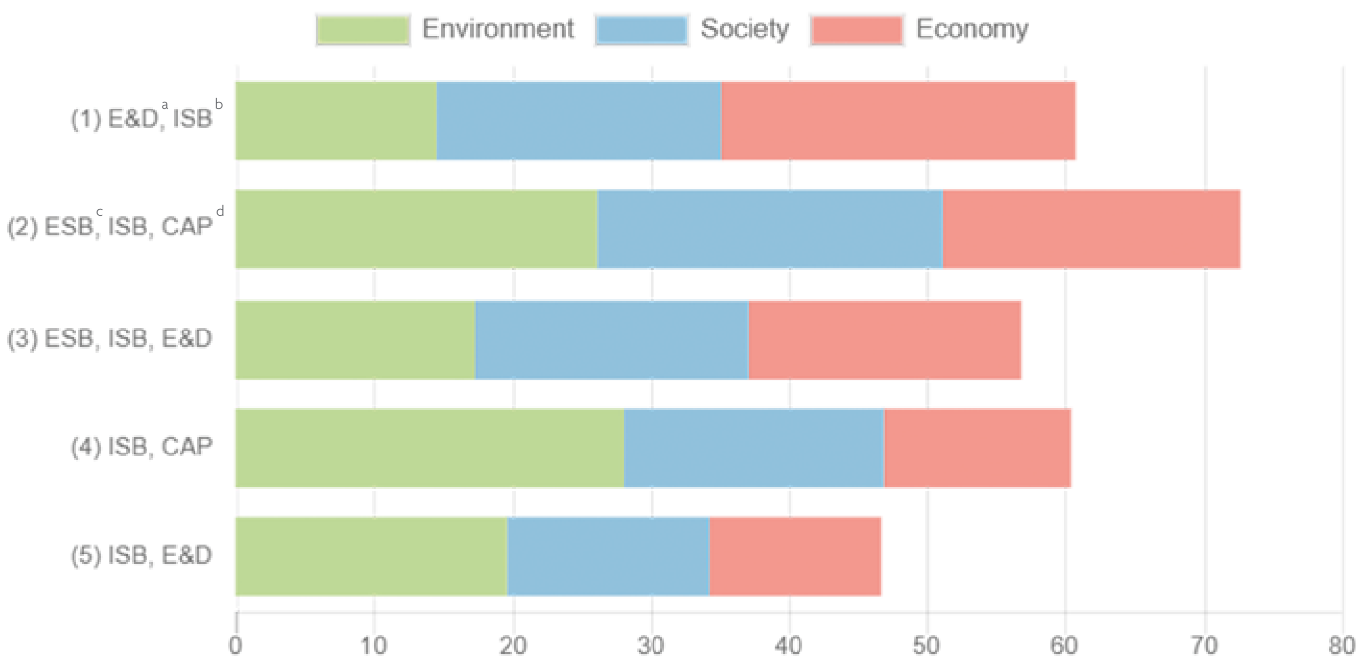
- SDG3: Ensure healthy lives and promote wellbeing for all;
- SDG6: Ensure availability and sustainable management of water and sanitation;
- SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; and
- SDG9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.

However, there are negative impacts associated with

▼ **Table 2: Shortlisted remedial options to be reviewed in SURE**

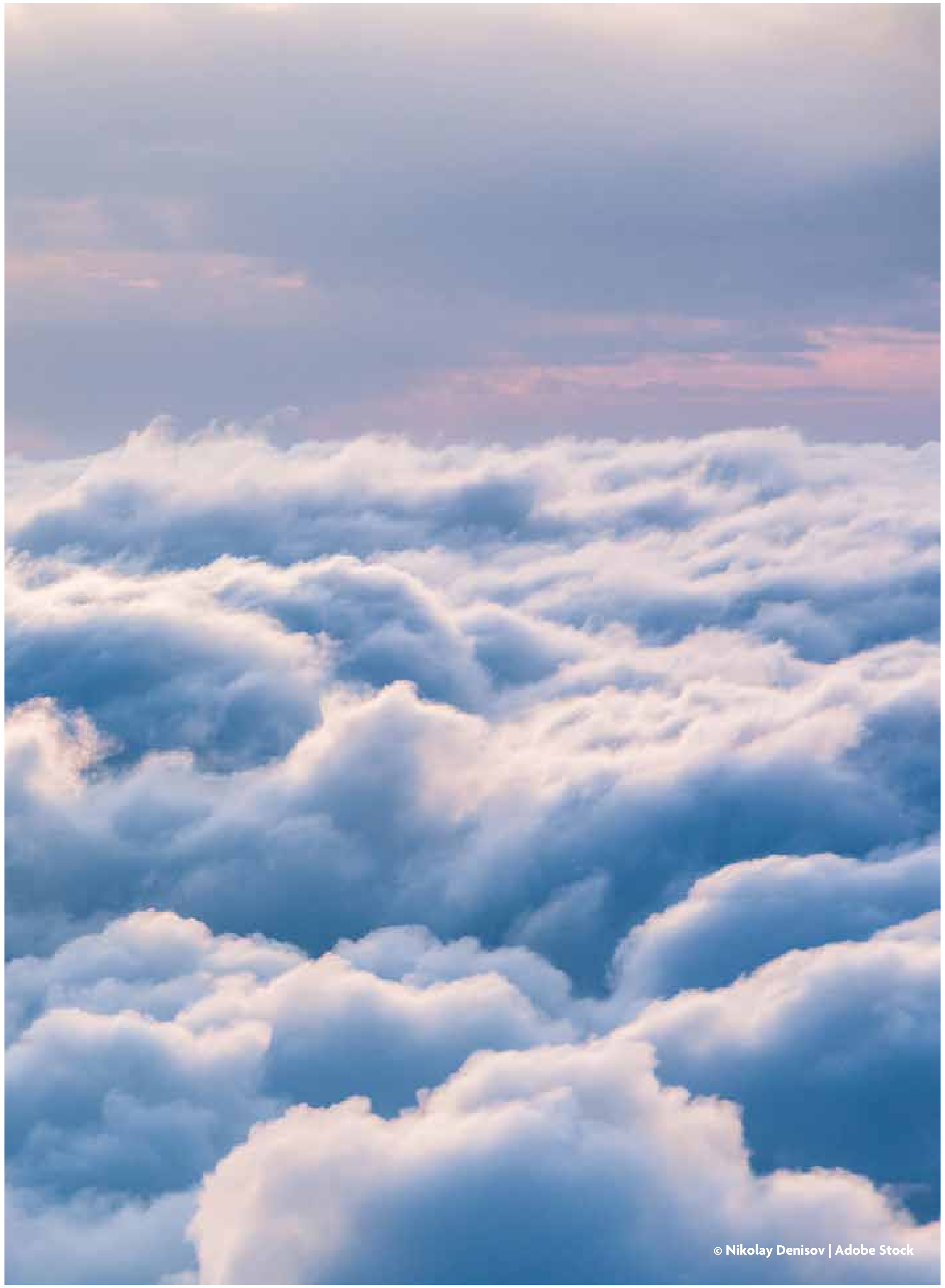
Option	Made-ground contaminants	Soil (total petroleum hydrocarbons)	Light non-aqueous phase liquids	Groundwater
1. E&D,[a] ISB[b]	Excavation and disposal		Skimmer/ absorbent	In situ bioremediation with optional chemical oxidation (as required)
2. ESB,[c] ISB, CAP[d]	Containment	Ex situ bioremediation	Skimmer/ absorbent	In situ bioremediation with optional chemical oxidation (as required)
3. ESB, ISB, E&D	Excavation and disposal	Ex situ bioremediation	Skimmer/ absorbent	In situ bioremediation with optional chemical oxidation (as required)
4. ISB, CAP	Containment	In situ bioremediation (proprietary: gypsum and granular active carbon filtration)		
5. ISB, E&D	Excavation and disposal	In situ bioremediation (proprietary: gypsum and granular active carbon filtration)		

Key:
[a] = excavation and disposal
[b] = in situ bioremediation
[c] = ex situ bioremediation
[d] = capping



Key:
[a] = excavation and disposal
[b] = in situ bioremediation
[c] = ex situ bioremediation
[d] = capping

▲ **Figure 2. Total scores for each option, showing contribution of scores by domain. (© Ramboll)**



Option 1 in terms of using valuable landfill capacity and moving the contamination problem from one place to another. Both options 2 and 5 made greater contributions than Option 1 to SDG7 (Access to affordable, reliable, sustainable and modern energy for all) and SDG13 (Urgent action to combat climate change); Option 2 also made contributions to SDG1 (No poverty). These greater contributions were due to lower development costs and reduction of the volume of contaminants present at the site without any off-site removal of contaminated material. What this highlights is that although a remediation option might have greater relative contributions to the SDGs, the charts do not show the negative contributions (see **Figure 4**) and therefore the assessor should pay greater attention to the overall sustainability score.

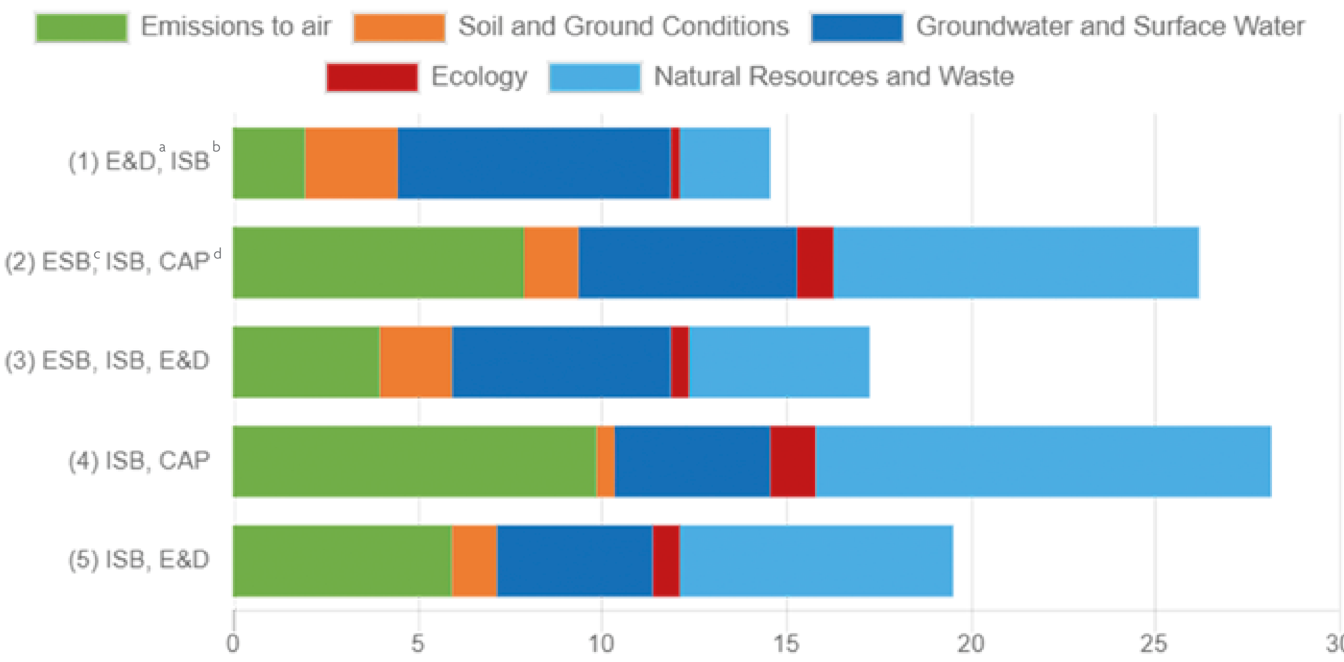
Based on the sustainability assessment undertaken and having achieved the highest overall sustainability score (see **Figure 2**), Option 2 was selected as the best approach and subsequently developed into a formal remediation strategy. The SURE outputs helped demonstrate to the regulatory authorities and client the greater sustainability benefits of implementing Option 2 compared to the other techniques. Option 2 was expected to have a lower contribution to climate change in terms of carbon and overall emissions than the other remediation options and was capable of leading to a permanent long-term improvement to the environment (air, soil and water).

CONCLUSIONS

Since 2021, Ramboll has applied SURE to a range of project types and locations, from historic timber-treatment sites and landfills in Finland to redevelopment of former fuel depots in England for residential use. SURE was Highly Commended at the 2022 Brownfield Awards in the Best Research, Innovation or Advancement of Science in the Brownfield Sector category and was an important part of the Plaistow Road project submission that won the Best Application of Remediation Technologies category, submitted jointly with Soilfix.

As remediation option tools should strive to be, SURE is easy to access, simple to use and an understandable tool for the layperson, facilitating a collaborative approach to projects, inclusive of stakeholder input. In summary, SURE:

- Is fully digitised and cloud-based, which enables rapid assessment and client and stakeholder engagement, supporting digital collaboration.
- Captures the key information for framing the assessment according to ISO 18504:2017, SuRF and NICOLE guidance.
- Includes over 70 indicators to be scored across the domains of environment, society and economy, as well as having automatic comparison of option performance with respect to the SDGs.
- Provides customisable assessments allowing users to modify assessment criteria to better suit each case and provides a fully transparent record of decision-making including stakeholder review comments.



Key:
[a] = excavation and disposal
[b] = in situ bioremediation
[c] = ex situ bioremediation
[d] = capping

▲ **Figure 3. Option scores per indicator category for the environment domain. (© Ramboll)**

Fig. 4a Option 1: ED[a] ISB[b]

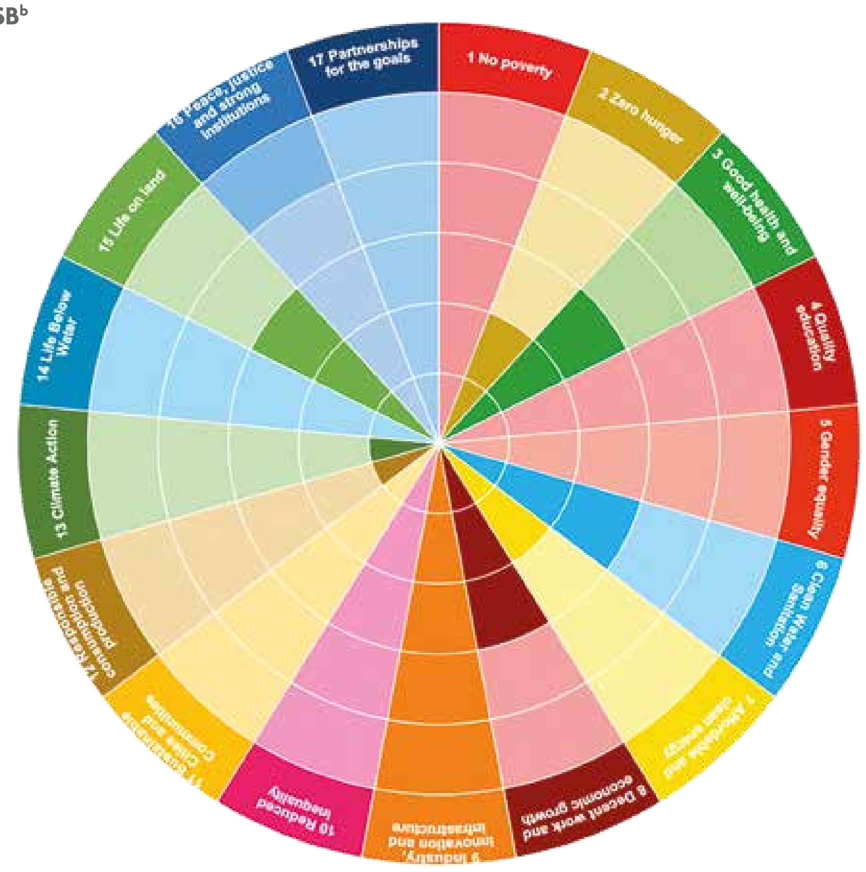
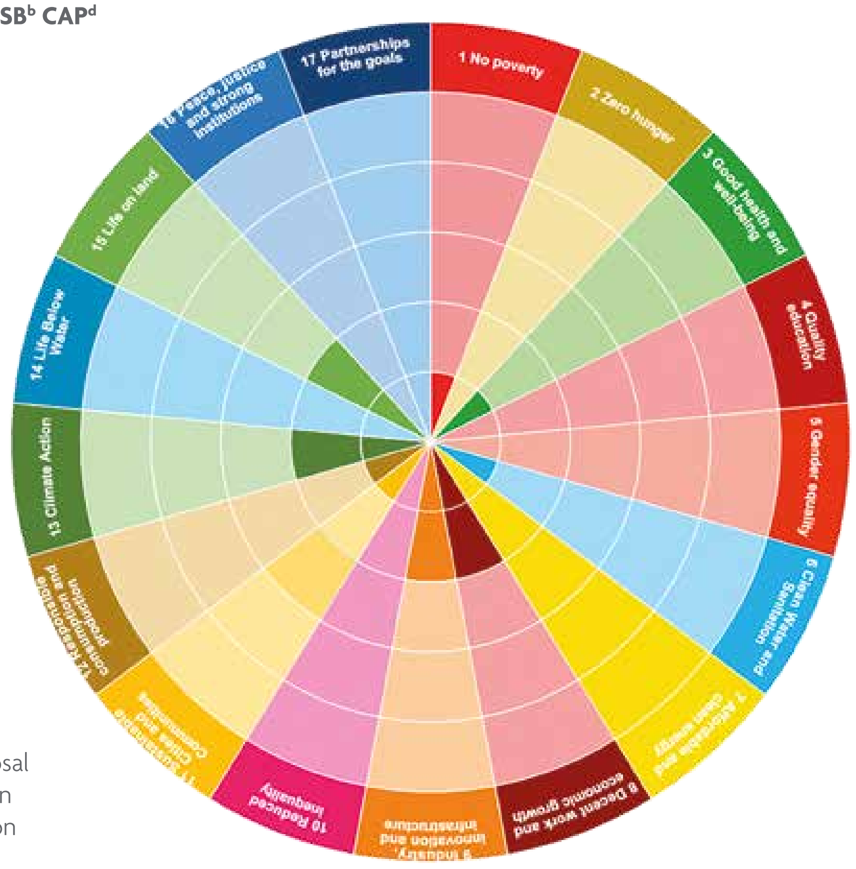


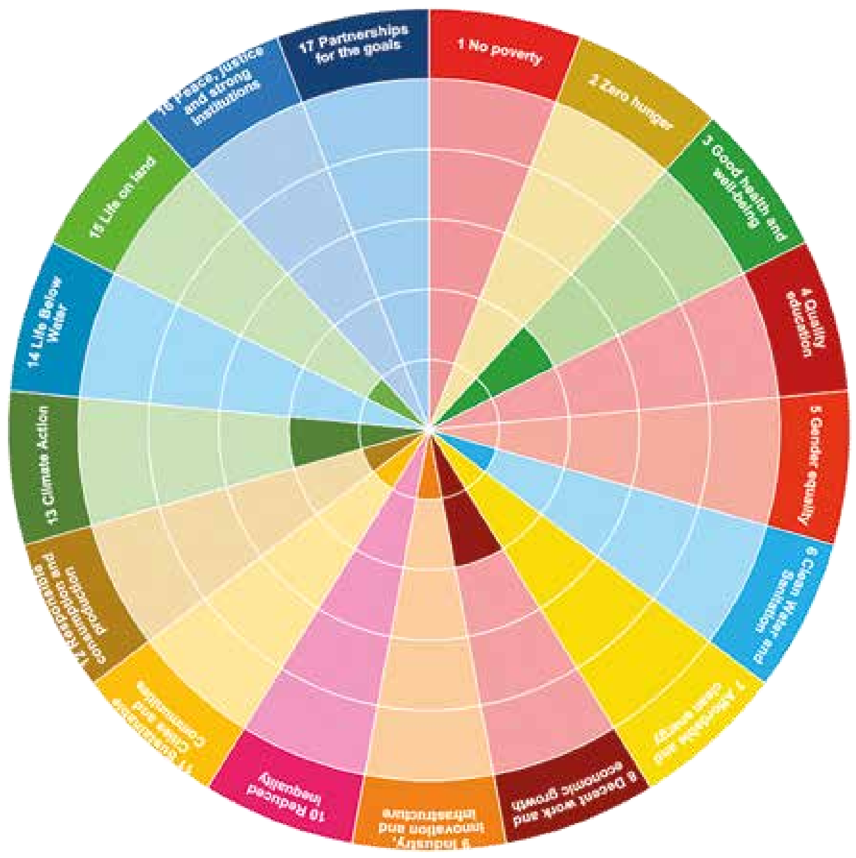
Fig. 4b Option 2: ESB[c] ISB[b] CAP[d]



Key:
[a] = excavation and disposal
[b] = in situ bioremediation
[c] = ex situ bioremediation
[d] = capping

▲ **Figure 4. Comparative contribution to Sustainable Development Goals: options 1, 2 and 5. (© Ramboll)**

Fig. 4c Option 5: ISB[b] ED[a]



It should be noted that sustainability is just one part of the overall remediation options appraisal process outlined in the UK Government's Land Contamination Risk Management process and so should not be used in isolation without consideration of other factors, such as regulatory requirements, cost, practicability and effectiveness.[4] There are a wide range of automated reporting options with clearly presented graphical results presentation. Educational guidance is provided for a broader understanding of sustainability principles.

The use of online tools like SURE can provide a more sustainable approach to soil and groundwater remediation, which will likely become more important as the European Environment Agency's global megatrends continue to influence the work of land condition professionals. ES

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Acknowledgements
The author would like to acknowledge the contribution of Richard Bewley (Retired) in drafting the original manuscript on which this article was based, as well as Ramboll's Dr Phil Studds and Andy Goddard for reviewing it.

Further reading
Access to SURE is available at www.ramboll.com/sure-by-ramboll, from where a new user can sign up and create an account.

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Antimicrobial resistance: the slow-burn pandemic

Lucy Bethell explains the enormous effects these tiny organisms can have on our environment and way of life.

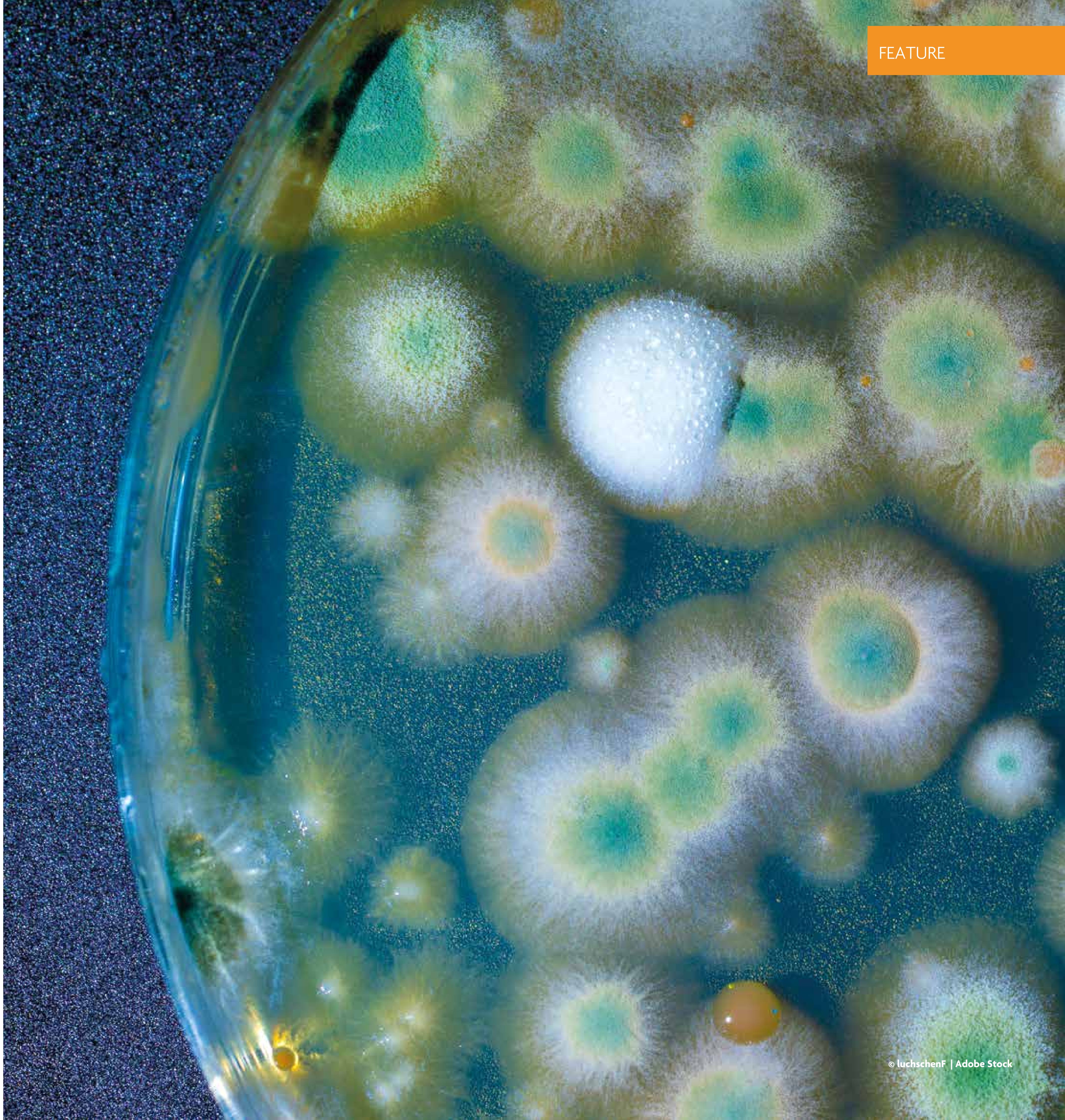
GLOBAL MEGATREND – 3

WHAT IS ANTIMICROBIAL RESISTANCE?

Antimicrobial resistance (AMR) is a recognised global threat that has been termed the 'slow-burn pandemic'. AMR occurs when microbes (bacteria, viruses, parasites and fungi) develop the ability to resist the drugs that are designed to combat them (antimicrobials), causing the standard treatments to become ineffective. Microorganisms that develop resistance to commonly used antimicrobials are known as superbugs.

An analysis of data from 204 countries in 2019 calculated that up to 5 million deaths were associated with drug-resistant bacterial infections, including over 1.2 million deaths that bacterial AMR caused directly.[1] It is estimated that AMR could cause 10 million deaths per year by 2050.[2]

The World Health Organization identifies AMR as one of the top 10 global public health threats facing humanity, while the European Environment Agency recognises that AMR has a role to play in its 11 megatrends considered to be of key importance for Europe's long-term environmental outlook – specifically, Changing Disease Burdens and Risks of Pandemics (GMT3).[3] The World



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Bank reports that, unchecked, AMR could shave US$3.4 trillion off GDP annually and push 24 million more people into extreme poverty in the next decade, largely due to extended illness with difficult-to-treat infections and the associated loss of economic productivity.[4]

WHAT CAUSES AMR?

When Sir Alexander Fleming, who discovered the first antibiotic (penicillin G in 1928), received the Nobel prize in 1945 he predicted AMR when he said:

'The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily under-dose himself and by exposing his microbes to nonlethal quantities of the drug make them resistant.'[5]

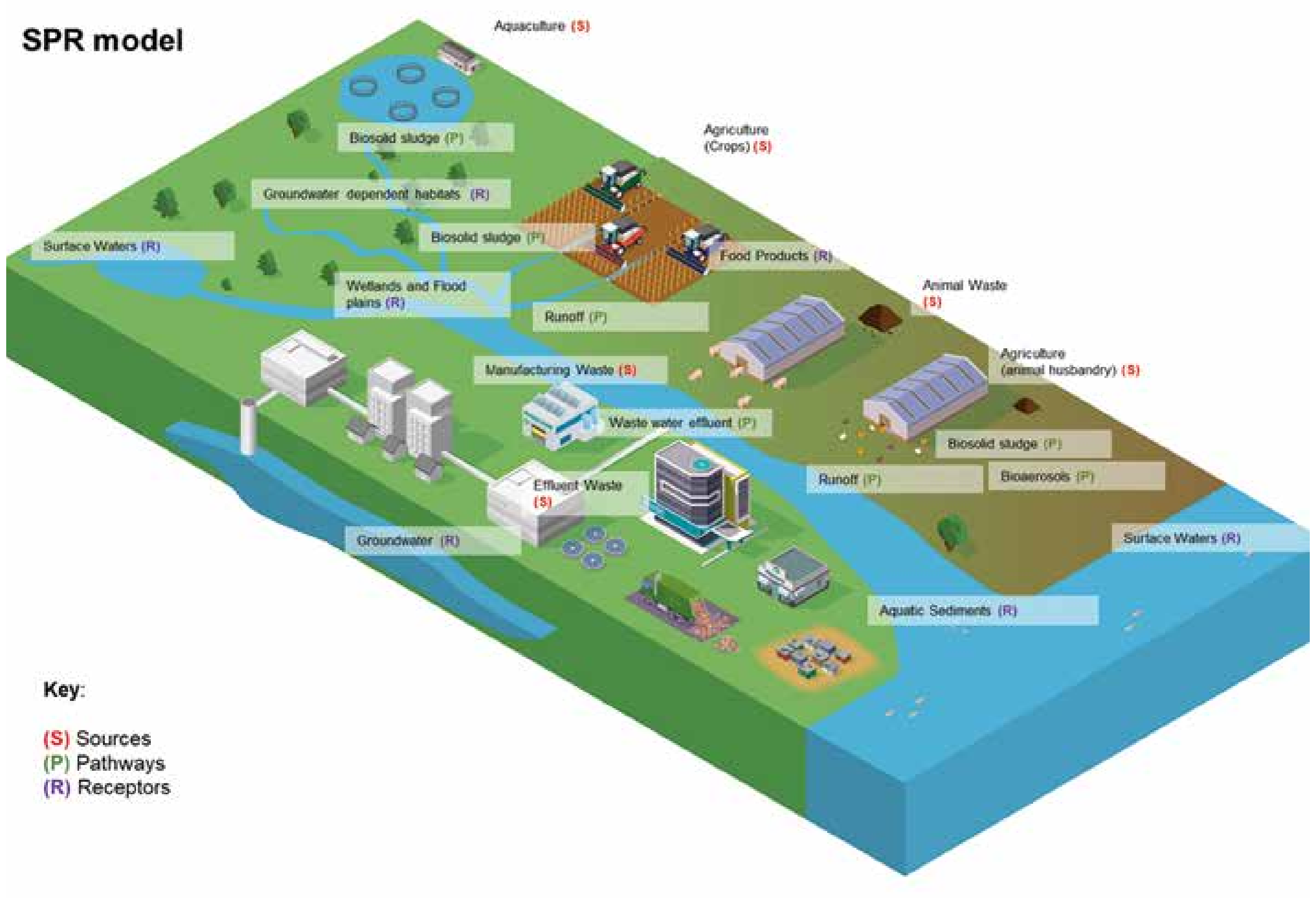
The main causes of AMR are often considered to be the overuse or improper use of antimicrobials in humans and the widespread overuse of antimicrobials (particularly antibiotics) in intensive animal rearing, aquaculture and agriculture. Resistance arises through one of three mechanisms:

- Natural resistance in certain types of bacteria;
- Genetic mutation for self-protection; or
- By one species acquiring resistance from another, known as horizontal gene transfer (HGT).

AMR is viewed as an emerging contaminant, but it is not new. It has been found in permafrost samples that are tens of thousands of years old. Natural resistance has been around for as long as bacteria have. However, as with other hazards, this resistance has been amplified by human behaviours. Key drivers – that is, elements that promote AMR – are:

- Antimicrobials and their residues (antibiotics, antifungals, antivirals and antiparasitics);
- Metals;
- Biocides; and
- Antimicrobial-resistant genes.

Genetic mutation is stimulated by exposure to sublethal doses of antimicrobials and their residues, metals or biocides. For example, antibiotics increase selective pressure in bacterial populations and cause vulnerable



▲ **Figure 1: Sources, pathways and receptors for antimicrobial resistance in the environment. (© Mott MacDonald)**

bacteria to die; if the dose of antibiotics is not enough to destroy the infection, this increases the percentage of resistant bacteria, which continue growing. It is a case of 'what doesn't kill them, makes them stronger'! Due to the short lifespan and rapid generational cycles of bacteria, meaning that they reproduce within minutes or hours rather than years or decades (unlike many mammals), bacteria with beneficial mutations can very quickly multiply and spread. Antimicrobial-resistant genes are involved in the process of HGT, whereby genetic information can transfer from one bacterium to another and across species, causing AMR to proliferate.

AMR is not just a health issue to be solved by better drugs; it is a global cross-sectoral issue. It disproportionately affects countries with predominantly low- to middle-income economies, not only due to direct loss of life, but also by putting excess demands on under-resourced healthcare systems. In addition, there is a threat of losing livestock herds and entire crops (e.g. to fungal disease in plants) if antimicrobials no longer provide effective treatment. Addressing the threat requires a holistic approach involving responses across water and sanitation, animal and food production, education, society, environment, and waste management and health facilities.

THE ROLE OF THE ENVIRONMENT IN AMR

The environment is increasingly being recognised for the role it plays in the global spread of AMR. The linkages and interactions within the environment are complex. In 2019, Mott MacDonald undertook an internal literature-based study to review AMR in the environment. It adopted a source–pathway–receptor methodology, which will be familiar to many environmental professionals, especially those working within the land condition sector (see **Figure 1**).

Key sources that were identified include:

- Human waste, which can carry AMR pathogens. Between 40 and 90 per cent of consumed antibiotics are excreted in their active form.[6] When this waste enters the wastewater treatment system, it will either biodegrade, be absorbed by sewage sludge, or exit through sewage works' wastewater unchanged.[7]

In many countries a high percentage of waste is discharged untreated directly into the environment – for example, through discharge into the closest drainage channel or water body or via latrines and pits (formal or informal).

- Animal waste. Approximately two-thirds (65,000 tonnes) of all antibiotics produced each year are used in animal husbandry and a large percentage of this is excreted.[8] Antibiotics are increasingly being used non-therapeutically or to encourage growth. In many countries, antibiotics for animals are readily available over the counter at a low cost, and do not need a veterinary prescription. The demand and use of antibiotics in animal husbandry is likely to increase in low- and middle-income economy countries as demand for animal protein increases. Conversely, as awareness grows, some governments are restricting the use of critical antibiotics in animals and banning their use in animal feed.

- Aquaculture. It is estimated that up to 75 per cent of antimicrobials used in aquaculture may be lost to the environment.[9]

- Antimicrobial manufacturing waste. Antimicrobials and their residues may be released into the environment where there are no effective control measures in place. There are no international standards for wastewater limits for antimicrobials and so they are not routinely tested for.

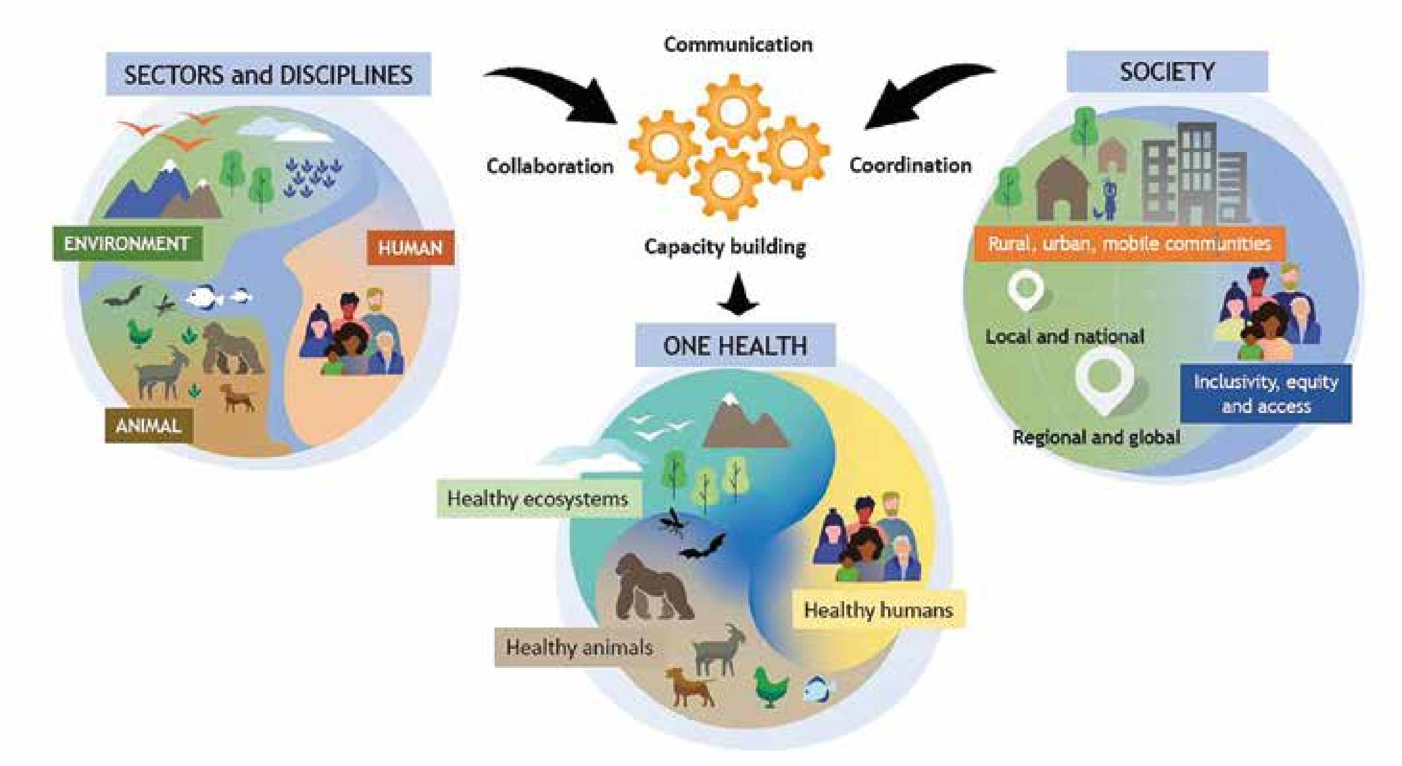
The main pathways of AMR that were identified include:

- The release of municipal wastewater into surface waters, coastal waters and potentially groundwater;
- The application of biosolids (sewage sludge) to land, which results in leaching into groundwater;
- Waters contaminated by aquaculture practices;
- Crop spraying; and
- Airborne particles and bioaerosols.

The ultimate receptor is humans; however, intermediary receptors also include microbial populations in groundwater, surface waters, food products and ecosystems. These ultimately impact human health via various routes, including groundwater abstracted for drinking water supplies, contaminated food, and direct-contact pathways such as inhalation or ingestion of soils or dust.

Through a simplistic risk ranking, key pollutant linkages were then identified. Linkages of moderate to high significance included discharge of untreated sewage, land application of animal waste and direct discharge of manufacturing waste to the environment. This risk ranking supports an approach of tackling the most significant sources, where solutions can have the greatest impact.

The study aligns with the more recent United Nations Environment Programme (UNEP) research, which identifies three sector value chains that profoundly influence AMR's development and spread:



▲ **Figure 2: One Health definition developed by the One Health High-Level Expert Panel. (Source: World Health Organization[11])**

- Pharmaceuticals and other chemicals manufacturing;
- Agriculture and food, including terrestrial animal production, aquaculture and food crops; and
- Healthcare delivery in hospitals, medical facilities, community healthcare facilities and in pharmacies, where a range of chemicals and disinfectants are used.

UNEP proposes that the response must be based on a One Health approach, recognising that humans, animals, plants and environment are interconnected and indivisible at the global, regional and local levels from all sectors, stakeholders and institutions (see **Figure 2**).[10] Prevention is at the core of the action needed to halt the emergence of AMR and the environment is a key part of the solution.

CONTAMINATED LAND AND AMR

The AMR challenge requires a cross-sectoral, multi-disciplinary response, which involves environmental professionals. All environmental professionals can support efforts to tackle AMR within their disciplines by developing an understanding of AMR with respect to their work, raising awareness, and most importantly through surveillance. At present, there is a limited and lacking dataset, making research and solution development challenging. AMR is an ever-changing phenomenon that needs adequate and regular monitoring in terrestrial and marine waters, flora, fauna and soils, to name a few.

AMR is relevant to land quality professionals working on contaminated sites, as heavy metals are a key driver of AMR. Heavy metals such as copper, zinc, manganese, nickel, chromium and iron in high enough concentrations act as antimicrobials, and the accumulation of other heavy metals with a non-biological role, such as lead and cadmium, may cause mutagenesis. The toxicity of heavy metals in the environment is strongly dependent on conditions including pH, organic matter and redox – and therefore bioavailability – of the metal ions. Given that heavy metals do not degrade within the environment, not only do selective pressures persist longer than pharmaceutical and clinical compounds, but due to industrial and urban pollution the scale of the selection pressure is far more extensive than any other driving agent in this environment.

Metals in sediments are also considered to be aquatic sediments and are a considerable reservoir of resistant microorganisms.[12] Microorganisms within aquatic sediments are exposed to a vast range of continually changing conditions due to annual cycles in water chemistry within river systems. Anthropogenic pollution to watercourses can lead to rapidly alternating

FEATURE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conditions, which may result in a switching of absorption and desorption reactions between metals and aquatic sediments. Sediments may store metals and nutrients through sorption on to the surface of sand and organic particles for significant amounts of time; eventually they destabilise due to changing water chemistry, resulting in a mass release. Metals do not degrade and are not easily mobilised.

Land quality professionals can target and integrate AMR with regard to remediation of polluted legacy sediments and soils and address and manage industrial waste entering the water environment. This could include modifying common practices within risk assessments to consider AMR risks and notify all stakeholders, incorporating AMR as a factor in options appraisal for remediation strategies, and to ensure we are not underestimating the significance of metals in risk assessments.

CONCLUSION

AMR, like other global threats, is a long-term battle, and many of the actions we take now will have longer-term results. The challenge is to act now to accelerate the fight against AMR by adopting a collaborative approach, globally and across all sectors, to increase surveillance by collecting robust data and to develop plans and solutions applicable to all.

Raising awareness of AMR in the environment is also a key priority. AMR is recognised by many national and global organisations such as the World Health Organization, the World Bank and the European Environmental Agency – the latter specifically within the global megatrend of Changing Disease Burdens and Risks of Pandemics (GMT3).

As individuals, we can use our skills to raise awareness and integrate AMR into our work and avoid excessive use of biocides. And if you are prescribed antibiotics, please finish the course! **ES**

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Acknowledgements

Thank you to Sarah Dobson and Chelsea Stefanska for their specialist health-related inputs, and to Allison Powell for reviewing the article.

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Future-proofing building foundations against climate change impacts

Roseanna Bloxham and **Tom Henman** explore the known and anticipated impacts and their implications for foundation design and construction.

GLOBAL MEGATREND – 9

BACKGROUND

Climate change has the potential to cause significant impacts on the environment, society and economy, such as biodiversity loss, water scarcity, food insecurity, health issues, migration, conflicts and poverty. The European Environment Agency's global megatrends, and in particular Increasingly Severe Consequences of Climate Change (GMT9), analyse the current trends and future projections of climate change and its implications for Europe and the world.[1]

In the UK, as required by the Climate Change Act 2008, climate change issues are considered in five-yearly climate change risk assessments. These set out the risks (and opportunities) resulting from climate change, together with a National Adaptation Programme developed to address them. The third such report, published in January 2022, presented strong evidence that even under low-warming scenarios, the UK 'will be subject to a range of significant and costly impacts unless significant further action is taken now'.[2]

The Climate Change Committee (CCC) provides technical input and independent oversight of the progress being made by the UK Government and devolved administrations. Its third Independent Assessment of UK Climate Risk (CCRA3), published in June 2021, included a call for action (see **Box 1**).[3] This was reaffirmed in the CCC's March 2023 report to parliament on progress in adapting to climate change, which further highlighted the urgency, taking account of the impacts of extreme weather experienced in the UK in the summer of 2022.[4]

CCRA3 identified a total of 61 risks and opportunities relevant to every aspect of life, including the natural environment, health, homes, critical infrastructure and the economy, and provided statutory advice to governments on adaptation. Of these, eight risk areas were identified as requiring the most urgent attention over the next two years, one of which was the risk to human health, wellbeing and productivity from increased exposure to heat in homes and other buildings. Also highlighted in the report were risks to 'building fabric', identified as requiring further investigation.

BOX 1. A CALL TO ACTION

'Climate change has arrived. The world is now experiencing the dangerous impacts of a rapidly heating climate. And further warming is inevitable, even on the most ambitious pathways for the reduction of global greenhouse gas emissions. Only by preparing for the coming changes can the UK protect its people, its economy and its natural environment. ... Our advice draws on extensive new evidence gathered. ... Alarmingly, this new evidence shows that the gap between the level of risk we face and the level of adaptation underway has widened. Adaptation action has failed to keep pace with the worsening reality of climate risk.' CCRA3, June 2021[3]

In the UK Government's Climate Change Risk Assessment 2022, the economic magnitude of each risk was assessed, with the risk to building fabric determined to be high (at a cost of hundreds of millions of pounds per year) by the 2050s and very high (at over £1 billion per year) by the 2080s, under either a 2C or a 4C warming scenario.[2] These economic costs are already starting to be reflected in increases in insurance claims relating to issues such as building subsidence.

▲ **Figure 1: An example of minor building damage caused by subsidence. (© RSK)**

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These identified risks and challenges, along with the requirement in national planning policies for new developments to take a proactive approach to mitigating and adapting to climate change, were drivers for the commissioning of the National House Building Council (NHBC) Foundation report.[5] In addition, as part of the drive to net zero, the report considers the carbon footprint of foundation systems, how it can be reduced and the interactions between climate change resilience and low-carbon design and construction solutions.

CLIMATE CHANGE PREDICTIONS AND IMPLICATIONS

The Met Office UK Climate Projections (UKCP18) are the most up to date for the UK and indicate that climate change should be considered an ongoing phenomenon rather than a step change.[6] Climate change impacts identified to be relevant to buildings include hotter and drier summers; warmer and wetter winters; continued sea-level rise; and increased frequency and intensity of storms with high rainfall events.[2,3] Risks to health and wellbeing from high temperatures indoors and risks to people, communities and buildings from flooding are the two most significant building-related risks identified by the CCC; however, there is also a wider range of climate risks to building fabric recognised as requiring further research.[4] Climate change risks and associated geohazards relevant to the design and construction of building foundations are detailed in the NHBC report (see **Table 1**).[5]

Shrink–swell in cohesive soils is perhaps one of the most widely documented and detrimental geohazards experienced in Britain today. This has the potential to be exacerbated by hotter and drier summers through desiccation effects in clays (as well as wetter winters causing increased swelling). This can lead to increased damage to buildings and structures from subsidence and heave. While this can sometimes be catastrophic, it more commonly manifests as minor damage and nuisance, such as walls cracking, doors and windows sticking and disruption to utilities (see **Figure 1**).

The presence of trees and vegetation close to buildings – increasingly promoted UK-wide through planning policy for its other benefits – may directly and indirectly increase the subsidence and heave risks to existing structures and infrastructure, including building foundations. This is particularly the case for areas affected by shrink–swell,

▲ **Figure 2. Damage to housing caused by a sink hole. (© RSK)**

▼ **Table 1. Climate change risks and associated geohazards relevant to the design and construction of building foundation.s[5]**

Climate change impacts	Climate-related risks	Geohazards that could impact existing buildings	Implications for new buildings
Hotter and drier summers	Desiccation effects in shrinkable cohesive soils (clays): shrink–swell.	Subsidence and heave leading to potential damage to existing buildings constructed in accordance with current standards (see **Figure 1** and **Figure 2**).	New buildings may require design and construction of deeper foundations or the use of alternatives to counter the effects.
	Wildfires spreading from vegetated areas.	Observed in the 2022 summer heatwave. Affects building fabric through fire or heat damage.	May affect siting of buildings but not directly applicable to building foundations.
Warmer and wetter winters	Increased moisture content of soils, higher water tables. Lack of ground freezing. Increased risk of flooding (see storms).	Wetter winters cause rebound of soil moisture levels leading to increased shrink–swell (see hotter and drier summers).	Increasing difficulty of construction of foundations and infrastructure in winter.
Continued sea-level rise	Coastal flooding and storm surges.	Direct and indirect effects on existing buildings in coastal areas. Coastal erosion and site inundation leading to rockfalls, subsidence and building damage (see also flooding). Higher sea levels in coastal areas may cause corrosion of foundations from contact with more saline groundwater.	Future siting of new buildings will require careful assessment, and corrosive effects of saltwater will need to be considered in foundation design, particularly for high-rise developments.
Increased frequency and intensity of storms with high rainfall events – prolonged and heavy periods of rainfall or rise of groundwater levels	Flooding – direct damage, erosion and site inundation.	Potential structural failure, water ingress, mould growth, contamination and corrosion, which can affect the durability and performance of building materials.	Same risks as for existing buildings but must be considered for building siting and at design stage.
	Washout-induced damage to foundations and structures.	Potential damage to existing buildings through undermining of foundations and infrastructure through the washout of soil particles by flowing water, such as from flash-flooding events (see **Figure 3**).	Design of foundations for buildings in flood-prone areas that considers the risk of washout and hydraulic modelling of drainage systems and watercourses will be required in areas that could be subject to flash floods.
Increased frequency and intensity of storms with high rainfall events – prolonged and heavy periods of rainfall or rise of groundwater levels	Reduction in soil strength associated with increases in porewater pressure on engineered structures. Collapsed settlements in earthworks and fills (principally cohesive and weak rock fills) due to inundation.	Where pore pressures increase, effective stresses and strength in the soil reduce, resulting in potential detrimental effects on structures such as embankments and retaining walls, as well as natural and human-made slopes. This can lead to a loss of stability and, in the worst case, failures to occur, ranging from small to large scale (e.g. landslips). These can have direct and indirect effects on existing buildings.	The degree to which slopes can cope with these rates of change needs to be assessed as part of design. Well-established technologies and methods can then be applied to facilitate the effective removal of excess porewater pressures. Potential requirement on new developments for pre-construction consolidation of fills.
	Dissolution of calcareous rocks, such as chalk and limestone, and evaporites. Increased mining-related hazards.	The slight acidity of rainwater dissolves calcareous rocks creating underground voids, leading to collapse and potential surface settlement, subsidence and building damage (see Figure 2). Such deposits, as well as coal and minerals, have been mined over millennia, with resulting geohazards. There is evidence to suggest that the occurrence of sinkholes and subsidence events in affected areas is increased by sustained periods of very wet weather. The level of vulnerability of existing building foundations to dissolution-related hazards depends on the foundation type, and, where relevant, mining features present.	Due to the increasing climate-related risks, it will be important to undertake a detailed investigation of sites considered vulnerable to dissolution or historical workings and to assess the geotechnical risks arising over the lifetime of the development, taking account of relevant climate change predictions. For new developments in mining areas, detailed assessment of old mine entries and associated backfill will be required in light of potential groundwater rise.

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▲ **Figure 3: Catastrophic damage caused by floods in north-east England in 2012. (© Tyne and Wear Fire Rescue Service)**

where careful selection of suitable tree species and design of layouts to accommodate future growth of trees without conflict is essential to minimise the potential risk of structural damage to buildings.

IN SUMMARY

The analysis undertaken by RSK on behalf of NHBC supports our understanding of climate change-related risks to building foundations and thereby contributes to efforts to adapt to the increasingly severe consequences of climate change. The NHBC report[5] concluded that the identified risks to existing buildings and associated future disruption may essentially be 'locked in' for swathes of the current building stock, including many of those that have recently been built. Costly remedial options, such as widespread underpinning of impacted foundations, are unlikely to present a viable or sustainable option. The geohazard risks identified relating to climate change impacts are based on current modelled predictions and it is acknowledged that there are uncertainties about the extent of change, particularly for longer time horizons. Greater changes in climatic conditions may result in significant changes in the physical and mechanical properties of the ground (relating to moisture levels within the ground), thereby causing significant structural damage, particularly on lightweight constructions built on swelling soils.

For new builds, the NHBC report recommends that developers and building foundation designers should consider the identified climate change risks and associated geohazards and how these may vary over the lifetime of each development.[5] New buildings may have to be designed and constructed with deeper foundations to counter these effects and to increase climate resilience. However, it is recognised that this needs to be balanced against net zero considerations and the need to reduce, rather than increase, embodied carbon associated with building construction. Alternative foundation options will therefore also need to be considered.

Research related to the impacts on building design and construction is ongoing and it is anticipated that updates to current standards and guidance will be required to combat the current and predicted future effects of climate change. **ES**

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New members and re-grades

Associate is for individuals beginning their environmental career or those working on the periphery of environmental science.

Alysia Akerman – Graduate Environmental Specialist
Shawn Almeida – Environmental Advisor / Chemist
Abdullah Alssubail – Environmental Engineer
Gabriel Aweya – Assistant Marine Officer (Hydrography)
Bethan Barkley – Environmental Assistant
Alexander John Batchelor – Assistant Consultant
Alistair Bell – Assistant Environmental Consultant
Laura-Jane Bingham – Graduate
Marie-Louise Bonzon – Graduate Environmental Planning Consultant
Tom Conboy – Environmental Technician
Holly Diggins – Environmental Consultant
Jemma Doyle – Environmental Scientist
Emily Elgie – Environmental Monitoring Technician
Maria Agustina Fernandez Zoppi – Assistant Air Quality Consultant
Hannah Fleming – Environmental Scientist - Air Quality
Anna Freel – Geo-environmental Engineer
Victoria Head – Graduate Environmental Scientist
Charlie Irwin – Graduate Geo-environmental Engineer
Hannah Jones – Geo-environmental Consultant
Simon Jones – Head of Air Quality
Richard Jovic – Technical Officer
Alexander Kani – Postgraduate Researcher
Rhys Laverty – Environmental Consultant
Dan Lee – Senior Energy & Climate Change Consultant
Jinho Looi – Air Quality Consultant
Daniel McGrath – Director
Alice Molyneux – Environmental Consultant
Lauren Nixon – Graduate Consultant
Amy Nyiri – Environmental Consultant
Matthew Park – Graduate Air Quality Consultant
Kirsty Paton – Environment & Sustainability Consultant
Natalia Perez del Postigo Prieto – Technical Specialist
Jessica Potts – Soil Consultant
Georgia Puleikis – Environmental Consultant - Climate & Sustainability Services
Lachlan Robins – Graduate
Elliot Ross – Graduate Air Quality & Climate Consultant
Japhet Santana Huizar – Scientist GIS
Grace Staines – Technical Advisor Air Quality
Nikita Vasilev – Sustainability Consultant
Rachel Whitty – Air Quality Consultant
Rieve Wishart – Environmental Scientist
Eunice Wong – Graduate Environmental Scientist

Affiliate is for individuals with an interest in environmental issues but who don't work in the field, or for students on non-accredited programmes.

Craig Beckington – Waste Co-ordinator
Adam Casey – Affiliate
Nicola Crabbe – Programme Manager
Virginia Cundy – Environment Monitoring Officer
Jinnawat Lertpradit – PHD student
Terin Raj – Graduate
Andrew Wilkins – Applications Engineer

Member is for those individuals who have substantial academic and work experience within environmental science.

Sadaf Aftab – Air Quality Consultant
Amjed Ahamed – Quality Control Officer
Rayhela Ahmed-Monju – Principal Environmental Consultant
Ricardo Arroyo – Senior Sustainability Consultant
Emily Bancroft – Environmental Consultant
Samuel Bradley – Environmental Consultant (Air Quality)
Emily Broughton – Senior Geo-environmental Consultant
Elizabeth Bruce – Senior Technical Officer
Gabriele Carlisi – Senior Environmental Advisor
Gareth Carroll – Senior Environmental Consultant
Wing Shan Cheung – Senior Air Quality Consultant
Robert Cooke – Sustainability Director
Nicola Courthold – Senior Officer - Environmental Monitoring
Rob Dalziel – Senior Ecologist
Andrew Dick – Director
Hazell Dinsdale – Senior Environmental Consultant
Jack Douglas – Associate
Paul Doyle – Technical Advisor & Acoustics Lead
Amy Dunne – Senior Environmental Consultant, Environment & Sustainability
Tomos Eaves – Senior Environmental Consultant
Rebecca Edwards – Senior Consultant
Ezeh Philip Emenike – Environmental & Safety Controller
Kerry Fairley – Senior Associate
Simon Farley – Associate Technical Director
Martin Feery – Environment & Sustainability Manager
Martin Ferreira – Associate Hydroecologist
Maeve Fryday – Director of Environmental Planning
Erin Galbraith – Geo-environmental Consultant
Nicholas Gilmour – Principal Consultant
Naomi Ginnever – Head of Environment
Olivia Hack – Senior Sustainability Manager
Sarah Hamill – Contaminated Land Officer
Francesca Hammond – Senior Consultant
Paul Hardwick – Consultant in Water Environment Sciences
Lynn Hassett – Associate, Environmental Impact Assessment Co-ordinator
Matthew Hogg – Principal Consultant
Phoebe Honan – Air Quality Consultant
Jacqui Hooper – Senior Environmental Analyst
Sarah Illingworth – Senior Environmental Consultant
Laura Jones – Senior Geo-environmental Engineer
Vera Jones – Associate Director & Water Quality Technical Authority
Dhruv Joshi – Air Quality Consultant
Graham Jukes – Parish Councilor
Stuart Kirk – HSE Supervisor - Electrification
Ho Ming Kong – Environmental Consultant
Ishmail Konteh – Geoenvironmental Engineer
Norbertus Kraakman – Associate Director of Process Engineering
Robin Lancefield – Associate Director of Land Quality
Lillian LeClair – Associate - Environmental Project Manager
Diane Leishman – Engagement & Behaviour Change Officer
Michael Loyns – Asset Engineer
Emily Macey – Senior Air Quality Consultant
Amy Marcham – Technical Specialist
Ellis Marshall-Padkin – Principal Air Quality Consultant
Giulia Matteoni – Senior Environmental Consultant
Leanne Matthews – Environmental Consultant
Laura McMurtry – Environmental Scientist
Laura McNeill – Environment Consultant
Laura Moore – Environmental Specialist (Stategy)
John Murlis – Independent Environmental Consultant
Evans Onyedikachi Nwachukwu – Environmental & Facilities Lead
Esteban Olmos – Associate Director
Helen Pearce – Consultant
Sophia Postoyko – Assistant Environment Manager
Carl Ramskill – Senior Air Quality Consultant
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Liam Ridley – Environmental & Sustainability Consultant
Spencer Robinson – Geo-environmental Consultant
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TECHNICAL

Measuring and mitigating volatile organic compounds and odour emissions from remediation sites

Sarah Horrocks outlines how urbanisation is bringing the need for this to the fore.

GLOBAL MEGATREND – 2

GLOBAL MEGATREND – 3

The European Environment Agency's global megatrend Towards a More Urban World (GMT2) recognises that urban growth is driving land-use change in Europe.[1] Compact cities are considered the most efficient and environmentally sustainable way to secure the welfare of a growing population. In many cities, however, space is at a premium and there are significant pressures on local authorities to identify suitable land for residential development. Furthermore, urban air pollution, especially ambient particulate matter and ozone, is set to become the main environmental cause of mortality worldwide by 2050, as identified by Changing Disease Burdens and Risks of Pandemics (GMT3).

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Brownfield sites offer many opportunities for urban expansion but often require substantial intervention to clean up legacy contamination. Former gasworks are one example of such sites in urban areas. Many have been decommissioned or repurposed for commercial activity but can remain a source of environmental contamination due to the way waste was disposed of prior to the introduction of environmental legislation many decades ago. These sites are a continued risk in terms of contamination, containing dense and light non-aqueous phase liquids (e.g. coal tar, chlorinated solvents, diesel and petrol) that can leach into land, groundwater and surface water, and so require careful remediation before residential development is permitted.

The methods for minimising soil and groundwater risks during the remediation of contaminated sites are well established in the UK, overseen through planning by local authorities and permitting by the relevant regulatory agency. However, when land is disturbed during remediation, a new risk of emissions to atmosphere arises. Volatile organic compounds (VOCs) and associated odours can be emitted to air, posing a potential health risk to nearby communities. VOCs can adversely affect human health, either through the respiratory system or because they are carcinogenic. Emissions also affect the environment, contributing to photochemical smog formation and secondary aerosols in the form of particulate matter ($PM_{2.5}$), with indirect effects on human health.[2] Proper management of remediation, including monitoring and mitigation of emissions to air, is essential for a holistic strategy that considers all potential risks.

Measuring and managing these emissions to air is critical to reducing human health risks; however, there is no standardised detailed methodology for doing so, and sites adopt different approaches and criteria in the absence of established guidelines. For example, the UK Government's land contamination risk assessment appears to focus on odour and nuisance control.[3]

Work on air quality around former gasworks and industrial sites has been subject to a high level of stakeholder scrutiny in recent years. Long-term health effects from VOCs and anxiety around odour releases

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occur below a level that is typically considered a statutory nuisance (defined in the Environmental Protection Act as unreasonable and substantial interference on the use and enjoyment of a person's property[4]). Low-level emissions over long remediation programmes can occur due to site workers becoming desensitised or because only strong odours are readily mitigated. It is clear from recent experience that a holistic strategy is needed that addresses nuisance odour and health impacts from acute VOC exposure as well as public anxiety about exposure to low-level emissions.

MONITORING STRATEGIES

The types and amounts of VOCs and odours emitted from gasworks sites vary depending on the former use (e.g. production or storage), contaminants in the soil, and remediation techniques used. When designing a monitoring strategy it is important to identify the type and potential sources of VOCs – of which there are thousands (see **Box 1**). The selected monitoring approach should distinguish between sources to enable targeted mitigation, should the need arise.

The monitoring and management of ambient odours and VOC emissions during remediation requires close co-operation between air quality and land condition specialists, something that is often missing until works commence, or in the worst case, when odour complaints arise.

HOW VOCS ARE MEASURED

Measuring VOC emissions and odours on a remediation site is challenging due to the number of pollutants, variability in emissions magnitude, and complexity of remediation processes. Sites regularly change shape (the boundary of working areas within a site, and type of work) and are often highly constrained, with deep excavations; therefore, the suitability of monitoring locations needs constant review. To address such challenges, a multi-purpose monitoring strategy should be established early on in consultation with air quality specialists. This ensures the right techniques are deployed at the right time to achieve reliable results to inform mitigation and public communication strategies (see **Box 2**).

The best approach for an individual site depends on factors such as proximity to receptors (i.e. the risk of public exposure), the type and quantity of VOCs likely to be emitted, and the measurement objectives – for example, as set by regulatory requirements: what order of magnitude needs to be measured and to what level of detail; what criteria are being applied?

CRITERIA

Except for benzene and 1,3-butadiene, there are no statutory ambient air quality criteria for VOCs in the UK.[5] Over 100 different VOCs may be identified in air monitoring at a gasworks site, and a hierarchy must be established to ensure a robust interpretation of findings.

The Environment Agency has developed environmental assessment levels (EALs) for use in environmental permitting.[6] In developing these, the Environment Agency explicitly excluded air quality standards (e.g. the limit values and objectives set in UK regulations) and occupational exposure limits, such as the Health and Safety Executive's workplace exposure limits (WELs).[7] This is because neither is based solely on the scientific and medical evidence of human health effects, having also accounted for factors such as the technical and economic feasibility of achieving the standards. In addition, workers do not represent the general public because of the nature of their exposure

BOX 1. GASWORKS REMEDIATION SITES AND VOCS

TYPICAL VOC EMISSIONS SOURCES

- **Soil** May be contaminated with VOCs such as gasoline, oil or solvents.
- **Groundwater** When pumped to the surface for treatment, VOCs can be released.
- **Equipment and machinery** VOCs can be released from the exhausts of pumps, generators and other site equipment running on hydrocarbon fuels.
- **Waste disposal** VOCs can be released if stockpiles of excavated soil are not properly managed.
- **Soil vapour extraction** If the extracted vapours are not captured or properly treated, VOCs can be released.
- **Chemical oxidation** Injecting oxidising agents into the soil to break down VOCs can also lead to their release to air if the oxidising agents are not properly contained.

COMMON VOCS

- **Benzene*** Sweet odour, carcinogenic, commonly found in petroleum products and solvents.
- **Toluene*** Sweet odour, commonly used as a solvent in paints, adhesives and other products.
- **Xylene*** Sweet odour, commonly used as a solvent in the manufacture of rubber, plastics and other products.
- **Ethylbenzene*** Sweet odour, commonly found in gasoline and other petroleum products.
- **Naphthalene** Mothball odour, by-product of the use of coal in the production of town gas.
- **Trichloroethylene** Sweet odour, commonly used as a solvent in industrial processes such as metal cleaning and degreasing.
- **Perchloroethylene** Sweet odour, commonly used as a dry-cleaning solvent.

(* together these are known as BTEX)

BOX 2. TYPICAL VOC MEASUREMENT TECHNIQUES

Direct VOC measurements. Advanced thermal desorption (ATD) stainless steel tubes, packed with a sorbent medium such as Tenax, can be exposed to ambient air for a defined period and analysed in a laboratory using gas chromatography–mass spectrometry (GC–MS) to provide individual VOC concentrations. Relatively cost effective, provides good spatial resolution and reliable results for comparison to health guidelines. Other direct methods include portable GC systems. Continuous monitoring, which typically measures TVOCs using a photoionisation detector (PID) or electrochemical sensor. Provides good temporal resolution, and units can be set up on the site boundary and programmed to send alerts when the concentration exceeds an SAL. Requires a source of power (solar or battery). Handheld PIDs give more indicative readings for occupational exposure.

Sniff testing. A systematic and common approach to assessing odours in the atmosphere using the human nose.

Emissions measurements. A closed chamber is placed over a small area of soil. VOC concentrations emitted from the soil are measured using a portable GC. The flux of VOCs from the soil can be calculated from the concentration and the diffusion coefficient of the VOCs.

Emission factors. Calculated based on the amount and type of contaminants in the soil and used either as part of a risk assessment or in atmospheric dispersion modelling. The latter can support interpretation of boundary measurements for individual VOCs, as can sniff tests.

(workers encounter much higher concentrations) and their response to it (workers are assumed not to include members of the population most vulnerable to health effects).

It is challenging to set appropriate criteria for public health risk assessments and it is not recommended that consultants develop their own. As a starting point, the top three sources in the Environment Agency's hierarchy for developing EALs can be applied.[8]

- Expert Panel on Air Quality Standards advice (NB: The panel no longer exists but guidance is still available);
- World Health Organization guidelines; and
- Tolerable concentrations in air, derived from advice from government expert committees and panels and a review of existing authoritative expert opinions and evaluations.

Consultation with planners, regulators and stakeholders may identify other sources of assessment criteria, such as Public Health England's indoor air quality guidelines for VOCs; these should be used on a precautionary basis with a solid understanding of how they were developed.[9] More guidance is needed in this area to ensure a consistent approach is applied across different sites.

Non-UK sources should be used only where they are directly relevant to the protection of public health, do not rely exclusively on animal studies and are from countries with similar regulatory framework as the UK, such as the EU, USA, Canada and Australia.

ACTION LEVELS

Site action levels (SAL) help contractors understand whether their activities require mitigation; if concentrations remain high, work may need to be paused while a solution is found. SALs are particularly useful when automated and based on real-time information (an approach often used on construction sites for PM_{10}).[10] There is no established health criterion for total VOCs (TVOC). However, a figure of 1 part per million (ppm) (3.35 mg/m^3) for TVOCs – derived from the 8-hour WEL for benzene over 15 minutes and several times the daily EAL for benzene (30 µg/m^3) or lower – is often applied to boundary monitoring at remediation sites. It has been developed as an exposure warning, assuming all TVOC emissions are benzene.

While the Environment Agency does not recommend using WELs for the general public, such an approach is pragmatic where (as is almost always the case) data are not available to characterise individual VOC concentrations in real time. A SAL for TVOCs in the order of 1 ppm is a reasonably precautious starting point since benzene – a carcinogenic VOC with one of the most stringent air quality criteria – would not typically comprise more than a few per cent of the TVOC component. (NB: This assumption should be verified through comprehensive gas chromatography–mass spectrometry [GC–MS] analysis of Tenax or equivalent type of sampling tube.) A figure of 1 ppm may not be appropriate for all sites and should also be informed by site setting, odour monitoring and complaints data, as these may indicate a more stringent value is needed to address indirect effects of low-level emissions.

ODOUR

Odour is a statutory nuisance as defined in the Environmental Protection Act 1990.[11] However, odour can also have an indirect impact on wellbeing at persistently low levels that may not be identified as a potential nuisance. Odour detection thresholds for individual VOCs are available in the literature but can vary significantly, do not take account of the effects of combinations of odorous compounds, and are not readily applied to results of passive monitoring for VOCs.[12] This approach should therefore be applied with caution. The value that can be gained from proper and consistent assessment of odours using sniff testing against the Verein Deutscher Ingenieure (Association of German Engineers) scale should not be underestimated.[13]

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MITIGATION AND MANAGEMENT

The primary aim in mitigating VOC and odour emissions should be to avoid or at least reduce the potential for emissions in the first place: source control. Reductions at source can be achieved by modifying the remediation strategy (e.g. treating soil off site at a specialist facility) or working methods – for example, only excavating small areas at a time to reduce exposed soil surfaces; minimising the agitation and shaking of material; and covering odorous stockpiles with impermeable material or suppression foam (which creates a physical and visible barrier that caps emissions when not in use). These measures can have co-benefits since they also reduce the potential for dust emissions.

Air pollution control equipment and treatment can be effective where emissions at source cannot be avoided. This is achievable at sources with a small area or volume that can be enclosed (e.g. retaining the lid on gasholders when degassing) but may be expensive and impractical for larger remediation sites. Misting sprays are most effective when targeted and applied at source prior to emissions being dispersed. Site-boundary misting sprays are less effective at 'capturing' diffuse sources of odour, while perfumed suppressants may be a nuisance to residents, as the additive odour can be perceived as being offensive.

COMMUNITY ENGAGEMENT

Community engagement should involve informing residents at an early stage about the remediation process: what may be expected and when, and what is being done to reduce potential health impacts. Engaging with stakeholders and providing educational programmes raises awareness. By involving nearby communities, developers and contractors can establish trust and

TECHNICAL

transparency, helping to address concerns and minimise disruption; they can also engage them by asking them to keep odour diaries.

RECENT DEVELOPMENTS

Some local authorities in London now request outline odour management plans as a pre-commencement planning condition. This is in response to increasing community awareness of risks and to encourage more comprehensive odour and VOC management strategies (see **Box 3**). Collaboration between air quality and contaminated land experts is needed to produce these for them to be both practicable and effective.

The Institute of Air Quality Management (IAQM)'s odour guidance provides a useful framework for odour risk assessments at the planning stage. However, it is important that gasworks remediation strategies also specifically address public health risks, with appropriate monitoring and management considered at the outline planning stage and updated regularly as remediation methods and ground investigation progress.[13]

BOX 3. MONITORING FRAMEWORK EXAMPLE

An air quality monitoring framework for former gasworks sites has been developed for a national house builder. It comprises a mix of passive, continuous and subjective VOC and odour monitoring techniques, commencing before remediation works being to establish a background.

Tenax sampling tubes, deployed at the boundary and then sent to an accredited laboratory for analysis, provide weekly to monthly average VOC concentrations for individual compounds such as benzene, toluene, ethylbenzene, xylene (BTEX), and naphthalene (these are of interest due to toxicity and low odour thresholds). At the start of a campaign, the top 20 VOCs are also checked for other key contributors, and total petroleum hydrocarbons used to correlate with TVOCs. The concentrations are compared to long-term health criteria selected using an established hierarchy. For scale, for a 1- to 10-hectare site with housing within 100 m, four Tenax tubes would be established.

For higher-risk sites, boundary monitoring of TVOCs uses continuous PID at locations upwind and downwind of the prevailing wind (positioned with consideration of sensitive receptor locations). These proactively inform the need for mitigation as opposed to reactively, which is the case with Tenax tubes. An interim SAL of 0.7 ppm over 15 minutes instigates an inspection of activities. Where measurements are 1 ppm over 1 hour, work is paused.

Daily odour sniff testing at the boundary informs whether TVOC concentrations translate to a discrete odour off site. Hedonic tones (i.e. sweet, pungent, acrid, etc.) help to interpret complaints data. Good-quality reporting templates, completed consistently and shared in a timely manner, support site management and mitigation. The tests are performed by acuity-tested individuals (to understand bias in olfactory sensitivity) not involved in remediation site activity but predominantly based in site offices.

CONCLUSION

Ambient VOC and odour emissions from gasworks during remediation have the potential for adverse effects on the environment and public health. Measuring and mitigating these emissions is critical to ensuring the safety and effectiveness of the remediation process and to protecting the health and amenity of local communities; however, this is not currently done in a consistent way due to gaps in the guidance and regulatory and planning regimes.

The issues associated with redeveloping former gasworks sites are a growing problem as the world becomes more urbanised, and as the global burden of health effects of air pollution is more fully understood. By bringing in air quality specialists to advise at an early stage, they can share experience on the design of surveys and selection of monitoring methods, olfactometry and emissions management techniques.

The IAQM is considering producing a short guidance document on this issue for contaminated land and air quality specialists. This would encourage a more consistent approach and application of guidelines across different types of remediation sites as the pressure increases to develop brownfield sites first in a more urban world. It will also support local authorities in interpreting the quality of developers' strategies and, as the global megatrends continue, support other nations which may be beginning to redevelop such sites. ES

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Acknowledgements

I would like to thank Dr Claire Holman, FIAQM, FIEnvSci, CSci, CEnv, IAQM President and Director of Air Pollution Services for her support in raising the profile of this subject and for reviewing this article.

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We must farm organically to save the UK's threatened soil ecosystems

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ANALYSIS

Gareth Morgan takes an in-depth look at the benefits of holistic farming techniques.

GLOBAL MEGATREND – 8

Soil – a complex system of minerals, organic matter, air, water and living organisms – is crucial to all life on Earth, and for the UK's environmental and food security. Healthy soil absorbs and stores carbon from the atmosphere and provides a natural barrier against floods and droughts. A massive 95 per cent of the world's food comes from soil, and it is home to billions of essential insects, which in turn provide food for declining wildlife like birds and bats.[1] Soil itself is an ecosystem, being home to a quarter of the Earth's species, including insects and fungi as well as single-celled organisms such as bacteria.

THE ROLE OF SOIL IN GLOBAL ECOSYSTEMS

Soil sequesters a vast amount of carbon and has significant potential in mitigating climate change. But badly managed soils can release carbon, threatening efforts to combat climate change as well as biodiversity: an estimated 10 billion tonnes of carbon are stored in UK soils.[2] Increasingly adverse effects on agricultural yields from declining environmental quality and climate change are also a threat to global food security. This is particularly relevant to soil, which is essential for food production.

Soil is being degraded by intensive farming practices. It is suffering from a loss of organic content, contamination from pesticides, and the loss of plants and animals that help keep the soil aerated and moist. In addition, a lack of vegetation cover leaves topsoil vulnerable to weather erosion. Industrial farming can compact soil through overuse, heavy machinery use and shallow-rooting crops.

It is easier to lose topsoil than to produce it, and the UK's soil health issues are coming to a head. In England and Wales, more than 2 million hectares of soil are at risk of erosion, costing an estimated £1.2 billion every year.[3] Long-term soil degradation has contributed to an increasingly fragile food system and prevents opportunities for carbon capture. It also actively releases the greenhouse gases carbon dioxide and nitrous oxide into the atmosphere. Greenhouse gas emissions from UK soils contribute to 21 per cent of total UK agricultural emissions.[2]

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In the UK, the drive to feed a growing population and a shift to unhealthy diets with more ultra-processed foods means that intensive farming has escalated through the 20th and 21st centuries. This is most notable in the introduction of synthetic pesticides and fertilisers after the second world war. This change in attitudes can be viewed as a shift to thinking about soil as a limitless, lifeless resource to anchor plants to rather than as a complex living system that itself provides habitats and crop fertility. In turn, this disregard for soil health has led to mounting anxiety over its suitability for producing food for an increasing population and its role in meeting the UK's climate targets.

The figures can be particularly stark. The Government estimates that intensive farming has caused arable soils in England and Wales to lose about 40–60 per cent of their organic carbon.[3] And a recent analysis suggested that unless action is taken to restore the UK's peat soils, carbon emissions from peat could cancel out all carbon emissions reductions achieved through new and existing forests, making net zero in the UK virtually impossible.[2]

The European Environment Agency's global megatrends (GMTs) chart the issues Europe is likely to face as the 21st century develops. Growing Pressures on Ecosystems (GMT8) tracks how ecological resilience will be affected by global pressures, and concerns soil directly. GMT8 warns that, at a conservative estimate, global terrestrial biodiversity is set to decline by another 10 per cent by 2050.[4] In addition, large areas of agricultural land are under threat from water erosion and soil degradation. Solutions to restore the underground ecosystems that reside in soils must therefore be implemented before we reach critical environmental tipping points.

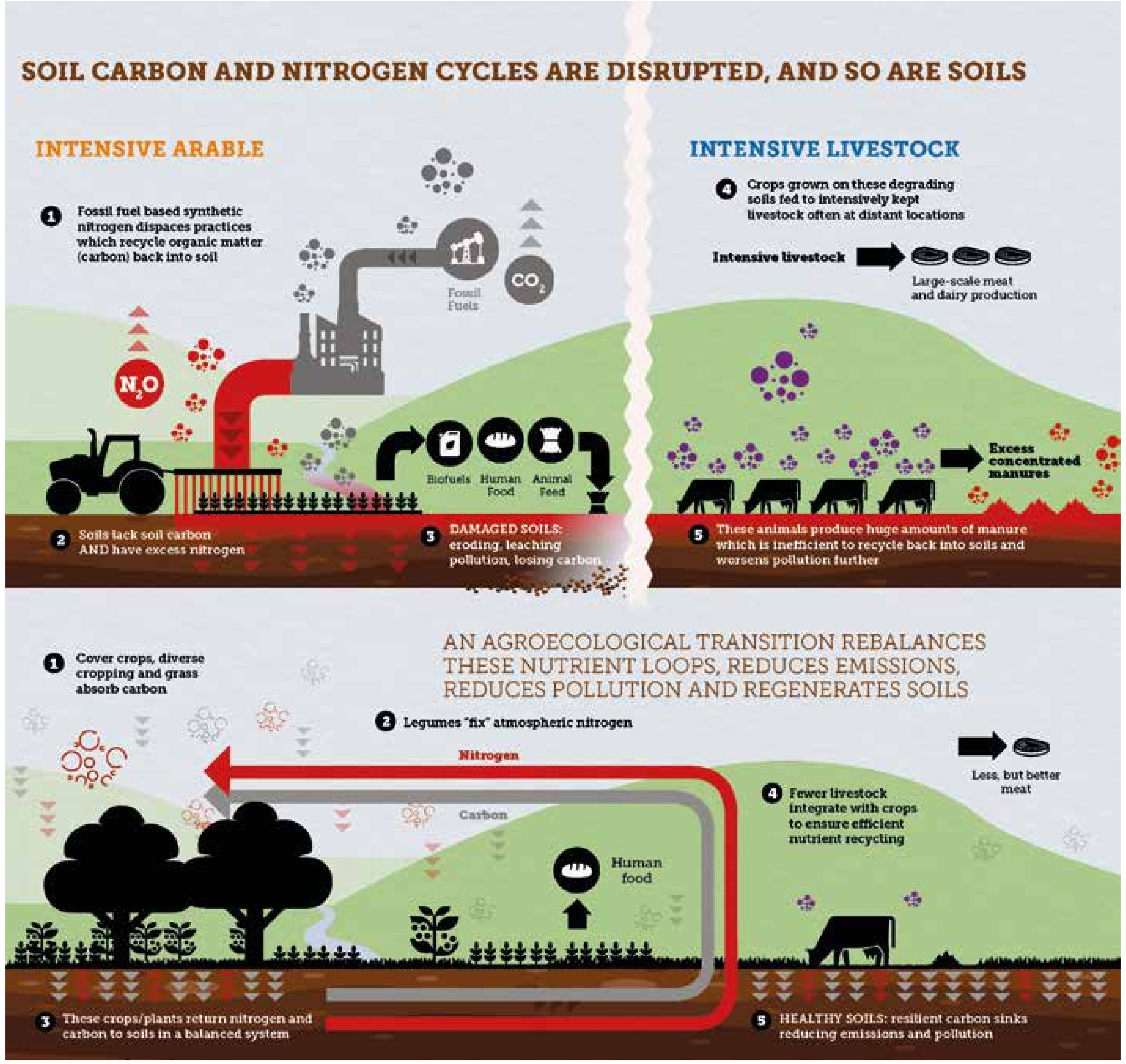
WHY SOIL IS VITAL

With soil in a vulnerable position, the UK's farming system is less able to adapt to a rapidly changing climate. The UK's concerns are part of a much bigger problem. A recent review found that 16 per cent of global soils were so eroded and had such damage to their biodiversity that their food-producing capability spanned less than a hundred years, a growing concern for global food production.[3]

Healthy soil supports biodiversity, being home to billions of micro-organisms and essential insects that can prey on pest species. This is critical to growing food and in turn provides food for declining wildlife like birds and bats. Healthy soils are also key to the prevention of pest and disease problems.

Carbon capture is key to the UK's environment strategy. Soils in the UK store 10 billion tonnes of carbon, and soil contains three times more carbon than the atmosphere. Degraded soils can leak carbon and nitrous oxide back into the atmosphere (**Figure 1**) rather than store it safely.[3]

The health of soils is crucial to the UK agricultural system's ability to work. Well-maintained soil stores and absorbs water, which can help prevent floods and mitigate the effects of droughts on crops, saving time and money and improving our ability to cope with extreme weather caused by climate change. Conversely, depleted soils are less effective at storing water. A survey of over 3,000 maize-growing sites in south-west England found that 75 per cent of fields could not let rainwater in any deeper than the upper soil layers. With soil affected in this way, heavy rainfall can wash it away, reducing its effectiveness as a natural flood barrier, polluting rivers and reducing its suitability for farming – a key concern outlined by the European Environment Agency.[2]



▲ Figure 1: Impacts of carbon and nitrous oxide leaks into the atmosphere. (© James Andrew Daniel, The Soil Association[2])

THE REASONS FOR AND EFFECTS OF SOIL DEGRADATION

Soil degradation is linked to poor soil management and overuse of chemicals. Artificial fertiliser use can mean soils receive excess nitrogen, leading to increased soil acidification. When this is combined with intensive farming techniques, such as reduced crop diversity, and losses in organic matter, it can permanently affect soil health. Research suggests that reduced soil life can affect crop growth and development and disease incidence, potentially resulting in a negative feedback loop leading to increased use of agrochemicals.[3]

Many of the pesticides and synthetic nitrogen applied to farm soils adversely impact soil microbial functions and biochemical processes, which affects the biodiversity and quantity of soil. In contrast, a focus on the maintenance of healthy soils mitigates the need for artificial fertilisers, providing minerals and nutrients via populations of bacteria and fungi.

Alternatives to artificial fertiliser include leguminous cover crops such as clover, beans and peas. Cover crops are used by organic farmers in between the cash crops that they grow to harvest and sell to keep soils covered and restore soil fertility. These legumes naturally add nitrogen to the soil, underpin the food chain with some alternative crops and encourage biodiversity. Cover crops can also smother unwanted weeds, and a layer of plant life protects soils from rain damage, reducing soil drying and wind erosion.

SOIL HEALTH NEEDS BOLD GOVERNMENT ACTION

England is currently without a detailed plan for soil health and protection. The Government's *Environmental Improvement Plan* commits to publishing a baseline map of soil health for England by 2028.[5] Until then, there is little in the way of an overarching plan to improve the UK's concerning soil condition. Support to assist farmers and landowners to make the necessary adjustments towards sustainable farming practices is much needed. New incentives for agroecological and organic farming practices – like avoiding insecticides and using legumes for soil fertility instead of chemicals – are welcome.

Post-Brexit, the UK Government has developed an Environmental Land Management Scheme in England, replacing the EU's Common Agricultural Policy. The vision behind it is to provide financial support to farmers to protect nature by rewarding practices such as managing crop pests without chemicals.[6] But the new scheme lacks a comprehensive vision for land condition and the environment that would spark transformative change. We need more than small tweaks to current practices. We must help farmers transition to nature-friendly, resilient farming across their entire farm, with a focus on producing diverse, nutritious food. Much of what the scheme covers was already set out in existing Countryside Stewardship policies that were in place to incentivise nature-friendly farming before Brexit, and it remains to be seen how the separate schemes will work together.[7]

In addition, there are clear solutions, like integrating trees with crops and livestock in agroforestry, that have so far been omitted. This is a straightforward solution that reduces soil erosion through tree roots binding the soil in place so it does not wash away during heavy rain. Trees also cycle nutrients that can be utilised by other flora and fauna. These can nourish the soil, allowing it to store more carbon.

The schemes also lack focus on the transition of farming to a more sustainable system: organic farming is an excellent example. This way of farming has soil health at its heart, with long crop rotations that do not use chemicals and instead focus on restoring soil fertility naturally. The benefits are clear. On average, organic farms have 44 per cent more carbon locked into soils and 50 per cent more wildlife.[1] These nature-friendly farming pioneers show that we can turn things around. Soil health can be restored, but it will take urgent action and long-term solutions.

A CALL FOR NATURE-BASED SOLUTIONS

The Soil Association advocates for a move towards an agroecological farming system across the whole agricultural system that works with nature rather than against it. To achieve healthy soils, we need to focus on nature-based solutions and on creating habitats above and below the ground. Some EU countries have seen success with this: in 2021, Germany's share of organically farmed land was 11 per cent.[8] This compares to just 3 per cent in England.

Changing to an agroecological system will require a shift in diets to ones that are healthier and in harmony with planetary limits. This will require a reduction in industrially produced meat and dairy, favouring less meat that is sourced more responsibly, and an increase in locally sourced produce. In contrast, the profitability of conventional farming often comes at a hidden cost to water, air and nature.

With this system, soil resilience is prioritised. Crops are farmed in a way that protects biodiversity and promotes carbon capture and durability against floods and droughts. For growers, farming in this way means promoting long-term health, which means soil is kept healthy for longer, enabling us to use it to ensure healthy yields well into the future. For shoppers, it provides a guarantee that fruit and vegetables have been grown with strict principles – the organic logo is the easiest way to identify and support agroecological and regenerative farming.

Routes to achieving real change can be opened by bringing forward a soil health action plan and using it to deliver policy that integrates soil management priorities with climate, nature and health objectives. The UK Government had previously committed to this, but it has now been shelved.[9]

There is an urgent need for a statutory target to improve soil health, with clear goals for organic matter in soils,

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reducing excess nitrogen levels in the wider environment and improved soil monitoring for better-informed future decisions. Systematic change is required to prioritise the health of soil. Farmers ought to be further incentivised to look after the health of their soils and adopt nature-friendly practices across the whole farm. This should include approaches where action is undertaken collectively – for example, at a river-catchment scale – to solve problems. Shorter, fairer supply chains that give farmers a just reward and create markets for sustainable farmers who care for soils – rather than prioritising cheap, environmentally damaging, unhealthy food – are also needed.

A key place to start is with public procurement – the food served in public settings such as schools and hospitals should be local and sustainable, with support for caterers to achieve this. The funding schemes and all food and farming policy should be synergised to ensure that the decisions taken have significant benefits over the longer term. An ambitious plan of this nature could encourage the growth of local, nutritious food and directly tackle climate change. Others are putting this into action – for example, the Municipality of Copenhagen is close to achieving 90 per cent organic in public service food.[10]

As the world and our climate change, the protection of soil as a whole ecosystem is vital to the health of future generations. Land conditions must be radically improved to ensure we have the capacity to deal with a growing population, and a whole-system approach to managing the farmed ecosystem must be taken.

Many organic farming pioneers are in the UK, but we risk falling behind. Consumer demand for food produced in harmony with nature is strong, but it needs concerted government action to satisfy this growing demand and regenerate the UK's soils. If the UK is to live comfortably within its planetary limits, restoring soil health is crucial, and nature-friendly farming holds the answer. ES

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FEATURE

Microplastics: an increasing threat to global soil health?

Paul Dumble, **Diogenes Antille** and **Robert Earl** shine a microscope on their environmental impacts.

GLOBAL MEGATREND – 6

GLOBAL MEGATREND – 8

GLOBAL MEGATREND – 10

For this year's World Environment Day, themed around solutions to plastic pollution, the Society for the Environment (SocEnv) highlighted the impact of microplastics (see **Box 1**) and plastic pollution on soil health and its wider consequences on land condition and the environment. Plastic is one of many issues affecting soil health, cumulatively increasing the burdens on our global environment.[2] These burdens have been described as global megatrends: key policy drivers, trends and implications.[3] In this context, SocEnv provided a call to action to prevent and address plastic pollution more widely, applicable within a sustainable resource-use framework.

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FEATURE

PROTECTING OUR SOILS AND STONES

Soils and stones have too often been neglected, polluted, and misunderstood as a waste as opposed to being highly valuable natural and finite resources.[4] Mistreatment of these vital resources causes significant threats to soil ecology, habitat biodiversity, food supply and soil security, and climate mitigation potential; all are significant challenges reflected in the 11 global megatrends.[3]

MICROPLASTICS: THE PROBLEM

Global annual production of plastic grew from 335 million tonnes in 2016 to 390 million tonnes in 2021, of which 50 per cent was from Asia,[4] with the cumulative global production of plastics exceeding 8 billion tonnes by 2017.[5] Microplastic pollution is an emerging global-scale threat affecting the atmospheric, aquatic and land environments.[6,7] As fossil fuel production is phased out, oil-producing countries will become more dependent on chemicals produced from oil, including plastics. This has been recognised in the Middle East:

'As plastic businesses contribute 40% to 45% of GDP in most Gulf Cooperation Council countries,[8] it is important that governments demonstrate to the world that plastics are valuable materials able to be responsibly managed in ways that do not contaminate marine or land environments.'[9]

While much attention has been focused on the impact of microplastics on the marine environment, annual plastic release to land is estimated at 4–23 times that released to oceans.[5,7] This is also of great concern, as soil represents one of the most precious resources on Earth, providing essential life-support functions for ecosystems, biota and food production, and finite mineral resources for humans.

HOW DO MICROPLASTICS GET INTO SOIL?

Loose primary plastic microfibres and nanofibres are shed into the air from synthetic textiles in manufacturing and everyday use, with the smallest fibres dispersing widely. The washing of garments made with synthetic fibres results in loose fibres entering the wastewater system.[10] Plastic microbeads are used in agrochemicals and synthetic fertilisers and in personal hygiene products such as soap, toothpaste, cosmetics and aerosol sprays.

Primary plastic microbeads are used in the manufacture of plastic products and can be released when the product is used or stored outside (due to weathering). The microbeads can be discharged into the waste or wastewater system or dispersed through the air into the environment, where they can subsequently be ingested by animals and humans.[11,12]
The storage of plastic products and plastic waste presents a degradation risk. Secondary microplastics arise from the degradation of plastic products. Exposure to solar radiation and biodegradation can embrittle or fragment these products,[13] which contain other organic additives used in manufacturing processes.[1] Degradation affects plastic piping and plastic polytunnel sheeting after each growing season. Embrittlement affects other products such as plastic bottles, sanitary items and nappies. Littering and fly-tipping are examples of the illegal deposit of waste on land and in aquatic environments, adding to the environmental microplastic burden. Globally, vehicle tyres shed over 1.6 million tonnes of microplastics annually[13,14] Textiles, tyres and city dust account for an estimated 80 per cent of all microplastics in the environment.[15]

At wastewater treatment works, 98 per cent of microfibres and microbeads are captured in the sludge.[16] Often, treated sludge (biosolids) is spread on land where it poses a risk of microplastics escaping into river and marine environments. In flooding scenarios, microplastics can be deposited onto land from drains in sewerage systems and in low-lying areas adjacent to riverbanks.[13] Plastic and textile recycling plants also generate microplastics.

The movement of microplastics into and within the soil is aided by soil characteristics such as cracking during dry and drought spells; soil biota, including worms that create pathways through the soil and may ingest microplastics; plant species, such as trees whose roots push microplastics through the soil; and land management activities, such as mechanical cultivation that may bury or expose plastics already in the soil. The transport of microplastics is affected by particle properties, and by processes such as percolation through the soil, erosion and runoff.[17]

Microplastics accumulate more in agricultural than in urban soils. Some sources of microplastic pollution include:[5,7,18]

- Environmental media, including runoff and air transmission;[19,20]
- Fertiliser coatings;[21]
- Littering;[22]
- Plastic mulching;[23]
- Application of biosolids;[24]
- Organic soil amendments;[25,26] and
- Twine, bale nets and stretch films intended to preserve straw.[27,28]

BOX 1. MICROPLASTICS: WHAT ARE THEY?[1]

Microplastics are tiny plastic particles less than 5 mm in diameter.[1] They are classified into two categories: primary and secondary. Primary microplastic beads are used in commercial products and applications – such as agricultural fertilisers and pesticides that are spread or sprayed onto crops – and cosmetics. Microplastics also include microfibres from textiles that are shed from clothing, netting and ropes. Secondary microplastics are particles that result from the breakdown of larger plastic items (e.g. water bottles) as a result of human activities, natural degradation and environmental factors.

BOX 2. HOW SOCENV IS WORKING TO PROTECT SOILS

In spring 2021, SocEnv published the well-received Soils and Stones Report.[2] Experts from a wide range of sectors were represented, including construction, resource management, forestry, engineering, agriculture and land management. Freely accessible, the report rectified the glaring need for a joined-up study on the use of soils and stones across sectors. Since then, SocEnv has been working to deliver the report's key recommendations. These recommendations focused on training across soils-and-stones disciplines, best practice, harmonised regulation and commercial mechanisms for compliant reuse, and supporting soil health improvements.

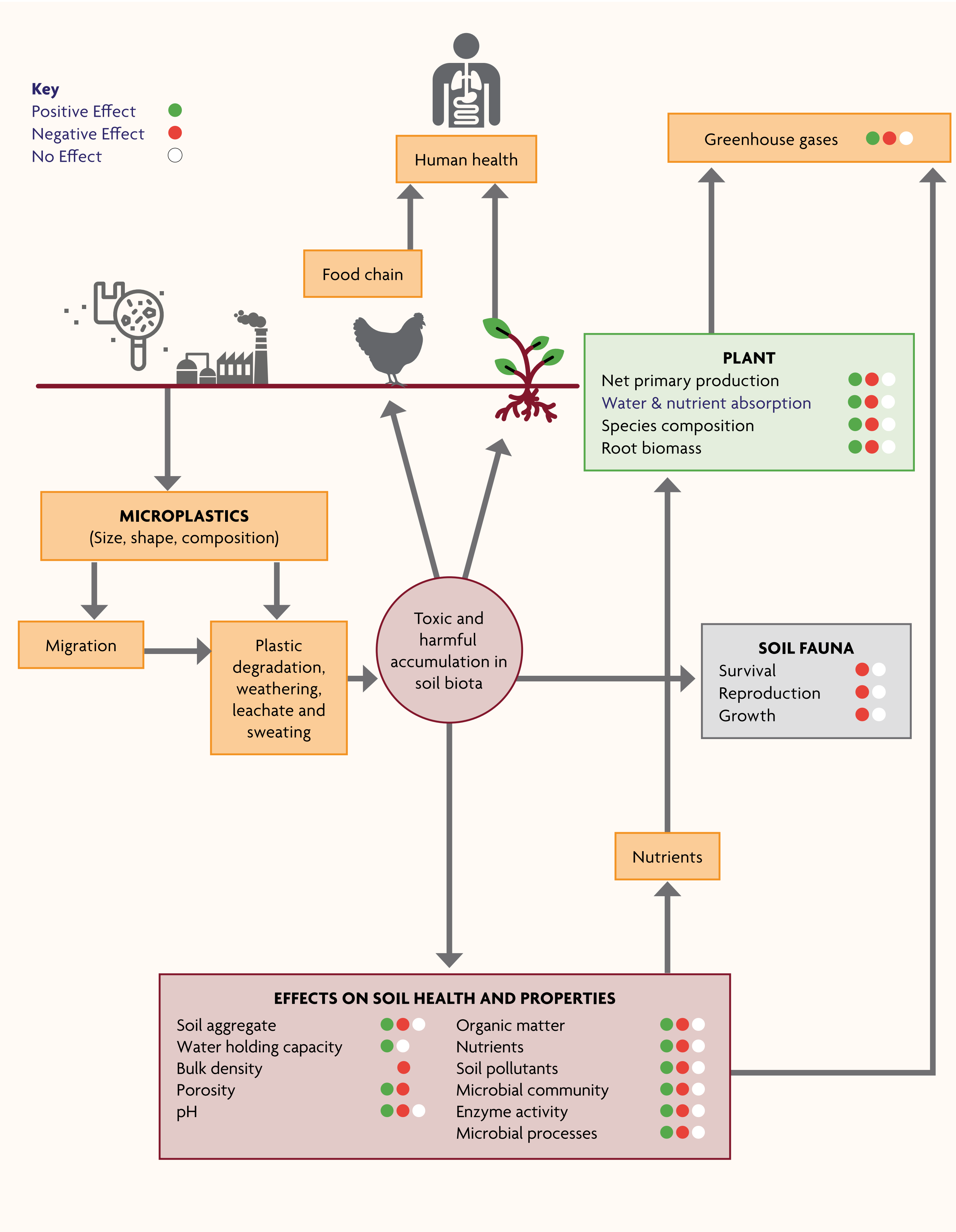
SOIL HEALTH AND MICROPLASTIC POLLUTION

A review of studies into soil health identified positive, negative and insignificant impacts of microplastics against key soil health indicators including those for plant and soil fauna.[18] The review highlighted variable impacts of microplastics on soil health in relation to the specific physical characteristics and polymer compositional makeup of microplastics, soil type and condition, and other factors such as weathering and biodegradation of microplastics in the soil (see **Figure 1**). In wetland environments, microplastic concentrations have been found to exhibit a negative correlation with vegetation cover and plant density and diversity.[29]

MICROPLASTIC POLLUTION

The growth in particulates entering the environment will increasingly and adversely impact soil ecosystems through negative effects on soil properties and soil function.[30,31] After microplastics enter the soil, they reside permanently in the environment, and therefore can (bio) accumulate, adsorb contaminants or be transported through the soil matrix. There are several levels in the transportation process, some of which involve enzymes at the cellular level, breaking plastics into smaller pieces, or invertebrates at the organism level, exposing microplastics to ingestion processes.[32]

As well as polymers, plastic products are made up of additives that provide properties such as flow, colour and stability.[31] These additives include plasticisers, flame retardants and other organic compounds. Heavy metals are adsorbed on the surface of microplastics and may adversely affect plant growth and soil organisms.[32] The rate of transmission (K) to adsorption and bioaccumulation of microplastic toxins in flora and



▲ **Figure 1. Sources of microplastics in agricultural soils and their impacts on the ecological environment. (Adapted from Yu *et al* 2022[18])**

fauna measured by an oil/water (ow) bioaccumulation factor log K_{ow}>5 is currently adopted for aquatic species. However, this transmission rate of toxins depends on factors such as soil type, location and condition, microplastic characteristics (shape, polymer structure), its degradation, additives used, their concentration, the extent of degradation and weathering of the plastic.[33,34,35,36]

Plastics in soil are subject to physical, chemical and microbial action causing ageing or degradation that results in the release or leaching of toxic and harmful substances from additives that may include phthalates, bisphenol A, polybrominated diphenyl ethers and heavy metals.[37] These substances can have harmful effects on the soil environment and may be transferred to the food chain.[38] Studies have shown that the toxicity of microplastics in soil is related to their characteristics and extractable additives.[39] For example, plasticisers can significantly inhibit seed germination of small cereal grains, affect plant antioxidant enzyme activities, and induce programmed cell death in seed cells by changing relative gene expressions.[40]

SUMMARY OF RESEARCH FINDINGS

Published research on the impacts of microplastics on soil largely concur with the findings of the Science Advice for Policy by European Academies (SAPEA) report that:[41]

- Microplastics arise from a variety of sources, with increasing accumulation of microplastic particles in the environment and food chain and with smaller particles potentially establishing long-term permanence in the soil and aquatic environments.[28]
- Most of the evidence collected relates to the marine environment, despite most microplastic sources being on land.[17] SAPEA concluded that: 'There is no reliable evidence about the levels or effects of these particles … but that evidence is limited, and the situation could change if pollution continues at the current rate.'[41]
- The toxic nature of many of the plastic components dispersed and spread into the soil environment contributes either negatively or positively or has no effect on key soil properties that affect soil health.[18–40] SAPEA referred to this differential in terms of an insufficient concentration of microplastics 'in the real world'.[41]

SOLUTIONS: WHAT IS ALREADY BEING DONE

In 2015, the United Nations Environment Programme initiated the process of phasing out the use of microplastics in cosmetics. Government policies have banned the use of plastic microbeads in specific products, mainly personal hygiene items – for example, the Environmental Protection (Microbeads) (England) Regulations 2017 and New Zealand's Waste Minimisation (Microbeads) Regulations 2017 – with similar bans introduced in the USA, Canada's Ontario province, Korea and Australia.[42,43]

Governments are working to improve wastewater treatment to limit the dispersal of microplastics into the aquatic environment. In 2018, Japan passed a law aimed at reducing microplastic production and pollution, especially in aquatic environments.[44] Based on the response to the SAPEA report, the European Chemicals Agency (ECHA) proposed to restrict added microplastics.[11] Global circular economy initiatives and net-zero policies play an important part in reducing the amount of plastic waste going into the environment. China's ban on imports of recyclables in 2018 is encouraging other countries to review and act on their recycling policies.[45]

CALL TO ACTION

There are three main approaches to reducing the impact of microplastics on our soils:

1. **Addressing the problem at the point of production.** Several countries around the world have adopted bans that prevent the use of microbeads in the production of mainly cosmetics products. To increase the global effectiveness of these policy instruments:

- The microbead ban needs to be extended to include other consumer products; and
- Other countries should be encouraged or advised to adopt these measures.

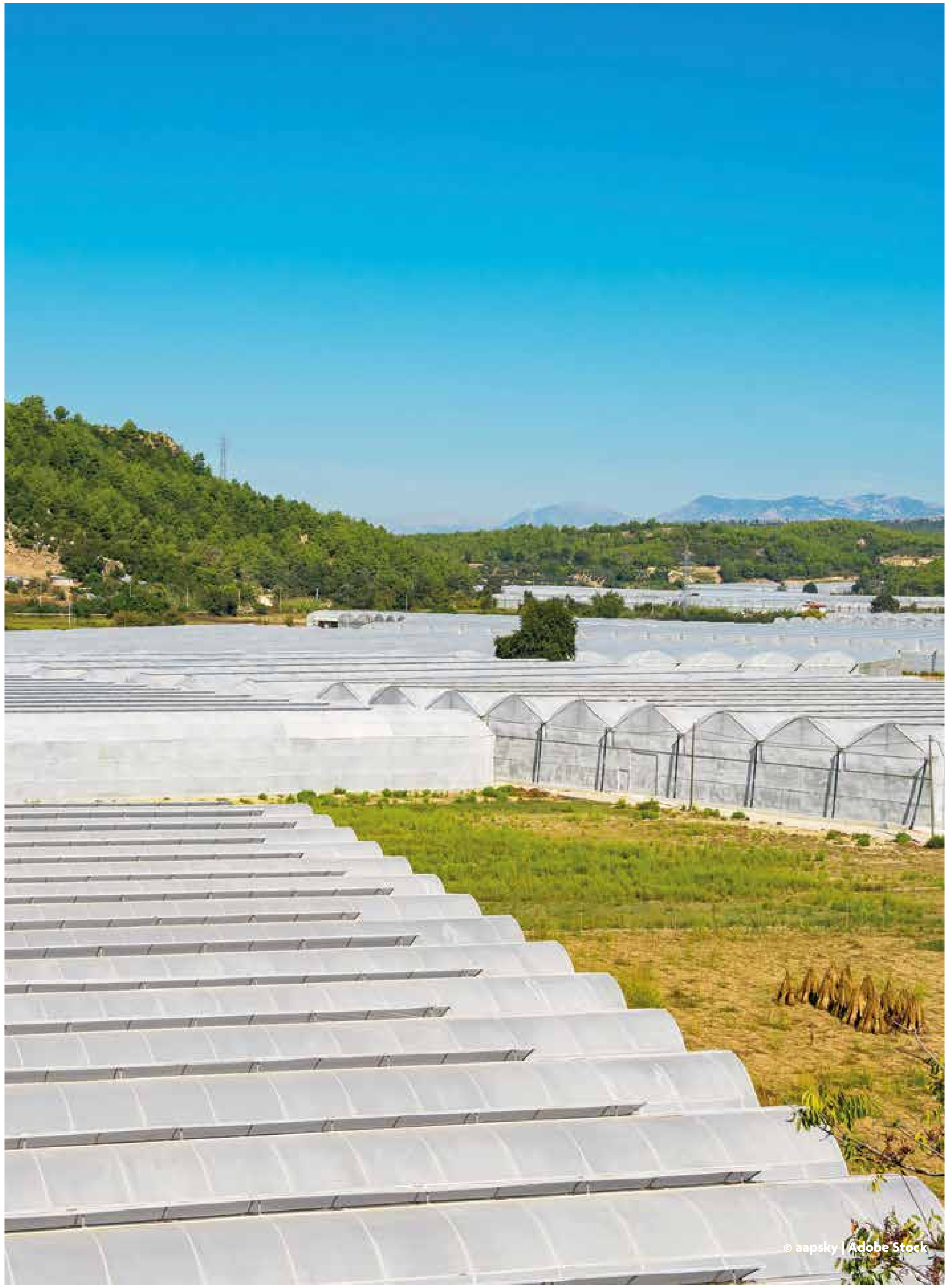
The microplastics issue illustrates the adverse consequences of a non-circular economy.[3] It poses an existential threat to good soil health, which will then be a risk to human health and food security. Awareness of the issue will encourage improvements in the management of governance, related to Diversifying Approaches to Governance (GMT11), and will provide governance to address the:

- Sustainable use of soils and stones (GMT1 to 11);
- Prevention and reduction of pollution (GMT8 to 10); and
- Requirements of human and economic growth (GMT1 to 7).

Action needs to be taken to understand, develop and establish universal standards in the manufacture and application of soil-safe plastics or suitable biodegradable materials (see **Box 3**). These will be needed to replace

BOX 3. WHAT IS SOIL-SAFE?

'Soil-safe' refers to non-toxic plastic that tests below the no-observed-adverse-effect limit for flora and fauna, and that does not degrade into sharp fragments that may be lethal or harmful to microbiota and grazing animals.



FEATURE

or prevent the formation and release of microplastics, particularly in:

- Agricultural use, tree planting, polymer-coated fertiliser and agrochemical products and applications, plastic sheeting and piping; and
- Consumer products such as plastic bottles and supply-chain packaging that are often discarded into the environment.

Emerging non-soil food production technologies (e.g. hydroponics and vertical farming) can also prevent microplastics contamination of agricultural soils, although the plastics used by these technologies must be minimised or designed out.[2] Manufacturers are considering how to address the environmental dispersion impact of textile microfibres. One approach is to improve filter systems in washing machines, which could significantly reduce the impact of microfibres reaching wastewater treatment plants.

2. **Influencing behaviour.** Consumer behaviour can help reduce microfibre generation by:

- Keeping clothes in use for longer;
- Buying clothes made from natural fibres;
- Washing clothes only when necessary; and
- Placing synthetic clothing into a filter bag before washing to reduce microfibre generation – removing microfibres at source.[46]

In the agricultural sector, microplastics can be reduced by encouraging and supporting greater seasonal reuse and better options for plastics recycling.

3. **Finding end-of-pipe solutions.** Developing protocols and training to support the movement towards the circular economy by:

- Developing the practical means to manage the removal, reuse and recycling of soil-safe agricultural plastics, significantly reducing the adverse impact on our soils and soil health.
- Influencing change in government policies that are currently limited by inadequacies and deficiencies in end-of-pipe solutions (e.g. wastewater treatment plants). In the UK untreated sewage, carrying microplastics, is regularly and widely discharged into aquatic environments.[47]
- Solutions could be implemented through investment and improvements in infrastructure, plant and the adoption of operational standards and permit conditions designed to capture 99 per cent of microfibres at all wastewater treatment plants.

These welcome actions should be encouraged and expanded. There are, however, gaps in our environmental and soil knowledge. To develop solutions at the appropriate scale and urgency, interdisciplinary skills and competence are required to address the global microplastics challenge. SocEnv will engage with Government, institutions, research organisations and funding bodies to bridge this gap.

On 16 May 2023, the United Nations Environment Programme released a road map outlining solutions to cut global plastic pollution by 80 per cent by 2040. To achieve this, countries and companies will need to make significant policy and market shifts using existing technologies.[48] A sustainable future will not necessarily be free of plastic, but should, with the necessary will and collaboration, become free of further microplastic pollution. ES

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Acknowledgements
The authors are grateful to Sarah Ridgeon at SocEnv for providing coordination and proofreading support for this article.

BOX 4. FURTHER READING

We can all play our part to address plastic pollution through our everyday behaviours and professional practices, as well as by influencing key decision-makers. In addition to the references listed below, further resources on the issue of plastic pollution can be found via the SocEnv website, published to coincide with this year's World Environment Day theme of Solutions to Plastic Pollution: https://socenv.org.uk/world-environment-day-2023.

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CASE STUDY

The impact of China's industrial expansion on the land condition community

Andrew Hursthouse delves into the environmental impacts and challenges raised by one country's rapid growth.

GLOBAL MEGATREND – 1

GLOBAL MEGATREND – 10

GLOBAL MEGATRENDS AND THEIR RELEVANCE

Split across social, technological, economic, environmental and political drivers, the European Environment Agency's global megatrends (GMT) look forward to the specific challenges faced by the continued intensification of human activities. From a land quality perspective, there are causal links to many of the other GMTs, particularly around intensification of the global competition for resources, population trends and disease burdens, which drive changes in land-use patterns and disruption of surface ecosystems.

Part of the challenge to drive towards sustainability and exist within the carrying capacity of the Earth and its subsystems is to understand the causal effects between global changes. We need to learn from past impacts and identify beneficial trends. The more recent example of China's economic and population growth provides an opportunity to evaluate megatrend interactions, specifically in relation to impacts on soil quality and the food chain.

URBANISATION AND THE ENVIRONMENT IN CHINA

Rapid industrialisation starting in the 1990s and the subsequent prioritisation of economic growth by China has led to its position as the largest consumer of energy and coal, and as the world's greatest air polluter. China's response to major regional air pollution events, particularly in Beijing, was to undertake significant pollution control reforms.[1] Since 2014, national initiatives were introduced to target emissions reductions of specific air pollutants, improve air quality monitoring and reporting, and implement focused environmental policies for carbon dioxide reduction and rail electrification. These initiatives resulted in rapid improvements in air pollution and data dissemination. Achieving these results in under a decade provides a good example of regulatory feedback on environmental quality in developing countries with strong political regimes.

Other environmental systems are not as responsive. In the case of soil, natural processes lead to the accumulation of potentially harmful substances by atmospheric deposition and low leaching rates of deposited contaminants by migrating soil water. Accidental spills, dumping of waste materials and the application of fertilisers and other agrochemicals exacerbate this issue. Poorly regulated industrial processes including mining and manufacturing add significantly to localised pollution hot spots. Urbanisation rates are particularly useful predictors of soil degradation;[2] the extent of the degradation is evident in existing case studies in China and shows remarkable correlation between soil pollution indicators and urban development.[3]

CASE STUDY

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CHINA'S 2014 SOIL SURVEY

A 2014 review of soil quality highlighted the findings of regional surveys and their development and focused on soil pollutants.[4] The regional surveys reported on the results of nationwide soil assessments in 2014, and the culmination of nearly a decade of investigation presented some stark data.[5] The assessment covered a wide range of land uses with soils sampled in industrial development zones, mining areas, arable and irrigated land, as well as around transport infrastructure. The findings confirmed that approximately 20 per cent of the current agricultural land exceeded the regulatory pollution thresholds, equating to over 3 million hectares being polluted and 2.5 per cent of all land being considered unfit for agriculture. To put this into context, the utilised agricultural area in England was 8.9 million hectares in 2022, making China's polluted area around a third of the size of England's agricultural land.[6]

The contamination identified in the assessment was dominated by potentially toxic elements, in particular cadmium, nickel, arsenic, copper, mercury, lead, chromium and zinc. In addition, persistent organic pollutants such as hexachlorocycloexane and dichloro-phenyl-trichloroethane (better known as HCH and DDT, respectively) and other organic pollutants, such as polycyclic aromatic hydrocarbons, were present.

RICE AND POLLUTION

Agricultural impacts are potentially development-limiting issues. The agricultural output in China is economically more significant than the economies of many developed countries. Almost 30 per cent of China's agricultural output is derived from the North China Plain, which is grossly polluted and suffers from water scarcity.[7] The agricultural sector is the largest water user and is also affected by pollutant discharges of fertiliser and industrial wastes. The implication of this for food chain security is significant. Demand for rice, as the country's staple food, is increasing, particularly in rapidly urbanising areas where affluence is growing.

The compromised food chain in China represents a powerful case study of the intersection of many of the GMTs. The overuse of fertilisers, mining and industrial development contaminating soils where paddy field systems enhance mobility of several potentially toxic elements has resulted in the contamination of rice crops. This is particularly acute in the Yangtse River Basin and particularly for the province of Hunan. Base metal exploitation in Hunan is extensive and has a deep history of activity. The 2014 data show that the contamination of soils in subregions of Hunan is some of the worst in China.[5] Rice production in the area is high and of good agricultural quality and yield as water availability is good. However, many potentially toxic elements, such as cadmium, arsenic, chromium, mercury and lead, accumulate in rice grains, and crops frequently fail food safety standards.

CLEAN-UP CHALLENGES

The terrestrial contamination arising from intense environmental degradation required a regulatory response that could deal with contamination issues at a regional scale, ensuring they were addressed while still recognising the financial impact of such large-scale problems. These issues at such a large spatial scale are not typically seen in other global contamination and remediation regimes. The history of pollution from the Industrial Revolution in Europe and the USA is typified by point-source locations and a relatively constrained spatial distribution.[9] Remediation is often integrated into planning conditions, and land redevelopment control, relying on private sector business opportunities, is sensitive to market conditions. The challenge for China's Government has been to rapidly stimulate an environmental sector to match and manage the impact of its economic growth and to establish a capacity and scale capable of identifying pollution sources, undertaking large-scale environmental investigation, ensuring responsible clean-up, and developing a highly qualified business base with a range of regulatory enforcement protocols.

THE REGULATORY RESPONSE SINCE 2014

The pace at which China has addressed the critical issue of a pollution-compromised food chain and wider soil degradation has been driven by the early introduction of regulatory instruments. In 2015, the Environmental Protection Law was enhanced to balance economic and social development with coordinated environmental protection and control of impact on human health. Implementation of development and remediation at the local government level was endorsed. In 2016, the top priorities identified at a national level focused on implementing new concepts of development, boosting the modern agricultural sector and improving society's finances, including tackling rural poverty. That same year, the Soil Pollution Prevention and Control Action Plan was introduced, establishing soil protection standards, which prioritised the protection of arable land, controlled pollution sources, and introduced risk management strategies for contaminated sites.[5,10] The Action Plan also looked to establish pilot trials for remediation techniques and strengthen monitoring and management of the soil environment.

The Action Plan sought to address limitations in several key areas:

- Policy: spreading responsibility across multiple ministries with limited regulatory understanding;
- Institutions and capacity: defining responsibilities and establishing clear management processes;
- Technology: offering demonstrations of treatment methods, but with a limited risk-based approach concept;
- Finance: establishing the scale of the challenge and outlining responsibility and up-front funding; and
- Information: establishing tracking and control of hazardous materials, processes to deal with waste, and information disclosure to address poor public awareness.

REGULATORY ACTION SINCE 2021

Regulatory development of the concept of a zero-waste city brought forward the holistic management of the development process to aid contamination reduction. In 2021, Measures for Funds Management of Soil Pollution Prevention and Control was implemented, while the regulatory aim of 'carrying out the construction of "zero waste cities" achieved practical results as a method to prevent and control contamination'.[10] This was the first explicit mention of the implementation of soil remediation since the launch of government funding for this purpose in 2011. It focuses on the final treatment goal being the control of waste production and the reduction of environmental pollution through remedial treatment. It also enhances the requirement for improved waste management and introduces the need for a range of treatment techniques.

AN EMERGING ENVIRONMENTAL PROFESSION IN CHINA

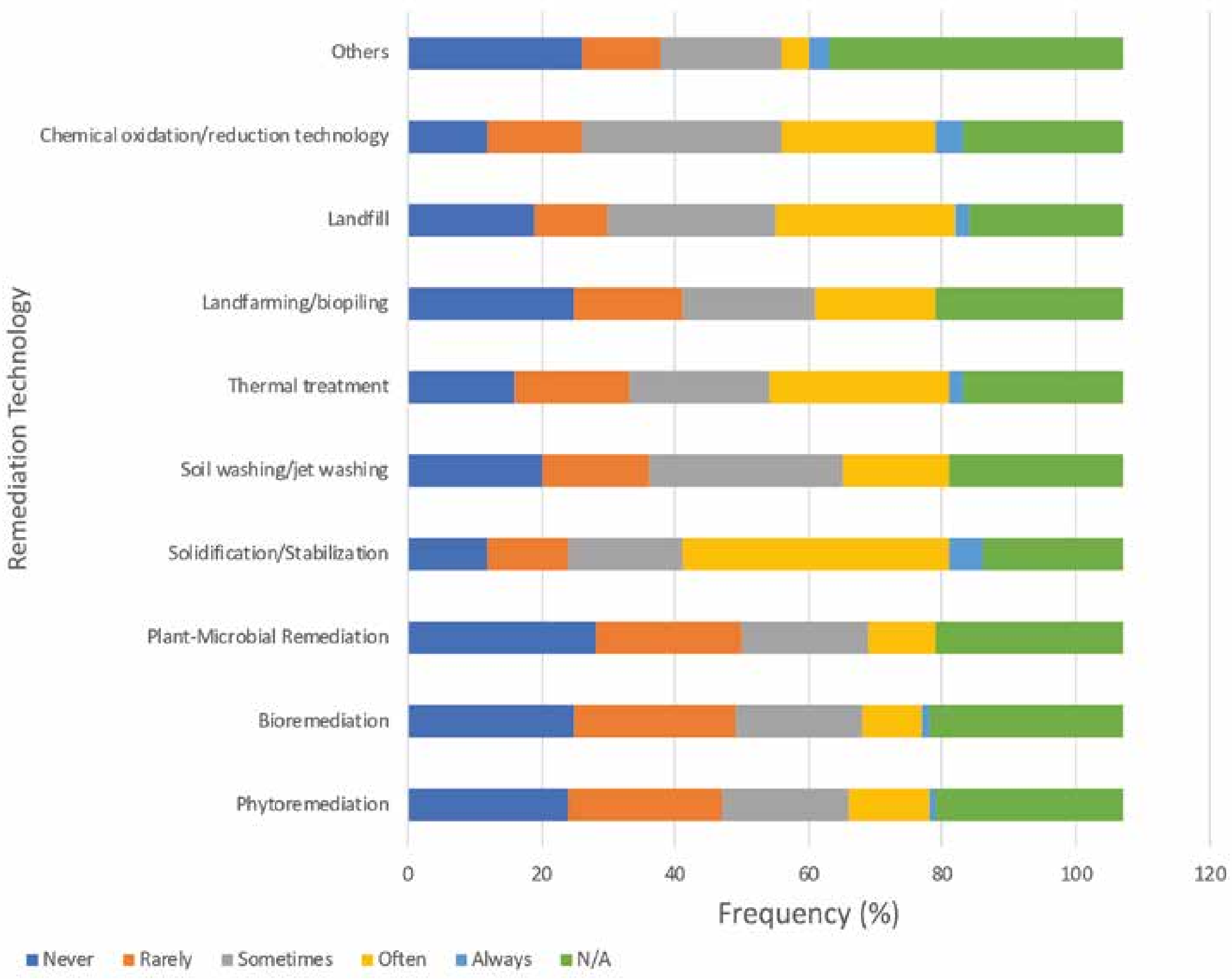
So has the well-documented improvement in air quality following the regulatory drive carried through into the contaminated land sector? Less than 10 years after the introduction and progressive refining of land quality regulations, how has management of the issue developed?

Our recent investigation on the status of decision-making and management of remediation projects in China was based on a series of online questionnaires and interviews over 2019–20.[10] This consultation took place during the Covid-19 pandemic and in the aftermath of other related regulatory interventions, such as the 2017 implementation of the ban on importing waste. That ban had global repercussions for waste flows and a major rebound effect on the domestic manufacturing industry, where material reuse was an important component.[11] Key points to note from the assessment:

- Priorities for remediation in a commercial decision-making process included a mix of remediation targets, the availability of proven technologies and financial guarantees. The original 2016 regulations and action plan established a tempting market for remediation businesses but with a weak industry base and little experience. Subsequently, regular revision and update of regulations brought increasingly tighter controls; site development was regulated by a diverse range of authorisations, permissions and evidence requirements, meeting the government's strategy promises.

- The remediation strategies used appeared to be dominated by more conventional physico–chemical approaches – landfill, solidification and stabilisation, thermal treatment and chemical reduction (see **Figure 1**) – perhaps reflecting the weaker evidence base for other technologies. However, in situ and softer remediation options, such as phyto- and bioremediation and land farming, were emerging as treatments. These strategies, however, did not meet the hope of many professionals commenting on the potential for innovation at the start of this regulatory reform.[5]

The professionals managing remediation projects were mainly well-educated young men, with limited experience in delivering remediation projects. This can explain the frequent use of conventional treatment strategies, but also recognises that regulatory stimulus is a recent development.



▲ **Figure 1: Relative frequency of the application of remediation technologies in site development. (Source: Song *et al.*[10])**

CLOSING THE GAP – WASTE AND REMEDIATION

So how is the sector performing? Data compiled from official government sources reveals the generation of classified hazardous waste on an annual basis. This covers many waste sources but is dominated by solid wastes derived from the treatment of pollution hot spots. The rate of treatment prior to Covid-19 had shown a general increase but was still below 50 per cent, allowing for a build-up of hazardous wastes (see **Figure 2a**). This contrasts with municipal solid waste treatment performance. Here, both waste generation and treatment capability have risen sharply from zero in 1989 to 50 per cent in 2004 and 100 per cent in 2018 (see **Figure 2b**). A small dip in waste generation in 2019–20 reflects Covid-19 impacts, but treatment still meets demand.

As the contaminated land sector in China emerges from its rapid initiation, the next phase looks towards refining remediation approaches. There is scope for more sustainable land management to deal with widespread lower-level food chain contamination. The confidence to adopt more risk-based strategies as well as implement regular post-remediation monitoring needs to be built upon. Changes to development strategies to incorporate more sustainable, proactive construction programmes with a lower environmental footprint should reduce new emissions, but catching up to deal with legacy contamination will be a long, slow task. ES

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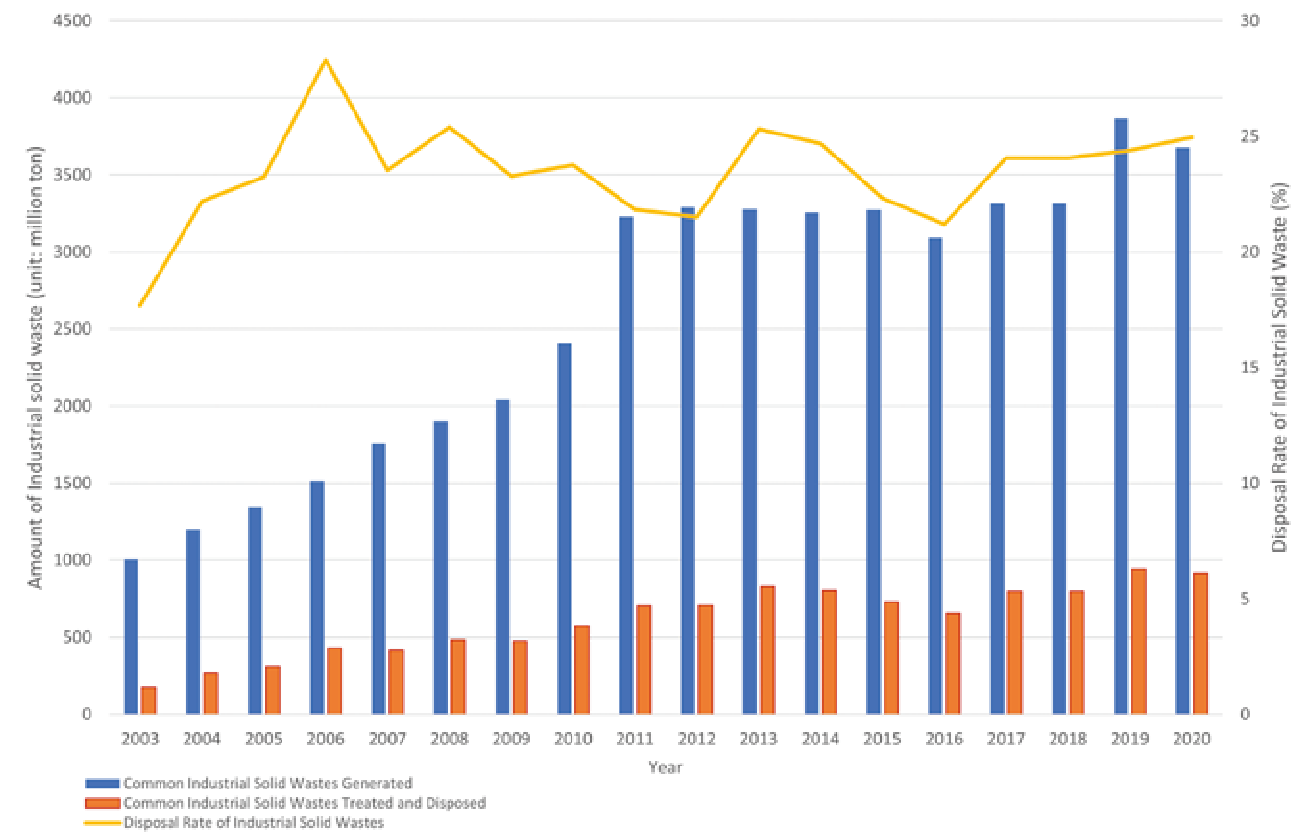
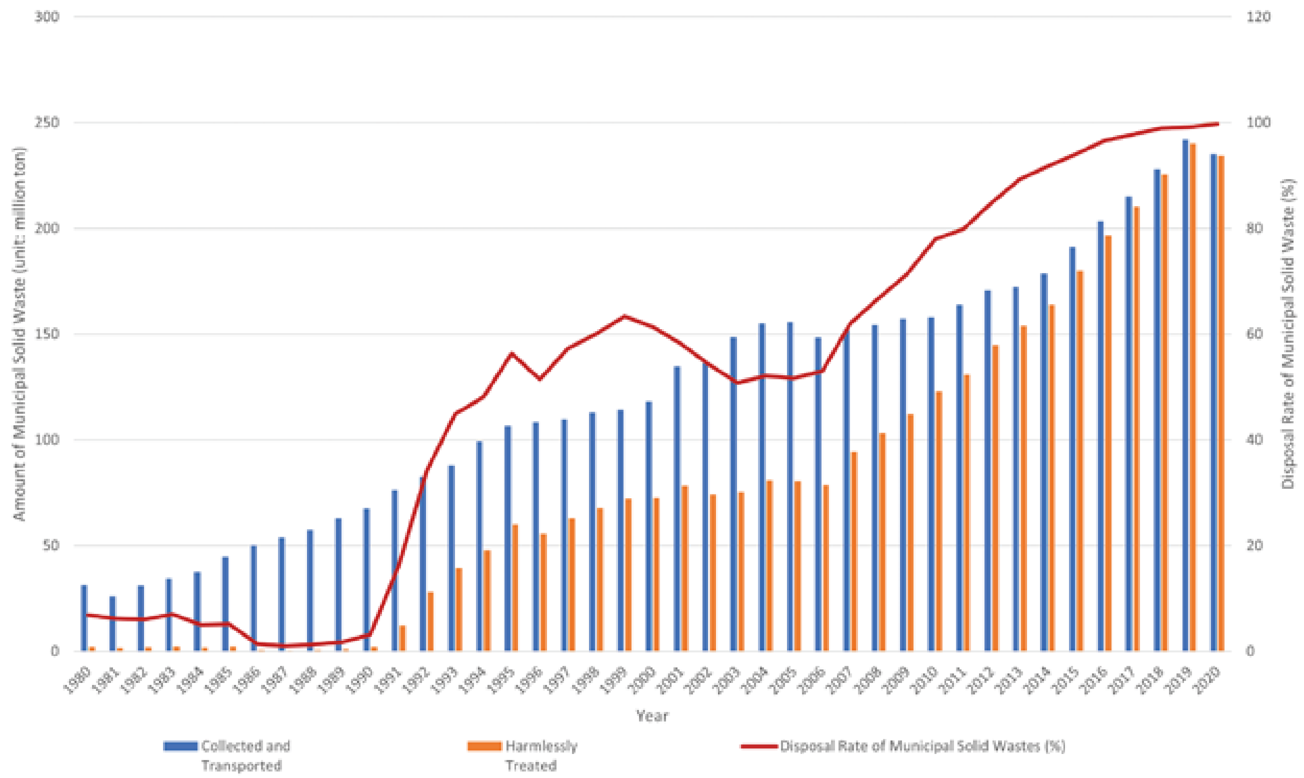


▲ **Figure 2a: Generation and treatment rates for hazardous solid waste across China. (Source: Song *et al.*[10])**



▲ **Figure 2b: Generation and treatment rates for municipal solid waste across China. (Source: Song *et al.*[10])**

CASE STUDY

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FEATURE

Climate change, extreme weather events and brownfield projects in the UK

Joanne Kwan sets out why we need to do more now before things get worse.

GLOBAL MEGATREND – 9

There is no doubt that our climate is changing and this has had significant impacts on our community and the environment (see **Figure 1**). In the words of the Met Office: 'Even if we were to stop all greenhouse gas emissions today, we would not prevent some changes.'[1]

The European Environment Agency (EEA) restated the findings of the Intergovernmental Panel on Climate Change in 2015 that continued global warming will increase the likelihood of severe, pervasive and irreversible consequences in many countries.[2] The European Science Academies Advisory Council has also revealed that climatological events, such as extreme temperatures, droughts, and forest fires, have more than doubled since 1980 (see **Figure 2**).[3]

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UK weather is also changing. For example, most parts of the country have been getting warmer over the past decades (see **Figure 3**).[4]

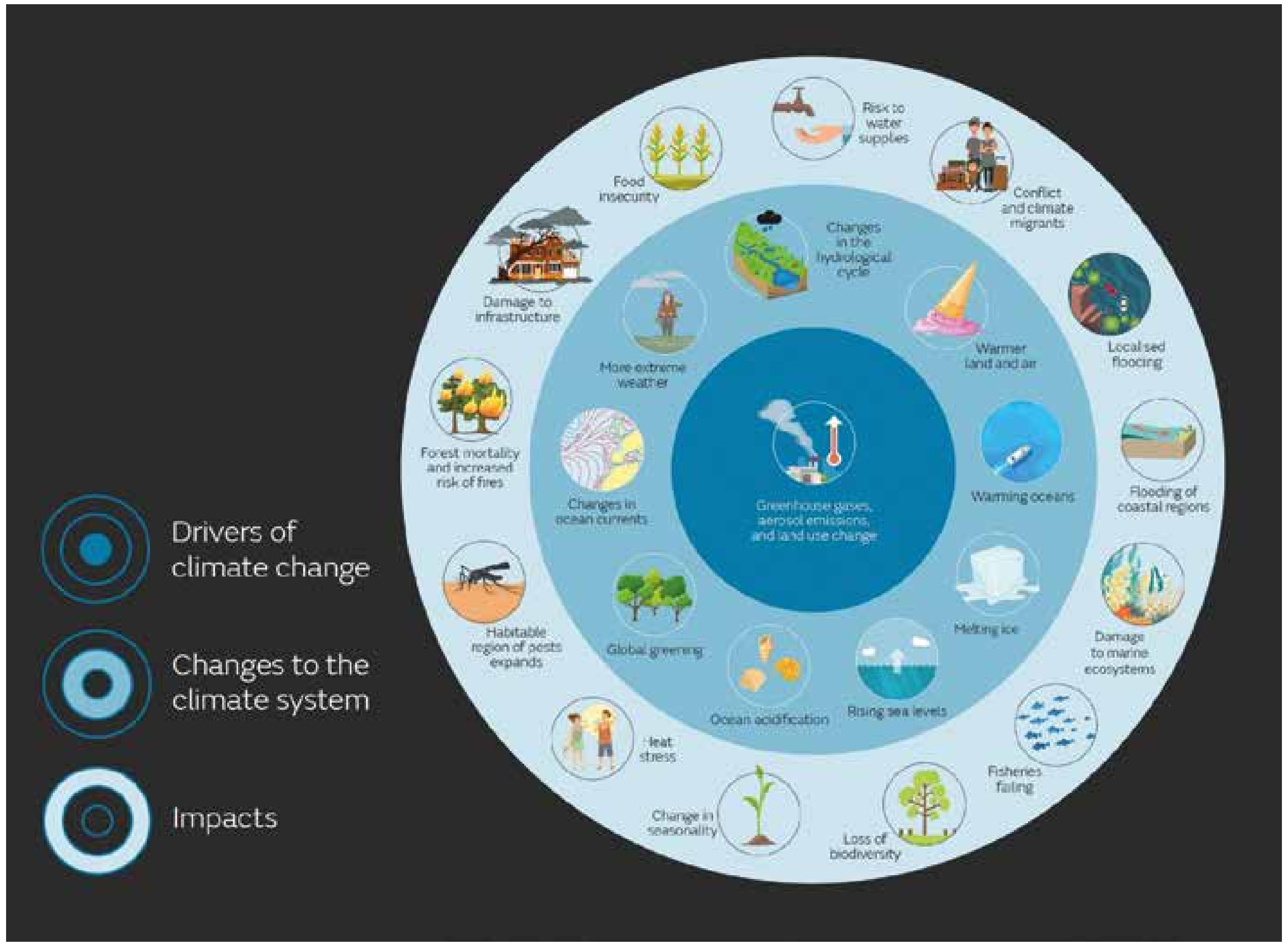
The Met Office has predicted that by 2070, there will be:

- Warmer (between 1 and 4.5C warmer) and wetter (by up to 30 per cent) winters;
- Hotter summers (between 1 and 6C). For southern regions, the average hottest day in summer could see temperatures of 40C;
- Drier summers (depending on the region, by up to 60 per cent); and
- Increases in the intensity of rainfall (by up to 20 per cent in summer and 25 per cent in winter).

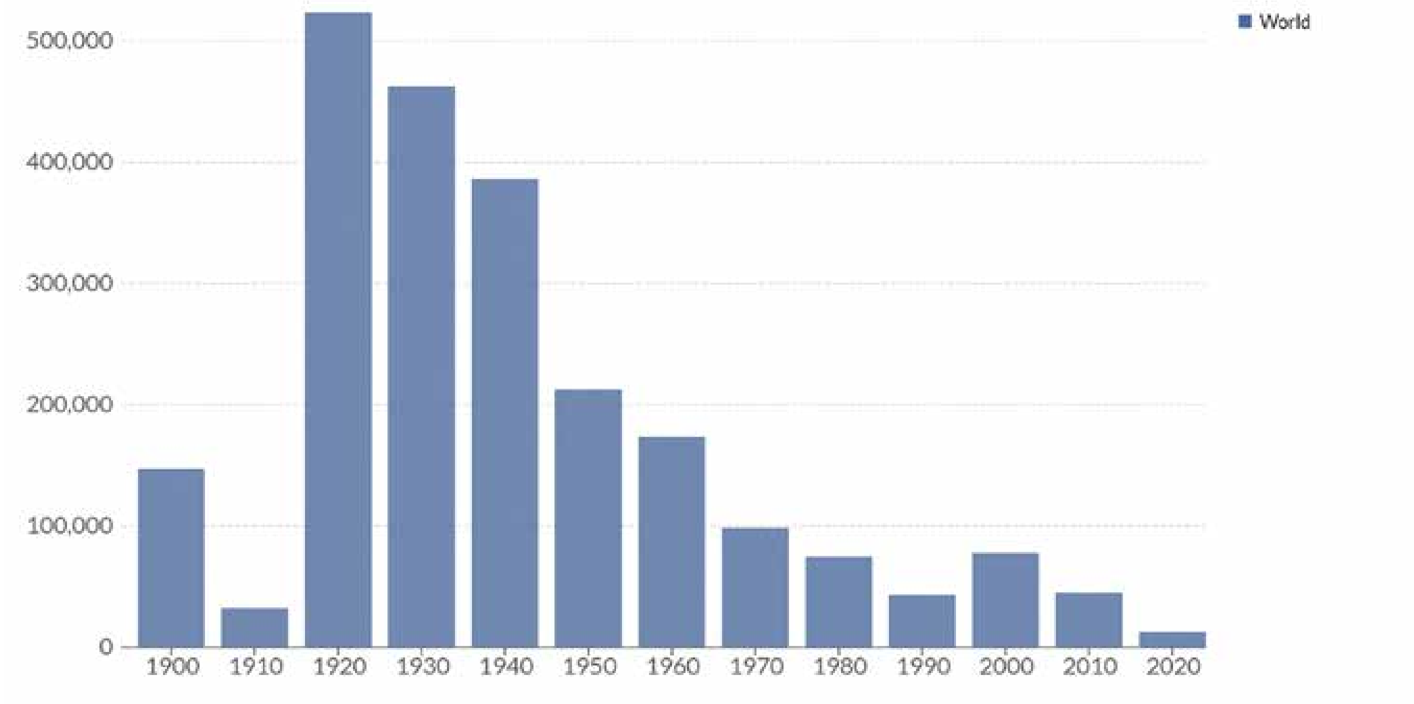
WHY ARE BROWNFIELD SITES IMPORTANT?

Brownfield redevelopment has been high on the UK Government's agenda for many years. *The Build Back Better: Our Plan for Growth* report stated that the Government will make significant investment into building 860,000 new homes in the next four years, many of which will be on brownfield, contaminated sites.[5] Floods, storms and other extreme weather events can cause damage to buildings, disrupt transport and affect health. These can also affect brownfield redevelopment projects, particularly if sites are contaminated. This is because:

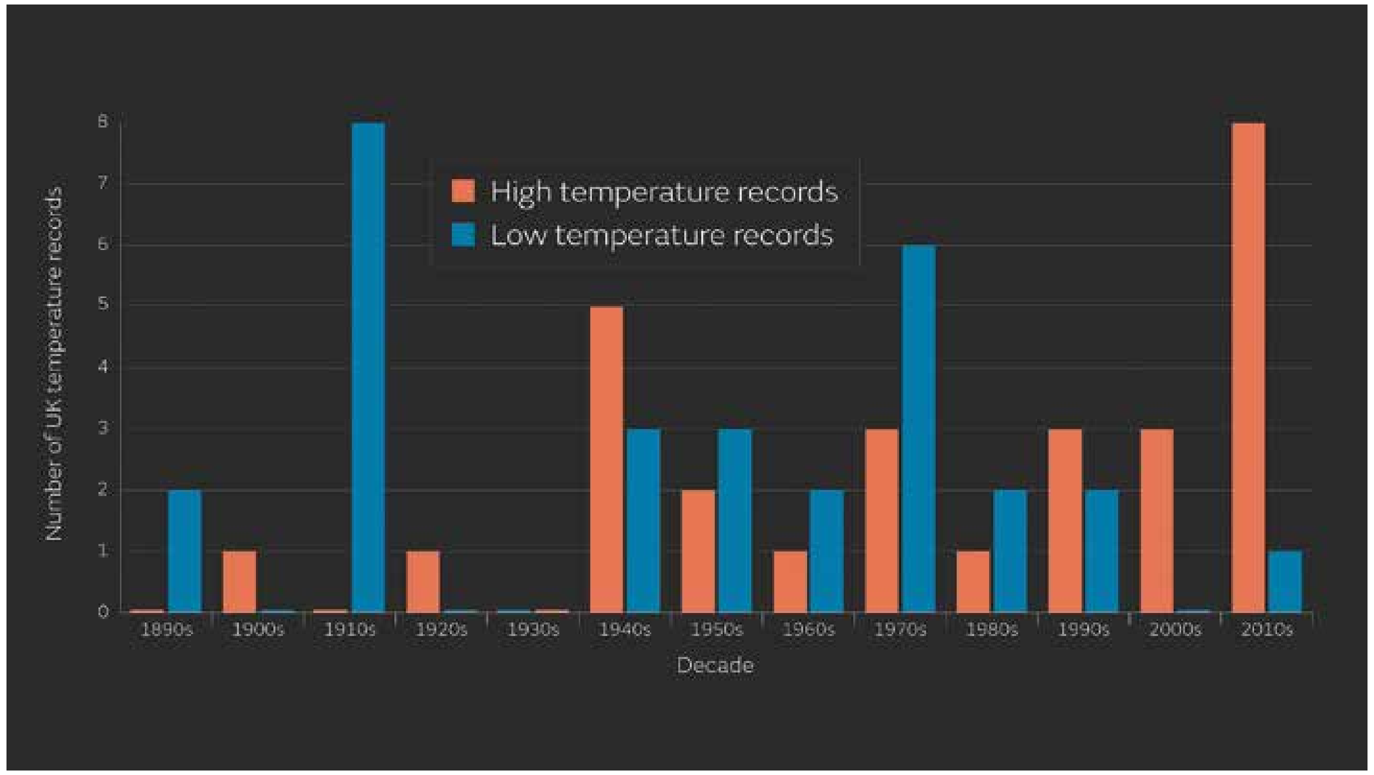
- Temperature changes can affect the biochemical and chemical properties of contaminants and, therefore, their behaviour. Such temperature changes will also alter the effectiveness of some remediation systems (e.g. bioremediation) and monitored natural attenuation.
- Events such as flash floods can increase run-off from contaminated stockpiles and mobilise contaminants.
- Prolonged drought desiccates clay caps causing them to crack.
- Intense rainfall can reduce land stability and increase erosion of the UK's 1,200 coastal landfills. Beaches and harbours can be exposed to waste, which will pollute the environment and enter the food chain through ingestion by fish and birds.
- Contaminated sediments can be re-deposited on to farmland by flood waters where they can affect livestock and crops.



▲ **Figure 1. Drivers, changes to our climate system and the impact of climate change. (© Met Office.[1] Contains public sector information licensed under the Open Government Licence v3.0)**



▲ **Figure 2. Decadal average: annual number of deaths from disasters. (Source: Our World in Data[4])**



▲ **Figure 3. UK temperature by decade. (© Met Office. Contains public sector information licensed under the Open Government Licence v3.0[1])**

- Extreme weather events can affect all risk management techniques during the implementation phase of remediation. However, long-term pathway interruption techniques are additionally susceptible to the chronic effects of climate change and associated environmental changes, including sea-level change.
- Hotter summers may require a change in working hours and health and safety precautions to protect site workers from the heat and sun.
- Climate change may become an uninsurable pollution risk. Many insurers are involved with sites requiring long-term contamination management and containment systems, and possible regulatory review of previously approved schemes could result in increased monitoring or remediation requirements.

DO WE KNOW HOW TO DEAL WITH THESE PROBLEMS?

There are two significant barriers to dealing with these problems.

1. **Low awareness.** Although the UK has declared a climate change emergency, and the National Planning Policy Framework is prioritising the use of brownfield land – which is often contaminated – the understanding of climate change within the contaminated land community is low, other than in relation to the risks from fluvial and surface water flooding.

The Construction Industry Research and Information Association (CIRIA) survey in 2020 found that 97 per cent of respondents think that climate change will affect their contaminated land projects in the future, but 56 per cent do not know if they are managing the risk well enough.[6] The survey also revealed that 60 per cent of respondents had not yet considered climate change in contaminated land projects.

A more recent internal study by CIRIA in 2022 revealed that although intensive rainfall and wetter weather are the best-known extreme weather events (see **Figure 4**), fewer than 50 per cent of those surveyed said their projects have been affected by the changing climate (see **Figure 5**).

The study also found that:

- Demand from clients is driving consideration of climate change on many projects;
- There is no consistent approach to the design of long-lasting remediation schemes;
- The resilience to erosion and degradation of cover and containment systems was the biggest concern regarding the long-term performance of remediation schemes;
- Remediation solutions that depend on the physical integrity of a barrier are vulnerable to extreme weather events; and
- The current risk assessment models and tools may not be able to account for a changing climate.

However, industry and regulators are beginning to pay more attention to extreme weather events and climate change. The Specialist in Land Condition Register recently set up a climate change group to help registered specialists deal with climate change on contaminated land projects.[7]

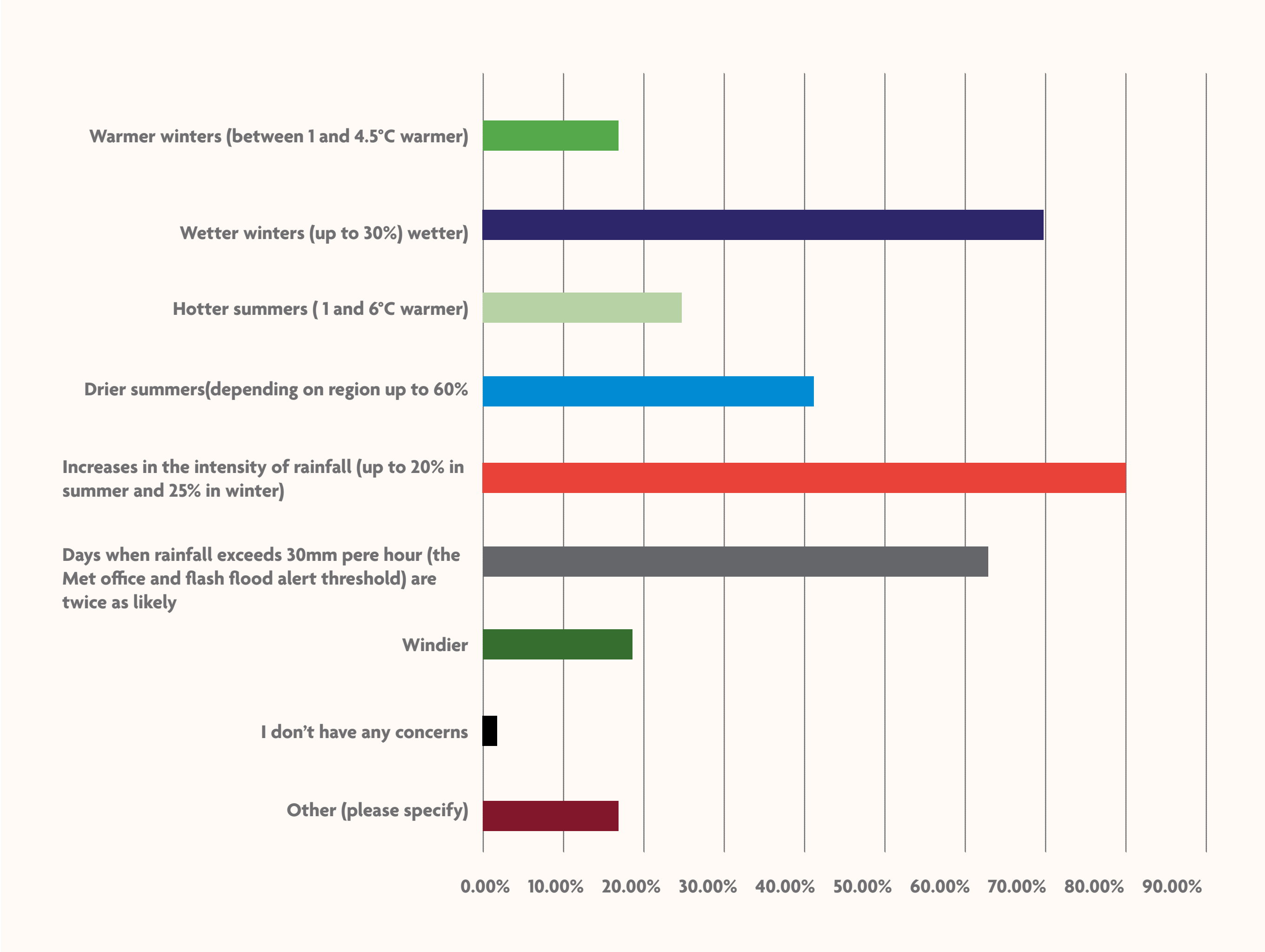
2. **Guidance on the subject is limited.** There has been little recent published guidance on the topic. The two latest guides include CL:AIRE's 2007 bulletin on climate change, pollution linkages, and brownfield regeneration,[8] and a response to frequently asked question 8 published in the Environment Agency's *Guiding Principles for Land Contamination (GPLC) Part 2* in 2010.[9]

However, the Society of Brownfield Risk Assessment published a report in 2022. This provides an overview of regulatory guidance and how varying effects (e.g. changes in soil moisture content or short-term oversaturation of soils) associated with a changing climate (e.g. protracted dry periods or extreme rainfall events) could be incorporated into risk assessment. The report also identifies the key model parameters that may be affected by climate change in detailed quantitative risk assessments for controlled waters.[10]

HOW CAN WE DO BETTER?

It is obvious that the construction industry needs to pay more attention to extreme weather events in brownfield projects – after all, such events are just part of the British weather! We also need:

- To establish a good understanding of the significance of the implications of extreme weather events on brownfield projects.
- Consistency across local authorities (the lead land contamination regulator) on how climate change and extreme weather events should be managed in the projects they are regulating or consulting on under the planning regime.
- To develop practical guidance on
  - how to incorporate climate change risk into the overall brownfield site risk assessment process, and what and where data will come from (other than for controlled waters)
  - how extreme weather events can affect major contaminants in the UK
  - how different remediation approaches will be affected by such events, particularly long-term pathway interruption solutions such as capping, permeable reactive barriers and monitored natural attenuation
  - what adaptation is required by individual remediation technologies
  - ongoing remediation projects where adaptation measures should be retrofitted.
- More empirical and theoretical research on
  - the effects of extreme weather events such as rainfall intensity on susceptible remediation approaches, pathway interception remediation options, capping, other cover systems and stabilisation
  - the effects of climate change on engineering geology practices, which in turn require an increased awareness of regional-scale forecasts for groundwater levels, rainfall intensity, temperature ranges and wind loadings, as well as amplified local groundwater level fluctuations.[11]



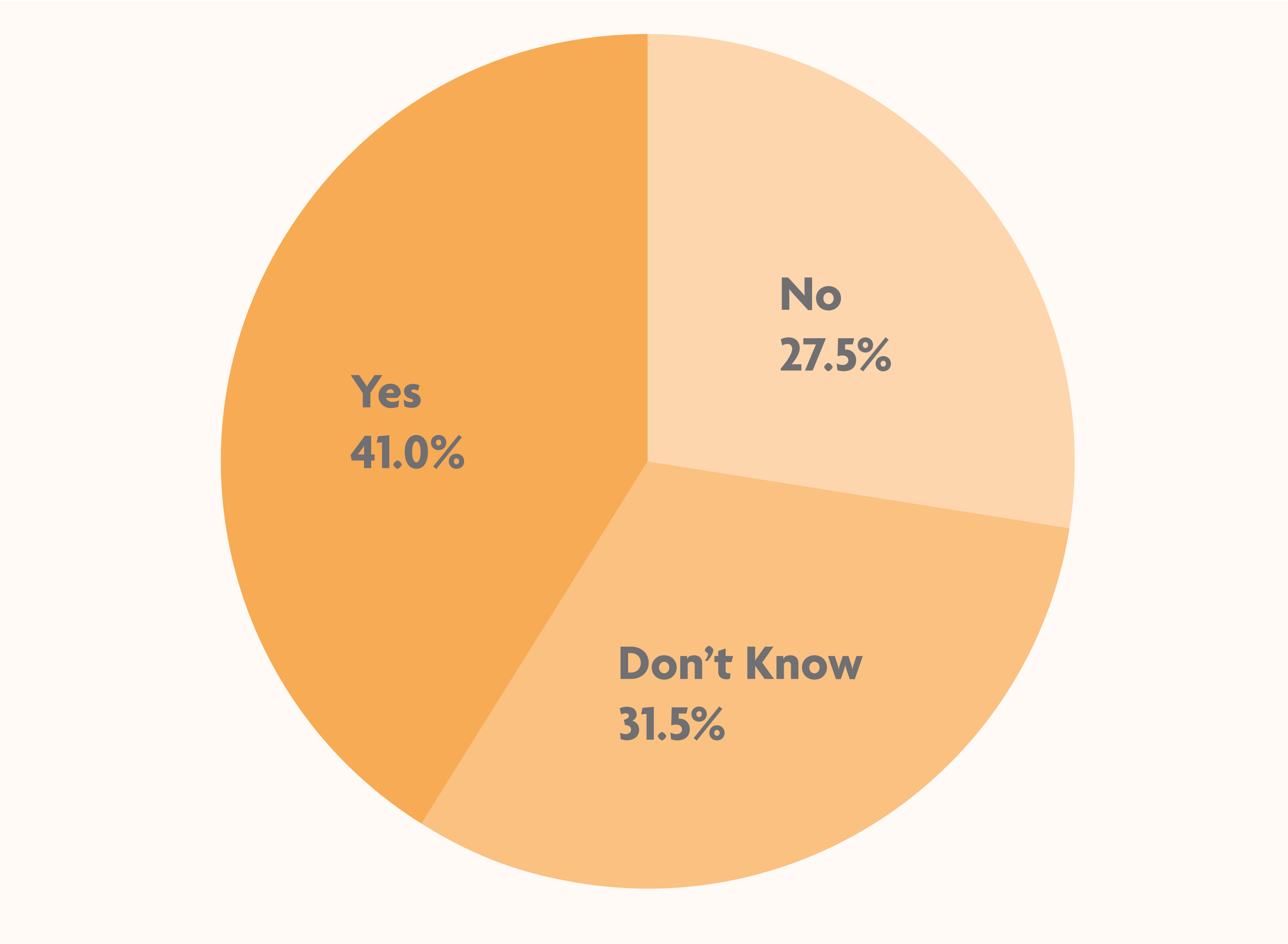
▲ **Figure 4. Responses to survey question 'What are your key climate change concerns in brownfield projects?' (Source: CIRIA)**

CONCLUSIONS

The United Nations has already stated that 'the impacts of climate change are global in scope and unprecedented in scale'.[12]

Most people agree with the EEA's global megatrend (GMT), Increasingly Severe Consequences of Climate Change (GMT 9), that climate change has led to faster rates of global mean temperature rise and that this threatens human health, ecosystems and biodiversity.[13] GMT9 also states that climate change can slow economic growth, which goes against the UK Government's commitment to rebuild the UK after the Covid-19 pandemic.[5]

However, the awareness of the general public and those in the construction sector of certain types of construction activities (e.g. brownfield land remediation projects where the impact is considered to be less visual) is much lower. Not seeing the impact does not mean extreme weather events have no effect on land remediation projects. There is already a wealth of national and international academic and industry research that demonstrates they will affect the physical and chemical properties of contaminants and the effectiveness of many commonly applied remediation approaches. This is not about just technical issues during the construction phase but also applies to liability and financial implications



▲ **Figure 5. Responses to survey question 'Have any of your projects ever been affected by changing climate/extreme weather event?' (Source: CIRIA)**

if remediation approaches are affected by bad weather or flooding incidents once buildings are constructed.

Development on brownfield sites forms part of major infrastructure changes in the UK. In the previous decades, the UK Government was promoting more house building on brownfield land, and many of these contaminated sites need to be remediated. The frequent extreme weather events have and will continue to cause significant adverse effects on the national house-building industry.

Finally, meeting greenhouse gas emissions targets will not stop the reality of extreme weather events from happening more often. Construction practitioners need to act quickly to apply a more holistic approach and sustainable management methods to managing such risks. ES

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ANALYSIS

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Geosciences: their role in the future of economic development

Rebecca Hearn and **Jonathan Atkinson** talk to land condition industry professionals for their on-the-ground analysis.

THE FUTURE

When you meet friends, do you ever feel like no one really knows what your job title means? Do you say you are an environmental scientist or environmental consultant, and blank faces look back at you? If our own generation does not understand what we do as environmental scientists, what chance do we have of getting the next generation of scientific minds and innovators into environmental science and geosciences?

For this year's science, technology, engineering and mathematics (STEM) week primary school children were given the opportunity to see what is involved in jobs within scientific industries. Making science exciting is easy; experiments and getting messy with soil and water is fun for everyone, but what is really fascinating is the comprehension that a four-year-old has about the environment. Being able to not only articulate what they think makes up the environment but also understanding that their own behaviours are vital for environmental improvement.

Our challenge is to nurture the passion of the four-year-olds and allow their creative minds to build on our understanding and find new ways of thinking about our precious environment. Getting the brilliant minds into our industry is a challenge that we all face. Is it of our own making? Has our drive for continued economic growth and a very traditional education system got us to this point? Does a sustainable future require a reset? How do we encourage future generations to pick up the challenge, and how do we adapt our education and growth models to encourage and equip them to face it?

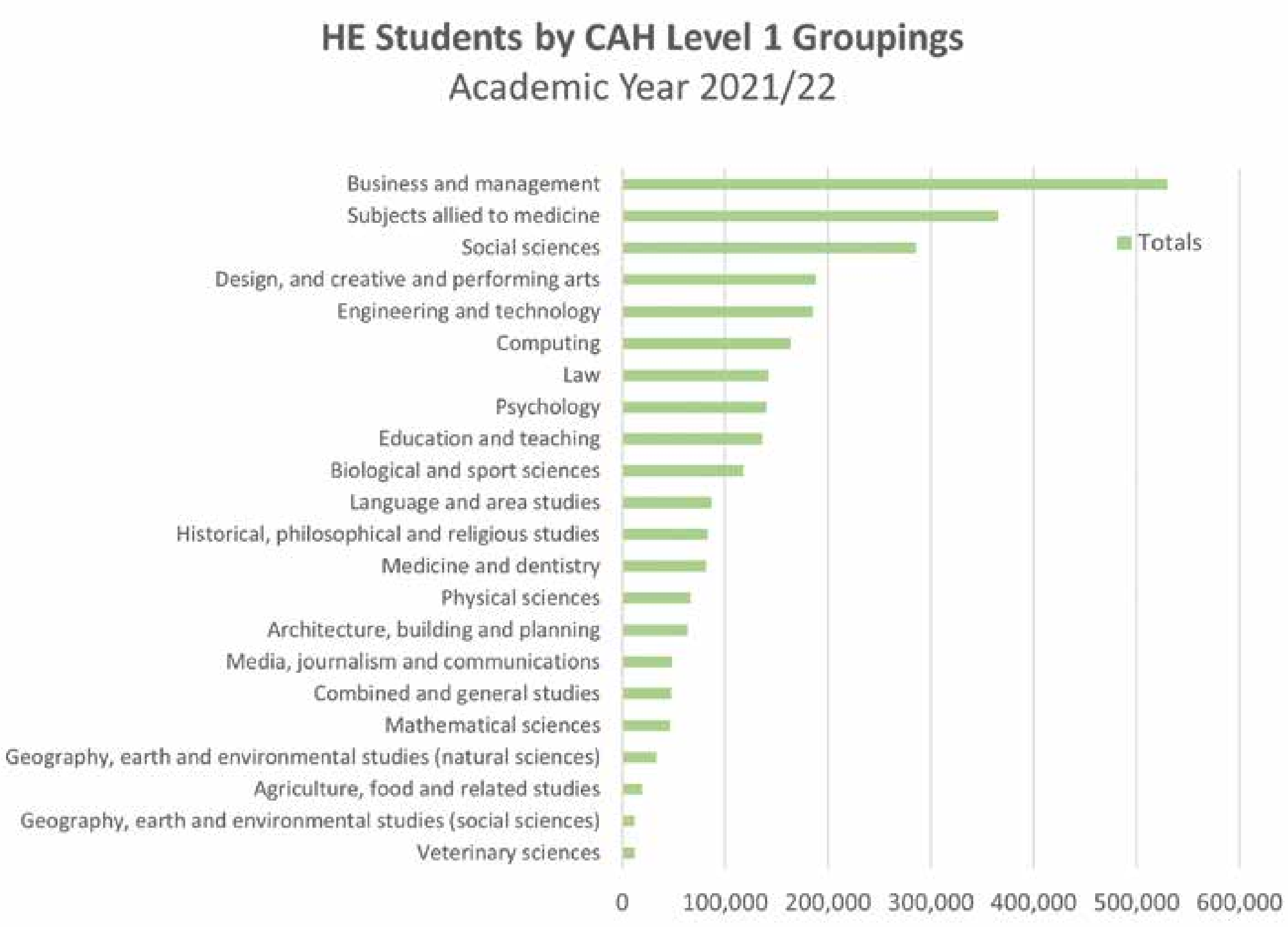
THE NUMBERS

A recent study suggests that postgraduate geoscience courses such as engineering geology, geotechnical engineering, soil mechanics, geological and environmental hazards, and hydrogeology are attracting fewer students than comparable courses in engineering and technology. Enrolment in the geoscience courses surveyed was down 6 per cent in 2021 compared with 2018 while overall enrolment in postgraduate courses was up by 42 per cent, according to data published by Higher Education Statistics Agency (HESA). HESA data also suggest that enrolment in other physical science courses increased by 80 per cent over the same period.[1] The IES currently accredits more general environmental courses and is exploring accrediting more specialist courses.

HESA data suggest that the total number of students enrolled in environmental science courses has increased from 6,700 (UK total) in 2019–20 to 7,950 in 2021–22.[2] However, the Common Aggregation Hierarchy (CAH) grouping of geography, earth, and environmental studies (natural sciences) remains near the bottom of the list. Only veterinary sciences, agriculture, food and related studies, and geography, earth, and environmental studies (social sciences) rank lower (see **Figure 1**).

What do these data mean? Are these figures showing a lack of interest or are there just a limited number of courses available?

The Complete University Guide indicated that 16 universities currently offer 60 undergraduate courses that fit the search term 'natural sciences'; however, if the search term is changed to 'soil science' there are only two available courses. Land contamination was only mentioned in a single, master's, degree title. The search term 'geology', however, returned 295 courses across 48 universities.[3] While this seems like a reasonable number of courses, a search for 'business finance' shows a staggering 1,841 courses offered across 179 universities.



▲ **Figure 1. Student enrolment number by Common Aggregation Hierarchy (CAH) level 1 grouping. NB: The science grouping is an aggregation of CAH level 1 codes CAH01–CAH13 and CAH26 except for Human geography (CAH21-01-03) and Geography and environmental studies (CAH26), which has been disaggregated so that Human geography is presented in the non-science grouping labelled as Geography, earth and environmental studies (social sciences). All other level 3 codes within CAH26 are presented in the science grouping labelled Geography, earth and environmental studies (natural sciences). (Data provided by Higher Education Statistics Agency Chart 11 under Creative Commons Attribution 4.0 International Licence[2])**

"Getting the brilliant minds into our industry is a challenge that we all face. Is it of our own making?"

This is not just a UK problem; geology courses are on the decline across Europe with a drop in enrolment generally cited as the reason.[4] Getting the brilliant minds into our industry is a challenge that we all face. Is it of our own making?"

VOICES FROM THE INDUSTRY

Caroline Martin (Principal Consultant and UK Land Quality Lead, Royal HaskoningDHV) and Alex Lee (Associate Technical Director, Arcadis) reflected in a recent discussion that the pool of applicants for technical roles has declined, with a limited number of candidates from this smaller pool making it through to interview stage. Those that come through the interview tend not to have a full understanding of the industry. Both businesses run a graduate scheme that allows graduates to be placed in an area of the business where their skills, academic background and personality best fit. Martin and Lee were also in agreement that if we do not find a way to get students engaged earlier in understanding natural sciences, and in particular geology, we are soon going to face a critical skills gap.

Elspeth Harris (Senior Consultant, Royal HaskoningDHV) added that skills gaps are not just found at the graduate level; many experienced individuals left the industry during the 2008 recession and chose to remain in jobs that offered greater financial security rather than re-join the industry they had left.

This is not just hearsay from the industry; physical scientists with job titles including engineering geologist and hydrogeologist (among others) are listed on the UK skills shortage register.[5] This is perhaps reflective of the fact that in 1994 the environmental education themes that were previously cross-curricular were no longer referred to in the national curriculum. A series of initiatives in the first decade of the 2000s aimed to add elements of environmental education back in, only to be scrapped again in 2010. Since then, environmental activists like Greta Thunberg have reignited climate talk and action among the younger generation, including multiple youth strikes across the UK. Teach for the Future has sought to put environmental issues at the core of the curriculum to equip the next generation with the right knowledge base and skills development needed for the challenges they will face across society as global environmental challenges increase.

ANALYSIS

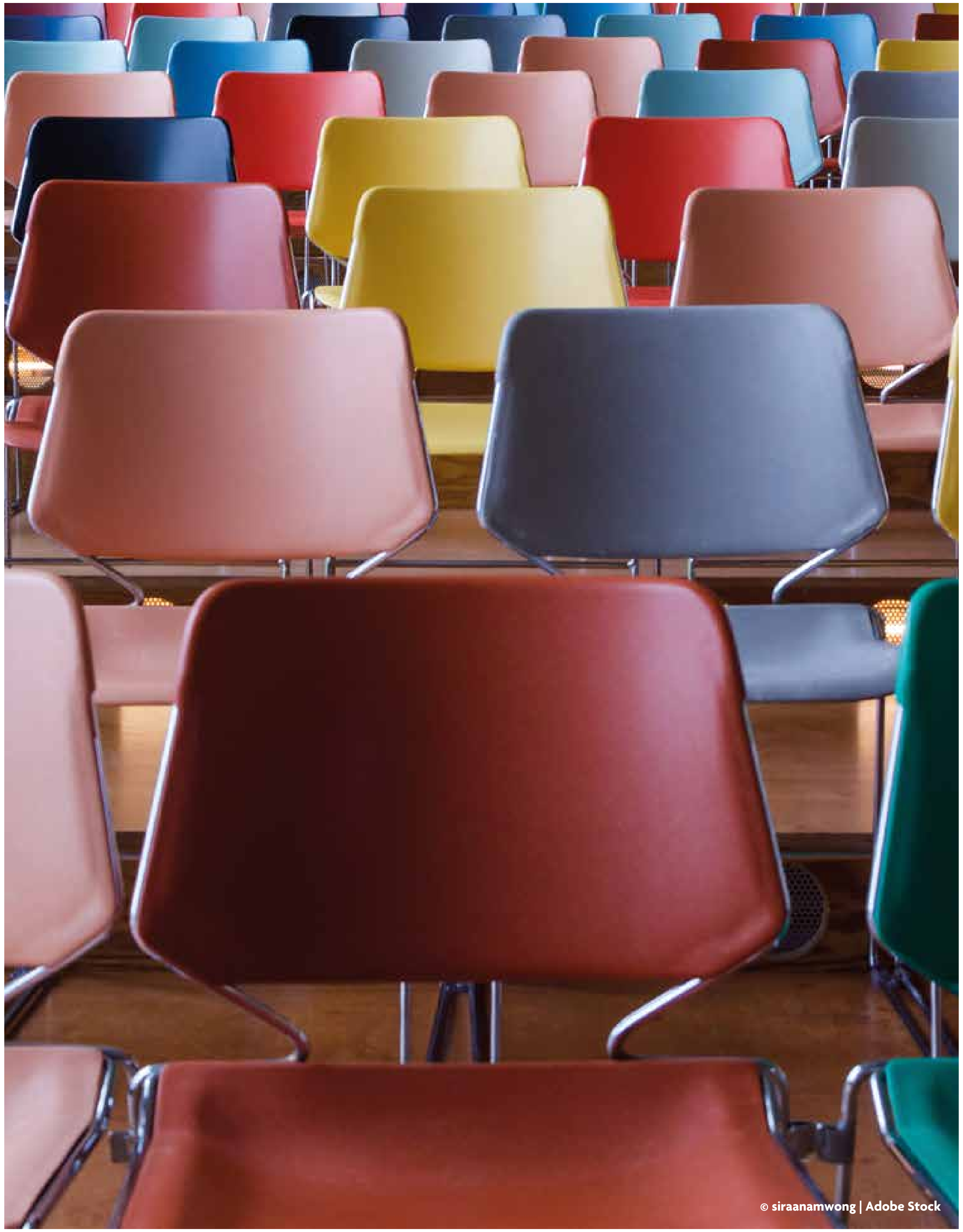
In 2021, the UK Government held a parliamentary debate on the inclusion of climate change and sustainability on the national school curriculum;[6] the responsibility for delivering these subjects falls to geography and science departments, with geography only compulsory up to Key Stage 3 for England (up to age 14). Does this provide our next generations with sufficient grounding? Is this lack of foresight now reflected in the declining uptake of geoscience degrees?
While we have STEM week, and some schools (as mentioned by Lee) have their own initiatives, such as Future Fridays, has the popularity of sustainability taken individuals who are passionate about the environment away from geosciences or are there similar issues within sustainability? Is sustainability, as currently practised, more about economic and legal drivers on environmental issues or is it truly about understanding and valuing the environment for its own sake? This is perhaps why geosciences need a new profile, alongside other disciplines like ecology, conservation and soil science, to properly balance the three strands of sustainable development.

Martin Ballard (Head of Environment, Wates) shared his insights into sustainability: 'In order to understand sustainability and to implement a sustainability strategy in a meaningful way, you need to have an understanding of the environment as a whole.' Ballard took a deliberate career route from the agricultural industry to the Environment Agency and then to the water industry, where he worked around the organisation to gain a full understanding to enable a true cross-discipline approach to sustainability. Ballard reflected that often there are excellent sustainability managers within teams who understand their organisation, the industry they work in and the people they work alongside, which are key to being a good sustainability leader. However, the cross-discipline approach of a sustainability lead in the development sector still requires input from core specialists in areas like geotechnics, land contamination, ecosystem approaches, water engineering, energy and materials management. Where will this cross-discipline link come from going forward?

CONTINUED ECONOMIC DEVELOPMENT

According to Ballard, economists consider anything above 1 per cent to be economic growth. He asks whether this is sustainable or if we should be striving to maintain balance. Markets seek a return, and we, as custodians of the environment, need to pursue that return for the environmental aspects of growth; if we do not, growth will slow or even reverse as the environment pushes back and the effects of climate change worsen and lead to more prevalent drought and flooding events, all of which have significant impacts on the economy.

Ballard raised an interesting point: the insurance industry has a good grasp of future potential liabilities. Instead of working single-mindedly in our own technical areas, recognising opportunities to learn and collaborate is going to be progressively key to sustainable growth and environmental management. Highlighting the future financial liabilities on projects may encourage investment since a realistic perception of the true returns would be greater. Our economic models cannot continue to be driven by short-term gain or the environment will expect a payback – as is increasingly obvious in the projected impacts over the next 20–50 years. Sustainable development is not just about balancing social and economic factors with environmental ones within a model; it is about recognising that social and economic wellbeing sit firmly inside the environmental bubble that supports us all.



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As with all industries, the land condition community faces price pressure with no return on its investment for a long period of time in terms of development. Lee highlighted the difficulty in balancing quality over profitability but sees tech-savvy graduates as key to improving this conundrum by using fresh eyes to develop innovative ways in understanding data and reporting to clients – a view echoed by all those interviewed. Our challenge is then driving meaningful outcomes from the data and reporting.

Just because we have always done something a particular way does not mean that it is right. Harris commented that continuing to operate in the same way in terms of how we recruit and treat graduates is comparable to continue to use outdated health and safety procedures, ultimately ending in degradation not betterment of the environment. This sentiment is backed by Jonathan Atkinson: 'Just because we didn't wear seat belts in the past doesn't mean that we shouldn't wear them now.' Although we accepted some environmental degradation to enable growth in the past does not mean we can continue to do that; the consequences will be far worse without some stronger policy and action to avoid a future environmental crash – one that appears nearer than perhaps some think.

Is the recent inclusion of biodiversity net gain (BNG) within the planning regime the catalyst for significant change? BNG has metrics in place that allow an investment return to be understood. The benefit of green space is already widely recognised by retail and housing markets, with Ballard highlighting an extremely relatable example: property of the same type overlooking park land will attract a higher price than that located several streets away. This shows the higher value placed on green infrastructure by those in the built environment. Green spaces, therefore, already have an inherent value, but BNG will ensure value is added to nature and the overall social and natural environment, not just property value gain.


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REFLECTION

In preparing this article, we had a lot of interesting conversations. What is the journey to becoming employed in the environmental sector? Is it having a cartographer as a parent or a geologist as a grandparent; having a rural background; being inspired by an amazing geography teacher; or hearing something from a university lecture that ignited a passion? The common response was that ending up in the land condition industry was for many a happy accident. Education provided the tools for learning and encouraging enquiring minds, which everyone interviewed said they felt was a part of them from a young age – picking up stones and soil and asking about them and how they got there.

The key question is this: has education inspired people in recent years, and what does this look like now and into the future? Has the important activity-led experience of exploring their environment been lost to so many? Do we need to re-introduce it, or perhaps make it a fundamental requirement for school children to explore and understand their environment so they can develop a passion to be the geoenvironmental scientists we need for the future?

There are benefits to getting our hands dirty and not relying solely on the virtual world. Information technology and artificial intelligence will be part of the solution. The UK population is ageing, with 3.2 people of working age for each pensioner, putting pressure on the workforce to achieve higher growth rates. The tech-savvy graduates referred to by Lee are the individuals needed in the sector to support the development and use of appropriate technology within the industry. However, it is important that these futures generations of scientists have played with soil and rocks and understand how the environment works at a practical level not just through modelling or virtual experiences. Our priority should be on quality science teaching rather than on passing exams.

How do we inspire others into geoscience to support the development industry? Do we need to consider apprenticeship routes? Should we be fighting to get environmental science added to the national curriculum in a coherent way? Whatever it is, it seems evident that something needs to be done in a holistic way and will likely need to be led by industry's demand for an enlightened and trained workforce, as well as the Government's recognition that we need to make education fit for future purpose.

Economic growth has historically been driven by resource use. Those resources are finite, and it follows that so, too, is economic development. Understanding and managing those resources is our business. Investing in the future of our industry is investing not only in the future of the environment but in the future of economic development. That is surely at the heart of a circular economy and healthy environment. ES

Rebecca Hearn is Co-director of Murray Environmental Limited working in the contaminated land field, with 15 years' experience on a range of industrial sites including gas works and military sites. She is passionate about knowledge sharing and is active with early careers engagement through the IES as well as Midlands Lands Events, set up by Rebecca and Midlands colleagues to support knowledge sharing among land professional in the UK's Midlands region.

Jonathan Atkinson is a Technical Director at CL:AIRE with over 30 years' experience as an environmental scientist in the UK and abroad, specialising in soil management, land contamination and risk assessment. He has worked as a regulator for the Environment Agency most of his working life and is passionate about leaving a viable future for the next generation. He actively supports the IES and Society for the Environment in land condition and climate change work.

Acknowledgements
With thanks to contributors Martin Ballard, Elspeth Harris, Alex Lee and Caroline Martin.

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Printer	Lavenham Press Ltd
Published by	Institution of Environmental Sciences 1st Floor 6–8 Great Eastern Street London EC2A 3NT
Tel	+44 (0)20 3862 7484
Email	info@the-ies.org
Web	www.the-ies.org
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