AquaConSoil

Reflecting on 40 years of innovation and impact in soil, sediment and water management

Index

Celebrating 40 Years of AquaConSoil

As we celebrate 40 years of AquaConSoil, we reflect on the tremendous progress that has been made in the fields of soil, sediment and water management, environmental science, and sustainability. This magazine, as a special edition, is not just a look back at our journey, but also a celebration of the innovations, collaborations, and shared dedication that have shaped the success of AquaConSoil over the past four decades.

Innovation, collaboration, and unwavering commitment have defined AquaConSoil's success over four decades.

Why we created this magazine
This magazine was created to capture and share the stories, insights, and innovations that have shaped AquaConSoil. It is a tribute to the community's passion and commitment and a way to inspire continued learning and collaboration. By reflecting on the past and highlighting current challenges and opportunities, we hope to encourage readers to contribute to a sustainable future for soil and water management.

From a small gathering to a growing community
What started as a meeting of like-minded professionals has grown into an active and diverse community focused on soil, sediment and water challenges. AquaConSoil has been at the forefront of addressing some of the most pressing environmental challenges of our time. We have seen breakthroughs in soil remediation, advancements in water quality management and the development of sustainable practices that are helping to safeguard the planet for future generations.

Honoring dedication and shared vision
This milestone is a tribute to the many individuals and organizations who have supported AquaConSoil's mission through research, projects, and partnerships. Each contribution, no matter the scale, has helped build a foundation for ongoing progress toward a more sustainable future.

Every contribution strengthens our shared commitment to sustainability.

Facing Future Challenges Together
Looking ahead, the environmental challenges we face remain significant. Climate change, biodiversity loss and water scarcity require continued attention and action. With innovation, cooperation and a shared commitment, AquaConSoil will continue to be a platform for exchanging ideas and fostering solutions that promote a healthier environment.

Together, we can meet the challenges of tomorrow with commitment and cooperation.

40 years of innovation, collaboration and impact

From ConSoil to AquaConSoil: A legacy of sustainable impact

By Siem Jansen and Prof Frederic Coulon

Siem Jansen is Project Manager of AquaConSoil 2025 and researcher at Deltares specialising in soil-water systems and carbon dynamics. Prof. Frédéric Coulon is Chair of AquaConSoil and Professor of Environmental Chemistry and Microbiology at Cranfield University (UK). In this article, they reflect on AquaConSoil's 40-year journey, highlight key milestones, and look ahead to the 2025 edition in Liège.

This year, we are celebrating our 40-years anniversary in Liège, hosted by the Université de Liège. An ideal setting with its strong commitment to environmental research and sustainability. In this magazine, we invite you, our visitors, to explore topics discussed during previous events as well as those featured this edition.

The innovations shared at AquaConSoil have shaped industry standards and sparked new collaborations

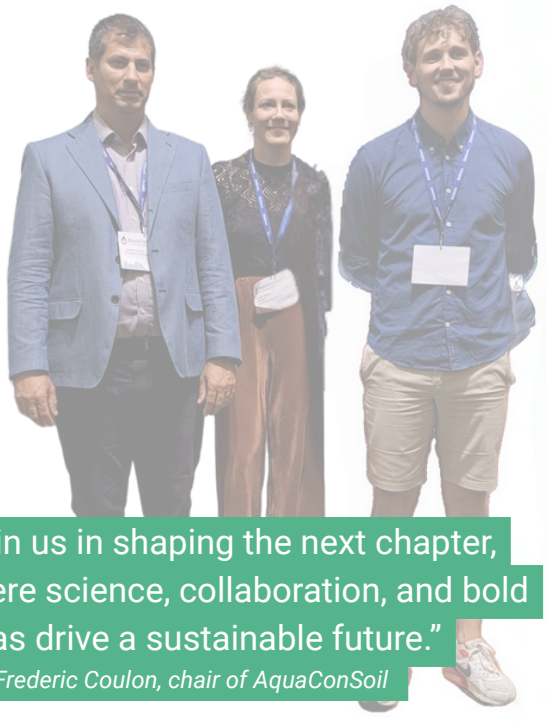
From 1985 to Today: The AquaConSoil Evolution
What started as ConSoil in 1985 has grown into AquaConSoil in 2010, a global platform where scientists, policymakers, and industry leaders collaborate on real-world solutions for soil, water, and sediment challenges. Over the years, the innovations shared here have shaped industry standards, guided policy development and sparked new collaborations.

Our core mission: Still strong
Yet, our core mission remains the same: bringing people together to drive sustainable resource management. As Prof. Huub Rijnaarts highlights in this issue, collaboration and innovation have been key to our impact and Sophie Moinier, former project manager of AquaConSoil, reflects on how exchanging knowledge and diverse perspectives keeps AquaConSoil ahead of the curve.

Our core mission remains the same: bringing people together to drive sustainable resource management.

A future-driven mission for AquaConSoil
In 2025, we build on this legacy with a reimagined programme. Thematic keynotes will anchor daily discussions, spotlight presentations will amplify diverse voices and expanded dialogue sessions will spark actionable ideas. We're also giving early-career scientists and professionals a bigger platform to shape the future, a topic Dr. Anjali Jayakumar explores in her article.

As we mark 40 years, AquaConSoil remains committed to pioneering solutions for a resilient planet. AquaConSoil aims to keep evolving for the new societal challenges. Join us in shaping the next chapter, where science, collaboration and bold ideas drive a sustainable future.



"Join us in shaping the next chapter, where science, collaboration, and bold ideas drive a sustainable future."
Prof Frederic Coulon, chair of AquaConSoil

Timeline 40 years AquaConSoil

1985
Utrecht

1988
Hamburg

1990
Karlsruhe

1993
Berlin

1995
Maastricht

1998
Edinburgh

2000
Leipzig

2003
Gent

2005
Bordeaux

2008
Milano

2010
Salzburg

2013
Barcelona

2015
Copenhagen

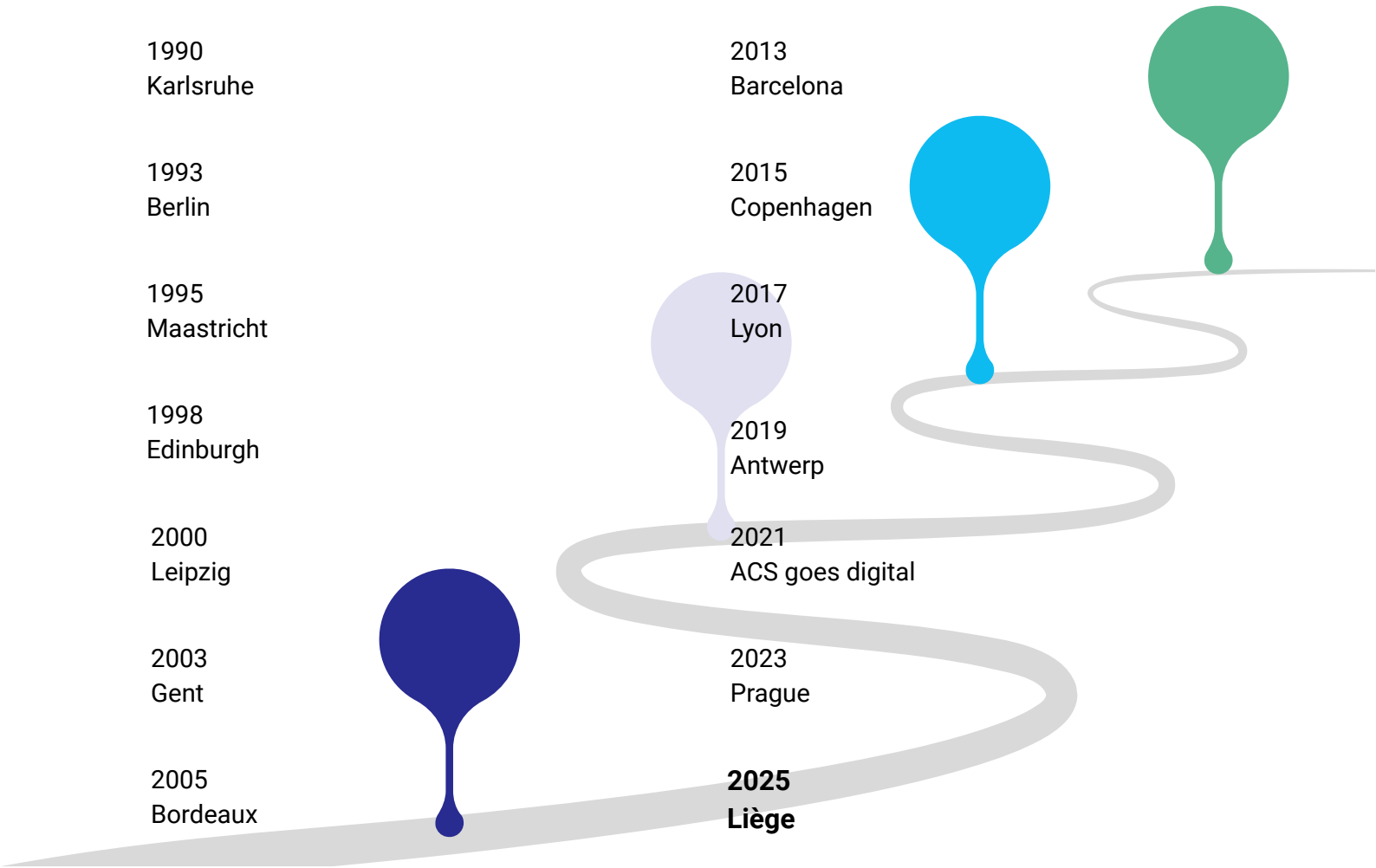
2017
Lyon

2019
Antwerp

2021
ACS goes digital

2023
Prague

2025
Liège



40 years of AquaConSoil

Relfections on a legacy of organisation and collaboration

By Sophie Moinier

Head of Subsurface and Water Quality, Deltares Sophie Moinier has played a key role in organising AquaConSoil since 2017. First as project manager and now as a Department Manager. With years of experience behind the scenes, she shares a personal look at the people, challenges and evolution that have shaped the conference over four decades.

AquaConSoil celebrates its 40-year anniversary. Reflecting on the past decades quickly brings to mind the topics that have been addressed in relation to important policy and societal themes. Our former chair, Huub Rijnaarts, beautifully captured this in his piece (see page 9). However, the behind-the-scenes organisation of such a large conference remains invisible to many. For 40 years, the organisation has been in the hands of Deltares (and its predecessor TNO), together with several partners. For us at Deltares, this 40-years anniversary is a wonderful moment to look back and look ahead at the organisation of the conference.

ConSoil was first organised in 1985, in Utrecht, the Netherlands. At that time, the applied knowledge institute TNO organised this first edition together with the German FZK- Forschungs Zentrum Karlsruhe. In 2008, Deltares was founded, by merging parts of four existing Dutch knowledge institutes and parts of the Ministry of Infrastructure and Water Management. The organisation of ConSoil moved to Deltares along with the part of TNO. In 2013, the new name of the conference, AquaConSoil, was officially adopted in Barcelona. The new name was selected to align with the new direction the conference had taken, with an increasing focus on the holistic management of the soil-water-sediment system, connecting knowledge, practice, and policy. In 2015, when UFZ decided they no longer wished to continue organising AquaConSoil, Deltares decided to take on the main organisation alone.

> *"Everyone remembers their first AquaConSoil."*
> *Sophie Moinier*

Over the years, unfortunately, not much documentation from this early period has been preserved in the archives of TNO/Deltares, due to the transition from ConSoil from TNO to Deltares. The colleagues who worked on ConSoil at that time are now retired or no longer work at Deltares or TNO. Although the archives are not very extensive, thorough searching yields nice finds sometimes, such as this photo of the Programme Committee of ConSoil 2008 in Milan.

Programme Committee of ConSoil 2008 – Milan

Since 2017, I have been involved in the organisation of AquaConSoil: first as deputy project manager (with Suzanne van der Meulen as the main project manager), later as project manager myself. What immediately struck me when I got to know the colleagues in the network was the warmth with which I was accepted and the beautiful memories. It is noticeable that everyone you speak to often still remembers their first (Aqua)ConSoil edition, and many people have wonderful anecdotes about sessions, conference dinners, organisational challenges, or other memorable events that happened during (Aqua)ConSoil. By now, in 2025, I have been part of the organisation for several editions and have made countless memories myself, which I reflect upon with great warmth. The upcoming edition will be the first in which I will take on a background role, as head of the department of Subsurface and Water Quality at Deltares.

Shaping the future, while honouring the past

Modern challenges and dilemma's
Each edition of the conference offers new opportunities for a unique and inspiring collaboration with a hosting consortium, with its own emphasis on topics important to the city, region, or country. In the past 40 years, AquaConSoil is hosted in many different cities in Europe. But of course, all this is not without some organisational challenges. These challenges often lie in the logistical part of the organisation, such as the conference centre with all it entails, or organising conference dinners and interesting tours. There have also been exceptional situations, such as the state of emergency in France in 2017 following the aftermath of the Paris attacks in 2015, which required us to drastically increase our security measures. During almost every edition, something happens that we did not foresee. Nevertheless, after 40 years of successful conferences, we can conclude that it always works out in the end.

> After 40 years of successful AquaConSoil editions, we can conclude that it always works out in the end.

Need for renewal: digital strategy GDPR and branding
In the Organising Committee, we have always worked as efficient and strucutred as possible with the aim to be reliable and recognisable. Although after some time our website was outdated, just as our visual identity. After the 2019 edition in Antwerp, we concluded that change was required and started creating a new digital strategy with a new logo, new visual identity, and a new website.

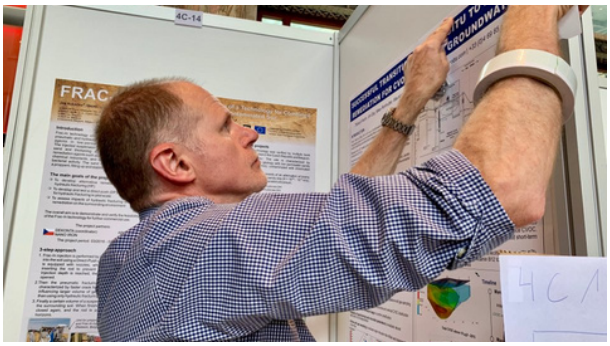
Another issue we faced, was the introduction of the General Data Protection Regulation (GDPR) in Europe in 2019. This made the rules regarding sharing personal data, such as photos and contact details of conference attendees stricter. The COVID pandemic gave us additional challenges for the 2021 edition. How do you organise a good online conference? What we learned from this online edition is that informing others about the research or projects you have done works well digitally, but social interaction is and remains a major benefit of AquaConSoil.

Next to these challenges, we face various dilemmas. We aim to establish a conference programme which is on the one hand, recognisable and not too new, but on the other hand, it is also important for the conference to keep innovating and add new elements and topics. Furthermore, from an operational standpoint, there is a trade-off; on the one hand, we do not want to make the tickets too expensive, but on the other hand, Deltares needs the revenue to ensure that AquaConSoil can continue to exist in the future.

Climate change makes us think more carefully about the trips we make. Many companies have Corporate Social Responsibility policies and therefore put a limit on the number of people tallowed to visit conferences or establish policies that stimulate using sustainable modes of transportation.

The Future: Youth, Complexity & Collaboration
Looking to the future, we see that the challenges in the water-soil-sediment system are becoming increasingly complex. We can measure and monitor more and more substances, while discovering that more and more substances can be harmful. To solve these challenges, it is necessary to continue exchanging knowledge and to find support and shared responsibility from practice and policy. The multidisciplinary nature of the challenges requires differentdisciplines working together. Therefore, it is important that we continue to meet to learn from each other's experiencesand that we dare to use the strength and creativity of the younger generations and combine this with the experience of the old hands in the field.

> To solve tomorrow’s challenges, we must bring generations and disciplines together.



Global North Soil-Water Quality Management

How Europe's response to pollution scandals sparked a global paradigm shift in environmental management

By Huub Rijnaarts

Prof. Huub Rijnaarts is a retired Professor of Environmental Technology at Wageningen University & Research and long-time contributor to AquaConSoil. His work focuses on sustainable water and soil quality, risk-based remediation, and circular resource management.

The Holistic Paradigm

In recent years, developed industrialized economies of the global north have increasingly adopted a holistic approach for the management of soil, sediment, groundwater and surface water quality. AquaConSoil has been a major platform in this development for the past 40 years. It is now well recognized in science, policy and practice that the qualities of these media mutually influence each other; chemical organic substances, nutrients, metals, pathogenic viruses, fungi or bacteria, etc, present in or applied to soils, can spread from soil to groundwater, surface water and sediment.

> It is now well recognized that the qualities of these media mutually influence each other.

Pesticides, livestock related pharmaceuticals, phosphates, and metals in manure applied to lands are well known examples. Similarly, pollutants that enter the environment via water or air can eventually accumulate in soils and sediments. Sulphuric compounds in acid rain, ammonia, viruses and bacteria in air originating from live-stock farms, and polycyclic aromatic compounds from fossil fuel driven traffic, all can be traced back in - and influence the quality of - soils, groundwater and surface water.

Policies and regulations in the EU are more and more accounting for this connectiveness, like the EU Soil, Water, and Air Pollution Control Directives. In addition, national environmental laws addressing the complete environment with all its compartments are implemented by various EU states. In case the quality is not as desired, either from a legal point of view, or from a healthy environmental perspective, remedial and preventive actions are prepared within this broader way of thinking. Moreover, the mitigating measures to improve soil or water quality are also considered in this wider environmental paradigm: often the question is posed whether the (remedial) measure itself is not worse (in terms of carbon, water or biodiversity footprint) than the negative effect of the pollution.

Pharmaceutical Compounds

Fortunately, combined sets of policies, along with mitigating and preventive measures can often be developed to solve soil-water pollution problems. An example is formed by pharmaceutical pollutants that enter the environment through waste-water treatment plants. These compounds are excreted by people taking medication and the chemicals end up in the sewer and treatment system. These systems are generally not designed to degrade these pollutants. Regulations have been developed in the last decade at national and EU levels that demand concentration reductions of 70-90% for wastewater treatment plant effluent. Effluent is now more and more treated to remove these compounds before discharging into surface water.

As alternatives for the traditional and less-sustainable treatment by activated carbon, new technologies have been developed and are now entering the market. One of these is the Aurea technology, that is based on biological removal supplemented by low-Ozon dosage. Additionally, a more generic preventative step is under discussion with the pharmaceutical industry and health care sector to consider a green-medicine policy; in case a better degradable and less environmentally harmful medicine is available why not prescribe this one instead of a more toxic and recalcitrant compound. Unfortunately, this discussion has just started...

A Mini Crisis: PFAS

The recent "mini-crisis" around PFAS pollution that has emerged in many industrialized countries recently, clearly showing that the soil-air-water-sediment compartments are connected, and mitigation and prevention need to be considered from this wider perspective. The PFAS pollution has spread, and is still spreading itself, over all these compartments, resulting in rather low but undesirable concentrations (at ng/kg level), deteriorating the quality of soil-water systems and negatively affecting their functionality as resource for food, fisheries, drinking water production or ecosystem. Remediating soils and sediments for complete regions impacted by a few nanograms PFAS per kg soil or sediment, may not be sustainable. A ban on PFAS production as a preventive measure combined with natural attenuation and restricted functionality is likely to be the only feasible management option for many regions. Luckily, technologies to remove and destruct PFAS from water for drinking and food processing are underway and to be expected in the market soon.

Mitigation and prevention need to be considered from this wider perspective.

From Crisis to Sustainable Solutions

This holistic and integrated way of thinking has evolved over the last years, and AquaConSoil has been for 40 years the EU platform for discussing and developing this approach. But it started differently. In the period of 1970-1980, EU counties and North American states were shocked by heavy soil pollution scandals: Love Canal in the state of New York, where people were exposed to dioxins and aromatic organic compounds via an industrially contaminated sewer system; Lekkerkerk in the Netherlands, where chemical waste with benzene and other aromatic compounds was mixed with foundation sand on top of which a complete new housing district was build; Bitterfeld in Germany, where a large chemical industrial complex discarded the solid and liquid waste of production of chlorinated compounds, including hexachlorocyclohexane (HCH), into surrounding soils and groundwater, threatening the nearby village and surrounding nature areas. These three examples, also debated at AquaConSoil conferences, stand for millions of contaminated sites in Europe and North America.

As a respons to the resulting societal rage, authorities chose to demand for quick dig, dump and burn approaches, very disruptive, costly and unsustainable. In the Netherlands, with 400.000 contaminated sites registered at the end of 90-ies this would cost 100 billion Euros, and a large part of the countries' land would have been excavated and burned. Soon it was acknowledged that this might be only feasible for hotspots, but not for 95% of the polluted subsurface.

Gradually, other approaches developed also because companies that had caused the pollution and national, federal and EU governments teamed up in financing and finding solutions. The problemholders worked together with universities, knowledge institutes, contractors, consultants and authorities, in knowledge generation, practical try outs in the field and supporting policies. Risk based approaches, such as seal and contain, and nature-based methods such as in-situ bioremediation, in situ bioactivated zones and natural attenuation stabilizing and slowly removing groundwater plumes, developed and matured. These methods were gradually integrated into larger scale approaches often under the umbrella of Brown Field Regeneration and Sustainable Land Management. In a later stage, combined approaches were developed, such as RemediATES, that is Aquifer Thermal Energy Storage combined with bioremediation. And from all this, the holistic integrated approach, which is now common practice, emerged.

Evolution of sustainable approaches:

- Seal & contain
- In-situ bioremediation
- Aquifer Thermal Energy Storage (ATES)

Global South

Though the global north has developed a sustainable way for soil and water quality management, the situation is different in other parts of the world. Many Asian countries like China, Japan and Korea are developing quickly towards a mature and sustainable soil-water quality management policy and practice. Unfortunately, not all countries have the means to change the tide, such as some developing economies in Africa, South and Middle America, and some Asian countries. Threfore, the time seems right to form bridges between AquaConSoil and these parts of the world, to also help to establish a sustainable soil and water management approach there. An improved environment in the global south - among many other factors that need to be addressed - may also help people to build a better and healthy life in that part of the world.

The power of nature-based design

A collaboration between a bio-design studio, municipalities and a knowledge institute

By Hilde Passier

POND (Power of Nature-based Design) is the world's first floating network that gives water a voice. POND (Power of Nature-based Design) is a floating network of lamps equipped with sensors that monitor and display water quality through light, using sustainable Microbial Fuel Cell technology to generate electricity from organic waste in the water. After successful testing at Rotterdam Zoo, Nova Innova and Deltares are now collaborating to further develop and implement POND in public spaces.

Hilde Passier, Expert Geochemist and Environmental Quality at Deltares:

"POND showcases the transformative power of nature-based design by blending cutting-edge technology with ecological insight. Through our collaboration with Nova Innova and municipalities, we're not only monitoring water quality but also inspiring communities to connect with and protect this vital resource. Together, we're proving that innovation and nature can work hand in hand to address our pressing water challenges and build a sustainable future."

The POND Initiative

The Netherlands faces a major challenge of achieving water quality goals. Monitoring the quality of surface water in the Netherlands, and awareness of the state of the water is necessary. POND provides for monitoring water quality and increasing water awareness.
POND merges the monitoring of surface water quality with the aesthetic and ecological value of nature. POND are special floating lamps in surface water that that register water quality and make it visible. The domes also magnify movements in the water, providing a view of aquatic life.

During the past 4 years, Nova Innova, a bio-design studio, designed a robust system based on sustainable Microbial Fuel Cell (MFC) technology: a biofuel cell, a biological battery that harvests its electricity from organic waste streams in the water. The generated energy is used to operate water quality sensors housed within the floating glass domes. The low-power sensors collect vital data on water temperature and quality, currently.
The captured energy is also converted into a unique light language, in which the colours of the light express the water quality.
POND has been tested in the water for more than 15 months in the testing ground of Rotterdam Zoo Blijdorp

Now POND is ready for the next implementation step. Nova Innova and Deltares join forces in a TKI project to further develop POND for a robust, functional and communicative implementation in public space.

The end users of POND and the measurement data of POND are diverse: municipalities, water authorities, drinking water companies, farmers, residents, recreationists, swimmers, managers, policy officers. The development of POND contributes to awareness of the value of nature, the security of supply of drinking water and to the mission to measure smarter and more sustainably.

community Engagement and Pilot locations
In collaboration with the municipalities, four pilot locations will be set up for this project: 1) Deltares Delft, 2) Oosterdok Amsterdam and 3) Municipality of Utrecht and 4) Municipality of Voorne aan Zee at Fieldlab Green Economy Westvoorne.
These sites serve as testing grounds for the technology and as platforms for community engagement. By transforming POND into a communication tool, the project aims to raise awareness about water quality issues and empower communities to take action.

Deltares
At the Deltares pilot location, POND will be validated, expansion of the current set of sensors will be explored, accessible information will be generated. In its current form, the colours of the domes are determined by a combination of dissolved oxygen, pH, turbidity, salinity and temperature data. Development of sensors for chlorophyll (algae) and nutrients are intended. The project is aligned with one of the research goals of Deltares to leverage digital technologies to enhance our understanding of nature. By utilizing Deltares' advanced facilities, the project aims to expand its monitoring capabilities, including the development of sensors for detecting harmful algal blooms. Machine learning techniques will be employed to analyse data more effectively, linking real-time information to existing monitoring systems.

Oosterdok
At the Oosterdok in Amsterdam, collaborating with Waternet, the focus is on promoting social dialogue about water quality. In order to balance the efforts and costs associated with expectations, a broader awareness of water quality is essential. The POND project is an example of how imagination and innovation can make the concept of water quality transparent to the general public.

Utrecht
In Utrecht, the POND pilot location is in line with the joint healthy water programme of the municipality of Utrecht and the Stichtse Rijnlanden Water Authority. With this programme, more than a hundred measures will be implemented in the period 2025-2028 to improve the water quality of the city of Utrecht. In addition to the realisation of measures, further research into water quality and increasing awareness among our residents of water quality in the city is also an important goal of the programme.

Voorne aan Zee
In Voorne aan Zee, the applicability of POND in more saline water will be tested . Here, POND will also be used by the municipality and water authorities to show a larger audience what influence our behaviour has on the water. It may also be possible to test the application for predicting blue-green algae here.

The goals of the development of POND in this collaboration are:

- POND can be used in multiple places, with multiple sensor combinations.
- Validated water quality indicators
- An online accessible portal with insight into the current sensor data.
- Stimulating dialogue with nature and education on how to take good care of water.

More information:

Dr. Hilde Passier is a geochemist and strategic advisor at Deltares, where she coordinates mission-driven research on resilient water and subsurface systems. Her work focuses on water and soil quality, climate resilience, and the sustainable use of natural resources through applied science and cross-sector collaboration.

PFAS as a prism for evaluating and renewing management of soil and groundwater contamination

By Nina Tuxen

Nina Tuxen is a Senior Geochemist at the Capital Region of Denmark and a member of the AquaConSoil 2025 Programme Committee. She has extensive experience with groundwater contamination and environmental risk management, and has been at the forefront of regional responses to PFAS. In this article, she shares a reflection on how PFAS is challenging long-held assumptions—and shaping the future of soil and groundwater contamination management.

Rethinking the Fundamentals
In recent years, PFAS has dominated the soil and groundwater industry. The overwhelming challenges have forced us to reconsider established principles and perceptions. What can we use from the last 40 years of experience with handling contaminated soil and groundwater, and how do we tackle the challenges in the future? In this article, I will share reflections on some of the topics and dilemmas I have thought about - in conversation with and inspired by a group of different people.

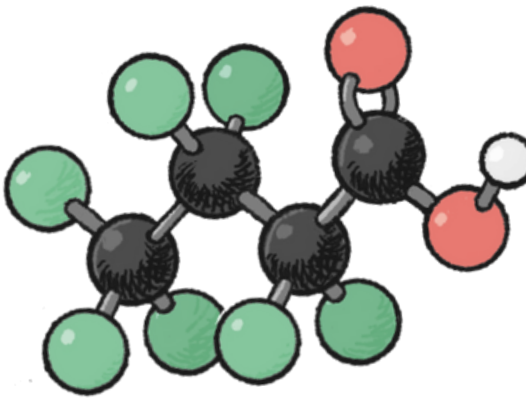
The loss of the last innocence
Among professionals, it has probably long been a recognized truth that there is contamination everywhere due to the industrialized world. But with the ubiquitous presence of PFAS - even in the most remote corners of the world and in human blood, it has really dawned on the average citizen, that the dream of a chemical-free environment is an illusion.

It has finally dawned on the average citizen that the dream of a chemical-free environment is an illusion.

Precautionary principle and quality criteria
The precautionary principle is a sound approach that sets ambitious requirements for maximum levels of contamination in the environment, even if there is not full scientific data for a complete risk assessment. Many health studies show that various PFAS substances can have health consequences, but it is not my understanding that there is a clear consensus on the magnitude. If you follow the precautionary principle, the result is really low quality criteria.

In my country Denmark for example, there quality criteria for the sum of PFOA, PFOS, PFNA and PFHxS in groundwater and drinking water is as low as 2 ng/L. In practice, this means that a considerable part of the water exceeds or is close to exceeding the quality criteria (even rainwater can reach this level). This can lead to citizens losing confidence in our drinking water, as many have the perception that exceeded quality criteria means that the water is “toxic”. At the same time, it can cause us professionals to lose direction. Because were to start and end? And is the effort of any use?

Perhaps one should include socio-economic assessments and not just toxicological assessments when defining quality criteria? This is done in some countries. And that is another challenge: definition of quality criteria is not done uniformly – not even within the EU.



Maximizing the benefit of the effort
With the occurrence of PFAS virtually everywhere, it becomes urgently necessary to prioritize efforts. As illustrated in Figure 1, PFAS will enter the groundwater from both strong point sources, small point sources and diffuse sources.

Even diffuse sources will be able to cause exceedance of the quality criteria in many cases. And we cannot remediate all groundwater and surface water. Especially not if we include sustainability in our assessments looking at the unimaginable resources (economy, energy and chemicals) this will require. But where do you draw the line? I work with contaminated groundwater, but when it comes to PFAS we are also exposed from food, consumer products, rainfall, etc. There must be a balance in the efforts, so we maximize the benefit of the effort.

We cannot remediate all groundwater and surface water, particularly when considering sustainability.

It is a pleasure to see that there are many initiatives underway regarding the phasing out of PFAS, and several studies evidencing that regulation works. There is no doubt that the most important thing we can do is to prevent the introduction of more PFAS into the environment, and then we must work in parallel to deal with the consequences that historical use has brought. Having said that, we also must realize that there is a reason why PFAS substances are as widespread as they are: they simply have some fantastic properties that we don't want to do without. And while the industry is working hard to formulate substitute substances – how can we be sure that these new substances do not also have undesirable properties? We must try our hardest not to introduce new problematic substances into the environment, because we let ourselves be blinded by their “attractive” properties.

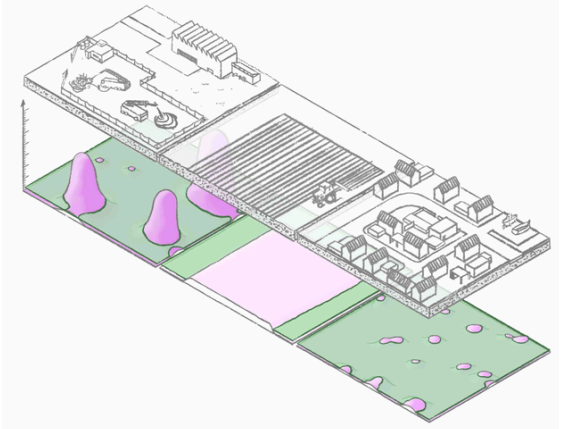


Figure 1. Contribution of PFAS to groundwater from a) strong point sources (e.g. fire drills and production companies, b) diffuse sources e.g. agriculture and c) small point sources from urban areas.

Technical challenges
PFAS is a (huge) group of substances that in many ways behave completely differently from our "usual" contaminants. This has resulted in countless research projects that attempt to understand the processes that control the fate in soil and groundwater and how we can remediate. Personally, I have had to go “back to school” digging in to the processes in the unsaturated zone, including sorption to the air-water interface, van Genuchten parameters, etc.

With the many thousands of substances with very different properties, there is no simple analytical method to measure "everything", and certainly not in the extremely low concentrations that we require. Luckily, there is a lot going on here as well. And what about remediation methods? We can't use traditional methods like dig & dump and pump & treat when you think about the huge volumes of contaminated soil and groundwater involved. We must be innovative, and here of course it doesn't help that PFAS is as recalcitrant as is the case.
All these technical problems are enormously challenging, and with the many thousands of scientific papers and research projects underway globally, it is of course impossible to have an overview and keep up with everything.

Interaction with other professions and the surrounding community
PFAS obviously affects us who work with soil and groundwater. But the interest is much broader, and one positive consequence is that I see increased collaboration between different professional groups. Health professionals, for example, are often very skilled at communicating about unpleasant topics to the layman, even with only limited data. In my organization, we have had great benefit of involving them when communicating with affected citizens in areas with PFAS contamination.
We also experience a great deal of attention from the press and politicians. It can sometimes be very stressful to be bombarded with questions and demands for actions when we hardly have an overview of the problem ourselves. But it is also a good thing that the surrounding society value our environment so much. Then you just must accept that in certain periods with intense media coverage, you cannot go to family and friend visits or leisure activities, without having to justify why we cannot just solve the problem in a flash.

You cannot visit family or friends without having to justify why the problem can’t be solved immediately

The role of an authority

I am employed in a Danish region that is responsible for handling all orphan point sources. We must deal with all the input and influences that come from research, legislation, health assessments, the press, citizens, PFAS findings in the environment etc. – both nationally and internationally (Figure 2). And we must translate that into an administrative practice knowing that new knowledge is constantly being added. But we can neither pause our work nor constantly update our procedures. So it is about finding the right balance between incorporating new knowledge while at the same time ensuring progress. And then accept that we will probably think differently about certain things just a few years from now.

Afterthoughts

The challenges with PFAS are many and point in all possible directions. But I think it is a great pleasure to see how the professional community has thrown itself into the fight – from authorities, researchers, and private actors. And with a great appetite for tackling the problem and finding solutions.

From my point of view, our long-standing and fine-tuned machine of mapping, investigating, risk assessing and remediating other types of contaminants, has really come into its own, and has shown that we have a solid foundation, organizationally, structurally, legislatively, and engineering-wise, to cope with new problems.

At the same time, the case has opened doors to new collaborative relationships also with the young professionals. Business as usual does not apply to PFAS, and we will have to renegotiate "fixed" principles and be innovative. Here, I see a great opportunity and need for the young generation in our industry to play an important role.

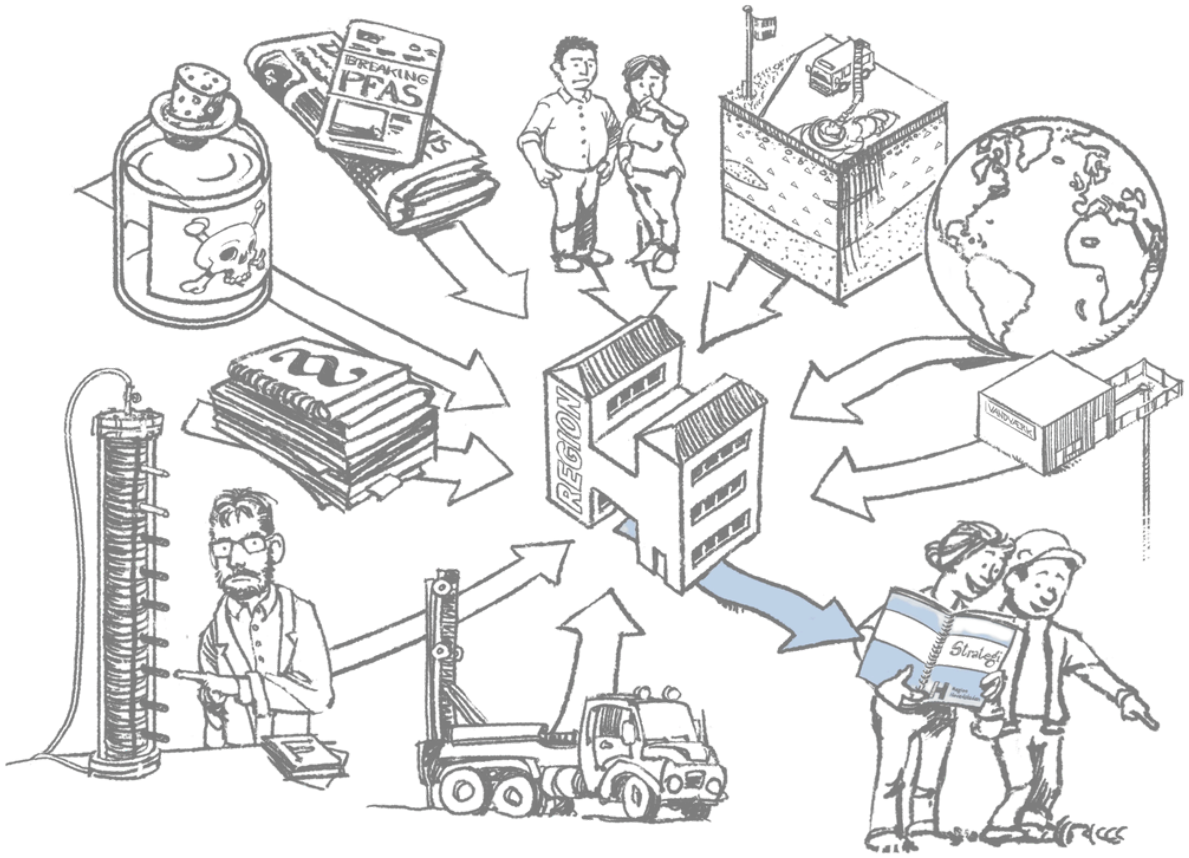
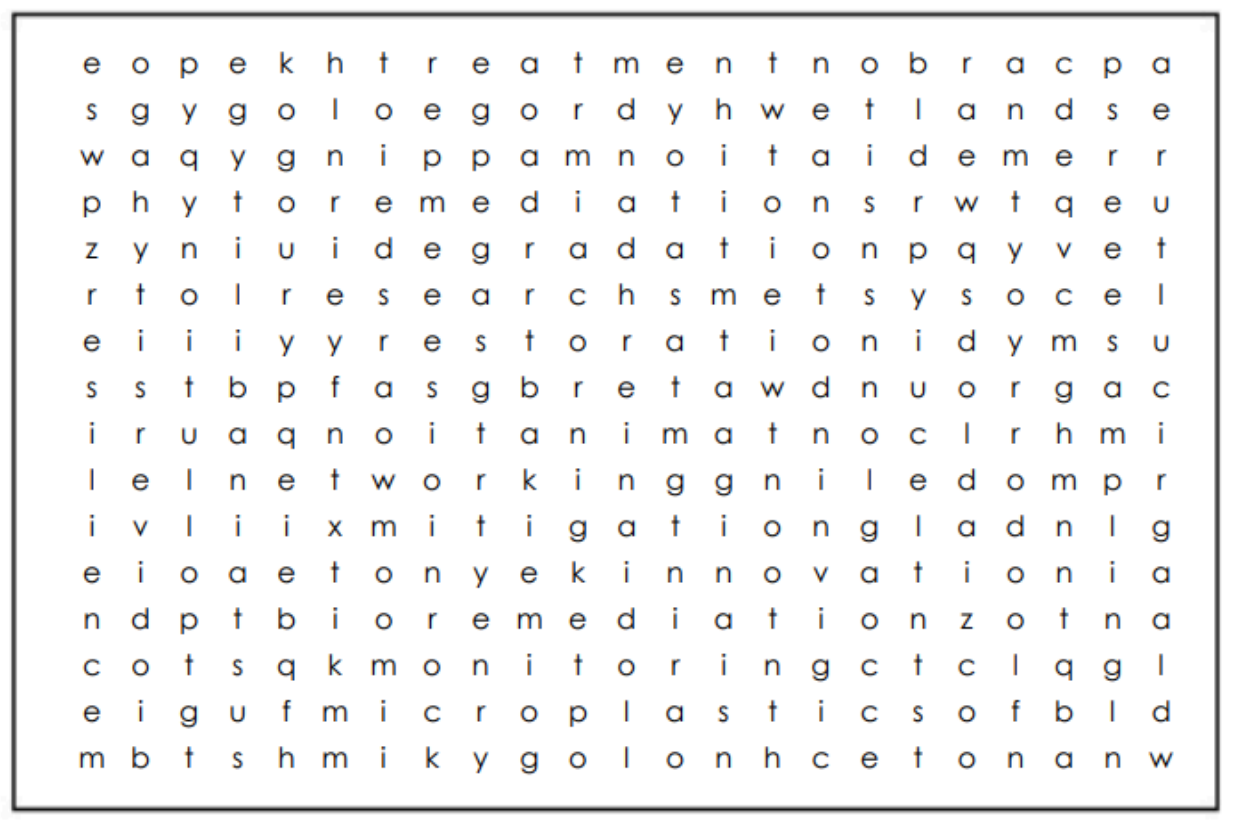


Figure 2. Influence of the surrounding society on an authority responsible for orphan point sources: findings in the environment, research, legislation, health knowledge, press, concerned citizens and local as well as international conditions. All of these must be included in the administrative strategy.

Puzzle



e o p e k h t r e a t m e n t n o b r a c p a
s g y g o l o e g o r d y h w e t l a n d s e
w a q y g n i p p a m n o i t a i d e m e r r
p h y t o r e m e d i a t i o n s r w t q e u
z y n i u i d e g r a d a t i o n p q y v e t
r t o l r e s e a r c h s m e t s y s o c e l
e i i i y y r e s t o r a t i o n i d y m s u
s s t b p f a s g b r e t a w d n u o r g a c
i r u a q n o i t a n i m a t n o c l r h m i
l e l n e t w o r k i n g g n i l e d o m p r
i v l i i x m i t i g a t i o n g l a d n l g
e i o a e t o n y e k i n n o v a t i o n i a
n d p t b i o r e m e d i a t i o n z o t n a
c o t s q k m o n i t o r i n g c t c l q g l
e i g u f m i c r o p l a s t i c s o f b l d
m b t s h m i k y g o l o n h c e t o n a n w

Find the following words in the puzzle.

phytoremediation
sustainability
bioremediation
nanotechnology
contamination
microplastics
biodiversity
monitoring
mitigation
ecosystems
innovation
networking
pollution
treatment
hydrogeology
remediation
groundwater
restoration
degradation
agriculture
resilience
modeling
sampling
wetlands
research
carbon
flood
pfas

Words are hidden → ← ↓ ↑ ↘

IMPEL Water and land remediation: progress and publications

By Marco Falconi

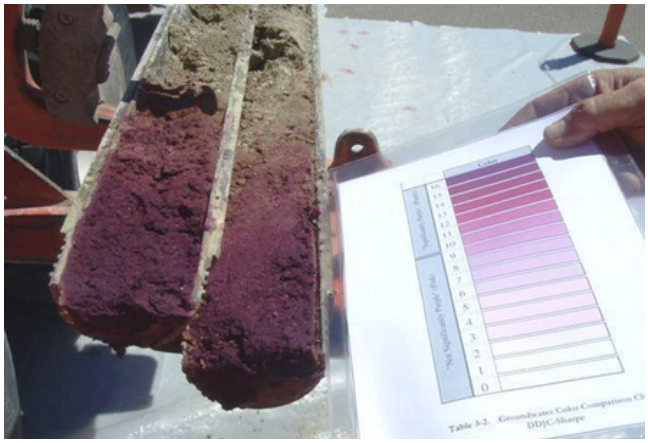
Marco Falconi is a member of the IMPEL Network and serves on the Programme Committee for AquaConSoil 2025. With deep expertise in environmental remediatio and regulatory enforcement, he is actively involved in advancing sustainable approaches to soil and groundwater protection across Europe. In this article, he outlines the role of the IMPEL Water and Land Remediation project in transforming contaminated site management through technical innovation and cross-border collaboration.

Across Europe, countless sites remain contaminated due to industrial activity, improper waste disposal, and historical pollution.
Cleaning up these sites isn't just about environmental protection—it's about public health, economic redevelopment, and ensuring a sustainable future. That's where the IMPEL Water and Land Remediation project comes in.

"Cleaning up these sites isn't just about environmental protection—it's about public health and a sustainable future."

Developed under the IMPEL Network (the European Union's collaborative framework for environmental enforcement), this initiative is driving innovation in in situ and on-site remediation technologies. Rather than relying on outdated methods like Dig & Dump or Pump & Treat, IMPEL is helping EU Member States transition toward more sustainable, cost-effective, and scientifically advanced approaches.

The project serves as a vital knowledge hub, equipping environmental regulators, industry professionals, and policymakers with technical guidance, case studies, and best practices.



Example of oxidant diffusion profiling in silt soil cores 90 days after fracture-emplacement of potassium permanganate oxidant slurry (photo courtesy of URS, Bures archive)

From Soil Vapour Extraction (SVE) to In Situ Chemical Oxidation (ISCO) and Phytoremediation (PHYTO), IMPEL has been steadily expanding its library of technical reports—resources that help experts make informed, evidence-based decisions for contaminated site management.

With new reports underway and an ambitious vision for the future, the Water and Land Remediation project is playing a pivotal role in shaping Europe's environmental remediation landscape.

By promoting collaboration and harmonizing remediation strategies across Europe, IMPEL ensures that cutting-edge solutions reach the people who need them most.

Published and In-Progress Reports
IMPEL has successfully released a series of technical documents that focus on key remediation techniques. These include Soil Vapour Extraction (SVE), which involves extracting volatile contaminants from the subsurface using vacuum pressure; In Situ Chemical Oxidation (ISCO), which employs chemical oxidants to break down contaminants in soil and groundwater; Soil Washing (SW), a method that physically and chemically separates contaminants from soil particles; and Multi-Phase Extraction (MPE), which simultaneously extracts liquids and vapors from contaminated sites.

> The goal is to systematically cover all remediation technologies outlined in Annex V of the proposed Soil Monitoring Law

These reports provide in-depth analyses, operational guidance, and real-world case studies to enhance confidence in their practical application. Additionally, IMPEL is finalizing reports on Phytoremediation (PHYTO), which utilizes plants to remove or stabilize contaminants, and In Situ Thermal Desorption (ISTD), a technique that applies heat to volatilize and extract contaminants. These reports, currently undergoing final approval, will further expand the knowledge base available to environmental professionals and policymakers.

IMPEL is also working on reports concerning Biopile (BP), a controlled biological treatment process for organic pollutants, and In Situ Chemical Reduction (ISCR), a remediation strategy that transforms hazardous contaminants into less harmful substances. The goal is to systematically cover all remediation technologies outlined in Annex V of the proposed Soil Monitoring Law, ensuring a well-rounded and scientifically robust repository of best practices and technical insights.

Areal view of the soil washing plant (front), sludge treatment facility (left hand side) and the reception hall (in the back). (Courtesy of Züblin Umwelttechnik GmbH)

Importance of Technical Guidelines
The IMPEL documents are not legally binding but serve as crucial technical references for environmental authorities, industrial operators, environmental consultants, and research institutions.

> "These guidelines help in standardizing assessment criteria, ensuring that remediation efforts are evidence-based and transparent.

Contaminated site management requires flexibility to adapt remediation solutions to the site-specific geological, hydrogeological, and contamination conditions. The documents provide structured yet adaptable frameworks to guide decision-making processes effectively. These guidelines help in standardizing assessment criteria, ensuring that remediation efforts are evidence-based and transparent. By providing a consistent approach to technology evaluation and implementation, these documents allow regulatory bodies to set benchmarks for environmental protection while offering remediation professionals a structured method for assessing site conditions and selecting suitable technologies.

> "They offer a valuable resource for training environmental inspectors, regulators, and industry professionals."

Furthermore, these documents foster cross-border collaboration by enabling EU Member States to adopt comparable strategies, thus promoting regulatory coherence across Europe. This alignment is particularly important for transboundary contamination issues, where consistent remediation standards can prevent pollution from spreading across jurisdictions. Additionally, by consolidating expertise from a broad network of environmental professionals, IMPEL's technical guidelines ensure that the latest advancements in remediation science are accessible to all stakeholders.

The inclusion of real-world case studies further enhances their value, providing practical insights into the effectiveness and limitations of different remediation technologies. The guidelines also support capacity-building efforts by equipping national and regional authorities with the necessary knowledge to oversee remediation projects effectively. They offer a valuable resource for training environmental inspectors, regulators, and industry professionals, helping to elevate the overall competency in contaminated site management across Europe.

Beyond immediate practical applications, these documents contribute to long-term policy development by informing legislative discussions and helping shape future environmental regulations. They serve as a reference for policymakers when drafting soil and groundwater protection laws, ensuring that regulations are grounded in scientific evidence and best practices. The overarching aim of these guidelines is to create a more sustainable and scientifically informed approach to soil and groundwater remediation, ultimately reducing environmental risks and safeguarding public health.

The Future of Water and Land Remediation

IMPEL is actively working to expand its repository of technical documents, aiming to cover all remediation technologies mentioned in Annex V of the proposed Soil Monitoring Law. By systematically addressing a broad range of remediation strategies, the project seeks to provide stakeholders with comprehensive and practical insights that facilitate informed decision-making.
Ongoing research and development efforts focus on refining the understanding and applicability of various in situ and on-site remediation techniques. Current work on Biopile (BP) and In Situ Chemical Reduction (ISCR) will contribute valuable new insights into biological and chemical remediation strategies.
The objective is to develop standardized monitoring parameters for these technologies, ensuring that their performance can be reliably assessed over time. These efforts are particularly important given that many EU countries still rely heavily on traditional Dig & Dump and Pump & Treat methods, which are often less sustainable in the long term. By promoting advanced remediation technologies with clear monitoring protocols, IMPEL aims to accelerate the adoption of more effective and environmentally friendly approaches.

> "The project represents a paradigm shift in how contaminated sites are managed."

The significance of these efforts cannot be overstated. Many contaminated sites across Europe remain untreated or insufficiently remediated due to uncertainty about the effectiveness of available technologies. By compiling case studies that demonstrate successful applications of in situ and on-site remediation methods, IMPEL provides decision-makers with the confidence to implement these solutions. This work not only helps to remediate contaminated sites but also contributes to broader environmental sustainability goals, such as reducing soil and groundwater pollution, conserving natural resources, and mitigating climate change impacts.

IMPEL's long-term vision is to foster a regulatory environment where innovative remediation technologies are recognized and integrated into national environmental policies. By bridging the gap between scientific research and practical implementation, the Water and Land Remediation project plays a crucial role in advancing soil and groundwater protection efforts. The continued development of technical guidelines and the expansion of IMPEL's knowledge base will ensure that EU Member States have access to the best available information for managing contaminated land effectively.

Ultimately, the project represents a paradigm shift in how contaminated sites are managed, moving towards a more sustainable, scientifically driven approach. By equipping environmental professionals, regulators, and policymakers with high-quality, evidence-based resources, IMPEL is laying the groundwork for a cleaner, healthier future for Europe's soil and water resources. The commitment to expanding research, refining methodologies, and sharing knowledge across borders underscores IMPEL's dedication to improving environmental management practices at both national and European levels.

Picture of the pilot MPE test system (courtesy of WSP Golder)

Soil Vapour Extraction System (courtesy of HAEMERS)

Bingo!

Introducing the AquaConSoil Bingo: your unofficial companion to all the quirky, classic, and totally conference-specific moments that make this event so memorable.
Keep your eyes and ears open, you'll be surprised how quickly your bingo card fills up.

- Tick off the boxes.
- Share laughs with colleagues.
- Collect a small prize at the info desk or Deltares booth

Ready to play? Let's bingo our way through Liège and celebrate four decades of soil and water science in style!

You hear "remediation"	Joined a keynote	Spotted an attendee from a different continent	Talked to someone who has attended 3 editions of AquaConSoil	You hear someone say "systems thinking"
Someone says "PFAS" during a coffee break	Take a selfie with the Welcome board	A speaker says "Sorry for the small font"	You hear "climate adaptation" in a talk	Spotted someone with a University of Liège badge
Take a selfie with the Meuse river	Someone says "digital twin"	FREE SPACE	Attend sessions from 3 different themes	Traded a business card
Joined a conversation that starts with "Where are you from?"	A speaker says "I'll skip this slide"	You have visited the Deltares Experience	Shake hands with Frederic Coulon	Someone says "This is just preliminary data"
You have visited 3 booths at the Exhibition	You have communicated using the conference app	Talk to someone who attends for the first time	A speaker says "Sorry for the small font"	Someone says "soil health"

Broadening the scope of soil policy: Soil health in planning and design

Linda Maring (MSc) is a soil and subsoil expert at Deltares, focusing on the role of the natural soil-water-sediment system in spatial planning and sustainable development. She works in co-creation with governments and stakeholders to embed soil knowledge into policy and practice, both in the Netherlands and across Europe.

Healthy soils are essential for our prosperity and well-being. However, healthy soils are increasingly under pressure due to growing demands on land and the impacts of climate change. As a result, soils are once again prominently featured on both national and international agendas.

The soil beneath our feet not only forms the foundation of our food system; soils also ensure clean water, support nature, and biodiversity. They also mitigate the effects of climate change, such as extreme rainfall and heat. Healthy soils provide critical ecosystem services to society, such as water storage, restoration of nature and biodiversity, and natural cooling and heating and are at the basis of reaching the many of the Sustainable Development Goals (Keesstra et al., 2016; 2020).

At the same time, these ecosystem services are increasingly under pressure due to how we use land and soils. In urban areas, we are demanding a lot of underground space—for parking, storage, housing, sewer systems, and cables—while also needing that space for water storage, energy provision, and tree roots. On top of that, we rely on the soil's carrying capacity for buildings and infrastructure. All these competing land uses place significant demands on soils and deeper subsurface. Human actions and the changing climate are putting further pressure on the vitality of our soils. An estimated 60-70% of soils in Europe are not in good condition (EC, 2021a), and conflicts over land, soil and water are already commonplace. Our future plans demand even more of our soils. So, this also requires careful management and protection so that future generations can continue to benefit from them (Figure 1). Soil is a fragile resource: One centimetre of soil can take hundreds of years to form, but can be lost in just a single rainstorm or industrial incident (EC, 2021a).

Soil health in policy over time

There are two peaks in the new millennium in which both Europe and many Member States are paying full attention to soil. In this text box an example is given how EU and Dutch policy on soils have evolved. Since 2004, a thematic soil strategy was prepared in Europe which included a proposed legal pillar. In 2006, the strategy was presented and a Soil Directive proposed. In the Netherlands, a soil policy letter (DG Milieu, 2004) initiated the broadening of soil policy: instead of just chemical, also the biological and physical properties of soil should be included. It also focused on the value of soil for other policy areas and the sustainable use of soil. In 2014, the proposal for the Soil Directive was withdrawn due to insufficient support. With this, soils were not off the agenda, in the Netherlands several (knowledge) programmes and covenants around soil and subsoil ran. Also in Europe, soil remained important but especially in terms of quality, including through the Seventh Environmental Action Programme (EC, 2013), but the 'buzz' was off.

Around 2020, soils revived on the policy agenda. Healthy soil takes centre stage as 1 of 5 European missions in the EU mission (EC, 2020; 2021a). In Europe, 15 years after the publication of the first thematic soil strategy in 2006, the EU soil strategy towards 2030 (EC, 2021b) was renewed in 2021.

This strategy positions soils in a broad way and focuses not just on threats, but on opportunities offered by healthy soils. The aim is to have healthy soils in Europe by 2050 under all types of land use. The strategy also proposed (again) a soil directive, which unlike the proposal in 2006 will now probably adopted: The Soil Monitoring and Resilience Directive (EC, 2023). EU member states will initially only have to monitor soil health, and possibly, if warranted, take measures to start improving soil health. Besides the policy and legislative side, the focus is also on knowledge and data. The European Mission Soil (EC, 2021a) supports the objectives of achieving healthy soils with a major research and innovation programme. Finally, the European Soil Observatory (EUSO) (1) will record European soil data.

In this period, also in the Netherlands soils came back high on the policy agenda. A Parliamentary Letter on water and soil-based planning was published (Ministry IenW, 2022). It focused on the need to take the water and soil system into account in spatial planning and design and to protect and restore this system as much as possible (Figure 2). In 2025, the Soil, Subsoil and Groundwater programme will be launched, which includes a.o. 4D planning of soil and subsurface , soil and groundwater quality and remediation, and soil health. Soil is thus once again prominent on the (policy) agenda.

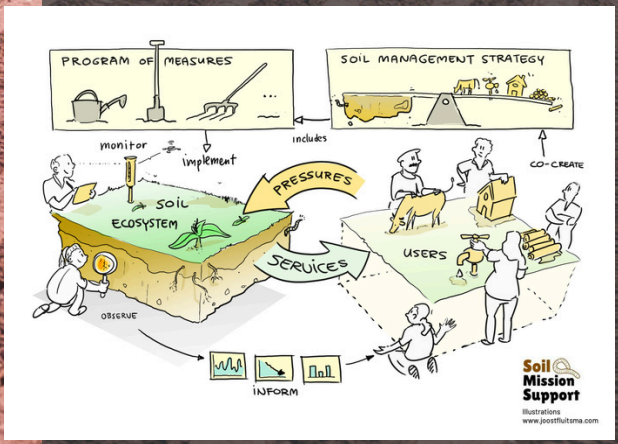


Figure 1: Conceptual model sustainable soil management (Nougues & Brils, 2023)

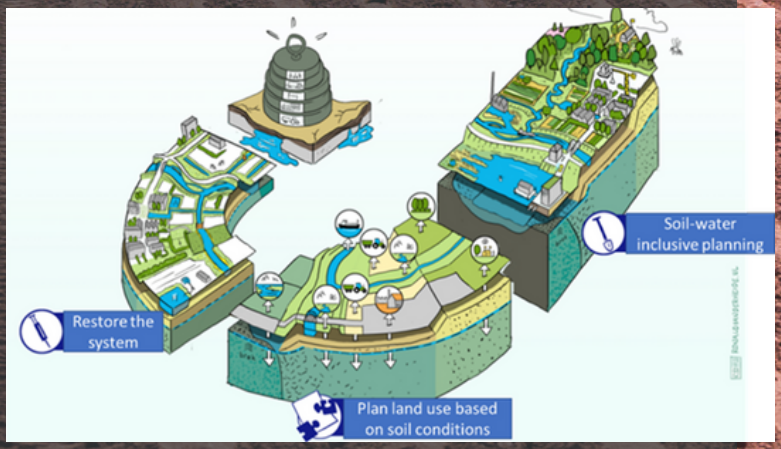


Figure 2: Water and soil-based planning

Research needs
More and other knowledge is needed to realise the European ambitions to safeguard healthy soils (EC, 2023, 2021a, 2021b). Especially in understudied areas such as urban areas. For instance, transforming former industrial sites often requires soil remediation. In areas with soft soils and subsidence, extensive measures are needed to prevent damage to infrastructure. A major challenge for provinces and municipalities is to integrate soil and subsurface considerations into spatial planning in a way that allows land use and soil conditions to reinforce each other. Furthermore, how do we define what constitutes a healthy soil? Underneath some research priorities

Definitions for and more knowledge soil health and ecosystem services
The current definition of soil health as set by the EC is 'the physical, chemical and biological condition of the soil determining its capacity to function as a vital living system and to provide ecosystem services' (EC, 2023). An important building block for the definition is that it explicitly mentions soil biology as an essential component of healthy soil and the provision of ecosystem services. The question here is to what extent science, policy and society have a shared picture of what a healthy soil constitutes and to what extent we succeed in being able to concretise a healthy soil ecosystem, for instance through measurements (Maring et al., 2023). Next to that, different land uses have different needs towards soils. Therefor in practice, it makes sense to differ between land uses. For example, urban land consists of many different land uses, each with different demands on the soil (Bayer et al., 2023). Sometimes infiltration for water is important. Sometimes fertility for urban green. Sometimes carrying capacity. This is currently under-researched. In addition, we know little about the urban soil itself. Urban soils are often heavily disturbed and, especially in low lying areas, raised with sand layers for building purposes.

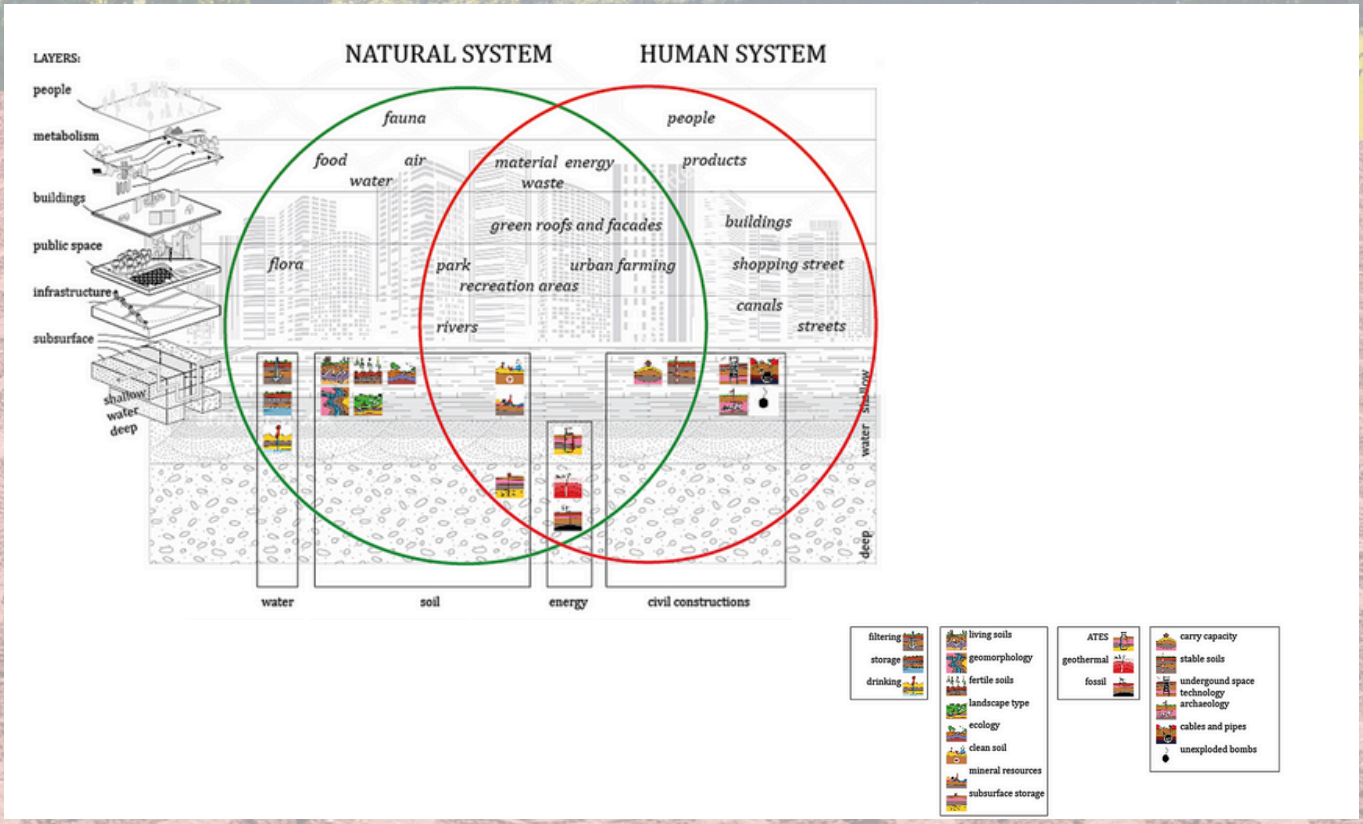
The soil map therefore shows grey areas in urban areas. More research is needed on, for instance, (microbial) soil life and subsurface processes in urban soil.

Monitoring soil health
The proposed soil monitoring law (SML) describes guidelines for the sampling strategy, the requested accuracy per soil district, a list of indicators, accepted measurement methods and an assessment framework, where available. And the European monitoring network LUCAS (2) will account for up to 20% of the monitoring required in a country But in addition, member states are encouraged to select additional indicators relevant to soil, climate and land use, specific to the member state's situation and an additional assessment framework, where available. Member states have different monitoring networks, even within countries. To ensure the continuity and effectiveness of the monitoring task it is needed to explore how these monitoring networks can be combined, and how direction on implementation can be strengthened. It would help here when validated transfer functions for (lab and field) methods are allowed, provided they are substantiated. Research and development of innovative sensors, measurement and analysis techniques can then be more easily initiated and implemented (Maring et al., 2023). But on a smaller scale, when looking at soil health: What should be measures and monitored in order to determine what the soil concretely can contribute in terms of ecosystem services for specific needs, and what can be concretely done to make a soil healthier and more resilient? This asks for action perspective and concrete management solutions.

Action perspectives for soil management
Based on monitoring results and soil health status, soil management can be adjusted. The EC proposes different principles and possible measures (e.g. in the Soil Monitoring Directive (EC, 2023). But it is up to member states to implement area-specific measures. These often involve complex spatial issues, while land use, the above ground system and natural system are very intertwined (Figure 3).
Besides soil and water system quality, these also involve social and economic choices. This requires sufficient knowledge and experience on such complex spatial issues and integrated impact analysis. Also cooperation, profound knowledge exchange and overviews of available knowledge and experience are necessary, but are still often lacking (Norrman et al., 2015; Hooimeijer & Maring, 2018; Maring, 2019). A transition to a new and integrated approach to spatial development is needed. Taking into account the possibilities and the carrying capacity of the natural soil-sediment-water system. This requires, among other things, strengthening governance. (Maring et al., 2023). The just started project SPADES (Spatial Planning and Design with Soils) (3) will look into these challenges.

To conclude

Soil is now on the policy agendas and this presents opportunities. Therefore much-needed research is to be carried out so that healthy soils are secured for future generations. It would be a shame to find out that we have failed to achieve the European goals to achieve healthy soils by 2050. The best time to work on healthier soils was 100 years ago, but the second-best time is now. This asks for collaboration between governments, knowledge partners, land owners, market parties and other stakeholders to make soils healthy for their users, residents, nature, its specific land use and the future. By knowing in advance the properties of the water and soil system and thus the preconditions and opportunities for land use, we can better take water and soil into account in our future and spatial plans.



How can digital twins change the management of soil-water systems?

By Maxime Cochennec

Maxime Cochennec specializes in hydrogeological modeling, environmental metrology, and the application of digital technologies in soil and water systems. He is involved in research projects across Europe exploring digital tools for sustainable environmental management.

But first, what is a digital twin?

From aerospatial

To answer this question, let's return to those who take credit for the concept, i.e., NASA. While the term was first coined decades later (Grieves 2023), it is thought that NASA's Apollo missions gave birth to the idea. In the 60s, during the space program, NASA built 15 simulators miming spacecraft. These simulators were used not only for training but also to find solutions in real time to any failure in space here on Earth.

NASA's Apollo missions gave birth to the idea of the digital twin

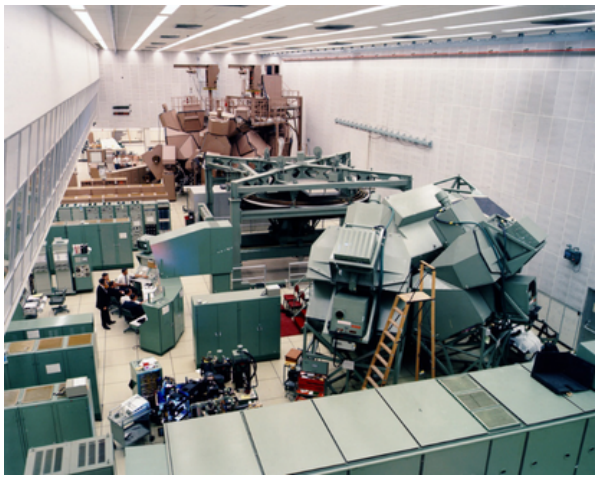
What makes them close to a digital twin is that a constant stream of information between the simulator and the actual spacecraft ensured that the current states of the original reflect as closely as possible on the twins. This feature helped the technicians validate workarounds before proposing them to the space crew. It is even said that such a protocol helped to keep them safe when an oxygen tank exploded. This flow of information and real-time alignment between the simulator and the object to mimic is one of the essential parts of a digital twin, which formal definition can be put as:

A digital twin is a virtual representation of a physical system (and its associated environment and processes) that is updated through the exchange of information between the physical and virtual systems" (VanDerHorn et Mahadevan 2021).

To complex industries

Since then, the concept of digital twins has flourished in multiple disciplines, most notably in the transport industry (aerospace but also automobiles, etc) and the energy industry (grids, nuclear plants). The common points between these two industries are the enormous complexities of these systems and the notion of the product lifecycle. The product lifecycle is, with synchronisation, a second fundamental notion intimately linked to the concept of digital twins. A digital twin is needed to anticipate and adapt to the transition between stages when a system is expected to evolve through fundamentally different states. Think about the nuclear plant, which will undergo at least the construction, operating, and dismantling phases.

While all three states are not simultaneous, they are tightly linked and thus must be designed to be at least compatible. That's where digital twins help with fast forwarding and anticipating transition. Unsurprisingly, other industries, such as architecture, health science, and…environment engineering, have embraced digital twins.



And to the Earth
Obviously, the water and soil systems also meet the life cycle and complexity criteria. But more than that, what could be more appealing than building a digital twin of the whole Earth? It is, finally, a rather complex system subject to sharp and crucial transitions whose consequences matter to us to the highest degree.

What could be more appealing than building a digital twin of the whole Earth?

The European Union recently founded an initiative to launch a digital twin of Earth (DestinE). The DestinE platform aims to model, monitor, and simulate natural phenomena, hazards, and related human activities. The platform is built around a whole ecosystem of services that, in turn, rely on a large set of data from numerous existing databases (e.g., from Copernicus). Exciting services are on the verge of being released, such as CityNexus, an innovative urban digital twin application designed to assess the environmental, social, and economic impacts of changes in road networks, mobility, and urban space design.
Zooming out, you will find a multitude of digital twin initiatives targeting specific subsystems of the Earth. For example, a hydrological digital twin model of a catchment area (Morlot, Rigon, et Formetta 2024), whose objective is to reproduce and predict key phenomena (potential evapotranspiration, hydrology, soil moisture, etc.) at a relatively small scale (~ 1 km2).
It is important to note that such digital Earth models mostly lack the synchronicity criterion, as they are under construction and primarily focus on data integration and validation, which are serious and complex tasks in themselves.

How can digital twins change the management of soil-water systems?
Based on the above, it is clear that, to the author's knowledge, no digital model meets all the criteria to qualify as a digital twin of a soil-water system. Most often, the two-way information flow is missing. While the information stream from the physical system (such as soil, a river, or a catchment) to the digital twin is easily understood (e.g., soil moisture, water level, discharge, etc.), the reverse flow is more challenging to comprehend.

In fact, the information sent by the digital twin to the physical system is mainly orders given to the actuators that are part of the physical system. A selection of examples include:

- Automatically adjusting hydraulic barriers to prevent saltwater intrusion into coastal aquifers.
- Triggering of shading or frost protection systems based on microclimatic forecasts.
- Automatic adjustment of valves to manage dams and reservoirs according to forecasts.

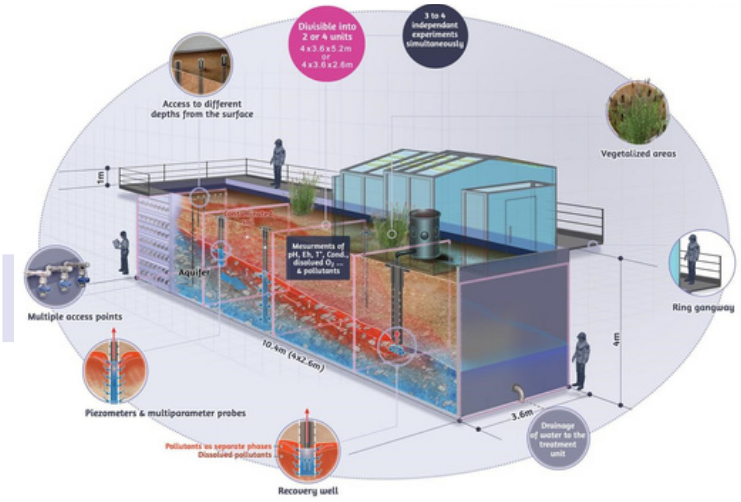
All the above information changes the physical system's state, provided actuators can receive it and act accordingly. In case actuators are not an option, the information is received by blood and flesh humans, who can serve as actuators—for example, to change farming practices to prevent erosion. In one way or another, these actions modify the system's state, which is then communicated to the digital twin through multiple sensors and a fast, reliable communications network.

These actions modify the system's state... which is then communicated to the digital twin.

Recently, authors have proposed a digital modeling platform to reproduce and predict natural source zone depletion of hydrocarbons on a contaminated site (Sookhak Lari, Davis, et Rayner 2022). Natural source zone depletion or monitored natural attenuation of pollutant plumes in groundwater are passive management strategies of polluted sites relying on natural processes (biodegradation, irreversible sorption). These techniques rely on analysing multiple data and risk conformity analysis. Therefore, a digital twin of a contaminated site is pertinent to digesting the data first and orienting the upcoming decision. One practical and proper application of digital twin in soil remediation would be monitoring the pollutant plume and making real-time decisions to modify source-zone hydraulic confinement.

In doing so, the digital twin would take the best of the two-way information exchange, and permit decision support, data-driven choice and environmental protection in the face of predictable but highly complex events. Each of these points is an accessible benefit of setting up a digital twin for the management of water-soil system.

Proposition and conclusion
All this is within reach, but we should not delude ourselves about the ease with which digital twins can be implement.



We should not delude ourselves about the ease with which digital twins can be implemented

By way of conclusion and food for thought, we propose a slightly more modest approach, seeking to produce the digital twin of a more controlled system.
For example, many research institutes have lysimeters. This type of device lends itself well to setting up a digital twin, because good quality data can be mass-produced. As an example, BRGM has embarked on the creation of a digital twin of its multi-metre pilot (10 * 4 * 4 m) dedicated to the study of the hydrology of contaminants.

Although the objective is less ambitious than that of the DestinE platform, it is possible to reach the synchronisation stage between the twin and the physical system more quickly, which is a crucial point of digital twins and their interest, but one that has not yet been sufficiently addressed, and which certainly reserves some technical challenges for the future.

This is a crucial point of digital twins and their interest… and which certainly reserves some technical challenges for the future.

AquaConSoil 2025:

Showcasing Strategic Innovation in Phytomanagement and Water Resource Management

By Cecile Nouet

Dr. Cécile Nouet is a researcher in environmental engineering at the University of Liège, where she leads research on soil and water management with a focus on remediation of contaminated land and sustainable land-use practices. She serves as coordinator of the Waste2Bio Strategic Innovation Initiative (S3).

In this article, she presents how the Walloon Region's S3 Initiatives—Waste2Bio and H_2O—are driving innovation in phytomanagement and sustainable water systems, setting the stage for AquaConSoil 2025.

As AquaConSoil marks its 40-year anniversary in 2025, the conference returns to Belgium—this time to Liège, a city with a rich industrial history and a dynamic vision for environmental innovation. This landmark edition is proudly hosted in collaboration with the Walloon Region and two of its Strategic Innovation Initiatives (SIIs): **Waste2Bio** and **H_2O**.

These initiatives are emblematic of how regional action can drive global transformation—a core theme that has echoed through AquaConSoil's four decades of science, policy, and collaboration.

Strategic Innovation Initiatives: Bridging Regions and Driving International Collaboration

At the heart of this partnership is the Walloon Smart Specialisation Strategy (S3)—a forward-looking framework aligned with the European Commission's goals for innovation, green growth, and inclusive employment. Through this framework, Wallonia has launched 19 SIIs, creating synergies between research, public institutions, industry, and citizens.

Two initiatives—Waste2Bio and H_2O—directly reflect the AquaConSoil ethos, combining environmental science with innovation, cross-sector collaboration, and community impact.

SII Waste2Bio: Transforming Wastelands into Economic and Environmental Opportunities

Coordinated by the University of Liège, Waste2Bio focuses on the rehabilitation of abandoned and contaminated lands through innovative phytomanagement solutions. By cultivating plants on brownfield sites, this approach restores economic value via biomass recovery while preserving soil, air, water, and biodiversity. The initiative unites Walloon landowners, researchers, bio-based material companies, service providers, citizens and public institutions.

Key Waste2Bio Projects

IASIS (Funding: Circular Bio-Based Joint Undertaking):

A consortium of 18 partners across Europe (Greece, Italy, Belgium, etc.), IASIS focuses on:

- Rehabilitating contaminated and saline lands with industrial crops.
- Ensuring biomass supply for high-value bioeconomy applications.
- Establishing sustainable value chains for bio-based products.
- Enhancing biodiversity, soil functionality, and ecosystem services.
- Involving farmers directly to create sustainable income opportunities.

INNO4CFIs (Funding: I3):

This consortium of 14 partners (Italy, Belgium, Spain, etc.) explores nature-based solutions for Carbon Farming Initiatives (CFIs). INNO4CFIs develops Living Hubs in four European countries, including Belgium, to rehabilitate contaminated lands using phytomanagement solutions in collaboration with ISSeP and the University of Liège.

Plant4Wasteland (Funding: ULiège):

Funded by the University of Liège, this program creates a portfolio of exemplary phytomanagement sites in Wallonia, forming part of a dedicated Living Lab.

SII H2O: Innovating for Sustainable Water Resource Management

Led by SPGE (Public Water Management Company) and SWDE (Walloon Water Company), SII H_2O brings together a coalition of stakeholders to improve water quality, availability, and sustainability. Its ambition: ensure resilient and low-carbon water systems in the face of climate change.

The initiative focuses on:

1. Developing alternative water resources.
2. Addressing extreme climate events.
3. Monitoring and treating micropollutants.
4. Enhancing energy efficiency in water management processes.

From phytomanagement to circular water systems, Wallonia offers a living lab of innovation. AquaConSoil 2025 celebrates not just 40 years of legacy, but also the regional voices shaping its future.

AquaConSoil 2025: A Platform for Innovation

These Walloon-led initiatives are more than regional success stories—they are proof of concept for the collaborative, interdisciplinary approach that AquaConSoil has championed since 1985.
As AquaConSoil 2025 convenes researchers, practitioners, and policymakers from across the globe, the featured work of Waste2Bio and H_2O will serve as inspiration for how regions can lead in land and water innovation. They demonstrate how local partnerships can deliver solutions that are technically sound, socially inclusive, and environmentally transformative.

Key H2O Projects

Rivialis (Funding: Greenwin):
Recent climate events that have highlighted the importance of managing water courses through measures such as restoration, flow improvement and flood protection. However, small streams, which constitute the majority in cumulative length, are little studied due to high costs. The Rivialis project offers a rapid and economical tool to assess the state of small water courses, a simulation of the impacts of restoration projects using modelling algorithms and AI, and by providing targeted services for stream restoration.

Orion (Funding: Interreg France-Wallonie-Vlaanderen):
This project aims to protect the ecosystem of the Meuse Valley (in Belgium) while adopting ecological management of water resources. Building on the DIADeM project, Orion develops a global vision of the pressures exerted on the aquatic ecosystems of the Meuse. To achieve its goal, Orion is mainly developing four actions:

1. Collect and analyze existing data to model the pressures and their impacts.
2. Carry out microbiological and chemical diagnostics on water quality.
3. Assess the ecotoxicity of aquatic species and water bodies.
4. Develop climate adaptation scenarios in collaboration with local stakeholders.

QualiSûre (Funding: Interreg Greater Region):
Focused on the cross-border Sûre River, QualiSûre aims to improve water quality through coordinated efforts in Belgium, Luxembourg, and Germany. Key actions include monitoring critical emission zones, installing advanced filters, and developing AI tools for decision-making.

Dear AquaConSoil 2085,

Dr. Anjali Jayakumar is a Lecturer in Chemical Engineering at Newcastle University, UK. Her research focuses on creating sustainable materials from biomass, mineral wastes and microorganisms to improve food-energy-water security. She specialises in thermochemical processes like pyrolysis for biochar-based solutions in water and soil remediation. Dr. Jayakumar is also the Early Career Professional Face of AquaConSoil 2025.

In this article, she pens a hopeful letter to future generations, imagining the world we could build together.

I hope you are in the midst of a remarkable conference, filled with inspiring discussions about how we have healed—and continue to heal—our rivers, lakes, lands, and oceans from the damage we once inflicted. I hope you are welcoming brilliant minds—old, young, and endlessly curious—from all corners of the world, united by a shared commitment to caring for our environment. May this gathering be a testament to the progress we have made, not only in restoring ecosystems but also in building a truly inclusive and collaborative scientific community.

Where we stand in 2025

As I write to you from 2025, our rivers still carry the weight of pollution, our lands bear the scars of overextraction, and entire communities remain displaced or disadvantaged due to environmental neglect. Too often, decision-making remains centralised, political, dismissing the generational wisdom embedded in local and global knowledge. I realise that scientific advancements alone cannot save us if they are not coupled with inclusivity, ethics, and a deep sense of responsibility towards everyone, especially the most vulnerable.

> Scientific advancements alone cannot save us if they are not coupled with inclusivity, ethics, and responsibility.

Listening Differently

My hope for AquaConSoil 2085 is that we have learned to truly listen—to the voices that have long been unheard, to the knowledge that emerges from different cultures, and to perspectives that challenge our assumptions. I hope we no longer rely solely on familiar methods but instead embrace diverse ways of seeing, understanding, and nurturing our water and soil. That we no longer fear what we do not know, but instead make time and effort to welcome those who can help us see differently, bringing skills and insights from unexpected places.

> My hope for AquaConSoil 2085 is that we have learned to truly listen—to the voices that have long been unheard, to the knowledge that emerges from different cultures, and to perspectives that challenge our assumptions.
> *Dr. Anjali Jayakumar*

From dream to action

I dream of special sessions at AquaConSoil 2085 where we celebrate groundbreaking achievements—where we no longer discuss PFAS contamination as an ongoing challenge, but rather share success stories of how we have completely eliminated these persistent pollutants, restoring cleaner water and healthier soils. I envision forums dedicated to examining the behaviour of the gigatons of captured CO_2 stored deep within the very reservoirs that once gushed oil and yielded tons of coal, assessing their long-term stability and impact.
I hope we come together to share best practices for maintaining our thriving afforested and reforested areas, fostering community involvement in their care and stewardship. We hold sessions that explore the positive impacts of our collective mitigation and adaptation efforts on soil and water health, using low-cost tools and sensors designed to support farming, agriculture, and food-energy-water security.

These innovations help us answer critical questions in the comfort of our homes: Are the microbes thriving? Are the plants healthy? Is the water safe? Through these advancements, we empower communities with accessible, science-driven solutions to sustain and restore our ecosystems.

TURN OVER

Empowered Communities and Everyday Science
We gather to reflect on how a once-scarce resource—clean water—is now widely available, thanks to an extensive network of affordable and highly efficient decentralised water treatment and desalination plants powered entirely by renewable energy. We discuss and strive to make them even better. These innovations will have played a crucial role in achieving the United Nations Sustainable Development Goal 6: Clean Water and Sanitation for All, ensuring that access to safe water is no longer a privilege but a universal reality.

Are the microbes thriving? Are the plants healthy? Is the water safe?

I dream of a slow-paced research and innovation culture where we do not merely pass down scientific discoveries and technological advancements, but also the joy of curiosity, the ethics of innovation, and the values that ground us. That we, as custodians of knowledge, have made ample time and space to mentor, uplift, and empower the next generation—not just as scientists, but as stewards of our shared home. That we have finally recognised the importance and true power of community, ensuring that those disproportionately affected by environmental harm are not just recipients of solutions but active architects of change.

"Science alone cannot save us if it is not coupled with inclusivity, ethics, and responsibility. The future of our planet depends not just on innovation, but on how well we listen, collaborate, and empower communities to be the architects of change."
Dr. Anjali Jayakumar

Borderless, Inclusive Collaboration
I also imagine a truly inclusive AquaConSoil, where virtual reality, holographic conferencing, and AI-driven translation tools make participation more sustainable—reducing the need for long-haul flights—while ensuring accessibility. No longer restricted by borders, visas, or regulations, researchers from all parts of the world can engage meaningfully, immersing themselves in virtual field visits, interactive labs, and real-time collaborative spaces that bridge geographical and disciplinary divides.

By the time you read this, I hope that principles of social equity, climate justice, and environmental stewardship are no longer ideals we aspire to, but values deeply embedded in how we work, govern, and heal our natural resources. That science is not just about innovation but about responsibility—responsibility to the planet, to each other, and to the generations who will continue this journey long after us.
A community built on trust, mentorship, and inclusivity, where knowledge is exchanged across generations and disciplines, and where every voice—regardless of background or geography—has a place in shaping the path forward for water and soil stewardship.

A community built on trust, mentorship, and inclusivity… where every voice has a place in shaping the path forward.

Signing off in hope for this future,
Dr. Anjali Jayakumar
UK, 2025

Colophon

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