AquaConSoil

BOOK OF ABSTRACTS

2021

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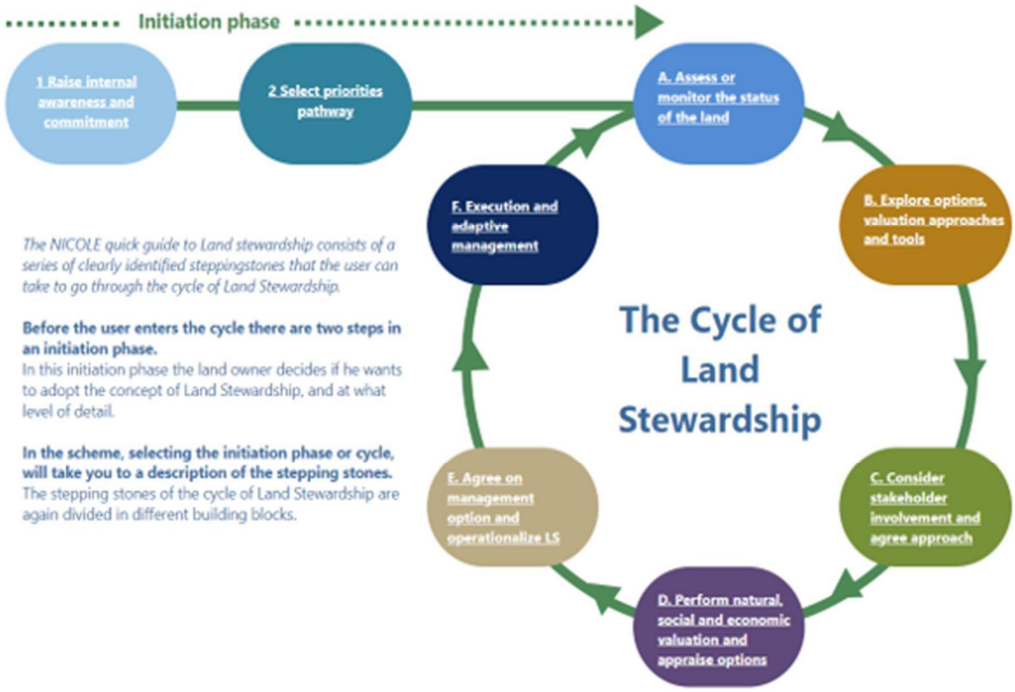
1 Sustainable use and protection of soil-sediment-water systems

1a) Land stewardship and achieving the SDG's: better implementation of land and the SSW-system

Special Session 1aSpS1: NICOLE session 1. Land Stewardship

Chair: Hans Slenders, Lida Schelwald



Outline NICOLE Aquaconsoil session on Land Stewardship

In this session you will gain more insight in the principles and potential of Land Stewardship at industrial sites. Surely, we will set the scene with some introduction to the guide to Land Stewardship and the difference with Soil Stewardship. However, we do not aim to create insight through listening to presentations, but rather by engaging actively in smaller groups to put the LS tool to practice yourself for a virtual case. You will also be challenged to look at the case from another perspective in order to gain more understanding of the value of a common undertaking. Last but not least, we aim to have a vivid discussion on how to promote Land Stewardship in Europe through a 'battle of the pitches". What is the optimal way to implement Land Stewardship? Whether you are an industrial site manager, service provider, academic of policy maker, you are very welcome to join us in this engaging event!

Program 1. Introduction to the digital Land Stewardship guide (15")

2. Exploring the potential of the LS tool using a virtual case (*in breakout groups*) (55")

3. "Battle of the Pitches (20") and debate;
    - Soil stewardship = Land Stewardship
    - "Carrot vs stick" or: Land Stewardship in legislation or not?

Special Session 1aSpS2 Soil Mission Support: Co-creating the European Roadmap for Land and Soil Related Research and Innovation

Chair: Linda Maring

Abstract[1]

The EU missions

In 2019, the European Commission defined five major and challenging missions in the areas of cancer, climate change, healthy oceans, climate neutral cities and healthy soil and food. The delivery of new knowledge that will enable the achievement of the missions is funded under Horizon Europe, the 2021-2027 EU research and innovation programme. The two-year EU project Soil Mission Support (SMS) – that started in November 2021 – helps the Mission on Soil health and food by developing a roadmap for related research and innovation (R&I) needs. Various actors in the field of soil and land use will engage in the co-creation of this roadmap and will help in trying to integrate these R&I needs in, amongst others, the Horizon Europe Work Programme.

R&I needs of actors dealing with societal challenges related to soil use and land management Sustainable soil use and land management are essential to meet societal challenges and needs. In addition, the pressure on land and soil continues to increase due to often competitive functions such as water and food production, energy and biomaterials, infrastructure and urbanization. This involves many different actors and knowledge fields, which do not always have a tradition of collaboration. Informed and knowledge-based choices are required and for this the actors need available, usable and acceptable knowledge. These are actors from different domains, such as spatial and urban planning, soil remediation, agriculture and forestry, climate, etc. Actors also include researchers, practitioners, young professionals, policy makers and citizens.

Main message of the session / Aim of the session

The SMS project aims to improve the coordination of soil and land management related R&I and thus to support the achievement of the Mission on Soil health and food, the European Green Deal, and the UN SDGs. In this session, we present the progress of the SMS project and will collate ingredients for the creation of R&I roadmap. With the session participants we explore and discuss the main challenges, R&I gaps (short and long-term) and priority areas in Europe, with a focus on urban and industrial soil and land management.

What is your take home message? What's in it for the audience?

With the results of this session, we 1) will emphasize the importance, as well as the potential of and challenges in urban and industrial soil and land management, which is momentarily less elaborated in the Mission's work, and 2) will identify concrete R&I gaps and actions. This will help SMS to achieve a balanced roadmap for ALL soils and land use functions, which can feed into the Mission's activities and programming of a.o. the Horizon Europe programme.

How to engage your audience in a digital setting

We plan to have alternating plenary presentations and discussion group sub-sessions. There will be plenary presentations on: 1) the mission on soil health and food; 2) SMS identified R&I gaps so far; and 3) actors' network. We might want to use a poll (e.g. Mentimeter) during the plenary part, to enable participants to engage in the session. Depending on group size, we plan to have multiple break out groups (10-12 people) under the lead of a chair, working in a structured way together on the roadmap co-creation using interactive tools such as MURAL/MIRO/PADLET. Thus, participants can provide written contributions, which ensures and optimal capturing of the input for development of SMS roadmap.

[1] Category Special session. This abstract relates to the EU H2020 funded project SMS which supports the Mission for soil health and food. Although this abstract as submitted for topic: 1a) Land stewardship, it would also fit under 1c) To achieve SDGs and particular LDN

Special Session 1aSpS3 TerrAgenda: A Manifest for healthy soils in 2030!

Chair: Margot de Cleen

In the Netherlands soil and land are under pressure. Societal challenges and the need for transitions increase this pressure with claims on space and soil ecosystem services, while the landscape and ecosystem services already suffer severe degradation. Soils and land are essential for welfare and wellbeing.

It's already more than 5 years ago that the Sustainable Development Goals were published. For SDG 15, life on land, only small progression is made. It's time for a change. How to speed up? We still have a lot of questions to answer and solutions to find: 'despite our soil protection policy degradation continues; do we need enforcement or other measures?' 'What do we need to connect farmers, nature conservators and civilians to find solutions to pay for carbon' 'how do we sustainably urbanize and control land take?' 'how can we diminish our footprint?' 'can or does only the land owner decide how land should be managed?'...

Dutch stakeholders from public and private sectors, the knowledge community and NGOs, got together and drew up a Manifest accompanied by a 'living action program' with actions and agreements to give a boost to achieving SDG 15.3 and thus to achieving a lot of societal goals.

Main core of the agenda is: 'embrace the natural system, give soils a voice, appoint an ambassador and connect networks, are part of the way to achieve sustainable land use on a regional level.

Can we share ideas and practices and can this approach be up-scaled to an international level

The aims of this session are:

- share information on the process towards TerrAgenda
- exchange ideas and good practices on ways to come to land degradation neutrality
- exchange ways to give soils a voice in decision making and activities
- exchange practices in rural and urbanized areas

Set up

Introduction to the TerrAgenda by Co Molenaar and Margot de Cleen

Pitch by one of the soil ambassadors of the TerrAgenda

Breakout sessions

1b) Circular economy approaches

Session 1b1 Approaches sustainable water re-use in urban areas

Chair: Tim Grotenhuis

AquaConnect

Hans van Duijne, Thomas Wagner

AquaConnect: Climate-robust water management in delta areas.

Throughout the year, the availability of fresh water is of vital importance to the Netherlands for the production of drinking water, for use in agriculture and for industrial production. In recent years, however, the Netherlands has had an increasing freshwater shortage in the summer and as a result of a lower amount of precipitation in the spring and summer as a result of climate change. Before the summer of 2020, a freshwater shortage has also arisen in large parts of the Netherlands. At the same time as this freshwater shortage in the summer, the Netherlands has a precipitation surplus in the winter. To prevent high water levels, this precipitation surplus is transported to the North Sea as quickly as possible. The temporary storage of this precipitation surplus in the subsurface, combined with the use of new freshwater sources that are currently not used, such as brackish groundwater and treated waste water, will enable the Netherlands to balance the supply and demand of fresh water over the year in the future. In NWO-TTW Perspectief program AquaConnect, innovative digital and chemical technologies are developed with universities, research institutes, the business community, including SMEs, all levels of governments, drinking water companies, with which regional water cycles can be closed by using these new water sources, in order to make regional water systems self-sufficient. The administrative and economic aspects and the international connection are also addressed.

These innovative technologies will be demonstrated in case studies in different parts of the

Netherlands, each with unique and overlapping problems: Amsterdam region, Province of South

Holland, Zeeuws Vlaanderen, Hoge Zandgronden. The NWO Perspective is funded by the Ministry of Economic Affairs and Climate. The aim of the NWO Perspectief program is to create more focus and mass in research in this thematic area and key technologies relevant to the Netherlands and elsewhere, in order to create strong international distinctive positions in Dutch business and the knowledge infrastructure. The entire chain of users is involved in creating this coherence in the research, so that the consortium can generate social and economic impact.

DEVELOPING EFFECTIVE WASTE AND WASTEWATER CIRCULARITY IN SMART MUNICIPALITIES

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Keywords:
circular economy, life cycle assessment, technology verification, best available technique, waste, wastewater, municipality

Introduction:

At present, municipalities and cities are undergoing a major challenge. They are under pressure of the fulfilment of the Circular Economy obligations and its target limits that are accompanies with requirements for the acceptance and the realisation of climate commitments. Municipalities must also continuously follow and adopt in short time rapid changes in the field of waste and water legislations.

In general, most new legislation in the waste as well as water fields recognise the principle of life cycle assessment (LCA) and the choose of best available techniques (BAT). E.g., in the packaging but also in waste Czech national laws, which follow the relevant EU directives, legally request for applying the eco-modulation principle. The eco-modulation is based on the LCA and at the most basic level is the concept of penalising the use of materials that are less environmentally friendly, and rewarding the use of those, which are better. How? Mainly through charging a higher rate of tax for products that are harder to recycle, or offering fee reductions for materials which can be easily recycled (Mapleston, ©2020).
In addition, the circular waste management enables to trade waste, not only for commodities, such as raw materials, which are recyclable and which are currently separated as part of waste collection and processed into secondary materials (recycled plastic, metal scrap, beverage cartons etc.). Which could be a strong point but on the other hand, it increases the pressure on the municipalities officers to apply and to have deep knowledge not only requirements of the related waste and packing laws but also the REACH regulation (ECHA, ©2021a).

Similarities can be found also in the water management, when the circularity principle is mainly based on the observation of water consumption and optimizing its usage, incl. activities such as decentralized water management and the usage of grey waters. But the water footprint should be seen more than the amount of water consumed and/or polluted to produce each of the goods and services we use (Water Footprint Network, ©2015). The water footprint should also fully follow the principles of LCA and should properly address all relevant impact categories. Also, now a days there is also connection to the REACH regulation, when is considered the latest amendment of the Drinking Water Directive (ECHA, ©2021b).

Eco-innovation and green technologies are the key for successful implementation of the Circular Economy strategy, not only in Europe. The Environmental Technology Verification (ETV) helps technology developers to gain credibility for their environmental technologies thereby facilitating their market reach (EC Environment, ©2021a). The EU ETV serves currently for both mentioned fields, waste, materials and resources as well as for water.

To achieve the Smart Environmental Management that evenly improves the environment and the economy without compromising the sustainability of developing ecosystems and stakeholders, municipalities must adhere to the principles of circulation and use updated tools such as the above to implement them.

Methods' definition and scope:

The Life Cycle Assessment (LCA) principles are given in the ISO standards 14040 and 14044. The both standards were amended in 2020 (ISO 14040:2006-ed.2.0/Amd1:2020; ISO 14044:2006/Amd2:2020). Generally, LCA I defined as the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. Along the lines of this standard and with the main aim to support LCA practitioners in operationalizing LCA, other codes of practice have been developed. In the EU context, the Joint Research Centre of the European Commission has released the International reference Life Cycle Data

(ILCD) system handbook. Since 2013, to enhance the comparability of LCA applied to products and organisations, the European Commission has launched the Environmental Footprint methods (EPLCA, ©2020a).

In general, LCA is based on four main phases:
1) Goal and scope, which aims to define boundaries of a study;
2) Inventory analysis (LCI), which involves data collection and all calculation procedure for the quantification of inputs and outputs);
3) Impact assessment (LCIA), which associates LCI results to environmental impact categories and indicators (basing on the applied LCIA methods) and
4) Interpretation, which should present achieved results from LCI and LCIA in accordance to the stated goal and scope (incl. comments on all discrepancies and uncertainties).
For the LCA method, the need for consistency and quality assurance of the used data plus reflection of all process chains is very important.

The EU Environmental Technology Verification (ETV) is the service provided by the European Commission to help technology providers with new innovative environmental technologies reach the market with a competitive advantage. The ETV process takes an innovative green technology through a third-party validation which assesses the performance of the technology based on independent and credible information (EC Environment, ©2021b) by applying the internationally recognised ISO standard 14034, which has been under revision recently (ISO 14034:2016). As a technical reference guideline for the ETV implementation is also used the General Verification Protocol (GVP), the version 1.3 from April 2018, which has been prepared during implementation of the EU ETV pilot programme and defines the ETV procedures to be followed by participating entities as well as information on the programme coordination at a European level (EU EC, 2018).

The ETV programmes can verify innovative technologies in three technological areas (TA):
1) Water treatment and monitoring, serving for new technologies for monitoring water quality and drinking water and wastewater treatment for microbial and chemical contaminants;
2) Materials, waste and resources, used for assessing innovative technologies in fields of recycling, separating, sorting, resource efficiency, material recovery and/or its substitution, mercury reduction and a production from biomass;
3) Energy technologies, addressing eco-innovations from renewable and green energy sources, waste and biomass energy reuse, energy efficiency at the industrial level, as well as generic energy technologies, distribution and energy storage.
Currently, the EC ETV group has been working on enlargement of the technical scope of the EU ETV programme for following TA: 4) Soil and groundwater monitoring and remediation; 5) Cleaner production and processes; 6) Environmental technologies in agriculture and 7) Air pollution monitoring and abatement.

The Best Available Techniques (BAT) are technologies approved by legislators or regulators for meeting output standards for a particular process, mainly for pollution abatement. Therefore, generally, the best available means the best feasible or the best practicable environmental option. The approved BAT are stated in reference documents, the so-called BREFs (as well as a few other reference documents) that have been adopted under both the IPPC Directive (2008/1/EC) and the IED Directive (2010/75/EU) (EC EIPPCB, ©2021a).

The European Integrated Pollution Prevention and Control Bureau (EIPPCB) was set up in 1997 to organise an exchange of information between Member States, industry and non-governmental organisations promoting environmental protection on the Best Available Techniques (BAT), associated monitoring and developments in them. The European IPPC Bureau is an output-oriented team which produces reference documents, BREFs. BREFs are the main reference documents used by competent authorities in Member States when issuing operating permits for the installations that represent a significant pollution potential in Europe. There are about 50 000 of these installations in Europe. In the international context, the European information exchange on best available techniques is considered to be an EU contribution to the global process initiated in 2002 at the World Summit on Sustainable Development so that non-EU countries can also reap the benefits of this ambitious work (EC EIPPCB. ©2021b).

Footprints are indicators of pressure of human activities on the environment. Footprint quantification is based on life cycle thinking along the whole supply chain (from producer to consumer) and aims to give a comprehensive picture of the quantified pressure (Vanham et al., 2019). Each footprint focuses on a particular environmental concern, and measures either resource appropriation or pollution/waste generation, or both (Hoekstra and Wiedmann, 2014). Among the most recognized footprints belongs the Carbon and Water Footprints, which is also ISO standardized (ISO 14067:2018; ISO 14046:2014), and also the Ecological Footprint, which is a concept prepared by the Global Footprint Network, aimed to measure how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices (GFN, ©2003-2021).

In 2013 the Environmental Footprint concept was proposed by the Commission Recommendations 2013/179/EU. The EC drafted the Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF) methods as a common way of measuring environmental performance. The PEF and OEF are the EU recommended LCA based methods to quantify the environmental impacts of products (goods or services) and organisations. The overarching purpose of PEF and OEF information is to enable to reduce the environmental impacts of goods, services and organisations taking into account supply chain activities (from extraction of raw materials, through production and use to final waste management). This purpose is achieved through the provision of detailed requirements for modelling the environmental impacts of the flows of material/energy and the emissions and waste streams associated with a product or an organisation throughout the life cycle (EPLCA, ©2020b).

Modern tools opportunities and their limits:

The targeted application of the Life Cycle Assessment (LCA) and the Environmental Technology Verification programme (EU ETV) can serve for smart municipality management in various fields. E.g., during the preparation of strategic documents and/or feasibility studies focused on technological modifications and improvements of municipal wastewater and waste management. The key of this approach lies in modelling individual life cycle flows, including carbon, water and ecological footprints and interconnecting these with the verified eco-innovative technologies, with already published Statement of Verification on the ETV web-page (https://ec.europa.eu/environment/ecoap/etv/verified-technologies_en) or the best available technologies (BAT), accessible via BREF documents on the IPPCB web-page (https://eippcb.jrc.ec.europa.eu/reference). Although, the most BATs are focused on the industrial level, municipalities can benefit from revised knowledge about BREFs, especially in the areas of wastewater treatment and municipal waste (e.g., Waste Incineration (WI) BREF/BATC 12.2019; Waste Treatment (WT) BREF/BATC 08.2018).

The tailored-based use of the combined LCA-EU ETV tool could help to strategically implement the concept of the Circular Economy in municipalities while considering their climate commitments. In addition, if the LCA approach is also applied to economic and social allocations, a broader perspective can be achieved, such as the approach of sustainability of smart cities and their social responsibility. However, it is important to remember that the use of LCA should be merely *a decision-supporting tool*, rather than *a decision-making tool*, since its specific impact focus as it particularly tends to exclude more local environmental issues. It is therefore necessary to use it in conjunction with other tools to assist in identifying areas of potential improvement.

Moreover, it is important not to confuse the Environmental Footprint (EF) and the Life Cycle Assessment (LCA). Although, they are both based upon life cycle thinking, they differ in aim and approach. While EF are resource use and emissions oriented, generally referred as *pressure* oriented, whereas LCA is *impact* oriented. *Pressure indicators* are thus different from *impact indicators*, as they inform users on the pressure human activities place on ecosystems (e.g., the land used to produce biomass) rather than on the potential consequences (impact) due to a such pressure. Nevertheless, some footprints, such the Water and Carbon Footprints covered by the ISO standards, can include the impact phase in their full assessment and these can be considered as comparable to the LCA approach.

It is clear that the success of the implementation of the Smart Environment cannot be attributed only to the use of modern environmental tools. From the point of view of the municipality, it is necessary to ensure in particularly:
(i) clear rules of an intervention / a support / assessed (i.e., green finance);
(ii) the development of a prosperous market;
(iii) the introduction of advanced technologies for recycling and material recovery of waste and wastewater treatment; and
(iv) enacting responsible institutional arrangements.

To maintain the long-term prosperity of circularity at the municipal level, it is also necessary to improve tools for certification of recycled products (eco-designing, environmental product declaration (EPD) certificate, WFD rules, etc.), urban land use and, last but not least, increase the level of information and have clear communication strategies for municipal residents.

Conclusion:

Over the last three decades, many modern environmental tools have been introduced to support municipalities and industry in their decisions. Moreover, some of them, such as LCA, have be in existence for much longer. The significant development in the application of these modern tools has been achieved at the industrial level, but the situation is much different in municipalities and cities. However, currently, there is a pressure on municipalities to use them (e.g. LCA) due to the adoption of legislations dealing with implementing of the Circular Economy concept. This will, on the one hand, facilitate the transfer of the modern environmental tools to the municipal and city levels, but on the other hand will require additional trainings for officials in this area so that these tools can be fully used to set up the Smart Environment for their municipality or city.

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50256 Management approaches of nature-based solutions using soil to attenuate nutrients and contaminants of emerging concern Lucia Barbero

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Nature can support and inspire cost-effective solutions to treat polluted water, providing environmental, social and economic benefits and helping the building of resilience. Vegetation filters (VFs) are a type of non-conventional wastewater treatment that mimics natural attenuation processes to remove contaminants. The VF evaluated in the present work consists in a forestry plantation irrigated with pretreated wastewater from an office building. Attenuation processes occur as a result of the mutual action of soil, microorganisms and plants (i.e. physical filtration, sorption onto the soil, biodegradation and plant uptake). This simple and low-cost technology can be further improved by amending the soil with a readily-labile carbon source provided by the VF itself to stimulate microbial activity. Nutrients and Contaminants of Emerging Concern (CECs), including pharmaceuticals and life-style substances, are the target contaminants.

The objectives of this work are: i) to investigate the efficiency of VFs to attenuate nutrients and CECs under different management conditions, and ii) to evaluate its potential impact on groundwater resources.

The VF is fully equipped with instrumental devices for monitoring redox conditions (oxygen sensors), infiltration dynamics (water content, temperature and electrical conductivity probes, and a tensiometer). Samples from applied wastewater, infiltrating water at 15 and 45 cm depth and groundwater at 10 m depth are being periodically collected since January 2018 to monitor the efficiency of the system. The overall time of the experiment is divided in three periods in which volumes, dynamics and irrigation system are modified.

Since real VFs are operated under natural conditions, the efficiency in the removal of target contaminants is affected by meteorological parameters. Indeed, rains influence hydraulic loads that in turn affects residence times, hence attenuation processes. Seasonal temperature fluctuacions mainly condition biodegradation processes. When hydraulic loads greatly exceed poplar water requirements, concentrations of NO3-N build up along the flow path increasing the background levels of groundwater. The use of poplar woodchips as soil amendments have shown a good potential to ameliorate removals of target contaminants (nutrients and CECs). However, the application mode is crucial to obtain the expected advantages. When woodchips are mixed with soil, the structure of the soil is lost, and its uppermost horizons become hydraulically connected enhancing fast infiltration and limiting therefore interactions in the rhizosphere. On the other hand, the application of a superficial layer combined with drip irrigation maximizes removals by controlling infiltration rates and favouring a dissolution of the labile carbon source. Low infiltration rates guarantee also protection from contamination of the underlying aquifer.

50997 Integrated regional program for deep urban groundwater quality management in Jurubatuba, Sao Paulo, Brazil.

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Keywords: Geographic information systems, groundwater management, groundwater monitoring, groundwater protection

Abstract

Today, the São Paulo Metropolitan Area (SPMA) is one of the most densely populated regions in the world, with almost 20 million inhabitants in an area of 8,000 km2. This region is almost totally situated in the Alto Tietê watershed, suffers periodically from water scarcity, has few green areas and a history of groundwater contamination, mainly as a result of industrial activities. On-going and completed site remediation projects may represent only the tip of the iceberg, given the possibility that deep urban groundwater may have large plumes of contaminants that have migrated beyond the boundaries of the site and out of reach of specific site interventions. On the other hand, the SPMA is one of those that experience the largest extraction of groundwater in the Alto Tietê Basin. The complex distribution of groundwater well locations and the presence of hundreds of registered contaminated sites requires the management of the deep, urban groundwater reserve at a regional scale. A multidisciplinary group, coordinated by the Ekos Brasil Institute, has been working with local stakeholders to create a road map for a regional solution that could benefit the problem owners, the state- and municipal authorities, the local water users and the general population. The Jurubatuba District, located in the SPMA, was chosen as the pilot area to implement a regional program for the management of contaminated areas, focused on improving the deep groundwater quality and urban groundwater availability. For such a program to be successful, the key stakeholders should participate, in particular the problem owners, partly responsible for the deep groundwater contamination. In order to attract problem owners, the value proposition of the regional program is as follows: a) Creation of a regional fund to implement the program, with financial mechanisms that limit the contributions made by problem owners over time; b) Suspension of existing Civil Action lawsuits related to environmental impacts, and their replacement by a collective agreement, offering legal security to the participating problem owners; c) Each problem owner remains responsible for the investigation, risk mitigation and remediation of their own source areas and shallow plumes (up to 20 - 30 mbg); d) Problem owners participating in the program will get access to shared data of high quality and innovative management tools; and e) Can label their action under a sustainable and socially responsible program. The pilot project will be coordinated by an NGO, with full participation by all the stakeholders.

INTRODUCTION

Today, the São Paulo Metropolitan Area (SPMA) is one of the most densely populated regions in the world, with almost 20 million inhabitants[1] in an area of 8,000 km^2. This region has few green areas and has a history of groundwater contamination, mainly as a result of industrial activities. Ongoing and completed site remediation projects[2] may represent only the tip of the iceberg, since the deep urban groundwater often contains large contaminant plumes that have migrated beyond site boundaries and beyond the reach of site-specific interventions. Such complex areas often requirea regional approach in terms of contaminated site management.

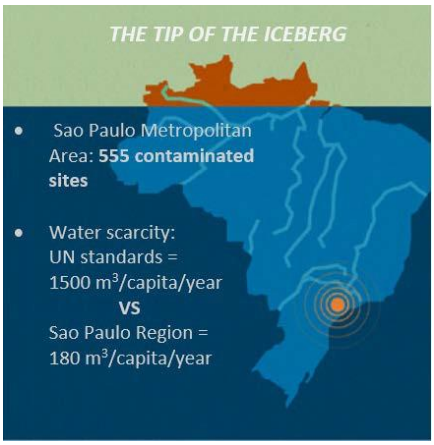

Figure 1. Ongoing and completed site remediation projects may represent only the tip of the iceberg, in terms of regional groundwater quality.

On the other hand, the SPMA is one of those that experience the largest extraction of groundwater in the Alto Tietê Basin. The water crisis, which hit the state of São Paulo between 2014 and 2015, is a phenomenon that is likely to worsen with climate change. Despite this scenario, the use of groundwater for public supply is still little explored, while studies point to a very significant potential for the exploitation of aquifers in the metropolitan region of São Paulo. The complex distribution of groundwater well locations on the one hand, and the location of potentially contaminated, industrial land on the other hand, illustrates the difficulty of managing the quality of the deep, urban groundwater at a regional scale (Figure 2).

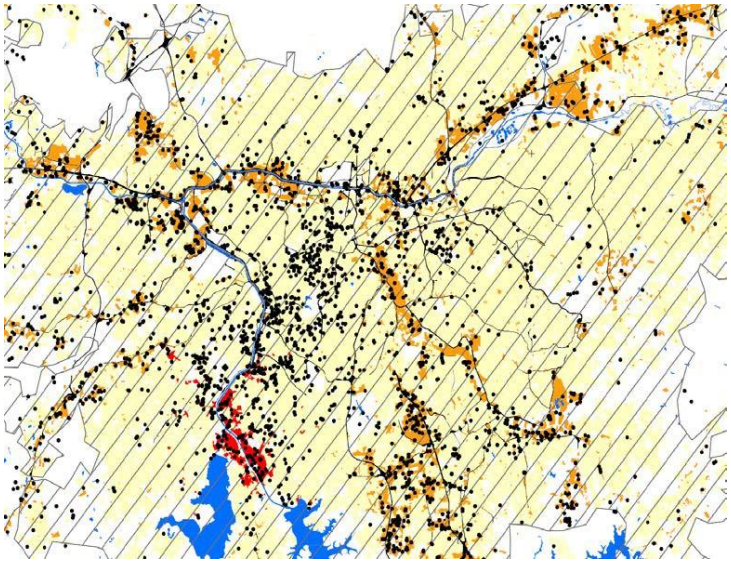

Figure 2. The distribution of groundwater well locations (black dots) and the location of potentially contaminated, industrial land (red and orange polygons) in the São Paulo Metropolitan Area, indicated in yellow (Bertolo, 2016).

[1] IBGE (Instituto Brasileiro de Geografía e Estatística) Sinopse Do Censo Demográfico 2010 (2011)

[2] Relatório de Áreas Contaminadas do Município, janeiro de2020. PMSP - SVMA - GTAC.

This is why, following the 2018 SUSTREM Seminar, a multidisciplinary group, coordinated by the Ekos Brasil Institute, has been working with local stakeholders to create a regional solution that could benefit the problem owners, the state- and municipal authorities, and the local water users. The Jurubatuba District in the south ("Zona Sul") of the SPMA, designated by CETESB as a Complex Area in 2005 (DAEE, 2009, p. 5) was chosen as the pilot area to test this new approach (Figure 3).

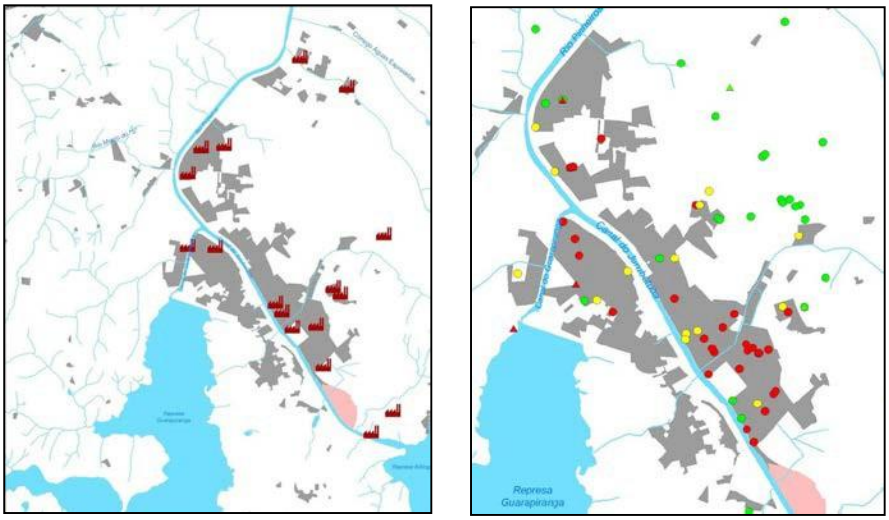

Figure 3. In the Jurubatuba district, located in the Zona Sul of the São Paulo Metropolitan Area, 84 areas were declared contaminated, according to CETESB, with29 industrial areas and 55 gas stations. In 2009, the area had 513 authorized wells, and an estimated total of 1000 of active, non-authorized wells, and summed total of 3.3 m^3/s in terms of well discharge.

The group build a roadmap following the Strategic Site Planning (SSP) process, widely used by industriesand consultants to solve complex problems. This methodology consists of the following steps:

Figure 3 The five steps of the Strategic Site Planning (SSP) process, used to find aregional solution for the Jurubatuba District.

During this process the following goals were identified:

- Create a regional program for the management of contaminated areas in Jurubatuba, focused on improving the quality of the deep aquifer and contributing to the continued change in land use in a safe manner;
- Develop decision-making tools for public agencies, for the management of the deep aquifer as a strategic or emergency water reserve;
- Attract the participation of legal contributors to a collective agreement;
- Increase the availability of groundwater for current and future users of licensed wells.

To reach these goals, five different working groups were created, focused on Governance, Technical, Financial, Legal and Communication issues. The results were presented at the ***XII Ekos Brasil Seminar***, in October 2020 and are shown in Table 1 on the next page.

Table 1. Key lessons from the Ekos 2020 Seminar

Governance session	Technical session	Financial session	Legal session	Communication session
• Stakeholders identification and inclusion to foster and reinforce representativeness • Transparency in decision-making • Consensus building & conflict management • Legitimacy in providing new solutions • Time and uncertainty management: offer/demand matching, calendar mismatch	• Monitoring strategy: transforming tubular wells into multi-level monitoring wells in the deep aquifer • Unique data set: geology, hydrogeology, pollution distribution and characterization, sociological and economic • Modeling & visualization • Management resource use, remediation intervention	• Describing the nature of opportunities to create new value • Integrated accounting: internalizing negative and positive externalities; identifying & quantifying natural capital; socio-environmental risk assessment • Building partnership programs: international organizations, development banks, public institutions, private funds.	• Building an integrated legal framework: residential, industrial, and commercial factors • Validity with existing legislation • Fair enforcing tools • Proportionality in responsibility assessments • Building a clear "protocol of intent" to ease stakeholder engagement	• Simple, clear, direct communication: adapt mediums & tools to the end public/user; identify communication relays • Building trust: do not hide negative issues, valorize positive externalities • Integrating culture & language factors [acculturation • Risk assessment to avoid snowball effect

PROPOSED REGIONAL PROGRAM

The SSP process resulted in the following proposed solution: Implementation of a regional program for contaminated site management in the district Jurubatuba of the São Paulo metropolitan area, Brazil. The main objectives of this program are:

- Improve the quality of deep, urban groundwater;
- Increase the local availability of groundwater; and
- Reduce the risk of exposure of the population to contaminated groundwater.

The regional program shares information and issues recommendations on a) Prevention of groundwater contamination; b) Regional groundwater quality; c) Hydraulic control of impacted groundwater and d) Source area and shallow plume remediation. Figure 4 lists the scope of the program, in terms of prevention, regional monitoring, hydraulic control and source area and shallow plume interventions.

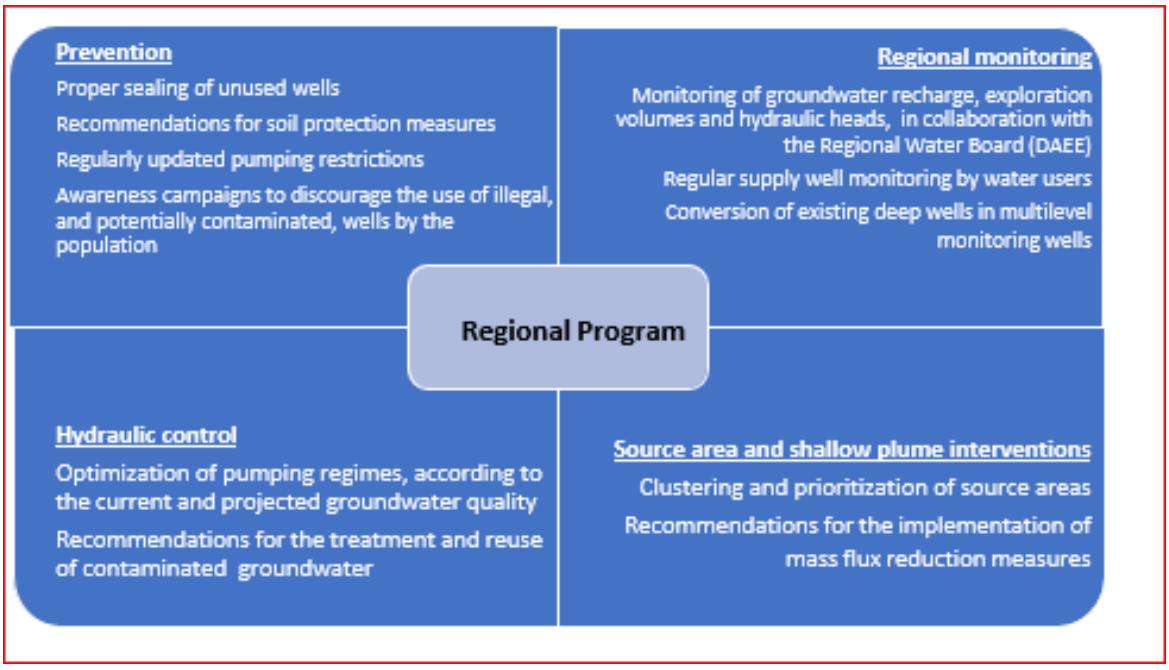

Figure 4. Technical scope of the regional program, in terms of prevention, regional monitoring,hydraulic control and source area and shallow plume interventions.

VALUE PROPOSITION

For such a regional program to be successful there is a need to convince the main stakeholders to participate,in particular the problem owners, partly responsible for the deep groundwater contamination. In order to attract problem owners, the value proposition of the regional program is as follows:

- Creation of a regional fund to implement the program, with financial mechanisms that limit the contributions made by problem owners over time;
- Suspension of existing Civil Action lawsuits related to environmental impacts of the deep aquifer, and their replacement by a collective agreement, offering legal security to the participating problem owners;
- Each problem owner remains responsible for the investigation, risk mitigation and remediation of their own source areas and shallow plumes (20 - 30 mbg);
- Problem owners participating in the program will get access to shared data of high quality and innovative management tools and can label their action under a sustainable and socially responsible program.

This value proposition would directly apply to problem owners in the Jurubatuba District. However, within a wider context in terms of sustainable development, the program can be seen as adding value to much wider range of aspects, such as:

- Water management
    - Sustainable management of urban groundwater
    - Treatment and reuse of contaminated water
    - Artificial aquifer recharge and flood control
- Public health
    - Population monitoring and awareness programs
    - Mitigation of population exposure risks
- Legal security
    - Collective agreements
    - Suspension of Civil Action lawsuits linked to environmental impacts
- Urban revitalization
    - Decontamination of soil, sediments and groundwater
    - Property development
    - Creation of green areas
- Biodiversity
    - Urban landfill management
    - Phyto remediation of shallow groundwater
    - Groundwater treatment by built wetlands
    - Ecological guidelines for urban parks

GOVERNANCE MODEL

During the EKOS 2020 Seminar, a survey was performed. One of the main results was that an NGO was seenas the best organization to increase trust between the different stakeholders.

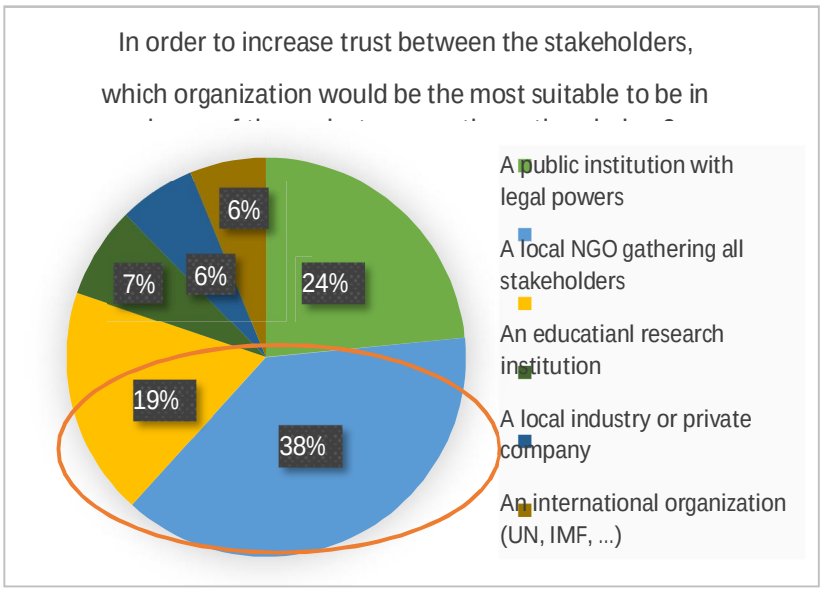

Figure 5. Results of the survey performed during the EKOS 2020Seminar in São Paulo, Brazil.

The governance model for the pilot project in Jurubatuba will be coordinated by the EKOS Brasil Institute, withfull participation by all the stakeholders.

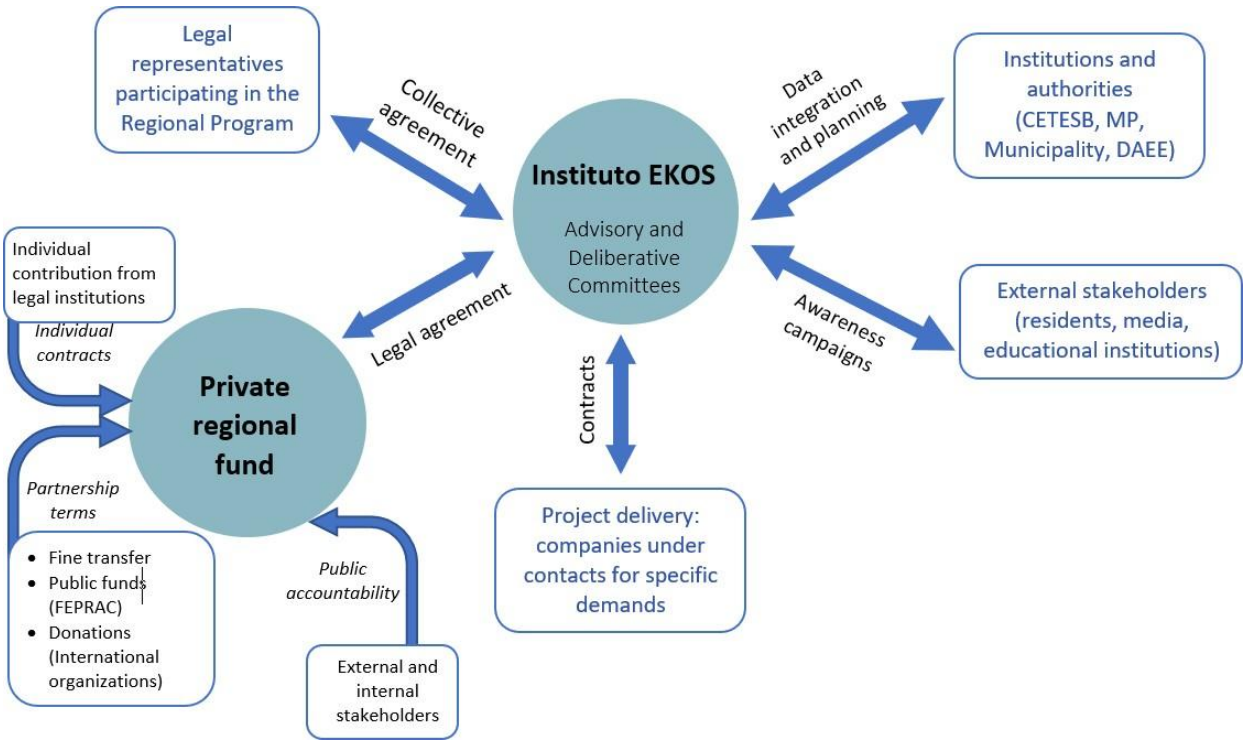

Figure 6. The proposed governance model for the pilot project in the Jurubatuba District, São Paulo, Brazil.

CONCLUDING REMARKS

The next step is to invite problem owners, such as industries and real estate developers, to participate in thispilot project. This will be done in the form of a start-up foundation, with seed money to further develop the concept over the next 12 months, prior to the implementation of the regional program by the participating members.

The start-up phase consist of a number of activities, some of which are:

- Overall coordination by the EKOS Institute;
- Working out a proper legal construction, based on the governance model; and
- Collaboration with NICOLE Latin America on the development of a guidance document for mega sitemanagement in Latin America.

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Session 1b2 Approaches to soil and sediment reclamation and reuse

Chair: Joke van Wensem

49824 Pilottest PFAS treatment in discharge water of IJsseloog, one of the three state sludge depot in the Netherlands

Main presenters: Wim Plaisier[1]. Support from: Tessa Pancras[1], Jan Frank Mars[2], Janco Portijk[2]; Roelof Smedes[2], Onno Epema[2], Hans Hakvoort

1:Arcadis Nederland bv; 2: Rijkswaterstaat (RWS); 3: Viritec bv

In the Netherlands hydraulic dredging of the waterways is necessary in order to safeguard transport over water, improve the (chemical) quality of the waterways and to protect the Netherlands from flooding. Since the Netherlands has many waterways, the amount of sludge being dredged is significant. The most contaminated sludge is deposited in three state owned sludge depots. These depots Slufter, Moerdijk and IJsseloog (design capacity of 175 mio m³) are confined depots, largely physically and hydraulically separated from their surroundings. The hydraulic separation is obtained by maintaining a lower water level within the depot related to the water level outside of the depot. The surplus of seepage and rainwater is discharged daily into the surrounding surface waters after a settling.

It is known that PFAS have affected the quality of soil, groundwater, sediment (sludge), surface water and even rainwater in the Netherlands.

RWS (the executing body of the Dutch State) and formal owner of the three sludge depots has assessed that the levels of PFAS in the discharge water were higher than in the surrounding surface water, likely due to leaching of PFAS from the sludge. The effluent discharge still complies to the surface water discharge test, which is based on the Kaderrichtlijn Water (Water Framework Directive).

Nevertheless, RWS would like to gain insight in the treatment of PFAS in the discharge water from the sludge depots. In the particular case of the IJsseloog depot, levels of PFAS were still in the ng range (sum PFAS ~60 ng/l) and a factor 2 higher than in the surrounding waters. Short chained PFAS are predominantly more present in the surrounding waters.

RWS ordered Arcadis and Viritec to perform a pilot test water treatment at the IJsseloog sludge depot in order to assess whether the PFAS in discharge water could be reduced to at least back ground levels without extensive pretreatment. Investigate the technical and economical efficiency of 5 different adsorbents being:
(1) a fresh, high quality GAC (Desotec 10AA), (2) a regenerated GAC (Desotec 20AA), (3) a cheaper type of GAC (AAA s-830X), (4) a mineral based adsorbent (Fluorosorb 200) and (5) a resin type of adsorbent (Purolite 894). Empty Bed Contact Times were set on the basis of input of the suppliers and adjusted during the trials.

Whereas PFAS adsorption is usually tested at relatively high concentrations, in this unique situation 5 PFAS adsorbents have been tested at relatively low influent concentrations (ng/l range), without intensive pretreatment, and hence in the presence of natural background levels of dissolved organic matter and suspended solids.

The test trial was executed at a total flow of 3 m3/hr and included a (minor) pretreatment of a sand and bag filtration prior to the treatment over the 5 different adsorbents (in parallel). The pilot test consisted of multiple sampling rounds, during 6 months. All samples were sent to and analyzed by the laboratory of RWS.

The test trials show that it is technically feasible to (almost) completely remove PFAS from the discharge water. Some clear differences between the absorbents in the development of the hydraulic resistance and uptake of natural organic material were shown. Empty Bed Contact Tims had to be adjusted for the Fluorosorb and the Purolite.

The regenerated Desotec 20AA turned out to be the best GAC type adsorbent from an economic point of view whereas the Fluorosorb showed good adsorption properties. Fluorosorb had the least preference for the uptake of dissolved organic matter.

49360 Definition of geochemical background values over the Parisian Basin to promote the circular reuse of excavated soils: the GeoBaPa project

Authors : Samuel Coussy* & Noémie Dubrac (BRGM), Claire Faucheux* (Geovariances), Coline Eychène & Bérénice Ranc* (Soltracing), Marie-Charlotte Favre, Benoît Maréchal & Houssem Yahyaoui (BG Ingénieurs conseils)
*Presenters

In France, wastes from the construction industry constitute 70% of the total waste production (227,000,000t)[2][3]. Among those wastes, 50.5% are excavated soils. A major issue is that the bulk of these excavated soils is typically landfilled because, in accordance with the Waste Framework Directive[4], these soils are considered as waste materials if they are taken away from the site of their excavation. A certain proportion is reused, but very little in comparison with landfilling, mainly because of the liabilities associated with their waste status.

In this context, a tiered 3-level approach was proposed in France to promote the reuse of excavated soils, from a country-scale, based on generic guideline values from national geochemical background values (level 1) to a target site-scale, based on the target site background values (level 3)[5]. An intermediate level (level 2) is based on regional or urban background values. For this purpose, the GeoBaPa project was implemented in the Île-de-France and Normandy regions, to build a geochemical background baseline for these regions. This project has been supported by the ADEME, by the Île-de-France and Normandy regions and by the French Ministry in charge of Environmental Affairs. The GeoBaPa project has been led by SOLTRACING, BG Ingénieurs Conseils, GEOVARIANCES, the BRGM and Althea Ingénierie.

By establishing the geochemical background values for part of the Parisian basin, the GeoBaPa project aims to gain better knowledge of the usual chemical quality of the soil and subsoil on the scale of the Îlede-France and Normandy regions. This is the first multi-regional reference frame providing natural and anthropic compounds' concentrations in soils - including urban zones. The work combines soil quality data from past scientific and urban development projects with data produced as part of this research program, leading to the statistical analysis of more than 3000 pieces of data.
The aim of the presentation is first to describe methodological and statistical choices made to set up the geochemical background and then to show typical values, representative of urban, suburban and rural areas in those two regions. Finally, the presentation will focus on how to use those values to reuse excavated soils, with practical examples. The main message of the presentation is that better understanding of the soil quality at regional scale would promote the circular reuse of excavated soils.

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50086 Minimizing sustainability impacts throughout dredging project – from decision making to stabilization

Chair: Jarno Laitinen

Background

Dredging of contaminated sediments requires the use of energy and materials, creates large quantities of dredging material, may impact the surrounding community, and can be costly to undertake. Implementing sustainable development practices in both design and execution of dredging projects helps to minimize environmental, social, and economic impacts.

Approach

Applying sustainable development principles to sediment risk management and remediation planning can help to identify potential environmental, social, and economic impacts. Also taking a holistic view on the project boundaries (spatial and temporal) and including various stakeholder to the planning, can help in identifying key social decision-making factors when deciding upon the scope and scale of the planned remedial works.

One novel approach for implementing sustainable development practices in sediment risk management and remediation planning is to use Multi-Criteria Analysis (MCA) method as a framing step in the project design phase. MCA methods are designed to incorporate both qualitative and quantitative information to assess the degree to which a project fulfills a set of performance criteria. In MCA, options are compared using information through a set of indicators, each of which represents an effect on sustainability (positive or negative). MCA explicitly evaluates multiple conflicting criteria in decision making, typical of sustainability assessments, and allows to integrate multiple simultaneous stakeholder views.

Implementing sustainable development practices at project level is more related to using best practices in implementation and monitoring. Ramboll has been involved during 2018-2020 on a large-scale remediation project in the port of Kokkola, where the dredging area crosses old ammunitions area and protected NATURA 2000 habitat. In the design stage environmental factors were highly appraised, and therefore on-site stabilization was selected as the preferred method for managing all dredged material on site, including the material with UXOs. The ambition of the project was to create a zero-waste solution that would both reduce the risks and at the same time advance site operations.

Lessons Learned

The presentation will introduce two large scale dredging case studies from Finland, where sustainable development has been taken in consideration from planning to execution.

First project focuses on a very Nordic problem of zero fiber (fiberbankar) sediments from pump and paper industry and application of Multi-Criteria Analysis for Sustainability Assessment of risk management and remediation alternatives.

The second case focuses on how environmental impacts were minimized during a large-scale harbor fairway and basin deepening project and how zero-waste stabilization solution was designed and implemented. The presentation also shortly highlights some other similar sediment re-use examples from Finland.

50136 Sustainable sediment management in coastal infrastructures through the innovative ejectors plant technology Marco Pellegrini

Marco Pellegrini[1], Alessandro Guzzini[1], Giovanni Preda[2], Cesare Saccani[1]

[1]University of Bologna, Bologna, Italy

[2]Trevi SpA, Cesena, Italy

Introduction: More than 90% of global trade is by far the most important means of transport of dependent on adequate ports and waterways a good port navigability is a challenging issue, hampered, as the vast majority of 10,000s of Traditionally, the sediment that causes the through maintenance dredging. Nevertheless, over the time. This objective may be reached operations, but would result in higher costs and Maintenance dredging also has considerable operations can: i) destroy or greatly modify fauna, ii) resuspend sediments and thus increasing the Suspended Solid negative effects for the ecosystem, iii) impact noise emissions, iv) generate a waste to be increasing expectation for infrastructure dimension since sustainability issues are of technology has been developed as a sustainable been tested by Trevi SpA and University of Marina of Cervia (Italy) [1]. The demo plant with the final aim of keeping water depth at the

Methods: During the 15 months of operation assess i) water depth, ii) energy consumption, species diversity, v) equivalent CO_2 emissions Water depth and energy consumption have through, respectively, bathymetry surveys and monitored by the University of Bologna in impact on seabed features and species diversity the sediment (organic matter and grain size) and assemblages, in the two areas of possible south and north of the port, in the periods of the system.

Results: After 15 months of continuous minimum water depth of 2.5 meters was seabed features and species diversity were noise was absent. Ejectors plant operation and of the organic matter content present in the compared to the initial values that were richness of benthic macro-invertebrates, initially carried by waterborne transport, constituting goods. Therefore, global trade is critically navigation status (navigability). Preservation of since port access and waterways are often ports worldwide suffer from sedimentation. problem is excavated, removed and relocated dredging is not effective in keeping navigability through a higher frequency of dredging complex authorization/permit procedures. environmental impacts, since dredging underwater habitats and resident flora and contaminants already present in the seabed, Concentration (SSC) in the water column with locally on greenhouse gas (GHG), pollutants and disposed, i.e. the dredged material. There is an projects to add value beyond the economic growing importance. The "ejectors plant" alternative to maintenance dredging and has Bologna in the first demo application in the operated from June 2019 to September 2020 Marina entrance over 2.5 meters.

the demo plant of Cervia has been monitored to iii) maintenance costs, iv) seabed features and through LCA, vi) underwater noise impact. been assessed by the Municipality of Cervia energy bill. The other parameters have been collaboration with Trevi SpA. In particular, the was assessed by analyzing the characteristics of the composition of the benthic and fish impact and in control areas located both to the before (2018) and after (2020) the installation

operation of the demo plant in Cervia the guaranteed. Monitoring actions revealed that improved and that the impact on underwater resulted in a reduction of the muddy fraction sediment in the areas affected by the plant, affected by previous dredging. The species reduced near the port, probably as a result of the previous repeated dredging, significantly increased eight months after the demo plant was put into operation. Underwater noise assessment in the port and periport environment showed that the contribution of hydraulic pumps and ejectors to the increase in underwater noise is not significant. It is therefore believed that the ejectors plant does not constitute an impact for the marine fauna near the port of Cervia. Based on energy consumption, it was also demonstrated that an optimized ejectors plant, if fed by renewable power, could cut more than 80% of GHG emissions and guarantee near-zero pollutants emissions in comparison with traditional dredging. Discussion: The results

suggest that the technology is effective and efficient, and that the demo plant operation is accompanied by an improvement in several parameters related to the ecological status of the marine ecosystem in the area affected by ejectors within one year.

Target audience: Port authorities, Marinas, Municipalities, Regional authorities, policy makers, dredging companies.

Acknowledgements: Activities financed by LIFE MARINAPLAN PLUS and STIMARE projects.

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1c) Nature-based solutions and ecosystem service implementation

Session 1c1 Phytoremediation

Chair: Lenka Wimmerova

49893 Feasibility testing and implementation of pilot experiments for phytoremediation within Life NARMENA. Mario Clemmens / PhD Sofie Thijs

Mario Clemmens[1], Sofie Thijs[2], Dirk Dubin[1], Froukje Kuijk[3], Jaco Vangronsveld[2]

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In Life NARMENA (NAture-based Remediation of MEtal pollutants in Nature Areas to increase water storage capacity), seven partners are exploring solutions for historical metal pollution in river sediments. Different types of non-invasive, nature-based remediation methods are tested, integrating soil remediation with nature conservation and water storage. One of these methods is phytoremediation.

Phytoremediation is a sustainable bioremediation technique that uses plants and their associated microorganisms to remove, degrade, extract or immobilise pollutants from soil and (ground)water. In order to increase the efficiency and decrease phytotoxicity, microorganisms equipped with the appropriate traits are augmented in the rhizosphere and inside the plant by means of inoculation. In addition to remediate polluted soil and groundwater, phytoremediation offers added values in terms of sustainability by reducing the use of materials and energy, CO_2 sequestration, increasing biodiversity, and producing biomass for bioenergy.

In 2019 OVAM (Public Waste Agency of Flanders) published a “Code of good practice for phytoremediation” providing guidelines for the implementation of soil and groundwater remediation by phytoremediation, authored by bio2clean, Hasselt University, Witteveen&Bos and Arcadis. Additional to this “Code of good practice for phytoremediation”, bio2clean and UHasselt are involved in Life NARMENA and two other field projects allowing to evaluate this guideline and to formulate recommendations for optimisation.

The presentation will focus on the feasibility testing, design and installation of the pilot experiments.

We highlight the various facets of the feasibility study like the literature review, environmental factors, design and execution of pot experiments and the search for suitable microorganisms.

Near the nature reserve ‘het Winkelsbroek’ (south of Turnhout, Belgium), the Grote Calie, a tributary of the Aa, is partly polluted with chromium. The highest concentrations are found in the sediments of the water course. Chromium is also found in bank soils and sometimes to a limited extent (mainly limited to 5m from the bank) in the soils of adjacent floodplains.

In Life NARMENA we apply microorganisms assisted phytostabilization of the chromium pollution. The plants and their associated microorganisms then stabilize or immobilize the pollutants in the soil, the root zone or the roots themselves. The uptake in the above-ground plant parts is aimed to be as low as possible. In this way the metals are immobilized and are less bioavailable.

Two pilot zones are installed, a phytoremediation zone on former farmland and a phytoremediation zone in the nature reserve. Both zones have been selected based on a detailed screening and are characterized by specific boundary conditions that may influence the selection of plants and bacteria.

We also highlight how, based on the feasibility study, we will obtain a specific selection of plants adapted to the environment and how the management in the nature reserve can be adjusted accordingly.

49241 Case study of land reclaim by phytoremediation: from TPH contamination to potential agricultural value Sébastien Kaskassian

Authors: A. Barrere, S. Kaskassian, J. Estival, F. Le Chevalier, H. Thouement, TAUW France*

Key-words: phytomanagement, biodegradation, land reuse, soil / plant health indicators, ecotoxicity

Main message: this pilot test was performed to evaluate pros and cons of a biopile remediation for TPH contaminated soils (traditional vs. vegetated biopile). The pilot was successful to achieve remediation efficiency targets (>90% reduction within 3 years), reduce carbon footprint for remediation, enhance soil health and prove potential for land conversion toward new agricultural uses: biomass growth for energy, bio-sourced products or even cattle fodder.

When dealing with contaminated lands, nature based solutions enable both the reduction of environmental hazards and the enhancement of soil health which has a central role for achieving many of the UN SDGs. Growing vegetation for agricultural and even industrial value onto reclaimed lands is now seen as an operational output for the remediation of contaminated soils. Even if they require more time, pilots and field demonstrators are key steps in order to prove concepts that has to be tailored to each situation.

In this case study, the drilling of a former oil/gas extraction well has produced 16,000 m3 of soils contaminated with diesel type hydrocarbons (concentrations # 29 800 ± 9 960 mg/kg) that have been stored on site within a clay capped area for the past 30 years. Because the site has to be restored to its previous agricultural use, the site operator set the following objectives for the remediation plan:

- Design a nature based remediation solution taking into account limited access and space on site,
- Develop a field pilot test in order to: i) test different biodegradation and / or rhizodegradation solutions, ii) monitor relevant media / parameters as a proof of concept, accounting for each remediation process (plant uptake, degradation by bacteria, fungi or induced by plants), and iii) compute all metrics for upscaling the remediation works,
- Demonstrate the potential reuse of reclaimed land: soil health, ecotoxicity, plant transfer, biomass value.

After less than 30 months, the pilot was able to achieve 85% of TPH mass reduction in the vegetation enhanced biopiles while enabling the increase in soil quality (texture, N content), the growth and diversity of fauna (bacteria, fungi, nematodes, etc.) and biomass (ray-grass, Alfalfa, Maize, etc.): all indicators of an healthier land and comparable to local arable lands. TPH and metallic co-contaminants transfer to plants (stem, foliage, buds) was minimal and showed compatible levels for biomass various uses, from energy (biomethane) to fodder production to even more industrial uses (e.g. bio-sourced products). Compared to traditional biopile techniques, phytomanagement also allowed to reduce the carbon footprint and the economic cost of remediation solutions.

The valuation of the produced biomass need further evaluation: defining a local chain of value (from biomass production to biomass uses) and creating a business model for a new type of agricultural practices. The aim is to make phytoremediation a sustainable solution for the other sites contaminated with drilling sludges that are often located in rural areas.

48851 The Power of Constructed Wetlands to clean water from nutrients and PFAS van den Brand Marco

Presenters: Mr. Paul Verhaagen – HMVT, The Netherlands

Mr. Dahn Rosenquist – Laqua, Sweden

Background/Actuality

Our society faces the major challenge of converting the overexploitation of our planet into a sustainable and much more circular relationship. We all know that our land/soil is also being depleted and our groundwater supplies are threatened, both in terms of quantity (drought) as well as quality. In particular, the massive leaching of nutrients, drug residues pesticides and PFAS pose a completely new challenge: the emerging pollutants. In contrast to the more point source-like pollutants in urban areas from (chlorinated) hydrocarbons, the emerging pollutants are found much more widely spread in the groundwater: big volumes, low concentrations. That makes them more difficult to 'grasp' when it comes to cleaning or control these type of pollutions.

Solutions

Both Laqua as well as HMVT have gained a lot of experience to treat (ground)water and leachates from landfills or agricultural areas contaminated with nutrients, heavy metals or (chlorinated) hydrocarbons in Constructed Wetlands, combined with Willow growth and recently a new invention to combinate different phytoremediation's technics. We are also experimenting with remediation systems that function entirely on wind, sun or aquathermie. We believe that we should integrate much more the power of nature into our remediation solutions: Cleantech Water Treatment. Especially for the somewhat lower concentrated challenges - such as is often the case with emerging pollutants - such solutions can be creatively & robustly integrated into existing landscapes to clean and protect our scarce groundwater with a minimal footprint.

Presentation

In collaboration with our Swedish partner "Laqua", we are now also focusing our efforts on the removal of nutrients and PFAS from water by using Hybrid Filter technics, a combination of traditional constructed wetland, filtration and plants all together in one close unit. During the presentation we will discuss the different types of phytoremediation, what they look like and what they can do. More specifically, we will focus upon the opportunities of nutrient and PFAS removal from water: where do we stand in terms of knowledge and what questions are still open.

Take home messages

For the audience there are the following 'take home messages':

- Phytoremediation / Constructed Wetlands are circular, zero energy impact solutions and can be a viable remediation approach;
- Phytoremediation can also treat water from PFAS.
- Looking out for test sites.

49262 Recovery of rare earth elements from mine tailings: using hyperaccumulating plant ash to produce a high-purity compound.

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In the last two decades, rare earth elements (REEs) mining from ion-adsorption deposits in South China left hundreds of hectares of abandoned mine tailings and eroded soils. Meanwhile, there is a growing research effort on the recovery of valuable and strategic elements from secondary sources. The fern *Dicranopteris linearis (*syn. *dichotoma)* has been identified as a REEs hyperaccumulator and aluminum (Al) hyperaccumulator growing on the acidic soils over the ionic adsorption deposits. Its biomass (fronds) is considered as an alternative source of lanthanum (La), neodymium (Nd) and praseodymium (Pr). Its superior Al content makes the recovery challenging, as the latter is known to cause separation problems, forming trivalent cations in the same manner as REEs.

The fronds of *D. linearis* collected on a former mine in Dingnan, Jiangxi Province (China) were ashed at 550 °C during 3 h. The ash underwent an alkaline leaching step with NaOH (6 M) in order to dissolve silicon and aluminum. The remaining solid was rinsed, and REEs were selectively dissolved in diluted HNO_3 at regulated pH 4.6 for 6 h. Pregnant leaching solutions were collected and REEs carbonates were precipitated using NH_4HCO_3. Crystals were aged 6 h at 40 °C in mother liquor, prior to filtering, drying, and characterization.

ICP-AES analysis revealed that the ashes contained 23 wt % Si, 6 wt % Al and 3 wt % REEs. Alkaline leaching proved to enrich the ash: REEs were concentrated from 3 to 14 wt %, while 90 % of the initial aluminum content was removed. Recovery yield of the REEs in aqueous solution at pH 4.6 exceeded 70 %, while only trace amounts of Al were dissolved. Despite being amorphous, resulting precipitates displayed high purities values (>99.5%), and characterized as a mix of normal carbonates ($REE_2(CO_3)_3{\cdot}xH_2O$, $x = 1.7$).

This work proved the feasibility of REEs recovery from *Dicranopteris linearis* ashes. Aluminum separation strategy showed to be relevant by successfully preventing unwanted coprecipitation in the last stage. The process is being subject to optimization and cost assessment before further scale-up. The recovery of such valuable elements could integrate a larger scheme of sustainable revegetation of former mines and abandoned mine tailings in South China.

Keywords: Agromining, *Dicranopteris linearis*, Rare earth elements, Hyperaccumulator plant

Session 1c2 Resource quality in sustainable, circular agriculture

Chair: Iwona Wagner

50098 Better use of clay for sandy soils Leon Claassen

Aim of the presentation: address great opportunities available for circular use of leftover clayey and silty topsoils from public works for improving resilience *and* mitigation potential of drought-prone sandy soils in agricultural use:

1. Agriculture has started suffering the consequences of climate change. Crop yields decline during prolongued droughts. Sandy soils are particularly vulnerable. The agricultural sector therefore faces the challenge of making these sandy soils, in interaction with farming systems, resilient to the effects of climate change.
2. Pursuant to the national Climate Agreement, the Dutch agricultural sector is to realise sequestration of an additional 0.5 Mtonnes CO2-eq/year as per 2030 by an increase of soil organic matter and a decrease of N2O emissions on farmland.
3. It is estimated that annually 1 Mtonne fertile clayey and loamy soil released at Dutch public works is disposed of as if it were waste. Take home message: this is excellent soil to use for increasing resilience of sandy farmland. In addition, research reveals that sandy soils enriched with clay and loam sequester significantly more CO_2 than sandy soils without such enrichment.

In Gelderland, pilots have been running since 2018 and farmers are enthusiastic.

What's in it for the audience

This is good news for farmers on sandy soils and for governments facing both circular economy, climate mitigation and climate adaptation challenges. Similar opportunities may be available in other regions with sandy soils in Europe / worldwide. The audience is challenged to help identify those opportunities and to benefit from these.

o How to engage the audience in a digital setting.

We plan to show a short film, about 5 minutes, followed by challenging the audience to identify opportunities.

49326 SoSEAL seepage screens, a nature-based solution for protection of drought-sensitive natural areas

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[1] TAUW bv, Deventer, The Netherlands; [2] Delft University of Technology, Delft, The Netherlands [3]Heijmans bv, Rosmalen, The Netherlands

Scientific research shows that humans have been influencing global patterns of drought for nearly a century. In recent years, drought in the spring and summer seasons has caused severe problems in Europe. In densely-used regions such as The Netherlands, sensitive natural areas are often surrounded by well-drained agricultural areas increasing the problems caused by the drought. On a national level, the increasing drought problems require a different approach in our water management. Locally, however, technical measures such as seepage screens can be very effective in mitigating the most serious problems.

Conventional technologies for seepage screens such as sheet pile walls and bentonite walls require heavy, energy-intensive equipment with unwanted effects in the sensitive areas. Here we present SoSEAL as a cost-effective, nature-based technology to create seepage screens in drought-sensitive nature areas

With SoSEAL, we mimic podzolisation for in situ permeability reduction. Podzolisation is a soil formation process where the mobilization and subsequent leaching of aluminium, iron and organic matter (OM) in the topsoil is followed by their precipitation at greater depth. With SoSEAL we add Aluminium and Natural Organic Matter to the soil, thus in situ creating zones with Podzol alike precipitates.

The concept of SoSEAL has been successfully demonstrated in full-scale field tests, e.g. at a dike stretch along the river Lek and at the dike of a drinking water basin. We were able to reduce the subsurface permeability with a factor in the range of 50-100 and seepage was strongly reduced. Based on further investigations and modelling of the pilot results, we were able to derive the engineering principles and prepare a practical roadmap for successful application of SoSEAL.

Realization of a SoSEAL seepage screen involves subsurface injections with low amounts of natural materials. This can be done with light injection materials and low-energy input at costs which are significantly lower than conventional technologies.

Currently we apply this knowledge for the testing, evaluation and design of the application of SoSEAL to create a seepage screen that reduces the drainage from a drought sensitive natural area. In the presentation we will present engineering principles of SoSEAL on the basis of the application at this drought sensitive natural area.

49820 Agronomic and environmental effectiveness of nutrients recovered from a wastewater treatment plant in fertigated horticultural crops.

Mar Carreras-Sempere; Marc Viñas; Rafaela Caceres; Miriam Guivernau; Carmen Biel.
Institute of Agrifood Research and Technology (IRTA)

Struvite and ammonium nitrate are products obtained from widely studied processes to remove phosphorus (P) and nitrogen (N) from wastewater treatment plant (WWTP) and other wastestreams. Current issues on the end-use of these recovered products as fertilizer in edible crops are of interest in the framework at circular horticulture and need to be further understood. Moreover, their use as raw material for nutrient solution (NS) as soluble fertilizer has not been investigated.

To this end, as part of the Life ENRICH project (www.life-enrich.eu), which focuses on a holistic point of view of the whole value chain, a greenhouse experiment with fertigation in soilless and soil system has been conducted for tomato and broccoli crops at IRTACabrils facilities (Barcelona, Spain). This study aims to compare the agronomic and environmental effectiveness of recovered WWTP products used in a NS to a conventional treatment, which encompasses a highly energetic and critical resource demand fertilizers. Moreover, two different N concentration (10mM and a dynamic 5-8-5mM) of the NS have been tested to evaluate the environmental impact on N-leaching of tomato soilless crop. In order to guarantee their safe and reliable use as fertilizers, both products were characterized in terms of macro and micronutrients, organic carbon, heavy metals and organic micropollutants. Previously, struvite dissolution tests were performed to ensure the P water solubility. At the end of the experiment, crop-yield and fruit quality was measured, as well as soil-plant-rhizosphere DNA-based microbiota assessment (functional genes of N cycle and predominant microbial diversity by means of 16SMiSEq).

Satisfactory results of struvite solubilization are obtained by using nitric acid as acidifying agent at pH range 1 to 2 in the stock concentrated nutrient solution 1:100. Then, the diluted NS that the plants uptake are at pH 6.7±0.3. First results show that both recovered products can be used as fertilizers in NS. For both crops, struvite treatment exhibited non-statistical significance in total yield production and fruit quality with conventional mineral fertilizers in tomato and broccoli crops. However, ammonium nitrate treatment showed similar or lower yield results compared with conventional treatment depending on the crop variety, being dependent on the ammonium tolerance of the plant species. Results of leachates showed few differences among recovered and conventional fertilizers treatments. However, the variation on N concentration input exhibited large differences, differing along the growing stage. While a higher N doses showed a percentage of N leached of 36±9%, a dynamic N concentrations NS reduce it to 13±4%. On the other hand, P leached percentage is about 6±4%. The study of functional gene linked to the N cycle and whole microbial diversity revealed different effects of the nitrate and ammonium ratio in the NS on the soil-plant-rhizosphere microbiota and its possible linkage on N_2O emissions.

These results will give deeper insights in the potential utilization of recovered products from WWTP and a practical and technical data to optimize fertigation strategies for efficient plant production minimizing their potential risk for health and the environment.

50278 Human biomonitoring surveys on adult populations exposed to contaminated soils (Pb, Cd, As), focus on health risks due to urban food production.

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Urban food production is increasingly promoted for its positive outcomes on the sustainable and resilient development of cities, on human health and on household purchasing power. However, urban soils may not always meet quality standards for health and food production. In pan-European countries, Pb and Zn smelting activities have been going on for almost a century near or within urban areas, and have permanently contaminated soils with toxic trace metal(oid)s such as Cd, Pb and As. Even after several decades of decline and regulations, chronic exposure to these soils contaminants remains widespread in cities with past metallurgical industry. Urban gardeners, intensively exposed via unintentional ingestion of soil/dust particles and consumption of (contaminated) vegetables grown on these soils, constitute a sub-population at risk with respect to health effects from heavy metal co-exposure.

Following environmental investigations and health risk assessments, three human biomonitoring surveys have been performed on adult populations of (i) gardeners/beneficiaries from a 6 ha community garden (n=88 in summer 2018 and n=55 in winter 2018) and (ii) non-gardeners (reference population, n=100 sampled in summer 2019) both located/living in the “Bressoux” area from Liège city (BE). This neighbourhood shows a widespread soils contamination in heavy metals (i.e. median Pb, Cd and As concentrations of 530; 4.5; and 40 mg/kg, respectively). The community garden therein is one of biggest (up to 230 allotments) and one of the most contaminated in Wallonia, with nearly 30% of vegetables above EU quality standards for Cd and Pb. As a whole, about 240 blood and 240 urine samples were measured for Pb, Cd, As biomarkers to determine if gardening on these soils and/or consuming vegetables products gave rise to higher internal exposures and potential health risks compared to (1) the general population and to (2) non-gardeners living on similar soils. The study allowed the investigation of seasonal change (summer vs. winter) in biomarker levels and contributed to tune the adequacy of precautionary and management measures in this peculiar situation.

Results show that urinary Cd (CdU), urinary speciated (Asi+MMA+DMA) As (AsU) and blood Pb (PbB) concentrations for gardeners were above reference values for the general population and higher than those measured for the reference population of non-gardeners. Differences in PbB, CdU and AsU concentrations were statistically meaningful between the two populations and showed a pronounced change with a decrease in winter for Cd and As. Urinary Cd concentrations for gardeners was 4 times the median value for the Belgian population and showed the strongest difference, with 55% above 1µg/L for gardeners against 8% for non-gardeners. Median AsU for gardeners was 2 times the median from ENNS survey (France). Median PbB for gardeners was above but close to the reference value from the ENNS survey that can be attributed to an upperbound estimate of current PbB median values for a general population. As, Cd, Pb biomarker levels of exposure in the reference population were close or typical of the general population. These differences are explained by a more intense exposure to contaminated soils for gardeners (consistent with a winter-summer difference in exposure for this population) compared to a more passive exposure for the reference population. However, discrepancies in socioeconomic and population factors between gardeners and non-gardeners could also partially contribute to the observed differences.

Contaminated urban soils, once they are devoted to vegetable gardens, may cause individuals to have internal exposures above those of residents living on the same soils but exposed less intensively.

2 Smart tools and methods to connect people, planet and profit

2a) Policy and legal tools (a.o. the European Green Deal)

Special Session 2aSpS1: Give Soils a Voice!

Chair: Margot de Cleen

Give Soils a Voice!

As the soil is the basis of all life, it is essential to take care of the soil and listen to its needs. Therefore Rijkswaterstaat took the initiative to research ways to give soils a voice in decision making processes and in development and land management plans. This study focussed on ways to stop soil degradation and secure its intrinsic value and al its functions for the long term. Four different realms have been studied. First the relation of the Dutch towards soil and nature, as part of the identity. This relationship is an essential element for making solutions successful, especially when support from citizens is needed. The second realm is the economy and its intertwined relationship to land use and ownership. This connection has far stretching results for the vitality of soil and its public functions. Soil is treated as a commodity in the current neoliberal capitalist system. The third realm focuses on the role of public authorities and their ability to both set laws and regulation to improve soil health and their ability to be an example when it comes to supporting innovative ideas on soil governance in public-private partnerships. The fourth and last realm centers the possibilities of law to protect soil and its intrinsic value, inspired by the efforts of the 'rights of nature'movement.

The conclusions show a set of solutions and actions enabling a voice for soils. These are based upon the following notions:

1. know the social and cultural relation to the soil as a basis to formulate solutions. However, actively question this relationship by dialogue, and at the same time create nature experiences (especially for children) to reshape this relationship.
2. Develop new business models that create value instead of commodification of the soil, such as rewarding the management of soil ecosystem services.
3. Public authorities can set the example by integrating soil functions in their land management, in public-private management of publicly owned land and can stimulate private businesses to sustainably manage their soils for example by financial support.
4. Legislation does not immediately fit in the Dutch culture but can be used to back the intrinsic value of soil. Most promising is the human right for a clean and healthy environment, slowly discussing and working towards a right for the soil itself.

The aim of this session is to show the results of this study, discuss the recommendations and exchange experiences (from other countries).

Set up of the session

Presentation of the study by Margot de Cleen and Co Molenaar

- Discussion in breakout sessions: (cultural identity, economy, role authorities, legislation)
- Plenary feedback and conclusions

This special session includes:

50243 Engaging in alternative communication to approach land protection: examples of projects between artists and scientists

Authors : H.A.A. Thouement (TAUW), J. Escoffier, T.J.R. Lippmann (VU), J. Hattink

Keywords : land stewardship, ecosystems, connections of stakeholders

Main message : Scientists concerned with SSW issues can connect with citizens and stakeholders through different gates, less top-down approaches. Two projects are presented in which conjoint work between a scientist and an artist lead to suggestions for alternative communication to support land protection.

Abstract: Land stewardship concerns multiple stakeholders, all with different incentives to protect or damage the soil. Disconnection between scientists, policy makers, residents, and users of the land can occur, leading to incomprehension or tensions. Projects crossing art and science can lubricate the dialogue and provide alternatives to collaboration over land stewardship and planning. One of the aims is to move closer towards a common understanding, and work towards mutual goals that are discussed, understood and agreed upon by all stakeholders. We present two projects of art/science collaboration in the field of SSW.

Taste for forests [1] results from the study of landscape transformation in the South West of France. Both study locations had in common the increase of pine tree monoculture, and the industrialization of the process, to the detriment of soil, water, biodiversity as well as the quality of the landscape. Through the 3 months project, interviews and site visits provided numerous information about the land stewardship potential. The project will result in multiple productions (publications inc. online, sculptures) which will interrogate the perception of forests and its current transformation to intensive monoculture in France.

Voice of a Sinking Landscape [2] is the multimedia installation that arose subsequent to conversations that took place between artist and scientists and artist and polder residents. These conversations sought to investigate the sequence of events that led to the polder's brief instatement as an independent republic within the Netherlands. On the side of the scientists, the voice of the community was received in an enjoyable and easily accessible format. Scientists felt heard by those attending the exhibition but not by the polder residents.

Take home message: These examples illustrate that the dialogue between artist and community can help the community project their voice. Such works engage the storytelling of the relationships with the land and the landscape, promoting its conservation and rehabilitation. Finally, conversation with communities is necessary and can occur through other means than scientific papers, without losing its scientific significance.

Question/way to interact with the public :

We think we should engage the audience with asking them questions (reactions/feelings to images related to landscapes) at the start of the discussion, then collect the answers and use some word-cloud program to discuss the words that were picked most by the audience at the end of the presentation.

References :

[1] Taste for forests: evernia | julieescoffier.com, 2021

[2] Voice of a sinking landscape : https://www.josjehattink.com/projects/2018-voice-of-asinking-landscape/, Den Haag, 2018

Special Session 2aSpS2: An 'alternative' soil strategy by young professionals

Chair: Sven Verweij

50061 An 'alternative' soil strategy by young professionals

Abstract Submission Session AquaConSoil Focusweek

Submission by: 'JongBodem' and 'Rijkswaterstaat (RWS)'
Sven Verweij (NMI), Marissa Frambach (Tauw), Sverre van Klaveren (RWS / UvW)

In recent years, reports and studies on climate change reported increasingly disturbing and urgent conclusions. Young people are increasingly worried about their future and are making this point heard in the social debate, for example with the protests of Extincition Rebellion. Although the EU makes efforts to connect to youth, its institutions are not perceived to be approachable. The European Commission is currently developing the Green Deal to make Europe to address climate change and fulfillment of the sustainable development goals. As part of this Green Deal, the Commission will launch a biodiversity strategy. As soils form an integral part of any environment, the commission has decided it will accommodate the biodiversity strategy with an update of the soil strategy.

EU DG environment has presented the preliminary contents of the strategy: 6 topics that are going to make up the baseline of the strategy. We, as young professionals, want to evaluate those six points from the climate perspective: will the contents of the strategy be suitable enough to face the climate crisis? Will the strategy give soil enough of 'a voice'? At the session during the AquaConSoil Focus Week we will present our vision for a sustainable soil in Europe "an alternative soil strategy", drawn up by young professionals from various European countries. We hope to reach as many young professionals and researchers to contribute to the alternative strategy. We will organise a conversation/discussion between young professionals and policy makers, politicians. Young professionals can offer a fresh view on current issues with their creativity and knowledge of new techniques. This offers young professionals and researchers a platform for their ideas and policy makers possible solutions they have not yet thought of.

Given the short timeline of the soil strategy, JongBodem will present our preliminary findings during the special AquaConSoil event on 27th of May where we hope to enthuse even more young professionals and researchers to contribute to the vision.

We welcome additional contacts and ideas from the AquaConSoil organization, if available.

Special Session 2aSpS3: NICOLE session 2. Liability transfer

Chair Lucia Buvé & Pascal Mallien

Lucia Buvé (Umicore, Be)
Pascal Mallien (BakerMckenzie, Be)
Ewa Rutkowska-subocz (Dentons, PL)
Carlos de Miguel Perales (COMILLAS University, ES) Françoise
Labrousse (Jones Day, Fr)
Wilhelm Bergthaler (Haslinger / Nagele, AT)

Environmental liability can be defined as a loss or potential loss due to damage to either humans or the environment. The loss is normally monetary but can take other forms, for example reputation. An environmental liability can either arise from statutory requirements, out of contractual agreements, or from civil actions (torts) and can lead to criminal sanctions. Environmental liability plays an important role when (potentially) contaminated land is transferred. Hence the possibilities and the mechanisms of liability transfer are very important to NICOLE's members. It is important to note that a total transfer of environmental liability is mostly not possible. There can always be a tort issue or criminal investigation against the original owner.

2020/2021 NICOLE members conducted a pan-Europe survey on Liability Transfer through EU countries. We try to understand approaches, opportunities for environmental liability transfer from the perspective of "problem holders" seeking a positive outcome for land no longer required for their operation.

To avoid "one way" communication with audience, we have designed this session as "panel discussion" format. Mrs Buvé and Mr Mallien will be the co-host of the discussion. We will invite the other 4 speakers to give a brief introduction first for 5 minutes on their specialties, then we will have panel discussions with prepared questions and also questions from the public.

Lucia will kick off with a brief case study to introduce and define the center topic of Liability Transfer

Pascal will provide a general EU scope definition on Liability Transfer

Ewa: Poland specific regulatory issues and transaction
Francoise: France specific regulatory issues and soil pollution litigation

Carlos:
(i) certain relevant differences between the ELD and the Spanish regulations on soil pollution (e.g., in terms of possible retroactivity and responsible parties), and
(ii) certain practical aspects when trying to transfer liability, namely related to the nontransferability of regulatory and criminal liabilities.

Wilhelm: Austria specific regulatory issues and focus topic on urban redevelopment with brownfield.

2b) Decision support tools for sustainable land management

Special Session 2bSpS1: Sustainable Remediation: New Practical Guidance and Tools

Chair: Nicola Harries

- How to approach a sustainability assessment for achieving sustainable remediation
- What are the updated indicators/criteria and how to use them in a sustainability assessment mapped against the United Nations Sustainable Development Goals
- Updated Sustainable Management Practices and demonstration of how to use the associated spreadsheet and the presentation of a case study
- Discussion

Paul Bardos[1], Richard Boyle[2], Vivien Dent[3], Frank Evans[4], Richard Gill[5], Nicola Harries[6*], Angela Haslam[7], Trevor Howard[7], Jonathan Smith[8], Chris Taylor[4] and Alan Thomas[9]
1. r3 environmental technology ltd, Reading, UK; 2. Homes England, Bristol, UK, 3. RSK Environmental Ltd, Cambridge, UK, 4. National Grid Property, Warwick, UK; 5. Shell Global Solutions International BV, Rijswijk, The Netherlands; 6. CL:AIRE, London, UK; 7. Environment Agency, Bristol, UK, 8. Shell Global Solutions (UK) Ltd, London, UK and 9. ERM, Oxford, UK.

***Corresponding author. Nicola Harries**

The aim of this special session is to inform about the new practical guidance and tools that SuRF-UK has recently published (2020-21) to support sustainable remediation that will be of interest to a broad international audience. It is particularly targeted at site owners/managers and service providers (consultants/contractors), regulators and authorities.

The UK Sustainable Remediation Forum (SuRF-UK) was established in 2007 to support the application of sustainability principles for remediation in the UK. It is a collaborative, multi-stakeholder initiative co-ordinated by CL:AIRE with a Steering Group that incorporates members from regulatory bodies, industry, consultancy and academia.

SuRF-UK has developed a comprehensive set of supporting guidance including a framework document, indicator categories and sustainability management practices to help practitioners carrying out qualitative sustainability assessment (see www.claire.co.uk/surfuk). Over the last two years, SuRF-UK has updated these guidance documents and tools and within this session SURF-UK want to share the updates and how to use the tools. The session will be split into three short presentations, a demonstration of the tools and the sharing of case studies as described below:

- How to approach a sustainability assessment for achieving sustainable remediation (15 mins)
- What are the updated indicators/criteria and how to use them in a sustainability assessment mapped against the United Nations Sustainable Development Goals (15 mins)
- Updated Sustainable Management Practices and demonstration of how to use the associated spreadsheet and the presentation of a case study (15 mins)
- Discussion (30 mins)

Following the presentations, there will be a 30-minute discussion session where the presenters and audience will be able to discuss what has been presented and how the tools can be used and adapted for a variety of regulatory settings.

Take Home Message:

This special session will look to demonstrate the advantages of the use of the updated guidance and tools, showing how implementing sustainable management practices is much easier than people think and build confidence in its successful implementation.

Red line linkage:

The guidance highlighted in this session provides a framework for practitioners to incorporate sustainability into the management of contaminated land. The framework is guided by principles that align with the AquaConsoil Redline and include protection of the environment to maintain a healthy soil-sediment-water system; and building connections with a range of stakeholders from inside and outside the industry to support project decisions based on sound science.

Presenters:

We would envisage several of the SuRF-UK steering group members would participate in this session. We are unable to confirm names at present.

Special Session 2bSpS2: Sustainability assessment as a tool for more sustainable and resilient remediation of soils, groundwater, and sediments

Chair: Jarno Laitinen, MSc., Senior Advisor, Ramboll

Co-author Richard Bewley, PhD., Managing Consultant, Ramboll, Gitte L. Søndergaard, PhD., Senior Consultant, Ramboll, Aldo Trezzi, MSc., Lead Consultant, Ramboll

Intro

This workshop will include the following: an introduction to sustainable and resilient remediation approaches; summary of sustainability metrics and weighting indicators used to assess site and remedy information; overview and instruction on the use of various sustainability assessment methods; best practices on stakeholder dialogue; site practice examples using the free on-line SURE by Ramboll tool; and discussion on participant results and open forum on the objectives of sustainable remediation and potential future uses.

Content

While risk assessment remains the primary trigger for remediation of contaminated sites and the basis for regulatory objectives, sustainable remediation aim to ensure that prudent, and ideally optimal, choices are made during the risk management decision-making process and that sustainable development principles are implemented during remedial design.

The workshop with cover the state of the art sustainability assessment practices for remediation, embodied with information and approaches from various international guidance documents, including Sustainable Remediation ISO Standard 18504, Sustainable Remediation Forum (SuRF-UK) guidance, ITRC's Green and Sustainable Remediation guidance, and SURE by Ramboll (SURE) tool for sustainable remediation assessment, communication, and reporting.

Preliminary program

0:00 Introduction to the workshop and learning goals 0:15 What is sustainable remediation?

0:45 Methods for sustainability assessment?
- CBA, LCA, NEBA, MCA, …
- Assessment framing

1:30 Discussion on potential uses and benefits
1:45 Short coffee break
2:00 Introduction to SURE by Ramboll
2:45 Exercises on applying sustainability assessment
3:30 Discussion on results
4:00 Stakeholder dialogue best practices
4:30 Wrap up

Learning goals

This hands-on workshop will provide participants an opportunity to learn how to complete a sustainability assessment for remediation of a contaminated site. The workshop will teach how to apply different assessment methods, select appropriate sustainability indicator parameters, and where necessary, engage in virtual stakeholder dialogue. The workshop is appropriate for regulators, project managers, scientists, engineers, and field personnel.

Session 2b1 Integrating digital solutions for sustainable land management

Chair: Thomas Track

49634 BIM for Environment – towards a site digital twin

Presenter / author: Nicolas Soenens, Project Leader Site Evaluation and Restoration, Arcadis Belgium,

Co-authors: Jan Verbraeken (Arcadis Belgium), Denny Schanze, Rudi Pelgrum (Arcadis Netherlands), Sanjay Kumar, Reddy Nayarana (Arcadis India)

In the context of asset management, the collection & visualization of all site related data is of outmost importance for an efficient & accurate asset management. All these data have to be stored on a common data environment (CDE), which acts as a 'single source of truth' for all asset-related info.

In the past, these visualizations have mainly consisted of above ground asset related BIM models.

However, it's also important to include environmental data in these models. During the lifecycle of site investigations and/ or remediations, a lot of site specific subsurface data is collected such as geology, soil quality, water levels, presence of subsurface structures, etc.

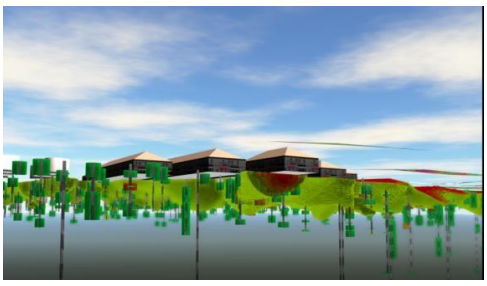
If this data is structurally captured & managed, it can be used to create insightful visualizations for the site, which will cater towards an efficient asset management & a sustainable spatial planning of the subsurface in the future. One important advantage is the possibility to do clash detection in the planning phase of a project. For example, planned above surface infrastructure can be planned in such a way that there is no 'clash' with a subsurface contamination.

This environmental site data can be stored & visualized together with all above ground data in a Digital Twin.

A first step towards this subsurface digital twin is an accurate 3D visualization of the site's conceptual site model (CSM). This is then combined with a visualization of the above ground infrastructure. During the presentation, we'll show a 3D visualization of a site showing both the CSM and the above ground infrastructure. This model was created as follows:

- In a first phase, we created a 3D contamination model in the EVS software (Earth Volumetric studio) from a database containing drilling locations & measured TPH soil concentrations.
- To this model, topography was added based on land surveyor measurements & public data.
- After finalizing the subsurface EVS model, the model was transformed and imported into AutoDesk Infraworks & BIM 360 to include above ground infrastructure and to allow further viewing & BIM modelling. This step proved to be the most challenging one, as multiple transformations where needed while retaining the high quality of the subsurface EVS model.

In the future, these Digital Twin can also be expanded with all other subsurface data that can be collected such as data from sensors measuring groundwater level/ quality & layout / performance of a remediation system.



49636 Give the people what they want: Insights into stakeholder needs and opportunities for digital decision support for brownfield redevelopment.

Ellis Hammond[1, 2], Darren Beriro[1], Frederic Coulon[2], Stephen Hallett[2].

[1]British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK.

[2]School of Water, Energy and Environment, Cranfield University, Cranfield, MK43 0AL, UK.

Abstract (Presentation):

The complex nature of brownfields means that making effective decisions about their regeneration can be challenging and requires the involvement of a wide range of stakeholders. Understanding these requirements is crucial. Our research measures the level of digitalisation of a range of organisations and identifies the main digital challenge areas for UK brownfield redevelopment. Methods used include face-to-face interviews with senior industry figures, an online questionnaire with 150 responses, and a literature search. Our analysis is supported by a combination of manual and automated theme coding with NVivio. We have identified three digital challenge areas: i) an appetite for consistent high quality data visualisation to avoid stymied risk communication; ii) a desire to increase focus on evaluating early-stage ground risk and associated costs to minimise project delays and cost-overrun; and iii) a need for enhanced communication and understanding between stakeholders to foster better engagement and trust. These results are being used to inform our research on the design and development of new brownfield decision support systems.

50011 Example of a cloud solution for seamless follow up of a sustainable remediation at an oil terminal site

15 min session, Suggested topic: 3.3 or 5.2

Denny Schanze , Geert Wijn, Bram Gerards, Marlies Bos (Arcadis Netherlands), Nic Barbian (Arcadis UK), Drew Knott, Monica Dupre (Arcadis US)

At an oil terminal site in the Netherlands Arcadis executes a TISR® pilot remediation. TISR® (Thermal InSitu Sustainable Remediation) is Arcadis' innovative and sustainable remediation technology using renewable energy or waste heat to stimulate biological degradation of contamination by warming up the soil to optimum conditions for bacterial metabolism.

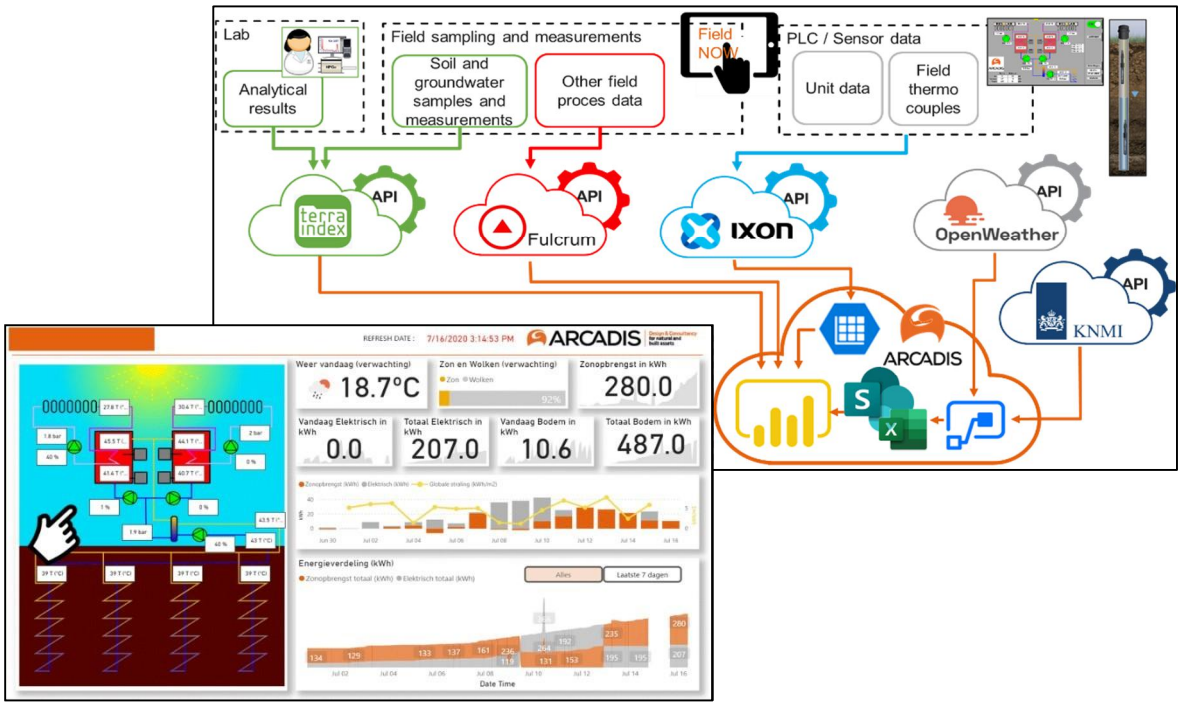
For the steering of the remediation process many data are collected during inspections, field sampling and measurements, by laboratory analysis of soil and groundwater samples and by sensors of the process unit. To enable real time insights in the remedial and system performance Arcadis developed a 100% digital solution for the follow up of the remediation, consisting of an all-cloud data collection, storage and reporting system using state of the art digital tools and services. The main components are:

- Digital Field forms, aligned with the Global Arcadis FieldNow® Program.
- Automated data exchange between field, laboratory and office utilizing.
- High frequency process unit and sensor data.
- Enrichment with open weather and radiation data.

The remediation system itself is operated manually on-site or remotely via a SCADA system, after evaluation of all collected data. Therefore the different data sources are linked together utilizing respective API's (application programming interfaces), processed using MS Azure cloud services and presented using interactive Power BI Dashboards. This set up allows for efficient data-driven decision making and process steering, as the data can be evaluated in real time and changes to process parameters can immediately be implemented. Furthermore, the dashboards improve client communication and engagement since all data are at hand during meetings and online.

To increase efficiency in the future even more Arcadis will apply machine learning so that in the mid-term the system will be capable to suggest changes for efficient operation. The long-term ambition is an autonomous AI driven process, keeping manual operation and maintenance at a minimum.

The presentation will give some general information about the project but will focus on the technical challenges to deliver the digital solution.


Lab
Analytical results
Field sampling and measurements
Soil and groundwater samples and measurements
Other field proces data
Field NOW
PLC / Sensor data
Unit data
Field thermo couples
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Weer vandaag (verwachting)
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207.0
Vandaag Bodem in kWh
10.6
Totaal Bodem in kWh
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Energieverdeling (kWh)
Alles
Laatste 7 dagen
Date Time

50109 Including the subsurface in spatial planning

- Name presenter: Henriëtte Keijzer – Consultant TAUW Netherlands

- AquaConSoil topic:

  3 - Smart tools and methods to connect people, planet and profit; 3c – Decision support tools for sustainable land management

- Main message of the presentation:

  The main focus of spatial planning has long been 'people' and 'profit'. In this presentation we will talk about the shift in focus where the 'planet' side is assuming an increasingly important position and the impact of this shift on how we see the subsurface. Climate adaptation, energy transition and biodiversity are themes that are no longer ignored in planning. To address many of the issues in these themes we argue that we have to give a more important role to the subsurface. To stop using gas for heating every Dutch household, we could use underground thermal energy. To limit the environmental impact of building a bridge, we should consider the impact on the water table. To be able to introduce more green spaces in urban areas, we need more fertile and well hydrated soil.

  The physical living environment of our planet includes the subsurface which is a dynamic system that could provide drinking water and sources of thermal energy. In addition, it forms a vulnerable system that, without adequate protection, will eventually lose the ability to perform functions for humans, plants and animals. The subsurface is already a very crowded space, especially in urban and urbanizing areas, with roots, pipes, cables and tubes it can look like a plate of spaghetti. If we want to benefit more from the subsurface we believe we need to fully include the subsurface in the spatial planning process and first come, first served is no longer valid.

  In The Netherlands, the upcoming new Environment and Planning Act (In Dutch: Omgevingswet) will bring necessary changes in policy, legislation and regulations. The changes are a result of the shift in focus to ‘planet’. This legislation is aimed at protecting the physical living environment and takes a defensive approach to activities. The underlying philosophy is: 'protect and utilize'.

  In order to respond adequately to the shift in focus, it is important to have knowledge of the subsurface and the role it plays in tackling the above mentioned challenges. Visualization of the subsurface with all its different functions, provides insight in the complexity within the subsurface and in the possibilities and challenges. In the presentation we will give an overview of digital solutions that help to understand the complexity of the subsurface. These tools can be used for decision making when new functions in the subsurface are introduced. It results in a common understanding of the current situation and makes it possible to include the subsurface in spatial planning with a focus on ‘planet’.

Different digital solutions will be demonstrated during the presentation:

- Subsurface challenge map: A map (2D) that shows the plate of spaghetti in the subsurface, but more over gives you a good insight in the space left in the subsurface for the societal challenges.
- Conceptual Site Model: An interactive model (3D) of the site location, with the possibility to add or alternate your input, it shows the possibilities or challenges for each new activity
- Virtual GIS: projecting the subjects (roots, pipes, cables, etc.) in the subsurface using a telephone or tablet when you are outside

- Aim of the presentation

  Demonstrating the audience exciting digital solutions that help stakeholders understand the subsurface better. Enabling inclusion of the subsurface in spatial planning by using 2D and/or 3D visualization on-screen in virtual and/or augmented reality.

- What is your take home message? What's in it for the audience?

  For spatial planning with a focus on 'planet' inclusion of the subsurface is essential. Development of new technology helps us understand the subsurface better, and it helps us to explain the needs, possibilities and challenges to others. It provides the stakeholders with an experience – and feel the complexity instead of reading about it.

- Think about how to engage your audience in a digital setting. Tips & Tricks will be shared.

  We want our audience to experience the 3D visualization using virtual reality, if possible.

Session 2b2 Decision support tools for soil and groundwater

Chair: Sophie Moinier

48963 Are we on the brink of a resurgence of decision support tools for brownfield redevelopment?

Darren Beriro[1], Frederic Coulon[2], Steve Hallet[2] and Ellis Hammond[1+2]

[1] British Geological Survey, Keyworth, UK; [2] Cranfield University, Cranfield, UK

Topic 3c – Decision support tools for sustainable land management

Decision support tools (DSTs) are just that, they support end-users to make decisions. They take a variety of forms from spreadsheets to on-the-fly interactive webGIS. Applications are widespread in engineering, computer science and environmental management. DSTs assist end-users understand problem complexity in an intuitive and useful way, saving time and money, increasing confidence in selecting a desired outcome. The will authors argue that, in particular, brownfield DSTs are due a resurgence. This is expected to be driven by policy initiatives around planning and housing. This renewed interest builds on significant work by many European researchers in the 2000s, particularly those based in Italy and the UK. The authors will highlight the history and development of brownfield DSTs in the context of the contemporary UK digital planning and housing policy landscape. We provide case examples of a current DSTs including one the UK. We will reflect on the trends, opportunities and future direction. The latter being driven by: i) a proliferation and competence in data-driven programming/ coding; ii) putting users at the heart of agile IT software processes; and finally, iii) a thirst for understanding and efficiency in bringing forward a pipeline of brownfield land for redevelopment by planners, developers and land owners alike.

Digital engagement tips: live surveying of participants with graphical results

49679 Tools for quantification of the duration and effect of pesticides to groundwater resources

Majken Frederiksen1,2*, Poul L. Bjerg2, Mette Christophersen1, Britt B. S. Christensen1, Liselotte Clausen3, Peter L. Tüchsen4, Nina Tuxen5, Gry A. S. Janniche6

1 Ramboll, 2 Technical University of Denmark, 3 HOFOR, 4 Novafos, 5 Capital Region of Denmark, 6 NIRAS

Groundwater resources in Denmark and across Europe are under pressure from pesticides, biocides and their metabolites. Within the last few years, a number of "new" pesticides have been discovered to be ubiquitous in Danish groundwater, in several cases in concentrations above the threshold value of 0.1 µg/L. One example is N,N-dimethylsulfamide (DMS). The existence of *two* mother compounds, tolylfluanid (ToF) and dichlofluanid (DCF), and diverse uses of these as both fungicide and biocide, complicate tracking the origin of DMS in groundwater. Affected water utilities need a decision tool to manage their water abstraction. Regional authorities need to clarify the source type – point sources fall under their legal responsibility, while diffuse sources do not. The overall purpose of this project is to develop such a decision tool, using DMS as a case. The tool should provide predictions of the duration and effect of DMS in groundwater systems for decision support for utilities and regional authorities.

The two water utilities HOFOR (Copenhagen) and Novafos (Northern Zealand), and The Capital Region of Denmark are project partners. A field site has been selected within a groundwater catchment of each water utility. At site A, the most affected drinking water well contains 1.4 µg/L DMS. At site B, the highest DMS concentration is 0.35 µg/L, likewise at an abstraction well. Site A has been investigated.

About 400 m downgradient of the proposed source, DMS is found across a 300 m wide transect. Concentrations exceed 2 µg/L in 20 of 32 water samples, the maximum being 20 µg/L. This indicates a diffuse source, perhaps in combination with a point source. The site history suggests that strawberry cultivation could be the diffuse source.

To elucidate the point source-diffuse source duality, a conceptual site model is built incorporating hydraulic head, DMS concentration and the former location of strawberry fields. Some correlation is seen between observed DMS distribution and the proposed zones of heavy fungicide application: water samples from the sand aquifer upgradient of the most affected field have DMS concentrations <1 µg/L. In contrast, the peak concentration is 27 µg/L 75-125 m downgradient of the field. 250 m downgradient of the field, a low DMS concentration (0.26 µg/L) is seen at the top of the sand aquifer, while DMS concentrations in the remaining sand aquifer are mostly >5 µg/L. This indicates that part of the DMS plume originates from the field, and that the plume gradually dives in the sand aquifer.

It has been suggested that the upper soil and unsaturated zone may act as a long-term reservoir of pesticide metabolites such as DMS, despite their logK_{ow} values suggesting they should be highly mobile. This will be investigated for DMS through sorption- and degradation experiments using sediments obtained from field site A (clay till, sand and limestone).

The conceptual understanding of the two sites in combination with field- and laboratory data can at later stages be used in numerical solute transport modelling in order to simulate the duration and effect of pesticides in groundwater. The results from this project can be applied to other complex contaminations with multiple sources to the same compound. The presentation will include the project aim in brief, current results and conceptual understanding of site A, and general perspectives.

49803 assessment tool for the metal pollution present in soil and groundwater in the belgian campine area

I. Van Keer[1*], N. Desmet[1], J. Bronders[1], N. Smeets[1], P. De Clercq[2]

1 *VITO, Flemish Institute for Technological Research, Boeretang 200,2400 Mol, Belgium*
2 *OVAM, Flemish Waste Agency, Stationsstraat 110, 2800 Mechelen, Belgium*
[*] *Corresponding author E-mail: ilse van keer*

Keywords: Belgian Campine area, Heavy metals legacy, non-ferro industry, evaluation tool

The Campine region, located in the northeastern part of Flanders (Belgium) and the southeastern part of the Netherlands, is polluted with heavy metals due to former activities of non-ferro industry smelters. The observed soil, ground and surface water pollution of mainly zinc and cadmium, has a regional character and covers an area of 700 km^2. Because of the permanent presence of heavy metal contamination in the Campine area it is not always clear to what extent pollution, observed at sites with ongoing economic activities or where a land ownership change took place, are on the one hand the result of the historical legacy of heavy metals in the area or on the other hand caused by on site activities. In the latter case additional soil investigation may be required to identify the need for remedial actions. To evaluate whether additional research on heavy metal contamination observed in high-risk soils located in the area around the (former) Balen-Overpelt smelters have to be carried out, newly measured concentrations are compared through static analysis with the reference situation derived from concentration maps (Van Meirvenne & Tariku, 2009; Bronders et al., 2010) and with available historical measurements (database of the Flemish Waste Agency, OVAM). The current evaluation tool allows for evaluating the metal pollution on arsenic, cadmium, lead and zinc in soil and groundwater

The methodology of the evaluation tool which makes it possible to check for a site whether or not the observed heavy metal contamination is related to historical contamination in the region, includes the following steps:

- Site location check: If the site is not located in the defined area around the smelters, there is no relationship with the historical pollution and the investigation procedures as specified in the Flemish soil decree have to be followed.
- Statistical evaluation of measured soil and groundwater concentrations:
  If the site is located in the considered area, (recently) maximum measured concentrations of heavy metals are compared with existing data from:
  - Reference maps: Comparison of the newly measured concentrations for soil and/or groundwater determined on the plot with the values from the reference maps derived in the vicinity of the plot.
  - Available historical measurements in an annually updated extract from the OVAM database: Comparison of the new soil and/or groundwater concentrations measured in the field with data obtained for sampling locations in the vicinity of the plot.

The result of the evaluation will be helpful not only for the OVAM but also for consultants and landowners who are confronted with historic pollution of heavy metals. The results will avoid additional unnecessary soil investigations or on the contrary, will clearly show where there are reasons to believe that additional contamination occurred for which additional soil investigations,

including an updated risk analysis, is required. The tool is not only applicable for heavy metal pollution, but can be adapted for the evaluation of other regional pollutions as well, provided that sufficient historical, area-covering, data are available. The tool will be demonstrated during an oral presentation.

References

Van Meirvenne M. & Tariku M. (2009) Geostatistical analysis and mapping of cadmium, zinc and lead in the BeNeKempen area (in Dutch). BENEKempen project.

VITO (2010) Additional groundwater study for the wider area around the Balen and Overpelt sites (in Dutch). Report reference 2010/RMA/R/106. BENEKempen project.

50187 SANISOL: a web tool to provide recommendations for users of trace metal contaminated vegetable gardens in Wallonia (southern Belgium)

Benoît Pereira[1], Maud Le Bel[2], Marie Jailler[2], Jean-François Heilier[2], Gilles Colinet[3], Amandine Liénard[4], Jérôme Petit[5], Suzanne Remy[5], Stéphanie Berzigotti[6], Esther Goidts[6], Pol Gosselin[6], Delphine Fontenoy[7], Benjamin Lobet[1], Aubry Vandeuren[1] and Pierre Delmelle[1].

1 : Université catholique de Louvain, Earth and Life Institute, Environnemental Sciences, Louvain-La-Neuve, Belgium 2: SPAQUE SA, Liège, Belgium
University of Liège, Gembloux Agro-Bio Tech, BIOSE Department, Soil-Water-Plant Exchanges, Gembloux, Belgium
4: Analytical Laboratory of Tinlot, Belgium
5: ISSeP, Direction des Risques Chroniques, Cellule Environnement- Santé, Liège, Belgium
6: Service Public de Wallonie, DGO3 – Agriculture, Ressources naturelles et Environnement, Namur, Belgium 7: Espace Environnement ASBL, Rue de Montigny 29, Charleroi, Belgium

Keywords: health risk assessment, vegetable garden, trace metal element, soil-to-plant transfer Wallonia

Vegetable gardening in urban soils increases food security and offers a wide range of social and ecosystem benefits. However, elevated soil trace metal element concentrations in urban and industrial areas may pose a health hazard, limiting the development of urban gardening. Such a situation is encountered in Wallonia (southern Belgium) where the atmospheric deposition of metals from industrial, mining and smelting activities originating from the industrial revolution have increased trace metal topsoil content. To provide appropriate recommendations for users of contaminated vegetable gardens in Wallonia, we developed a web tool, called SANISOL, which is described in this work.

SANISOL provides recommendations concerning (1) the health risks posed by the presence of As, Cd, Cr, Cu, Hg, Mn, Mo, Ni, Pb and Zn in soil and (2) the products that can be cultivated safely in the vegetable garden based on the estimation of the garden product metal content. The recommendations concerning health risks are provided from the results of SANISOL's human exposure and health risks assessment model based on the S-Risk model (Cornelis et al., 2013). Relevant S-Risk parameters were updated, in particular for soil and dust ingestion rates and vegetable consumption. The model estimates the gardener's external intakes from different pathways (ingestion and inhalation) based on the gardener's profile (age, consumption of products and attendance of the vegetable garden) and the garden's pedological properties and soil trace metal contents. If the model predicts that vegetable gardening and the consumption of garden products pose a potential health risk for the gardener, the tool reports information and insights into the sources of the exposure to the trace metals that causes the health risk and provides recommendations to reduce the gardener's exposure. SANISOL's estimation of the garden product metal content is based on a database gathering 1718 pairs of Walloon soil and plant analyses. We use these data, representative of regional conditions, to estimate soil-to-plant transfer models when a linear relationship is found between the soil properties and the plant metal content. When no statistically significant model can be established, trace metal content in garden products is determined based on expert judgement from a graphical examination of the available data. Garden product metal content estimates are provided for the 14 fruits and vegetables for which there are at least 20 paired data in the Walloon soil and plant database. SANISOL indicates if a specific garden product is likely to have trace metal contents higher than a commercially purchased product, or than the maximum level in foodstuffs (for Cd and Pb; EC 1881/2006).

In conclusion, while this work demonstrates that it is possible to develop a tool that provides appropriate and tailored recommendations for gardeners living in areas with high trace metal content in soil, it also highlights the uncertainties and progress that needs to be made to properly manage the human health risks associated with soil trace metals such as As, Cd and Pb.

Cornelis, C., Standaert, A., & Willems, H. (2013). S-Risk-Technical guidance document. Flemish Institute for Technological Research (VITO), Mol, Belgium (Report number 2013/MRG/R/76).

3 Integrated management of contaminated land

3a) Dealing with multiple pathways and scales

Special Session 3aSpS1 Industry perspectives on incorporating sustainability into portfolio-scale management of contaminated land: A panel discussion

Chair: Richard Gill

Proposal for Session Sharing Best Practices

Category:

Free set-up

Contact Person:

Dr Richard Gill

Soil and Groundwater Scientist, Shell Global Solutions B.V.

Title:

Industry perspectives on incorporating sustainability into portfolio-scale management of contaminated land: A panel discussion

Abstract:

This session aims to bring together different professionals (up to 6) from across the contaminated land sector and give them a platform to share their approaches or ambitions towards embedding sustainability within portfolio-level activities with a wider audience. The contributors will be from different corners of the industry. At present, expressions of interest are being sought from the following:

- Oil and gas (confirmed)
- Utilities (confirmed)
- Insurance (confirmed)
- Regulatory (confirmed)
- Civil service
- Nuclear (confirmed)

The take home message for the audience is that there are different methods and approaches to embedding sustainability into portfolio activities and that these approaches add value to the operations of the contributors.

Red Line: Strong connections for Sustainable Use and Management of Soil, Sediment and Water Resources

This session will bring together representatives of the industry to talk through the practical application of existing sustainability frameworks into their operations.

Special Session 3aSpS2 Natural Source Zone Depletion (NSZD): From principles to effective Implementation

Chair: Jonathan Smith

48902 Natural Source Zone Depletion (NSZD): From principles to effective Implementation

Overview: We would like to propose a themed session at AquaConSoil 2021 on the topic of Natural

Source Zone Depletion (NSZD). We have established a small team of leading international experts on NSZD to share latest science, guidance and case studies related to effective implementation of NSZD at hydrocarbon contaminated sites. The material would be presented in a (proposed) 75-minute session consisting of five short presentations (10 + 2 mins) as summarized below followed by 15 minutes plenary discussions. We thank you in advance for your consideration.

Take home messages: We aim to introduce the concepts of risk-based LNAPL management and latest best practice in a European context. We then delve into wider international experience of natural source zone depletion (NSZD) and cover the principles, monitoring and assessment, field depletion rates and case studies.

Contact person: Dr Jonathan Smith, Shell Global Solutions (UK) Ltd

Speaker(s)	Affiliation	Topic
Dr Mike Rivett	GroundH2O Plus, UK	Risk-management at LNAPL sites, the LNAPL Handbook and CL:AIRE guide to NSZD
Dr Sanjay Garg	Shell, USA	Principles of NSZD: Processes, controlling factors and composition change
Dr Charles Newell	GSI Inc, USA	Methods for monitoring and assessing NSZD
Dr George DeVaull	Shell, USA	NSZD rates. Field data analysis of total and constituent NAPL depletion based on recent published method https://doi.org/10.1111/gwmr.12410
Dr Greg Davis	CSIRO, Australia	Implementing NSZD: NSZD vs Active Recovery - Australian Case Studies

Session 3a1 Dealing with multiple pathways and scales

Chair: Domique Guyonnet

50063 Does unplanned water reuse for maize irrigation pose a threat? Ana de Santiago Martín

Ana de Santiago-Martín*[a], Raffaella Meffe[a], Gloria Teijón[a], Virtudes MartínezHernández[a], Isabel López-Heras[a], Leonor Nozal[b], Irene de Bustamante[a&c]

[a] IMDEA Water Institute, Avda Punto Com 2, 28805, Alcalá de Henares, Spain [b] Center of Applied Chemistry and Biotechnology (CQAB). University of Alcalá, A-II km

33,000, 28805, Alcalá de Henares, Spain [c] Geology, Geography and Environment Department, Faculty of Sciences, External

Campus of the University of Alcalá, Ctra. A-II km 33.6, 28871, Alcalá de Henares, Spain

The health risk associated with the unplanned water reuse in agricultural activities is mainly linked to the introduction of undesirable compounds into the food chain, such as contaminants of emerging concern (e.g. pharmaceuticals). After being discharged by wastewater treatment plant (WWTP) effluents, pharmaceuticals can undergo natural attenuation processes that reduce their concentrations or toxicity in water or soil or they can be taken up by crop plants. This research aims to evaluate under real field conditions if natural attenuation processes mitigate the concentration of a set of pharmaceuticals and transformation products (TPs) or if they are taken up by maize (the cereal with the highest worldwide production), inducing a potential risk to human health. Target pharmaceuticals are analgesics, anti-inflammatories, antibiotics, cardiovasculars, lipid regulators, antidiabetics, antiulcer, psychiatric drugs and lifestyle compounds. This research has been carried out in an agricultural parcel located south of the city of Madrid (Spain) irrigated by a gravity-fed surface system supplied by the Jarama river. The river is strongly impacted by WWTP effluents whose contribution to the river flow can locally reach 80%. Campaigns were carried out to collect samples of irrigation water, water infiltrating through the vadose zone at 30 cm soil depth, agricultural soil (before and after the irrigation campaign) and maize differentiating among roots, stem-leaves and fruit. Then, 23 pharmaceutical and TP concentrations were measured using liquid chromatography coupled to a triple quadrupole mass spectrometer, equipped with an electrospray ionization interface, in positive and negative mode. The threshold of toxicological concern approach (TTC) has been used as a first screening for assessing possible risk to human health from maize consumption.

Although the 23 compounds have been detected in irrigation water (from 4.0 to 12,867 ng/L), results demonstrate a high natural attenuation in the soil for most compounds. Average removals are higher than 60%, with the exception of carbamazepine, carbamazepine epoxide and sulfamethoxazole that behave persistently (-28.9, 1.4 and 0.5%, respectively). However, even when removals are high, leaching concentrations can still have some concern in view of contaminant propagation to groundwater, as it is the case of the metamizole TP (average leaching concentration > 400 ng/L). Pharmaceutical contents in the soil are in the order of ng/g and with few exceptions, there are not significant differences between the two sampling campaigns. Concerning uptake by maize, results show that plants are able to bioaccumulate many of the compounds, mainly in the roots. Pharmaceuticals detected in the fruit are all assigned to Class III, a category in which no significant risk is assumed. The only exceptions are ibuprofen that belongs to Class I (low order of oral toxicity), venlafaxine to Class II (intermediate order of oral toxicity), and acetaminophen that is recognized as having potential genotoxicity. Globally, results indicate an insignificant threat to human health since consumption is far above the European daily intake of maize (26.86 g/d). However, in the case of acetaminophen, additional tests are required to check for toxicity.

50071 FROM THE PILOT TO THE FULL-SCALE INTERVENTION: 3D DYNAMIC MODEL GUIDING THE REMEDIATION STRATEGY OF A POLLUTED INDUSTRIAL SITE

Paolo Ciampi[a], Carlo Esposito[a], Ernst Bartsch[b], Eduard J. Alesi[b], Marco Petrangeli Papini[c]

[a] *Department of Earth Science, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185, Rome, Italy.*

[b] *IEG Technologie GmbH, Hohlbachweg 2, D-73344 Gruibingen, Baden-Württemberg, Germany.*

[c] *Department of Chemistry, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185, Rome, Italy.*

Background/Objectives.

Knowledge of the geology and hydrogeology of the polluted site is a crucial prerequisite for environmental remediation, through the assembly and synthesis of contributions from multiple lines of physical evidence. In an increasingly virtual era, digital and geo-referenced archives may serve as tools for handling, combining, linking, and interpreting multi-source data. The goal of this research would be to demonstrate the contribution of the 3D hydrogeochemical model to the refinement of the conceptual site model, to the evaluation of the pollution status evolution, to the design of a suitable remediation strategy, and to the interpretation of the effects arising from multiple remediation actions at a highly contaminated industrial site.

Approach/Activities.

A multi-scale, multi-phase approach was followed to build a 3D hydrogeochemical model that handles and releases data during various remediation stages, from site characterization via pilot testing to full-scale remediation, thus allowing users to monitor, analyze and manipulate information in 3D space. High-resolution hydrochemical reconstruction identifies a large mass of chlorinated solvents associated with fine material lenses, representing a slow-release source of pollutants in the saturated zone. A new strategy for the remediation of secondary sources of dense non-aqueous phase liquid (DNAPL) contamination was therefore evaluated in this study. Coupling groundwater circulation wells (GCW) with a continuous electron donor production system was planned to boost in situ bioremediation (ISB) at the site.

Results/Lessons Learned.

Monitoring and evaluation of the operating conditions at the field scale oriented the design, the configuration, and the implementation of full-scale interventions. 3D solid simulations representing index chemicals as a function of time reveal the ability to evaluate the effect of the applied remediation approach to the progressive abatement of pullutants and the mitigaton of secondary contamination sources still active at the site. The fusion of multi-source and multi-phase pictures can potentially reveal the impact of ongoing hydraulic dynamics and depict the decontamination mechanisms in near real time, quantifying the performance of the adopted interventions.

50988 Leveraging PRISM® to Assess Contaminant Migration Pathways at a Complex Geologic Site, Washington DC

- Ryan C Samuels – AECOM
- Oral presentations (15 min + 5 min of discussion)
- Topic: 4a) Managing pollution in the water-soil-energy-food-nexus

Abstract

Background/Objectives. Sound conceptual site models (CSMs) are essential for developing a comprehensive understanding of natural attenuation processes and preferential groundwater flow pathways at contaminated sites. However, as groundwater remediation projects are commonly challenged by inherent geologic complexity in the subsurface, the development of CSMs and a quantification of the associated uncertainties often yield results that are less accurate than desired. In this study, we leverage PRISM®, an integrated approach that harnesses sequence stratigraphy, facies analysis, and subsurface geophysics, to better understand the subsurface geology and accurately characterize preferential flow pathways within a complex groundwater remediation site.

Approach/Activities. High Resolution Site Characterization (HRSC) tools, including membrane interface probe/hydraulic profiling tool (MIP/HPT) borings and the analysis of grab and monitoring well groundwater data are used to characterize a stable contamination plume. HRSC methods and EVS software are used to build a dynamic 3-D CSM, refine mass flux/discharge estimates, and evaluate contaminant discharge zones through a focused remedial approach, while PRISM® is used to refine the stratigraphy and accurately predict contaminant migration pathways at the site.

Results/Lessons Learned. Correlation of existing MIP/HPT borings and complementary wells logs from the Site reveals a previously undetected Horst and Graben system that induced the development of structurally controlled incised valleys. In light of this high-resolution stratigraphic interpretation, re-examination of the subsurface heterogeneity and impacted groundwater data shows significant structural control on plume concentrations. Contaminants appear to be primarily moving through highly-connected channel bars within grabens, which can be explained by the fact that grabens are flanked on both sides by normal faults (i.e. natural barriers to groundwater flow). Thus, the refined PRISM® CSM helped to better characterize preferential contaminant migration pathways and provide a basis for an optimized remedy design.

- Engaged audience – a short movie depicting the 3-D PRISM® CSM will be used to demonstrate refined understanding of subsurface conditions.

49801 Contaminants of emerging concern reuse of sediment Jonas Rabaey

Jonas Rabaey[1], Karen Van Geert[2], Ruth Cartuyvels[1], Griet Van Gestel[3] and Dirk Dedecker[3]

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2 Arcadis Belgium NV, Markiesstraat 1, Brussels, Belgium
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4 Presenter: Jonas Rabaey or Ruth Cartuyvels

Introduction: In recent years, there has been a growing awareness of the presence of so-called "emerging contaminants" (contaminants of emerging concern or CECs) in the environment and the potential and/or actual risks these chemical components pose on humans and the environment. However, as their properties differ from known contaminants, the existing policy on the reuse of sediments contaminated with these emerging substances is insufficient. Consequently, the need for a sustainable policy on how to deal with sediments contaminated with these emerging substances is growing. In this context, the European Interreg Sullied Sediments project aims to develop knowledge and tools to support watermanagers in their decision-making on the management of contaminated sediments. One of the key elements in this project is the investigation of possible effects of contaminants of emerging concern.

Therefore, the OVAM ("Public Waste Agency of Flanders" and one of the partners of the European Interreg Sullied Sediments project) intends to gain insight into the risks involved in re-use and relocation of contaminated sediments and find out how these risks can be avoided.

Aim: For this purpose, Witteveen+Bos Belgium NV and Arcadis Belgium NV developed a decision system to supplement and update the code of good practice, which describes the methodology applied in Flanders, to support policymakers in their decisions regarding sediment management.

Methods: Through a targeted literature study we identified the key bottlenecks in the development of a decision system (unclear definition of emerging contaminants and the lack of data available for emerging contaminants), detected essential steps in the construction of the decision system (international comparison and determination of the end-point receptors after application of contaminated sediment on land), and learned the practicality of working with substance categories based on data availability to avoid excluding substances with only limited data available.

Next, an international survey was conducted to obtain an overview of existing international target values. This overview supports the bottleneck identified in the targeted literature search that there is only limited data available. Finally, to portray the main characteristics required to determine the reuse possibilities, we identified the key exposure and spreading pathways involved in the application of sediments on land.

Results and discussion: The basic principle of our decision system states: the combination of availability in physicochemical and toxicological data and uncertainty/variability in these data (input) determine the reuse possibilities of the contaminated sediment (output). Thus, the more data available for a specific emerging contaminant and the lower the uncertainty in these data, the more reuse possibilities exist for the contaminated sediment. The actual reuse

scenario depends on the reuse possibilities defined in the decision system on the one hand, and the concentration of the emerging contaminant in the sediment on the other.

The decision system is structured as a tiered approach. The first step is a screening step, in order to make fast decisions regarding very clean and very contaminated sediments without running through the whole decision system in depth. In the second step, the categorization step, the emerging contaminants are assigned to a category ranging from category 1 (high data availability and limited uncertainty in the data resulting in the most reuse possibilities) to 4 (limited data availability and high uncertainty resulting in no reuse possibilities except after treatment).

Given that this categorization depends on data availability and that the knowledge on emerging contaminants is growing rapidly, it is important to note that this is an evolving system where emerging contaminants can switch categories over time when more data becomes available.

Acknowledgment: This project was commissioned by the OVAM as part of the Interreg Sullied Sediments project.

Aim of the presentation: Inform attendees of our approach to create a decision systems that supports water managers in their decisions regarding contaminated sediments.

Take home message: An evolving and tiered system was designed to support decisions regarding contaminated sediment based on availability and variability in physicochemical and toxicological data.

3b) Area-based risk approaches, uncertainties and scales of pollution pathways

Session 3b1 Area-based risk approaches, uncertainties and scales of pollution pathways

Chair: Dietmar Mueller-Grabherr

48739 Evaluation of soil health in response to emerging contaminants exposure Federica Persico

FEDERICA PERSICO1, FREDERIC COULON2 , MELISSA LADYMAN1 & TRACEY TEMPLE1

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Federica Persico is a PhD Researcher at Cranfield University.

This project relates to integrated management of contaminated land; area-based risk approaches, uncertainties and scale of pollution pathways topic of AquaConSoil.

This presentation will explain the relationship between Emerging Contaminants (ECs) and soil which involves a complex scheme that requires a better understanding of the connection between the contaminant and the matrix. From the source of the contamination to the receptor, several chemical reactions are happening which can be altered by a change in chemical or physical properties by both the soil and the contaminant. These processes can be influenced by the land usage that can modify different soil characteristics making it more susceptible to different external input. The importance of understanding this relationship in the soil has a great value since, generally, studies focus their effort on understanding toxicity to humans derived from this type of contamination, overlooking different environmental impact. Event tough, soil provide multiple importance functions, is the most overlooked matrix due to undirect link between the soil and human toxicity.

The interest in soil evaluations has been previously focused on the soil productivity rather than the soil itself making most assessments directed on crop productions and farm activities. Soil investigations are dependent from the soil purpose, and evaluation techniques are chosen differently as the site suitability changes meaning that soil investigations should be carried out also thinking about future purposes and uses of the land. To understand the consequences of different contaminants in the environment, studies developed Soil Quality indexes and Soil Health evaluations to determine the effects of new contaminants on the soil environment. Although, these studies have been limited to known contaminants, leaving a big gap in soil health evaluations related to ECs exposure. Therefore, the aim of this project is to develop a new soil health evaluation, to understand the consequences of ECs in the soil environment. Results from this project will help to inform environmental risk assessment evaluations to protect the terrestrial ecosystem.

During the presentation consequences of ECs on soil will be explored. Specifically, Insensitive High Explosive (IHE), pesticides and Perfluorooctanesulfonic acid [PFOS] presence and consequences will be analysed into different soils using a new develop soil health evaluation. The audience will understand the importance of soil evaluations and how this will help to understand and predict future consequences of these contaminants in the environment. Understanding that every aspect of our ecosystem in related and that by looking into a single problem a wider solution can be found.

49670 To remediate or not: ecosystem responses in a heavy-metal contaminated natural area

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Scientific research.

Main message of the presentation: A substantial part of legacy contaminated sites are natural or semi-natural areas, with existing vegetation covers and little human exposure. Questions have emerged about the actual disturbance of soil functions at polluted sites, which is linked to the urge to remediate or not. In this presentation methods are presented which can be linked to functional ecosystem responses (nutrient cycling) and may be used for such evaluation. We present a case study on a lead-polluted shooting range and answer the question: To remediate or not?

Aim: Present research on methodology to evaluate ecosystem responses of polluted natural areas. Take-home message: We should look beyond soil reference values, also for ecological risks. The need for remediation of natural sites is site-dependent.

Abstract

Introduction: A substantial part of legacy contaminated sites are natural or semi-natural areas, with existing vegetation covers and little human exposure. Questions have emerged about the actual disturbance of soil functions at polluted sites, which is linked to the urge to remediate or not. Heavy metals may pose risks to one of the most important functions of soil: microbial nutrient cycling. The microbial degradation and transformation of complex organic material (e.g. litter, dead plants) towards smaller inorganic compounds and nutrients that can be taken up by plants, is a crucial soil process that determines soil fertility and productivity of terrestrial ecosystems. Few field studies, however, have assessed systematic ecological changes in polluted soils, where conditions are very different from lab studies.

Methods: As microorganisms break down organic compounds, CO_2 is respired ("soil respiration"). This parameter is the most direct way to assess whether this soil function is impaired. To enable field studies of soil respiration *in situ*, we add cane sugar (naturally isotopic labelled) to bypass root interference and stimulate microbial activity. C and N content and the natural isotopic abundance of ^{13}C and ^{15}N in plant, soil and microbial biomass is deployed to complement the microbial activity study, and provide a more time-integrated response on the nutrient cycling function of the soil.
Results: In a Pb-polluted grassland, a decreased microbial decomposition in high Pb polluted plots was suggested by a lower substrate-induced respiration of the cane sugar in the field. However, other results indicated this was rather by indirect effects than by direct toxic effects to the microbial community, indicating adaption. Furthermore, from the combined results of soil, plant and microbial biomass C, $\delta^{13}C$, N and $\delta^{15}N$, we could draw conclusions about disturbance of soil N cycling, as well as nutrient- and/or water stress to plants. Results from other field sites and semi-field-studies are currently under evaluation, and indicate that some of the responses show similarities among sites, while other responses are site-specific.

Conclusion: We show that a combination of functional microbial, plant and soil parameters, and the aid of stable isotope techniques, may help to detect changes in ecosystem functions in polluted sites and semi-field studies. Our research shows that, even though a polluted site is well vegetated, hidden changes in ecosystem functions can be detected. Pb slowed down the C and N cycles at the Pb-polluted shooting range, but possibly by indirect effects rather than by direct toxicity. The ecosystem seems to have adapted to altered conditions.

49946 Detailed Assessment of Risks to Human Health from Arsenic at a former Colliery and Coking Works Site Simon Hay

4. Integrated management of contaminated land: 4c. Upgrading contaminated and degraded land

Simon Hay[1], Laura Garland[1], Joseph White[1], Neil Thurston[1], Annie Vergette-Hollingworth[1] and Katy Baker[1]

[1] Arcadis UK

For certain human health exposure pathways, such as direct contact with soils and dust, evaluating the risks presented by contaminants at a site specific level can be challenging. This is as a result of limited potential for modification to model input parameters, for example frequency of soil ingested and quantity of soil ingested. The default parameters used in many countries are based on national or international studies associated with behaviour patterns at population level. While modifications to default exposure parameters can be difficult to justify, there is potential to collect empirical data to support better understanding of the bioavailability of contaminants in the soil. Further, for multireceptor land contamination sites, such as residential housing estates, the careful use of statistical testing can support decision-making regarding potential risks to human health which is targeted but protective.

A case study will be presented for a former colliery and coking works site in the UK, now redeveloped as residential properties. Through the process of quantitative risk assessment, a potential risk to human health from arsenic in soils was identified. One pathway of key concern was the direct contact exposure via ingestion of the contaminants. Site-specific criteria testing was undertaken on soil samples, leading to the development of relative bioavailability values for arsenic which compared favourably with those identified in literature. The relative bioavailability criteria were used to calculate revised soil screening levels for both contaminants.

The revised soil screening levels were subsequently adopted for the purpose of statistical evaluation. This comprised a detailed review of the site conceptual site model, to enable the derivation of statistical zones. Zoning of the site was a complex and iterative process, with the final zoning defined based on a review of vertical and lateral contaminant distribution, soil type, historical land use, topography, visual and olfactory indicators of contamination amongst other parameters. While a number of samples were collected from each garden, statistical analysis over larger averaging areas allowed for greater confidence in decision making.

The methodology employed and the results of the bioaccessiblity testing and statistical analysis will be shared from the case study to demonstrate how this impacted upon decision-making at the site.

48614 Study on the sorption of Oxygenated Polycyclic Aromatic Compounds onto soil: towards a better human health risk-oriented remediation of PAH-contaminated sites

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A lot of PAH-contaminated sites can be identified in industrialized countries. Remediation of this kind of contamination is relatively well known. When the objectives of the remediation are achieved, it is considered that the site will no longer trigger a risk for human health. Groundwater quality is often monitored after the remediation and the 16 US EPA PAHs are measured. However, it has been documented that other polycyclic aromatic compounds (PACs) could be formed during and after the application of some remediation techniques on PAH-contaminated sites, particularly oxygenated polycyclic aromatic compounds (O-PACs)[1,2]. These emerging contaminants are of particularly high concern because they are toxic, persistent and mobile in soils. Previous studies done by Ineris proved that the presence of O-PACs in groundwater could trigger a risk for human health. Nevertheless, in contrast to the 16 US EPA PAHs and due to the lack of regulations and data regarding their behavior in soils, O-PACs are not taken into account on these sites. The first step towards a better consideration of O-PACs at PAH-contaminated sites is a better understanding of their behavior in soils since data are scarce in literature. **The aim of this study is to assess O-PAC migration in groundwater in order to know if they could form large contamination plumes and therefore trigger a risk for sensitive targets such as human beings and drinking water wells.**

Two PAH/O-PAC couples were chosen for this study: fluorene/fluorenone (FLU/FLUone) and acenaphthene/dibenzofuran (ACE/DBFUR). Sorption isotherms onto a non-contaminated soil were individually determined using controlled batch experiments for all four compounds. Effects of ionic strength and liquid to solid ratio (L/S) on the sorption of FLU and FLUone were investigated through controlled batch experiments. Then, their migration in soils was assessed by means of column experiments in order to obtain their breakthrough curves. Stop and flow experiments were as well carried out in order to further evaluate mechanisms responsible for O-PAC retention/release in soils.

For all studied compounds and in all experimental conditions, linear sorption models best fit the isotherm data. Results revealed that ACE and DBFUR were similarly adsorbed onto the soil (K_{oc} = 1184 and 1153 L/kg, respectively). In the same experimental conditions, K_{oc} of FLU (1931 L/kg) was higher than that of FLUone (1355 L/kg), showing a smaller affinity of FLUone towards the solid phase. Furthermore, decreasing the L/S ratio from 100 L/kg to 50 and 30 L/kg, increased the sorption of FLUone onto the soil by 64 and 77% respectively, while the sorption of FLU was slightly increased by 13 and 31% respectively. Moreover, increasing the ionic strength of the aqueous phase by a

[6] Lundstedt, S., White, P.A., Lemieux, C.L., Lynes, K.D., Lambert, I.B., Öberg, L., Haglund, P. and Tysklind, M. "Sources, Fate, and Toxic
Hazards of Oxygenated Polycyclic Aromatic Hydrocarbons (PAH) at PAH- contaminated Sites". AMBIO: A Journal of the Human Environment 36 (2007): 475–485

[7] Ramdahl T. "Polycyclic aromatic ketones in environmental samples". Environmental Science and Technology 17 (1983): 666–670.

factor of 6 favored the sorption of FLUone by 62% while the sorption of FLU slightly decreased by 13%. Flow interruptions during column experiments showed a sharp decrease in PAH concentrations at the outlet of the column after the stopped-flow event whereas O-PAC concentrations were significantly higher. The difference in PAH and O-PAC behavior during all these experiments suggested that mechanisms responsible for OPAC fate and transport in soils could be different than the ones responsible for PAH retention in soils and could be governed by surface processes such as adsorption onto soil particles.

Take home message: These results provided meaningful first information regarding O-PAC behavior in soils: highly soluble O-PACs such as FLUone could easily migrate in groundwater, form larger contamination plumes than PAHs and reach drinking water wells. Therefore, remediation and monitoring of PAH-contaminated sites should consider these emerging compounds. Further studies are in progress at different scales (lab and field scales) in order to better understand the migration potential of O-PACs.

3c) Upgrading contaminated and degraded land

Special Session 3cSpS1 PFAS – Best practices on the interface between soil/sediments and excavated materials which are becoming waste

Chair: Joerg Frauenstein

Hosts: Common Forum: Joerg Frauenstein, Dietmar Müller-Grabherr; SedNet: Carmen Casado

Objective

Remaining residual PFAS in soils and sediments is a serious problem for the circular economy within the countries!

It massively hinders the reuse of these soils and sediments. The session wants to focus on solutions and best practice examples based on a status description in Common Forum (CF) member states and try to provide a communicative format in order to exchange on existing regulations, bottlenecks and practical solutions. Based on initial briefings, approaches will be presented that are already working or are currently being worked on. The session is intended to address regulators, public servants and consultants who are confronted with these problems on a daily basis.

Problem outline

Due to the wide range of uses, PFAS are released by a broad variety of sources and pathways into the environment.Due to their physical-chemical properties they hardly can be eliminated suitably, and also any mitigation measures might be extremely costly.

For contaminated excavated soils and sediments, interfaces with waste legislation are crucially relevant. The regulations of a circular economy in Europe are consistently geared to the goal of avoiding waste or keeping waste for within material cycles. In this context the existing capacities of landfills in Europe are systematically decreasing. At the time being it seems unlikely that PFAS-contaminated soils can be cleaned to an extent, which may allow for reuses and without a recycling option, the mass flow balance will worsen and increase in future. Moreover, without reliable set of trigger or limit values for excavated materials and sediments, we have to expect a growing uncertainty for landfill operators and a decreasing acceptance to landfill PFAScontaminated materials.

Planned session schedule:

Memorandum COMMON FORUM „Comprehensive challenges in Contaminated Land Management“, Dietmar Müller-Grabherr SedNet

position on PFAS, Carmen Casado Statements:

- Overview about the situation in Europe, Joerg Frauenstein The
- Dutch way handling excavated soils and sediments, n.n.
- Best practices from OVAM, n.n.
- Beside European regulation – a British solution?

Open discussion (15 min)

Panel discussion (EU, NL, Flanders, N, UK….) 30 min

The session will be designed in proactive way to provide sufficient space for discussion and exchange and to help outline new solution concepts.

Special Session 3cSpS2 Inspiration from Dutch soil by Lean Start-Up

Chair: Martin Doeswijk

Introduction

Over the last 40 years a huge remediation operation has taken place in the Netherlands. Thousands of sites have been thoroughly investigated and remediated. During this operation much research and methods of research have been carried out and much practical knowledge has been gained. The efforts and input of engineering and consultancy companies have been of crucial importance during this operation. They have supported the owners of contaminated sites and the governing authorities by executing the required investigation and remediation activities.

Six experienced Dutch soil experts, with roots in the previous millennium and with different backgrounds, offer their knowledge for a brainstorm session on the solution for a complex foreign contaminated site (brownfield).

Method

Submission of a case site

Participants from countries outside The Netherlands are invited to bring forward their case of a contaminated site. We are looking for a site for which the preparation of remediation is complex due to a variety of reasons: for instance the type of substances and extend of the contamination, the concentration levels, the location of the site in the vicinity of residential areas or other sensitive areas, etcetera. Due to the complexity it is hard to decide how to proceed in the process. An innovative approach may support the responsible organization to make a step forward.

Selection and preparation

After receival of a brief case description (1 page note) we will contact the submitting organization in order to exchange information. This will include analysis of relevant reports of the site and a preparatory video-call. This video-call will be attended by experts of our companies. In this call further questioning and answering will lead to a clear picture of the present situation.

In case we receive proposals for more than one site we will select one case. For the other cases we will consider in which way support can be provided, maybe during a second event or as follow-up of AquaConSoil.

Brainstorm during event using the Lean Start-Up Method

The Lean Start-up Method is a way of creating new products and innovations quickly and efficiently. Working like a Lean Start-up saves time and money and enables creating a product or service the customer will actually benefit from. The key points of the method are to build, measure and learn. Instead of spending months writing extensive plans and doing research, participants start to experiment to test their hypotheses. They build a simple prototype and immediately check the prototype with the customer (measure). The feedback of the customer helps to further develop the product (learn). The Lean Start-up method uses a bottom up approach. Employees are in charge, from the ideas to the execution. Their skills are fully utilized. This way, they are more involved in the entire process of innovation.

Structure of the event in the week of 14-18th June

- Opening of the session by the host: explanation of the procedures during the 75 minute session
- Brief presentation of the site situation by the submitting organization (client)
- Summarizing the information in a Conceptual Site Model by the 6 experts (visualized)
- Summarizing the 3-4 major issues which are relevant for a breakthrough, by the host
- Suggestions by the 6 experts for remediation and further preparational investigations
- Adding to the provided suggestions by other guests
- Brief evaluation of the provided suggestions by the client
- Closure of the session by the host

Aftercare

After 3 months the expert group will have a videocall with the client to discuss the progress of the preparation. Did the provided suggestion lead to a breakthrough? If not, which of the previous suggestions may be considered for further application? The progress of the project and implementation of the provided suggestions may be presented for a live audience at AquaConSoil 2022.

Contactperson

On behalf of *NLingenieurs expertnetwerk bodem en ondergrond*, Willem Hendriks, chairman

Session 3c1 Upgrading polluted sites: tackling sites with emergent & conventional contaminants (PFAS, Hg and As)

Chair: Rob Sweeney

49270 Testing PFAS Immobilization

Thomas Bierbaum, Norbert Klaas, Claus Haslauer, Jürgen Braun

Universität Stuttgart, IWS/VEGAS, Stuttgart/Deutschland

Frank Thomas Lange, Gudrun Nürenberg, Marco Scheurer

TZW: DVGW-Technologiezentrum Wasser, Karlsruhe/Deutschland

In the region Rastatt/Baden-Baden in the Upper Rhine Valley, Germany, approximately 1000 ha of predominantly agricultural land has been contaminated with per- and polyfluoroalkyl substances (PFASs) about one decade ago when paper-fiber biosolids mixed with compost was applied. These substances affect various land uses (agriculture, open pit gravel quarries, and urban planning) and the underlying aquifer as the main drinking water resource for surrounding cities and municipalities.

Remediation attempts have been limited to date, particularly due to the large spatial extent of the contamination and the related high costs. One strategy currently being investigated is to immobilize the PFASs in the soil in-situ. Substances with a high sorption capacity would be applied on the ground surface and mixed with the soil. The then altered soil should still fulfill its original purpose (e.g., for agriculture). Another strategy could be to remove the contaminated soil and use it for construction (e.g., noise protection embankment) after treatment with the immobilization agents.

The purpose of this research is to develop a test strategy to evaluate the long-term leaching characteristics of soil treated with substances to increase its sorption capacity. Treated soil is tested on three different scales (batch, column and lysimeter experiments) and under different saturation conditions (saturated and variably saturated). Effluent concentrations are monitored over time with different analytical methods (target analysis, determination of sum parameters (EOF/AOF) and total oxidizable precursor (TOP) assay). Mathematical models are employed to evaluate the appropriateness of various processes (e.g. equilibrium sorption) and the leaching behavior for time scales larger than possible in laboratory experiments.

A special challenge for both the analytical strategy and the numerical modeling poses the fact that PFASs consist of more than 4700 compounds (according to OECD), from which currently only about 20 usually are quantified in routine analysis. A number of these analytical targets are breakdown products, derived from larger precursors, which makes the source term undefined.

The current data illustrate significant reductions in PFAS desorption rates in some of the treated soils. In saturated column experiments, effluent concentrations in treated soils are lowered by a factor of up to 1000 compared to the (untreated) control material, the total desorbed PFAS mass being less than 4% of that desorbed from untreated material. In the variably saturated lysimeter experiments, after an initial significant decrease effluent concentrations start increasing, which could indicate additional processes (source term).

The presentation focuses on the illustration of PFAS desorption characteristics in the differently treated soils, on the discussion of the PFAS increase in the lysimeter experiments and on perspectives to future research needs related to long-term PFAS immobilization.

49810 TCH removes PFAS from soil – but where does it go? Removal and fate of PFAS during thermal soil remediation

Presenter: Søren Eriksen, Krüger A/S, Søborg, Denmark,

Introduction

Current technologies available for PFAS remediation are limited to stabilization in situ or excavation followed by incineration or land filling – on site or elsewhere. Since the long term results of in situ stabilization are still to be seen and incineration is extremely costly most PFAS impacted soil has been landfilled. Recent restrictions on moving and land filling PFAS contaminated soil threatens the redevellopment of PFAS impacted land e.g. former air ports, since the comtamnated areas need to be remediated, but there is nowhere to take the contaminated soil.
Thermal conductive heating remediation offers an on site alternative approach that achieves removal and destruction of the PFAS contaminants from the soil at a fraction of the energy consumption of incinerating the soil.

Back ground

PFAS compounds have low vapor pressures making them less obvious candidates for thermal desorption methods, however thermal decomposition is feasible[1].

Data and Discussion

Thermal remediation of soil containing 195 mg/kg mixed PFAS compounds have been tested in laboratory scale. 200 g samples were heated to 250-500°C for 8 days. Soil samples as well as condensate and volatiles collected on sorbent tube were analyzed for total organic fluorine, total extractable organic fluorine total fluorine as well as 30 PFAS with and without TOP assay. Volatile PFAS compounds and decomposition products have been analyzed by mass spectrometry.
Heat treatment simulating thermal conductive heating remediation reduces the PFAS concentrations by 99.998 % at treatment temperatures of 350°C or higher. The soil heat treated at 350°C contains traces of PFOS (6-13 µg/kg) whereas all other PFAS compounds are below the detection limit of 5 µg/kg.
The total organic fluorine concentration of the soil is reduced by 100 mg/kg corresponding to the removal of all PFAS compounds thus indicating that the fluorinated material is removed from the soil rather than converted into other fluorine compounds not analyzed for. The PFAS compounds recovered in condensates and sorbent tubes are short chain PFCAs precursors and account for merely 0.5% of the original PFAS content of the contaminated soil samples. The absence of PFSAs and longer chain PFCAs lead to the conclusion that the remaining PFAS has been thermally decomposed.
Mass spectrometry of outgassing vapors has identified precursors of PFBA and PFPA as well as numerous per fluorinated degradation products using the SRI-MS technique.

Conclusion

PFAS compounds and their precursors are efficiently removed from soil by heating to 350 °C making thermal conductive soil remediation, on site (in pile) or in situ (vadose zone only) applicable. The evaporated thermal decomposition products and short chain PFCA precursors are suitable for adsorption on activated carbon filters.

The results suggest that TCH is a viable solution for negotiating PFAS impacted soil whether already stock piled or yet to be remediated to proceed brown field redevelopment.

References 1 Krusic P. J. et al. (2005). Journal of Fluorine Chemistry 126, p. 1510–1516

50247 Remediation of persistent arsenic groundwater contamination in a fractured rock aquifer in a coastal area by using IEG-GCW® Groundwater Circulation

M. Petrangeli Papini*, G. Rehner **, P. Ciampi*, E.J. Alesi**, E. Bartsch**, M. Pellegrini***, S. Olivieri***, F. Bonfanti***, G. Liali***

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** IEG Tachnologie GmbH

*** Eni Rewind

Background/Objectives.
On an inactive industrial site close bordering on the adriatic sea, a groundwater contamination with arsenic, as a consequence of a major incident in a fertilizer manufacturing facility, continues to represent a significant environmental problem even almost 45 years after the event. Apparently, the arsenic fall-out after a major explosion has in part been transported vertically into the fractured rock formation of the acquifer where the deposits continue to act as an active secondary source contaminating the groundwater. Traditional pump and treat technology has been applied over many years in order to manage and reduce the impact of this contamination outside of the site boundaries, but significant mass of As is still trapped in the fractured aquifer contaminating groundwater until 40 meters below ground surface.

Approach/Activities.
Groundwater Circulation Well (GCW) technology has been considered as a feasible approach to significantly enhance As mobilization in the identified source area. The GCW technology provides for the recirculation of water by the extraction and reinjection in the same aquifer through different screens made in the same well. The creation of vertical hydraulic gradients induces the formation of circulation cells that potentially allow the mobilization of contaminants trapped in areas of the aquifer that cannot be reached by traditional horizontal pumping systems. The possibility of using different extraction and reinjection couplings between the different well screens, potentially allows to increase the effectiveness of the contaminant removal. A pilot plant (the first of this type) consisting of a 40 meters deep IEG-GCW®, equipped with 4 screens at different depths and equipped with a treatment system for the removal of dissolved As by oxidation and filtration on Macrolite (Enki), has been installed and started in the source area during the health emergency period (September 2020). The first months of operations have clearly demonstrated the hydraulic effectiveness of the IEG-GCW® in a fractured rock aquifer (pumping rate around 2.5 m^3/h and ROI around 15 meters) but also the capability to increase pollutant mobilization significantly compared to the traditional pumping wells. It has also been possible to confirm the hypothesis that, with a properly designed groundwater circulation well, upconing of the coastal saltwater present at 45 m bgl can be controlled and even reverted.

Results/Lessons Learned.
The encouraging results from the first months of operations offer a perspective of a more sustainable remediation approach through appropriate source remediation with respect to traditional P&T system for the As removal in a deep fractured aquifer. This should reduce the time horizon for future remediation efforts and effectively cancelling the huge consumption of sweet water resource currently employed in the damage control process. The Pilot test is still ongoing and will generate general design parameters for the remediation plan for industrial sites in coastal areas with fractured rock aquifers.

49933 Progress in the management and securing of mercury-polluted sites

Communication title: Progress in the management and securing of mercury-polluted sites

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Company : SUEZ Remediation

Summary :

Mercury is a toxic metal widely used in the chemical, mining, and metrology industries in the past. The ancient sites of chlorine chemistry used it in the electrolysis of salt.

Elemental mercury is liquid under current conditions, and poses health problems, mainly through inhalation of vapors and by ingestion.

The spatial dispersion of mercury (horizontal and deep in the soil) occurs mainly by volatilization recondensation of mercury vapors, favored by atmospheric pressure gradients and by temperature differences between day and night.

To stabilize the mercury in the long term in a stable form under pH ranges and wide redox conditions, SUEZ has developed a solution for the dry sulphidation of elemental mercury, making it possible to create sulphides of the metacinabrous HgS type.

Applied on the emitting sites, this method makes it possible to secure the transport of mercury-containing soils to the treatment centers. This also makes it possible to accept for treatment by stabilization in the hazardous waste landfills, soils with contents up to 1% of total mercury.

On the sites, it also opens up the possibility of stabilizing the less impacted mercury soils on site, and proposes management measures for capturing mercury vapors from the soil by active cappings.

These multi-technical solutions therefore offer a whole range of treatment allowing global management of sites contaminated with mercury.

Session 3c2 Upgrading polluted sites: tackling sites with complex mixtures and conventional contaminants (HM, TPH, PAHs, Mineral oil)

Chair: Marc Viñas

49672 Planning for flexibility: a case study in creating robust remediation designs that can handle the realities onsite

Jack Shore , Gareth Leonard - REGENESIS, UK

Background

A commercial property sited on a historic former timber yard was impacted with high levels of petroleum hydrocarbons and a mixture of pentachlorophenol, trimethyl tin and pesticides (lindane, dieldrin and aldrin, plus others) thought to be a result of the timber yards industrial practices. The property owner wished to remediate the site before divestment. An integrated remediation strategy was created comprising excavation of the impacted vadose zone soils, in situ chemical oxidation (ISCO) to target high levels of contamination and in situ sorption and enhanced biological degradation through the injection of colloidal activated carbon and an oxygen release compound, to achieve low groundwater concentrations. Once on-site, it was discovered that conditions differed from that identified in the site investigation, due to the location of site services, more heterogeneous geology and lower permeability threatening the ability to apply the necessary in situ substrates. The remediation team responded rapidly and effectively to better understand the site and change the remedial approach to ensure success within the project programme and cost.

Aim

The aim of the presentation is to describe the planned remedial approach, and the challenges overcome onsite. Activities undertaken included: flux zone identification, injection testing, alternating use of ISCO agents, targeted deployment of enhanced natural attenuation and tailored dosage of colloidal activated carbon. Site activities will also be presented. Full validation results will be presented, differentiated to show each treatment approach and its effect on the individual contaminants in this complex mixed plume.

Conclusion

This presentation will be of interest to regulators, problem owners and contaminated land practitioners in understanding what approaches can be used to target complex contaminant mixtures and how robust remediation strategies can be devised to allow adaptions to real-world site conditions.

49814 From site closure to a clean platform ready for redevelopment: the successful and sustainable remediation of a large industrial site in eastern France

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RAMBOLL France, °REMEA

The whole process of the 7-year remediation of a large chemical site in eastern France will be presented. They comprise the cleaning and demolition of superstructures (100,000 tons) and infrastructures (40,000 t), the recycling of concrete for reuse on site (95%), the excavation of soils (173,000 m3) with more than 70% being performed under large confinement tents to avoid any nuisances to neighbourhood in order to remove the 80,000 m3 of impacted soils, their onsite treatment on an industrial-scale soil washing unit allowing a 93% reuse as backfill of cleaned materials from 30 cm gravels to 0.1 mm sands and the 100% recycling of washing waters.

2 years of extensive lab and pilot studies were required to define the final design for the soil washing and wastewater treatment (poster Aquaconsoil 2017) allowing the implementation at full-scale for 2,5 years of the treatment train during the remediation works(poster Aquaconsoil 2019).

Focus will be made on the successful achievements in terms of contaminant mass removal, recycling and reuse of materials, water savings and general reduction of environmental impacts.

49610 Bio-engineering solutions as catalyst for redevelopment of impacted sites Rogier de Waele

Rogier De Waele, Michela De Camillis, Martin Slooijer, GreenSoil Group

The intention of the present abstract is to highlight show cases where bioengineering and total remediation contracting has unlocked redevelopment issues at (brownfield sites). Often, due to conflicting interests, projects lie in a stand still situation. Identifying and disclosing conflict of interests, by finding an overall solution to best overcome the impasse, becomes of primary importance.

1) Bioengineering as solution for conflicting site clean-up and windmill constructions.

On a former telecommunication site two source zones with TCA and PCE contamination were present to a depth of 21 m-bgl. A groundwater plume contamination of about 400 m was formed.

The implementation in the field was complex due to the presence of multiple stakeholders on the site and the construction of a windmill on top of one of the source areas.

The remediation approach consisted of excavation of the two source zones followed by an enhanced anaerobic biological in-situ remediation (integrated with the foundation of a windmill). Various biobarriers were installed to remediate the plume and avoid off-site migration of groundwater contamination.

A decreasing trend of the contamination products is ongoing, and the active phase of the remediation is going to be completed within 2 years form the beginning of the project.

2) Biological site solution unlocks development potential of cVOC impacted site for client and new owner.

Due to historical manufacturing activities, soil and groundwater at this former industrial brownfield site are contaminated with chlorinated volatile organic compounds (cVOC).

GreenSoil proposed implemented an alternative remediation technique by combining excavation of the hot spots and in-situ by enhancing bioremediation. The project's aim is a full-scale cVOC remediation to enable redevelopment of the site by achieving the risk-based target values and achieving a 90% contaminant mass removal. All of this was proposed as a lump sum contract.

Full anaerobic degradation is taking place; this is clear from the trend towards final degradation products. The biological remediation is advancing as planned and targets will be achieved on time.

3) Total (bio)remediation contracting unchains blocked brownfield site.

Former industrial activities of an international automotive company resulted in a significant impact of soil and groundwater with different contaminants (e.g. cVOC, mineral oil and heavy metals). The new owner had major concerns about the use of the site, therefore a tender was open to present plan of approaches to prepare the site to redevelopment after long time of deadlock situation. To get out of the impasse, GreenSoil offered to take over all liabilities regarding the contaminants and was awarded a lump sum contract for demolition and remediation works. The remediation included excavation and offsite cleaning of the source areas. Subsequently, an in-situ recirculation remediation system was installed which considered the construction of a new building on top of the installation.
The remediation operation is going according to plan and will be completed within two years after installation of the in-situ system.

49947 Substrate enhanced sorption of Pintsch gas tar PAHs in microcosms Alex Hockin

Authors: Alexandra E. Hockin[1,2,3*], Johan A. van Leeuwen[1,2], Jan Gerritse[2], Niels Hartog[1,3], S. Majid Hassanizadeh[1]

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Tar DNAPL (dense non-aqueous phase liquid) source zones result in long-lasting contamination of groundwater worldwide, for which effective source bioremediation approaches are complex. To evaluate the potential and controlling factors for enhanced bioremediation of tar DNAPL source zones, microcosm experiments were conducted, over a period of four years. Microcosms contained sediments contaminated with a complex tar mixture originating from a former manufactured gas plant, with mono- and polycyclic aromatic hydrocarbons (MAHs, PAHs) and soot-like material (also known as carbon black or lampblack).

Experiments were conducted with several treatments (addition of nitrate, nitrate plus succinate, nitrate plus acetate, sulfate or chlorate), in addition to unstimulated and sterile control microcosms. After four years of incubation at 20°C in the dark, one replicate of the microcosms was extracted with acetone to obtain mass balances of MAH and PAHs. Microcosms with nitrate and a substrate (acetate or succinate) were found to have lower measured PAHs than other treatments. However, no loss of nitrate could be attributed to the loss of PAHs. Furthermore, there was no appreciable chlorate or sulfate reduction in the chlorate and sulfate microcosms, respectively. Methanogenesis was also insufficient to explain PAH degradation in the microcosms. Therefore, we propose that the added substrate could have resulted in enhanced mobilization of PAHs from the DNAPL. Subsequent sequestration of PAHs from the DNAPL to the soot particles could have resulted in lower measured PAHs in the microcosms, as a fraction of the total PAHs in the soot could not be extracted. The addition of organic acids to contaminated soils has been shown to enhance desorption and dissolution of PAHs and other persistent organic contaminants. In addition, tar in the nitrate/substrate microcosms appeared more diffuse than in the other treatments.

The strong sorption of PAHs to soot is well documented in the literature and is known to be orders of magnitude stronger than sorption to, for example, natural organic carbon (K_{oc} 6.6-9.3 for 3-5 ring PAHs). Moreover, soot is highly porous (see Figure 1), and PAHs entrapped in the small pores of soot particles are extremely difficult to extract. The use of acetone, while a compatible solvent, was not optimal. This is because acetone did not have sufficient extraction time, its access to the very small soot pores was hampered and, being an aliphatic solvent, it is not likely to have efficiently displaced the aromatic PAHs in question. Sorption of PAHs to soot is a key process controlling the fate of PAHs in sooty, multi-component DNAPL. Therefore, to effectively remediate these sites, we must have a solid understanding of how remediation methods, including the addition of substrate to stimulate biodegradation, can also affect sorption processes *in situ*.

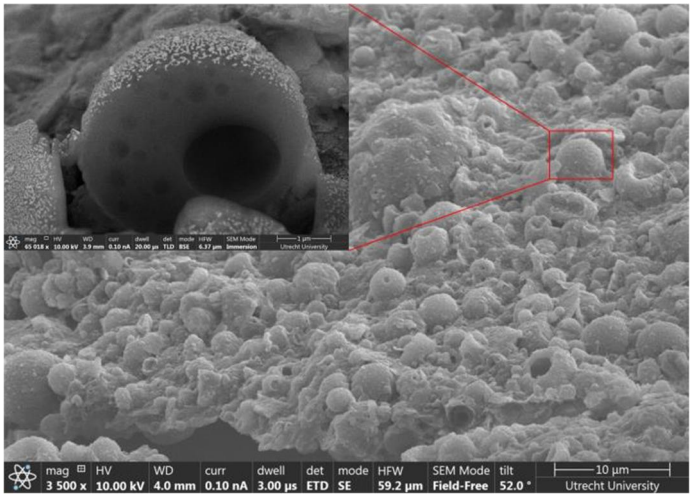

Figure 1 SEM image of agglomerated soot particles extracted from contaminated sediment, with cross section of soot particle showing porous nature. SEM: Helios Nanolab G3-UC focused ion beam scanning electron microscope (FIB-SEM) vacuum chamber (Thermo Fisher Scientific, Landsmeer, Netherlands).

Session 3c3 Upgrading polluted sites: tackling sites contaminated with pesticides

Chair: Ilse van Keer

48980 Directional Groundwater Recirculation Combined with Oxidative Biodegradation for the Remediation of Groundwater Contamination with Benzothiazoles and Biocides

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Background/Objectives At the site of an agricultural production facility a groundwater contamination with benzothiazoles and biocides is encountered, with concentrations up to 50 ppm – 100 ppm in the source area. The contaminant plume has a length of more 400 m and migrated up to depth of 35 m-bgl. The local geology consists of glauconitic (iron) fine sands, divided in two separated aquifers. The large extent of the contamination, the complex hydrogeology (e.g. tidal influences) and the highly recalcitrant character of these contaminants, make the search for a cost-efficient remediation challenging.

Approach/Activities For the remediation of the groundwater pollution in situ biostimulation was selected, in combination with a groundwater recirculation system in order to deliver the reagents effectively over the large contaminant plume.

As a first step in the evaluation of the feasibility of biostimulation, batch lab tests were executed to investigate if the compounds of interest could be degraded under sulphate reducing conditions. These labtests reveals that biodegradation did occur, but not all present contaminants could be degraded under sulphate reducing conditions, representing less than 50% of the contaminant mass. Based on the results of these tests it has been concluded to further evaluate the applicability of nitrate or oxygen as electron acceptor for the microbial degradation of the contaminants of interests. Also the applicability of the groundwater recirculation system under ‘aerobic’ conditions has to be controlled and evaluated.

As next step, a field pilot test has been implemented to evaluate the feasibility and cost effectiveness of the selected remediation concept.

Results/lessons learned The recirculation system was started in December 2019, initially without the addition of any reagents. From June 2019 nitrate was added to the recirculation flow in order to stimulate the degradation of the contaminants under nitrate reducing conditions. After more than a month, the arrival of nitrate was observed in the monitoring wells, the biodegradation of the contaminants will be monitored during the following months. Depending of these results, aerobic degradation can be evaluated as well in a later phase.

In the presentation the results of the recirculation feasibility test with respect to biological degradation of the recalcitrant benzothiazoles and biocides will be presented. We will discuss also the distribution of the reagents, problems encountered during the recirculation and how they were resolved.

50246 Remediation of trifluralin polluted soil by cold atmospheric plasma in a novel cylinder-to-cylindrical grid DBD reactor Maria Hatzisymeon

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During the last decades, many remediation techniques have been proposed for the remediation of herbicide-polluted soils. Cold Atmospheric Plasma (CAP) is considered a highly competitive advanced oxidation process for the removal of organic pollutants from soil layers, as it provides advantages in terms of energy consumption, removal efficiency and treatment time. In the current study, CAP technology was applied in a cylinder-to-cylindrical-grid dielectric barrier discharge (DBD) reactor, driven by a high voltage nanosecond pulse generator, in order to investigate the degradation of trifluralin in soil, a widely used toxic herbicide which is persistent in soil. In this layout, CAP discharges are produced directly inside the pores of the soil. The initial pollutant concentration in soil was set equal to 200 mg/kg, CAP treatment time ranged from 30 sec to 10 min, and air was injected through the soil at constant flow rate of 0.075 L/min. The effect of different operational conditions was examined, such as treatment time, pulse voltage and pulse frequency, soil type and electrode gap. CAP experiments showed that increase of pulse voltage resulted in the improvement of degradation efficiency of trifluralin. On the other hand, the increase of electrode gap and the use of a field loam soil seemed to decrease the degradation efficiency, whereas pulse frequency did not seem to affect substantially the degradation process. Under the optimized conditions, it is remarkable that CAP treatment was proved to have excellent performance since trifluralin was completely removed from soil within a few minutes (3 min < t < 5min). At the same time, the energy efficiency of the process was outstanding and several orders of magnitude higher than that reported for conventional soil remediation methods.

Acknowledgements. This project has received funding from the Hellenic Foundation for Research and Innovation (HFRI) and the General Secretariat for Research and Technology (GSRT), under grant agreement No [1754].

49834 Green Remediation of Pesticide-impacted Soils During Conversion of Agricultural Land to Residential Land Use Alan SEECH

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AquaConSoil Topic: Upgrading contaminated and degraded land

Background: Agricultural land has been converted to residential use as urban centers grow. A problem encountered during such changes in land use is the presence of chlorinated pesticides and herbicides at concentrations above regulatory criteria. Over the last 25 years, many pesticide/herbicide-impacted sites have been successfully remediated using *in situ* chemical reduction (ISCR) treatment based on a reagent composed of zero valent iron (ZVI) powder and organic carbon. The ZVI powder and organic carbon are both byproducts of industrial processes and can therefore be considered a green material supporting objectives of the EGD. The treatment is applied in a cycled, anaerobic/aerobic approach and has enabled attainment of residential remediation standards. It provides an environmentally sustainable, greener alternative to costly excavation and off-site disposal of soil. This form of ISCR-based soil remediation is now a proven alternative to traditional excavation and off-site disposal.

Approach: Large-scale soil treatment is usually preceded by completion of bench-scale testing on a representative soil sample to determine if adequate removal efficiency can be attained. The bench work also provides estimates of the required reagent dosage and treatment time. In some cases, bench results indicate that remedial objectives cannot be attained. After successful bench-scale testing, a pilot-scale demonstration may be conducted to ensure successful scale-up under field conditions. Treatment can be conducted *in situ* or on excavated soil using a variety of soil mixing equipment to incorporate the ISCR reagent and water (required to achieve a soil water content conducive to reductive dehalogenation processes).

Case Study, Results, and Lessons Learned: During conversion of a large agricultural site (14 ha) near Toronto Canada to residential land use, the soil was treated to reduce elevated pesticide concentrations, primarily DDE. Soil DDE concentrations ranged from approximately 300 µg/kg to 1,800 µg/kg and the remedial standard was 260 µg/kg. Soil impacts were confined to the upper 60 cm bgs so the soil could be treated *in situ* without excavation. The ISCR reagent was spread over the surface and blended into the soil using agricultural equipment. Irrigation of the soil was also conducted. Soil sampling results indicated a step-by-step reduction in DDE concentrations with each reagent application until DDE was reduced to below the remedial objective. The presentation will focus on the chemistry of DDE degradation, economic aspects of the ISCR-based remediation approach, and the green benefits associated with this type of in situ soil remediation and the use of reagents manufactured from industrial byproducts. This technology also helps in achieving a circular economy, by maximizing the inherent value in recycled materials and by-products, whilst reducing overall energy costs. The push to achieve these goals is stronger than ever, motivated by ongoing regulatory and cultural shifts in the wider society.

50163 Biodegradation study of bromoxynil in two German soils Namini Mahsa

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Pesticides such as bromoxynil play a key role in maintaining the agricultural yield to meet the demands of the growing world population. Bromoxynil dissipates in soil within a few days, but also contributes to the formation of non-extractable residues (NER), whose chemical nature remain mostly unknown and are referred to as a 'black box'. The pool of potentially hazardous NER harbour environmental risks in case of remobilization from the solid matrix. Pesticides can also be utilized as carbon and energy sources by soil microorganisms which leads to biodegradation and incorporation of carbon into their biomass for microbial growth. After the death of these degraders, the microbial biomass is stabilized in soil organic matter forming biogenic NER, which do not pose any environmental harm.

In this soil incubation study, stable isotope labelling was used to trace biodegradation and NER formation processes by mass balance approach. The extracted microbial biomarkers such as phospholipid fatty acids (PLFA) and total amino acids (tAA) were analysed for their amount and isotopic composition. This analysis allows the estimation of microbial activity and biodegradation of bromoxynil as well as a clear distinction of biogenic NER from potentially hazardous non-identified NER. Correlating these results with data on mineralization and extractable residues provides a detailed fate analysis for a proper environmental risk assessment.

This study shows detailed results on biodegradation kinetics of $^{13}C_6$-bromoxynil over a period of 64 days according to the OECD guideline 307 in two German soils with different pH and organic matter contents. Both soils exhibited similar degradation trends. At the end of the incubation, about 20% of applied $^{13}C_6$-bromoxynil was mineralized. Based on the label remaining in the soils after extraction of readily available bromoxynil and its transformation products, 80% of the ^{13}C label was assigned to NER already after 4 days of incubation. Only a minor contribution of PLFA to the biogenic NER fraction was found with about 0.2% of $^{13}C_6$-bromoxynil equivalents. The Gram-negative bacteria were major bromoxynil degraders as they incorporated the highest amount of label into PLFA in the early degradation phase. The tAA fraction is assumed to be the most reliable marker for quantitation of biogenic NER. Approximately 5% of $^{13}C_6$-bromoxynil equivalents were measured in the tAA in one of the two soils suggesting that the majority of NER remains non-identified. Such detailed fate studies are necessary to reveal the true proportions of potentially hazardous non-identified NER and biogenic NER. Furthermore, the degradation kinetics and NER formation can vary between different soil types. This detailed knowledge will contribute to proper risk assessment.

Keywords: Organic contaminants, biodegradation, biogenic NER, fate, environmental risk assessment

Session 3c4 Tackling sites impacted by groundwater contamination

Chair: Marco Petrangeli Papini

49413 1,4-Dioxane - A contaminant of emerging concern at contaminated sites in Sweden? Michael Pettersson

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Keywords: dioxane, CEC, chlorinated solvents, 1,1,1-Trichloroethane, remediation

AquaConSoil topic 5c) Dealing with information on, and action perspectives for, emerging and diffuse contamination

Introduction

Internationally, 1,4-dioxane has highlighted as a contaminant of emerging concern (CEC), mainly because it is classified as a possible carcinogen and has increasingly been found in drinking water. In the United States, 1,4-dioxane has been detected in more than 20% of "municipal" drinking water sources. The USEPA has classified 1,4-dioxane as a "high priority chemical", and several US states have introduced limit values for 1,4-dioxane in drinking water. In Germany and Belgium, 1,4-dioxane has been highlighted as a contaminant in surface and groundwater. Common purification methods for drinking water have been shown to be ineffective for 1,4-dioxane.

In Sweden, the substance has received limited attention. In a screening study of environmental pollutants in groundwater 1,4-dioxane was detected only in a few samples mainly in groundwater deposits in connection with landfills (Herzog and Maxe 2019). There is a need to investigate whether 1,4-dioxane can constitute a contaminant of emerging concern at contaminated sites in Sweden. As a first step in such a process, SGI has conducted a literature study on 1,4-dioxane. This aim of this paper is to present the outcome of this work.

Methods

Data on the sources to and use of 1,4-dioxane, as well as its properties and occurrence in the environment have been collected mainly from international agencies, for instance Canada Health, United States Environmental Protection Agency (USEPA), European Chemicals Agency (ECHA), European Union (EU), Swedish Chemicals Agency and Swedish Environmental Protection Agency. Some information has also been taken from the scientific literature.

Sources to 1,4-dioxane

Production and import to Sweden. There is no information that 1,4-dioxane has been manufactured in Sweden (Swedish Chemicals Agency, 2020). 1,4-dioxane has been manufactured in the USA (Dow Chemicals and Ferro Corporation), in Germany (BASF) and in Japan (Osaka Yuki and Toho Chem) (ATSDR, 2012). Until 1990, Dow also had production in the Netherlands (EU, 2002). Production in Europe in 1997 amounted to 2,000 - 2,500 tonnes, of which between a quarter and a third were exported outside Europe (EU, 2002). No information was found about how large volumes that has been imported into Europe (EU, 2002).

The Swedish Chemicals Agency's Products Register contains information on chemical products that are manufactured in or imported to Sweden and how the products are used. A summary of the amount of 1,4-dioxane that was imported as a raw material or in a chemical product between 1992 and 2019 is presented in Figure 1 (Swedish Chemicals Agency, 2020). The figure shows that around ten tonnes or more were handled annually during the 1990s. The number of companies that handled the substance

during the same period was between 10 and 20. A few years into the 2000s, the quantity used began to decrease, while the number of companies handling 1,4-dioxane started to increase. From the 2010s and onwards, a larger number of companies have been using 1,4-dioxane and the amount have also increased to the levels that prevailed during the 90s. What caused this increase is not known, but the trend indicates a broader use of 1,4-dioxane.

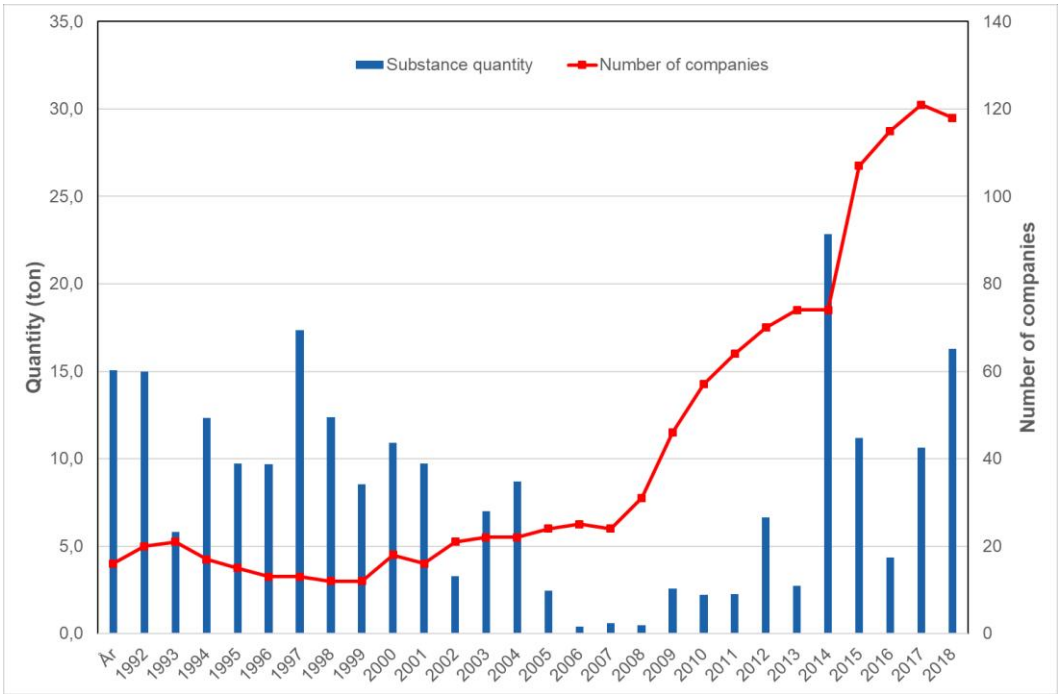

Figure 1. Total reported use (ton) of 1,4-dioxane in Sweden during 1992 – 2019 (Swedish Chemicals Agency,2020).

Areas of use. The main use of 1,4-dioxane has been as a stabilizer in chlorinated solvents. About 90% of the 1,4-dioxane produced in the United States in 1985 was used as a stabilizer in chlorinated solvents (EU, 2002; Mohr, 2001). 1,4-dioxane may also be present as a contaminant in cosmetics, food additives, food packaging, medicines, rubber chemicals, coatings, in pesticides and as a by-product in production of polyethylene terephthalate (PET) plastics (EU, 2002; Mohr, 2001; WHO, 2017).

Inoue et al (1983) investigated the presence of various substances in products that have been used as organic solvents on the Japanese market. 1,4-dioxane was detected in 10% of the products used for degreasing with a mean content of 2.7% and appeared mainly as an additive in 1,1,1-trichloroethane (1,1,1-TCA).

In Sweden 1,4-dioxane is mainly used as a synthetic raw material or raw material in pharmaceutical manufacturing (Swedish Chemicals Agency, 2020). The substance also occurs in various products, for example paints, but generally in low levels.

Stabilizer in chlorinated solvents. Chlorinated solvents are used in many industrial processes, for example as detergents in dry cleaning operations, degreasers in the electronics industry and metal surface treatment. The solvents can decompose in the presence of light, heat and oxygen, and also react with acids and metal salts, with a deterioration in performance as a result (Mohr, 2001). To prevent degradation, stabilizers are added. It is mainly in 1,1,1-TCA that the need for stabilizers is significant (Mohr, 2001). 1,4-dioxane is one of the substances that has been used as a stabilizer. The addition of 1,4-dioxane as a stabilizer in 1,1,1-TCA was patented in 1957 (Bachtel, 1957). Addition of 1,4-dioxane in 1,1,1-TCA prevents corrosion of aluminium, zinc and iron surfaces (Morrison, 2000). Based on information from large producers, the use as a stabilizer in 1,1,1-TCA ceased in 1995 as a result of the phasing out of 1,1,1-TCA (EU, 2002). Table 1 gives examples of different stabilizers in 1,1,1-TCA and how large a proportion these normally constitute. According to this compilation, the proportion of 1,4-dioxane amounts to 3.5%. Other data suggest that the proportion of 1,4-dioxane could amount to

8% (Mohr, 2001).

Table 1. Additives (in percent by volume) in 1,1,1-TCA used for vapor degreasing in the USA, Europe and Japan(Morrison, 2000).

dditive	USA	Europe	Japan
?-Butylene oxide	0.5 – 0.8	0.6 – 1.0	0.1 – 0.6
romethane	0.4 – 0.7	0.4 – 1.0	0.1 – 0.4
-Dioxane	2.0 – 3.5	3.5	3.5
c-Butanol	1.0 – 2.0		
t-Butanol		3.5 – 6.5	
3-Dioxolane	1.0		
ethyl butynol		2.0 – 3.0	
-Propylnitrate		2.0	
etonitrile		3.0	

The use of 1,1,1-TCA in Sweden was close to 2,000 tonnes/year during the 1970s and 1980s (Englöf et al, 2007). The use of 1,1,1-TCA during the period 1992-2002 is summarized in Table 2. Assuming that the addition of 1,4-dioxane is 3.5%, this means that the amount of 1,4-dioxane in the form of a stabilizer in 1,1,1-TCA consumed during the first half of the 1990s is greater than the amount of 1,4-dioxane that has been imported to or used in products in Sweden during the corresponding period (see Figure 1). Historically, the main use of 1,1,1-TCA has been for metal degreasing (Englöf et al, 2007). Another area of use has been for degreasing in tanneries.

Table 2. Total reported use (tonnes) of 1,1,1-trichloroethane (1,1,1-TCA) in Sweden during the period 1992 - 2002(Swedish Chemicals Agency, 2020) and estimated amount of 1,4-dioxane in the form of stabilizer.

ear	1,1,1-TCA		1,4-dioxane
	Quantity	Number of companies	Quantity [a)]
92	1543,2	50	54
93	894,9	34	31
94	752,7	25	26
95	13,5	23	0,5
96	6,9	14	0,2
97	0,4	4	<0,1
98	0,2	4	<0,1
99	0,1	3	<0,1
00	0,1	1	<0,1
01	0,0	1	<0,1
02	0,0	1	<0,1

a) Estimated amount of 1,4-dioxane in the form of a stabilizer in 1,1,1-TCA.

Behaviour in the environment

Physical and chemical properties. 1,4-dioxane has a cyclic structure with four carbon and two oxygen atoms (Figure 2). Other names used are 1,4-diethylene dioxide, dioxyethylene ether, glycol ethylene ether, p-dioxane and tetrahydro-1,4-dioxane (Mohr, 2001). At room temperature, 1,4-dioxane is a hydrophilic colourless liquid that dissolves in both water and organic solvents. 1,4-dioxane can form explosive mixtures (USEPA, 2017a).

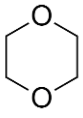

Figure 2. Structure formula of 1,4-dioxane.

1,4-dioxane has a high solubility in water (>800 g/L) and a relatively small tendency to adsorb to soil particles (log Koc = 0.4-1.23). In polluted areas the substance is mainly found in groundwater and has an ability to spread over large distances from a source of pollution. Due to a high vapor pressure (40 mm Hg at 25 °C) 1,4-dioxane evaporates from dry surfaces and dry soil, but due to a high solubility in water, Henry's constant is low ($K_H^{cc} = 10^{-4}$) which leads to a low volatility from water surfaces and moist soil (USEPA, 2018).

There is some biological degradation in aerobic soil environments. However, it seems to occur with some delay. In one experiment, no degradation was detected after 120 days, but after six months, 60% was degraded (Kelley et al, 2001). 1,4-dioxane is not degraded by direct photolysis in terrestrial or aquatic environments. However, the substance is broken down in the atmosphere by photooxidation, with a half-life in the order of hours (USEPA, 2018). The substance is not hydrolysed in water (ATSDR, 2012).

Toxicological data

Within the EU, 1,4-dioxane is classified as probably carcinogenic "presumed to have carcinogenic potential for humans", Carc. 1B (ECHA, 2018), IARC (International agency for research on cancer) classifies the substance as a group 2B carcinogen (“possible carcinogenic to humans”) (WHO, 1999 and USEPA in group B2 (“Probable human carcinogen”) (SCCS, 2015). USEPA regulates 1,4-dioxane as a carcinogen without any threshold (oral cancer slope factor = 0.10 (mg kg^{-1} day^{-1}) (IRIS, 2013), WHO (WHO, 2005), EU (EU, 2002) and Canada (Environment Canada/Health Canada, 2010), on the other hand, believes that there is a threshold for negative effects, even for carcinogenic effects (Chiang et al, 2016).

1,4-dioxane shows a low toxicity in the aquatic environment (USEPA, 2019). The log Koc of 1,4-dioxane (0.4-1.23) is lower than 3, the limit stated by JRC (2015) for compounds that should be considered to pose a risk to the sediment environment.

A BCF-value of 0,2-0,7 L/kg wet weight is reported (Environment Canada/Health Canada, 2010; USEPA, 2017b). These values indicate a low uptake of 1,4-dioxane. For comparison, within the EU classification of PBT (persistent, bioaccumulative and toxic) and vPvB (very persistent and very bioaccumulative) substances, a substance is designated as bioaccumulative (B) if the BCF is higher than 2,000 and as highly bioaccumulative (vB) if the value exceeds 5,000 (EU, 2018).

A bioaccumulation factor (BAF) of 0.93 for 1,4-dioxane has been reported (USEPA, 2018).

Based on data for Koc and Kow and BCF, the assessment is made that 1,4-dioxane has a low potential to accumulate in biota, also supported by USEPA (2019), and thus is not a substance that primarily poses a risk to the sediment environment.

Experiences from different countries

USA. USEPA has conducted a preliminary risk assessment of 1,4-dioxane (USEPA, 2019). The risk assessment includes exposure via inhalation and skin uptake in the work environment (both persons using 1,4-dioxane and persons exposed indirectly). The conclusion drawn is that 1,4-dioxane poses a risk to persons who are directly exposed, for example in the manufacture of 1,4-dioxane. However, it is judged that there is no risk for workers who are exposed indirectly, regardless of the type of industrial activity in question.

It has also been assessed whether 1,4-dioxane may pose a risk to the general population. It can be concluded that that most people in the USA are unlikely to be exposed to the substance, which means that the potential risks for 1,4-dioxane are considered to be low (USEPA, 2019).

Risks to the aquatic environment due to emissions of 1,4-dioxane by wastewater and liquid waste have also been assessed (USEPA, 2019). 1,4-dioxane is not considered to pose a risk to the aquatic

environment or to sediment living organisms. In this paper we did not assess if USEPA: s conclusions are relevant to Swedish conditions.

Using a database on environmental data, Adamson and co-workers (Adamson et al, 2014) have evaluated the co-presence of 1,4-dioxane and chlorinated solvents at more than 2,000 sites in California where groundwater has been found to be contaminated with chlorinated solvents and/or 1,4-dioxane. Of these more than 2,000 sites, 1,4-dioxane has been investigated at 605 sites and detected at 194 of them. In 95% of the sites where 1,4-dioxane is detected, 1,1,1- trichloroethane, trichloroethene or 1,1-dichloroethene were also detected. 1,4-dioxane was analysed at 160 sites where 1,1,1-TCA occurred and was detected at 122 of these, corresponding to 76% of the sites. For TCE, the corresponding proportion is 51% (182 of 360 sites) and for 1,1-dichloroethene 68% (168 of 247 sites).

In the same study, the extent of the pollution plume in groundwater has also been evaluated. The plume for 1,4-dioxane was shorter than for the chlorinated solvents in about 2/3 of the cases, but the ratio was the opposite in about 20% of the cases.

Adamson and co-workers describe the problems surrounding 1,4-dioxane (Adamson et al, 2014). It can be summarized in the following points:

- 1,4-dioxane often occurs as a co-impurity with other chlorinated solvents such as TCE andPCE
- The presence of 1,4-dioxane has been mapped to a limited extent. This is due to, for example,focus on TCE and PCE in investigations and that the 1,4-dioxane plume may be more wide- spread than for other for chlorinated solvents.
- Because of its hydrophilic properties 1,4-dioxane is transferred to the groundwater and thushas a potential to spread from the area where the source of pollution is located.
- As for PCE and TCE, 1,4-dioxane often occur in widespread groundwater plumes with concentrations that are relatively low, but still at levels above risk-based comparative values.
- Existing remediation techniques for 1,4-dioxane in water have a limited efficiency

In Flanders, OVAM has had the presence of 1,4-dioxane and other additives in 1,1,1-TCA investigated in groundwater (OVAM, 2017). Samples were taken in 16 sites where it was previously known that the groundwater was contaminated with 1,1,1-trichloroethane. 1,4-dioxane was detected at all sites, with a maximum content of 26,000 µg/L. The WHO drinking water standard (50 µg/L; WHO, 2017) is exceeded in 80% of the surveyed sites. The levels of 1,4-dioxane were generally significantly higher than would be expected from the concentration ratio of 1,4-dioxane to 1,1,1-TCA. Groundwater plumes for 1,4-dioxane were significantly larger than for 1,1,1-TCA and its degradation products.

According to OVAM 1,4-dioxane can pose a risk to surface water, groundwater and drinking water due to its high mobility in groundwater. The authors recommend that 1,4-dioxane is included in the list of "contaminants of concern" when investigating contaminated areas within Flanders.

In Sweden, the substance has received limited attention, but 1,4-dioxane has been included in a study of environmental pollutants in groundwater (Herzog and Maxe, 2019). 1,4-dioxane was detected on a few occasions (two samples of sixty-five). The levels detected were 0.35 µg/L and 0.13 µg/L respectively (limit of detection 0.025 µg/L). The substance was mainly detected in groundwater deposits close to landfills. The report states that the substance can be of great importance at the local level, and more studies of groundwater and surface water at the national level are recommended. Here, sewage treatment plants are pointed out specifically because these have been identified as a specific source in other countries.

The dominant exposure route for humans is intake of drinking water (Godri Pollitt et al, 2019). The levels of 1,4-dioxane that have been detected in Swedish groundwater so far are significantly lower that WHO's drinking water standard. The intake via drinking water is estimated to be between two and three orders of magnitude smaller than TDI (5.4 µg kg^{-1} day^{-1}). The basis on which this assessment is based on is, however, too small to dismiss 1,4-dioxane as a problem in Swedish drinking water.

Typical sources for the spread of 1,4-dioxane in the environment are landfills and via wastewater (Herzog and Maxe, 2019).

Conclusions

1,4-dioxane has a significant solubility in water, which means that the substance primarily occurs in groundwater at contaminated sites and could spread over large distances from a source of pollution. This entails a significant risk of spreading to drinking water. Information in the literature also states that drinking water is the dominant route of exposure for humans.

There is no information that 1,4-dioxane has been manufactured in Sweden but 1,4-dioxane has been imported and used in Sweden. Statistics on use are available from 1992 and onwards. This shows that the used amount has been relatively constant during the period between 1992 and 2019, with a dip over a period of almost ten years from 2006. How much that has been used before 1992 is unknown. It is noteworthy that the number of companies that have reported a use of 1,4-dioxane has increased in the last decade, which indicates a broader use of the substance.

Globally, a significant use of 1,4-dioxane has been as a stabilizer in chlorinated solvents. Of the chlorinated solvents, the largest admixture of 1,4-dioxane has been in 1,1,1-TCA. Based on data on the use of 1,1,1-TCA in Sweden, we can conclude that the amount of 1,4-dioxane included in chlorinated solvents historically is probably larger than the amounts of 1,4-dioxane used in other applications.

Studies in both the USA and Flanders have shown that 1,4-dioxane often occurs as a co-pollutant with chlorinated solvents in groundwater. There are hardly any measurements of 1,4-dioxane in groundwater in Sweden (based on what has been found in the literature). It is therefore unclear whether the conditions in the USA and Flanders also apply in Sweden. Chlorinated solvents have, however, been used in large volumes and in several different areas. It is therefore not possible to dismiss that 1,4-dioxane occurs in groundwater also in Sweden and can pose a risk to drinking water.

We conclude that 1,4-dioxane have the potential to constitute a contaminant of emerging concern at contaminated sites. This is based on:

- the substance has been used in Sweden. The main source of 1,4-dioxane is probably as astabilizer in chlorinated solvents, and then mainly in 1,1,1-TCA
- the substance has a high solubility in water and a relatively small tendency to attach to soil,which is why spreading to drinking water sources is seen as a significant risk.
- internationally, 1,4-dioxane is a substance that is increasingly being detected in drinking water
- the substance is classified as possibly carcinogenic

From the data presented in this paper, 1,4-dioxane has been mapped to a very limited extent in Sweden. A first step could therefore be to carry out a screening study of the presence of 1,4-dioxane in groundwater. Such an investigation could initially focus on areas where 1,1,1-TCA has been handled.

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49883 Safeguarding drinking water resources: engineering niches of microbial activity for organic micropollutant biodegradation Sutton

Main Message: Clean groundwater is an essential source of drinking water. However, its quality is threatened by contamination with organic micropollutants (OMPs) arising from our use of pharmaceuticals, household chemicals, and pesticides. This presentation provides an overview of the challenges of OMPs in drinking water aquifers. And it elucidates the chance for engineering proper conditions for OMP biodegradation in oligotrophic, anaerobic groundwater. Focus is particularly placed on the use of dissolved organic carbon (DOC) to stimulate microbial activity and consequently support biodegradation of OMPs. We examine the geochemical and flow conditions present in groundwater, and how these can be exploited for OMP biodegradation. The results provide insight in the potential of in situ bioremediation technologies to treat OMPs in drinking water aquifers.

Overcoming oligotrophic conditions in drinking water aquifers to support bioremediation: DOC dictates microbial activity and OMP biodegradation. Research suggests that the OMP-degrading community utilises

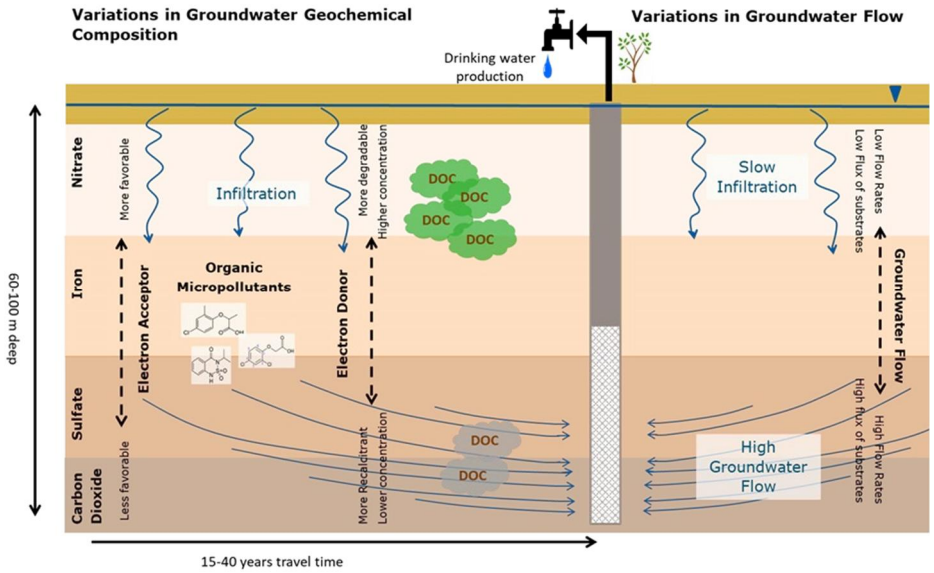
incidentally degrading OMPs. Our results show that dosing natural DOC can stimulate OMP biodegradation.[1,2] In column experiments, we showed that DOC was used as a substrate for metabolic activity and biomass growth (Table DOC as an occasional substrate to sustain growth, while

Table 1. Removal of 2,4-D in column experiments under nitrate-reducing conditions. The period without DOC was from day 0-228. From day 229-440, DOC was added to the column influent. Results amended from published research.[1]

1). The experiments simulated a variety of conditions typical for groundwater, namely the presence of different terminal electron acceptors (different redox conditions) and low flow conditions.[1] Most biodegradation was observed coupled to nitrate as terminal electron acceptor, indicating that nitrate-reducing conditions were most favorable.

	Incubation days	Removal efficiency %
2,4-D	No DOC (0-228)	23.5±10.2
	+DOC (229-440)	82.3±11.6
NO_3^-	No DOC (0-228)	3.3±4.2
	+DOC (229-440)	29.9±17.5

Groundwater flow selects for niches of microbial activity: Groundwater is not homogeneous: variations in composition and flow rates create niches for microbial activity (Figure 1). Freshly infiltrated water contains more favourable terminal electron acceptors (nitrate) and more easily biodegradable DOC. Niches of microbial activity and OMP biodegradation occur at interfaces where DOC, electron acceptors, and OMPs are simultaneously available for biofilms. We have demonstrated the selective pressure of groundwater composition on microbial community



composition, linking both geochemical composition of groundwater but also OMP presence to microbial community composition.[3]

Figure 1. The influence of variations in groundwater geochemical composition (left) and of groundwater flow (right) on microbial growth conditions

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50020 Green solutions for treating nitrate and micropollutants in groundwater to meet drinking standards Biel

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Topic 5a: *New low-carbon solutions for conventional and emerging contamination*

People living in rural areas from Mediterranean countries predominantly use. Nevertheless, they suffer from severe drinking water shortages due to groundwater pollution. Anthropogenic pollution by nitrate and pesticides is one of the major water quality problems in small and very small water supplies. In fact, approximately 13% of groundwater monitoring stations across Europe exceed the 50 mg NO_3/L limit (91/676/EEC), thereby reducing the amount of usable drinking water. In addition, a major public health concern has been raised across Europe during the last years due to the occurrence of antibiotics and antibiotic resistance genes (ARGs) in groundwater via manure application in agriculture.

To this end, the main objective of the present study enclosed in LIFE SPOT project (lifespotproject.eu) is to remove groundwater pollution (nitrates concomitant with pesticides/antibiotics/ARGs) to supply drinking water for human and livestock in decentralized areas, and prove an alternative water management technology in very small water supplies. To achieve this objective, a combined photobioreactor and corkwood pellet filter treatment technology, from lab pilot scale (1-200L) to field scale (1-10m^3), are being assessed by means of a deep physicochemical and microbiological characterization in real polluted groundwater collected from different rural sites affected by nitrates, pesticides, antibiotics and ARGs.

Initial lab scale experiments with a photobioreactor (PBR) of 10L and cork filter (CF) operated in a continuous feeding mode at a hydraulic residence time (HRT) of 8 days showed a depletion of 60% of nitrates (from 200 mg/L to less than 100 mg/L). However, its effectiveness decreased (<20%) at lower HRTs (4 and 2 days). In addition, nitrates depletion decreased from 60 to 36% after 170 operational days (HRT of 8 days) and needs of additional denitrifying step in cork-wood pellet filter to achieve effluent nitrate concentrations below 50 mg/L. Importantly, the PBR-CF was effective for reducing a mixture of pesticides (Bromacil, Atrazine, Diuron, Bentazon, Mecocrop) and antibiotics (Sulfacetamide Sulfamethazine, Sulfamethoxazole), at a HRT of 8 days (about 97%, on average), whereas at a HRT of 4 and 2 days the efficiency decreased (72%, on average),

It is noteworthy that high denitrifying potential was revealed (*nosZ* gene) in the microbial biofilms both on foam biofilm (PBR) and in cork-wood pellet filter materials. PBR microbial populations were mainly composed by *Scenedesmus and Chlorella* microalgae (18S-Miseq), and a more diverse Bacterial community (*H*: 1,34 in microalgae vs 3,86 in Bacteria), composed by *Rhodanobacter*, *Rhodopseudomonas* , *Bradyrhizobium*, Dongia, and *Terrimonas* as the main assigned Bacterial genera. Beta diversity assessment confirmed the high contribution of native microbiota of groundwater to the final microalgae and bacterial diversity of PBR. It will be considered as a critical step during scaling up of PBR at field scale.

Currently, 200L PBR (continuous and HRT 8 of days), built with floating light wells, is treating polluted groundwater (Caldes de Montbui (Barcelona, Spain)) contaminated by on-going long term organic fertigation (manure), containing high levels of nitrate (523-403mg/L), antibiotics (Sulfamethazine and enrofloxacin; 20250 ng/L, and two ARGS detected (*intl1* and *sul1* in the range of 10^4-10^5 copies/L) and low levels of pesticides (<20 ng/L, as desethylatrazine, DEET and surfactant Surfynol 104). An in-deep

physicochemical and microbial characterization of PBRs running at different HRT (8, 4 and 2 days), and different groundwater sources are being assessed previously to their application at field scale (1-10 m^3 PBR reactor).-

The high content of nitrates and micropollutants such as pesticides, antibiotics, and ARGs in the groundwater in rural areas affected by on-going intensive agriculture and/or organic fertigation imply to further optimize the developed PBR-CF technology to treat water reaching proper water quality standards

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Marco Britto, Fernanda Martins, Steve Huysman, Kathleen Verhoeyen, Nicolaas van Belzen and Claudia Walecka-Hutchison (Dow)

Background/Objectives. On a former toluene-di-isocyanate production site in Brazil, a variety of contaminants are present, including nitrotoluenes, chlorobenzenes, BTEX and some chlorinated compounds. The main components of concern are 2,4 and 2,6-dinitrotoluene (DNT). Highest maximum concentrations for DNT that were found were 937,174 µg/l 2,4-DNT and 538,508 µg/l 2,6-DNT. Greensoil was given the opportunity to investigate the feasibility of both aerobic and anaerobic biodegradation of the different contaminants with the focus of DNT by means of laboratory degradation tests.

Approach/Activities. Based on scientific literature DNT can be biodegraded both aerobically via removal of the nitro groups, leading to the production of nitrite as degradation product and anaerobically, where the nitro group is being reduced to an amino group. Since aminotoluenes are considered more recalcitrant under anaerobic conditions, the anaerobic conditions are typically followed by aerobic conditions, to further biodegrade the aminotoluenes. Even though switching from anaerobic to aerobic conditions takes extra effort, costs etc. from a practical point of view, this approach was considered since dichlorobenzene (DCB) was being used as solvent for DNT. In case of aerobic degradation, it is expected that DCB is preferentially degraded over DNT with the potential risk of crystallization of DNT, that has been observed at the site.

Results/Lessons learned. A first series of laboratory degradation tests were conducted in Brazil with highly contaminated groundwater and soil from the source zone. Only under anaerobic conditions a strong decrease (> 98%) of 2,4- and 2,6-DNT was observed together with the formation of aminonitrotoluene (ANT) isomers and di-aminotoluene (DAT). However, due to a strong fluctuation in the analytical results it was decided to repeat the degradation test with material with lower concentrations (max. 50,000 µg/l for the sum of 2,4-DNT and 2,6DNT).

During the second test similar results were obtained under anaerobic conditions, with > 99% DNT degradation. Since the natural pH was ± 6.0, it was decided to also test a buffered condition with neutral pH. At natural pH, the main degradation products in the presence of an electron donor were ANT isomers, while at neutral pH they were 2,4-and 2,6-DAT. Only at neutral pH, the degradation products were completely further degraded under aerobic conditions.

Under aerobic conditions complete degradation of 2,4-DNT (> 99%) was observed in all biological conditions, including the biological control. Degradation rates of 2,4-DNT were however higher at buffered pH and in the presence of additional phosphate. No degradation of 2,6-DNT could be observed under aerobic conditions.

NGS and CSIA are being performed for a better understanding of the involved degradation pathways and microorganisms under the different conditions.

Based on the degradation tests, anaerobic degradation of high concentrations of DNT, followed by aerobic degradation of the formed reduced degradation products seems a promising in-situ remediation technology.

4 Sustainable remediation technologies in context of the EGD and energy transition

4a) New low-carbon solutions for conventional and emerging contamination

Special Session 4aSpS1: NICOLE session 3. PFAS and other emerging contaminants: status and advances made on monitoring, detection and remediation

Chair: Frederic Coulon & Tomás Albergaria
Dr Tomas Albergaria (University of Porto, Portugal)

Prof Frederic Coulon (Cranfield University, UK)

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Hans Slanders (Arcadis, NL)

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Poly- and perfluoroalkyl substances (PFAS) are a group of over 6000 synthetic chemicals including PFOA (perfluorooctanoic acid), PFOS (perfluorooctane sulfonate) and GenX (hexafluoropropylene oxide dimer acid). PFAS have been used widely since the fifties due to their excellent properties: water and fat repellent and heat resistant. Unfortunately, PFAS are toxic, persistent and bioaccumulate. They are detected worldwide in soil, groundwater, surface water and sediment. Governing bodies are therefore working on adequate regulations to protect biota and humans. However, traditional methods used to determine the level of PFASs are often not appropriate for continuous environmental monitoring and management.

Similarly, several conventional technologies have been tested with limited success, often at bench scale and in several cases being shown as ineffective in removing PFAS. Therefore, selecting the most appropriate remedial technologies for PFAS remains challenging especially for commercial applications. A plethora of treatment train technologies to manage PFASs are emerging but their developments are still in their infancy, so there are opportunities for much innovation.

The joint NICOLE-ACS session will provide an update on the most recent innovative technologies being applied through a range of case studies and provide a forum to stimulate exchange of ideas for future opportunities and translation to real application. Key topics to be covered include:

1. Advanced monitoring techniques and future challenges for emerging contaminants in groundwater (Goedele Verreydt)
2. PFAS omnipresence in nearly everything and the pressure of decreasing target values (Hans Slanders)
3. PFAS detection and monitoring challenges and solutions (Alan Wilson)
4. Managing PFAS, pragmatic solutions to a persistent problem (Ian Ross)

Session 4a1 Enhanced bioremediation

Chair: Zhongbing Chen

48123 In-situ biostimulation of nitrate-reducing aromatic-hydrocarbon-degrading microbial communities

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Ted Vendrig (HMVT, Ede, The Netherlands)

Background/Objectives

To assess bioremediation potential in contaminated groundwater plumes at high concentrations for aromatic hydrocarbons (50-60 mg/L), long term biostimulation and bioaugmentation field tests were accomplished. The field tests were conducted at a former manufactured gas plant, using a multi well recirculation system in duplicate. Enhanced biodegradation was observed for most aromatic hydrocarbons such as BTEX, naphthalene, indene and styrene. Biostimulation and Bioaugmentation with a laboratory-grown culture in combination with nitrate injections, increased concentration of *Peptococcaceae*, benzene carboxylase (*abcA*). The laboratory grown culture was able to degrade benzene at nitrate reducing conditions in the bioreactor. Inoculating the lab culture in the subsurface could benefit the degradation of benzene at field conditions.

Benzene degradation was successfully enhanced under anaerobic conditions at the field scale by nitrate additions. Although an adaptation time of more than one year was observed, changes in fractionation of ^{2}H stable isotopes indicated that after adaptation, benzene degradation was faster than toluene.

This study demonstrates the potential for biostimulation through nitrate injections and bioaugmentation at sites contaminated by aromatic hydrocarbons. However, adaptation time for the indigenous contaminant degrading microorganisms can take up to one or year or more.

Approach/Activities

The field test was conducted at the highly contaminated section of the contaminant plume, approximately 20 meters downgradient from the DNAPL pool zone.

The multi-well recirculation field test set-up consisted of a duplicate system, sections A and B. The purpose of duplicate parallel operating sections was to subsequently compare effects of flushing only, biostimulation and bioaugmentation. Groundwater was pumped from extraction wells, kept anoxic, and then re-injected in upgradient wells. Wells were installed in the aquitard embedded in a gravel pack and screened from 10 to 12 mbgs. Monitoring wells were positioned along the downgradient path of flow.

An extensive set of data was obtained through groundwater sampling and analyses of: contaminant concentrations, DOC, electron acceptors, DNA of bacteria and enzymes, groundwater flow, redox potential, electric conductivity, pH, temperature and compound specific isotope analysis for carbon and hydrogen.

Results/Lessons Learned

In this presentation we will guide you through our design process, performance of the recirculation system, additions of electron acceptor and laboratory grown bacterial injections in the field. The biodegradation and flow condition results will be illustrated in graphs, tables and pictures. From the results we learned that biodegradation was successfully enhanced under anaerobic conditions at the field scale by nitrate additions, after a lag time of more than one year. Changes in fractionation of ^{2}H stable isotopes indicated that after adaptation, benzene degradation was faster than toluene, and degradation was faster than xylenes. Although indigenous microorganisms *Peptococcaceae* and benzene carboxylase were present at relatively low or undetectable levels, their population grew considerably by nitrate additions during the field test. This suggests that benzene degradation was coupled to indigenous micro-organisms.

51408 Improvement of bioaugmentation and biostimulation techniques for the biodegradation of hydrocarbons in contaminated soils Sandra Curiel Alegre

Sandra Curiel Alegre, Carlos Rad, Carlos Rumbo Lorenzo, Blanca Velasco Arroyo, Juan Antonio Tamayo Ramos, Sonia Martel Martín, Rocío Barros García.

Contact person: Sandra Curiel Alegre; Affiliation: ICCRAM, Universidad de Burgos (Spain).

Today's society is characterized by having a great dependence on hydrocarbons. The movement of both people and products, industrialization and rapid urbanization promotes an excessive use of hydrocarbons sources, which may pose serious problems. Due to this steady increased use, the levels of Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH), along with potentially toxic metals and metalloids are rapidly increasing in soils and water, posing a high risk to human and environmental health. Controlling the sorption processes and the performance of hydrocarbons in the soil is a determinant factor to predict their mobility and availability, along with their effects on the underlying microbial communities.

As more and more hydrocarbons are polluting the environment, it is requested to implement soil remediation techniques to solve this growing problem. Techniques must be sought to degrade these emerging pollutants, but at the same time, those must be the most effective, efficient and economically viable to be applied at a large scale.

As revealed by many studies, bioremediation techniques for soils and sediments contaminated with hydrocarbons represent profitable cleaning techniques. Among those, there is a wide range of techniques like biopiling, landfarming, phytoremediation, biostimulation and bioaugmentation. Those demonstrating the best fate of biodegradation of hydrocarbons are bioaugmentation and biostimulation. The present work focuses on the former, aiming at seeking for the most effective and economic one. The investigations stand upon soil microcosms at controlled conditions of temperature, humidity and ventilation, with the main objective of optimizing these techniques to achieve a greater biodegradation of hydrocarbons (TPHs and PAHs). Although the two techniques have the same purpose, the difference relies on the need of inoculating exogenous degrading microorganisms to the soil in the case of bioaugmentation, whereas for biostimulation, nutrients are added to improve the metabolic functions of the native microbial community present in the soil, without the need to add more microorganisms.

The identification of microbial communities that biodegrade hydrocarbons, the study of bacterial growth and its stimulation by formulating different chemical compounds used as nutrients for these communities, represent the key parameters considered to improve these bioremediation techniques. Besides, the effectiveness of applying an organic amendment to the soil has been tested, aiming at increasing the organic matter content in the soil, a key property to many of its functions such as microbial activity, mineralization of recalcitrant materials, and elimination of xenobiotic residues due to the promotion of biotic and abiotic processes, which can be a determining factor in the biodegradation of hydrocarbons. For this study, an agroindustry vermicompost has been used as organic amendment, a residue that has been stabilized by composting.

The University of Burgos, within the framework of the European GREENER project (CE-BIOTEC-042018-GA 826312), has designed and tested different bioaugmentation and biostimulation strategies with the aim of improving the effects of these techniques on soils contaminated with hydrocarbons in presence of potentially toxic metals and metalloids. The current work has achieved important results till the date, exhibiting differences in the degradation of TPH, LAH (Linear Aromatic Hydrocarbons) and PAH for the different treatments applied. Interestingly, an improvement in the bioremediation treatment in which a certain amount of organic amendment was added has been observed.

Jeff Roberts, Sandra Dworatzek and Phil Dennis SiREM, Guelph, Ontario

Bioaugmentation with dechlorinating cultures is an established remediation technology for the enhanced anaerobic bioremediation of chlorinated solvent contaminated sites. Specific dechlorinating bacteria and functional genes are well known and able to dechlorinate chlorinated solvents. *Dehalococcodies* (*Dhc*) can completely dechlorinate chlorinated ethenes to ethene, and *Dehalobacter* (*Dhb*) is involved in chloroform and 1,1,1-trichloroethane dechlorination.

There are other microorganisms that have significant roles in dechlorination but are less well known and tested for less frequently. *Dehalogenimonas* (*Dhg*), which can dechlorinate *trans*DCE, chlorinated propanes and more recently has been reported to dechlorinate vinyl chloride (VC) to ethene. *Geobacter* species are capable of dechlorinating high concentrations of PCE and TCE and may play a role in DNAPL dissolution as well as participating in biogeochemical reduction processes at many sites in conjunction with sulfate reducing bacteria (SRB). Cultures for anaerobic benzene, toluene and xylene (BTX) degradation are now becoming available and this widens the number of sites and contaminants for which bioaugmentation can be considered.

Recently, there has been significant milestones in characterizing anaerobic benzene biodegradation and their applications to developing better groundwater bioremediation solutions. It has recently been documented that anaerobic benzene biodegradation is catalyzed by a very narrow subset of microorganisms. Two such microbes reside in a methanogenic consortium (DGG-B; harbors *Deltaproteobacteria* ORM2) and a nitrate-reducing consortium (NRBC; harbors *Peptococcaceae* sp. Pepto-Ben now renamed as *Thermincola* spp.).). ORM2 and *Thermincola* related microbes have been detected in almost every established benzene-degrading enrichment culture worldwide and are frequently present in benzene-contaminated groundwater. Four field pilot applications (October 2019, November 2019, April 2020 and October 2020) are currently being monitored. These first-to-field projects will establish clear guidelines and approaches for using these novel bioaugmentation cultures, including a better understanding of dosing requirements, timeframes for obtaining results and ranges of conditions over which the cultures are effective.

Bioremediaiton for chlorinated solvents and BTX compounds has the potential to decrease remediation time frames and increase the range of sites to which bioremediation is applicable. This presentation will discuss recent advancements in bioaugmentation cultures are provide case studies where bioremediation was the remedy of choice at chlorinated solvent and petroleum hydrocarbon sites.

47848 DCE Stall – Causes and Cures Prof. Robert C. Borden
PRESENTATION IN A REGULAR THEMATIC SESSION

Oral presentations (15 min + 5 min of discussion)

Scientific project: DCE Stall – Causes and Cures

Robert C. Borden, Ph.D., PE
Professor Emeritus, North Carolina State University
Principal Engineer, EOS Remediation, LLC.

Dr. Robert C. Borden serves as Principal Engineer at EOS Remediation, LLC and Professor Emeritus at North Carolina State University. Bob has over thirty years' experience in the development and implementation of technologies for in situ remediation of contaminated soil and groundwater. Specifically, Bob has developed technologies to stimulate in situ biodegradation of petroleum hydrocarbons, chlorinated solvents, explosives and propellants, and 1,4-dioxane. Results of this work have been documented the numerous journals articles, reports, design tools and protocols, computer models, and on ENVIRO.wiki.

AquaConSoil topic: 4.1 Managing pollution in the water-soil-energy-food-nexus

Aim of the presentation:

Improve on the know how in operating enhanced reductive dechlorination (ERD) projects.

Enhanced Reductive Dechlorination (ERD) has developed into a reliable and robust technology for in situ treatment of PCE and TCE. However, at too many sites, DCE and VC conversion to ethene is rate limiting, increasing the time and cost to meet remediation goals. Common causes of slow DCE conversion to ethene include absence of *Dehalococcoides*, competitive and/or toxic inhibition by other CVOCs, absence of substrates that can be fermented to hydrogen (H2), low nutrient levels (N, P, B12), and low pH. In this presentation, we will review the microbiology of DCE reduction to ethene and strategies for accelerating biodegradation.

This presentation will help consultants to understand why ERD sometimes stalls and how to solve this problem.

48855 Implementation and Performance of Injected ZVI PRB to Control Chlorinated Hydrocarbon Plume Migration in Denmark Przepiora

Presenter: ***Andrzej Przepiora*** Geosyntec Consultants, Guelph, Ontario, Canada)

Coauthors: Lars Nissen, Torben Højbjerg Jørgensen (COWI A/S, Odense Denmark), Neal Durant (Geosyntec Consultants, Columbia, MD),

Background. Historical practices at a former manufacturing facility in Odense, Denmark have resulted in chlorinated solvent and oily waste contamination in shallow glacial till deposits beneath the site. Although the main source area was excavated over twenty years ago, chlorinated hydrocarbons (CHCs, primarily cis-1,2dichloroethene [cDCE] and vinyl chloride [VC]) continue to leach from the clay till into an underlying sand aquifer. A CHC plume has formed in the aquifer, which extended off-site toward a municipal drinking water supply well. An injected microscale zerovalent iron (mZVI) permeable reactive barrier (PRB) was implemented to limit the migration of CHCs in groundwater and mitigate off-site CHC impacts in the aquifer.

Approach. Laboratory batch and column tests were performed with site groundwater to select the most appropriate mZVI material and refine the mZVI dosing requirements. A pilot-scale injection test using direct-push technology (DPT) injection equipment followed to optimize the site-specific installation methodology, including the injection sequence (bottom-up vs. top-down), injectate composition (i.e., content of mZVI and guar gum in the injected slurry), injection pressures and the achievable injection radius of influence. The full-scale PRB is a 25 m-wide system that was installed by DPT injection into the impacted sand aquifer at a depth of approximately 12.5 to 14 m below ground surface (bgs). A slurry mixture of mZVI, guar gum, and *Dehaloccoides* (DHC) culture was injected into a total of 40 injection points spaced 3 m on center. A total of 12,000 kg of mZVI and 20 L of a DHC culture were injected to form the PRB.

Results/Lessons Learned. Results from the 3-year performance monitoring, showed substantial degradation of cDCE and VC in the ZVI-amended zone and offsite, with corresponding increases in ethene and ethane concentrations. Clean-up standards were achieved within 1 year in monitoring wells located approximately 5 to 10 m downgradient of the ZVI zone. Reduction of CHCs has continued over the second and third year of monitoring, resulting in substantial decreases in the plume footprint, with the clean-up targets achieved in most wells located in the ZVI amended zone, in addition to all downgradient off-site monitoring wells. Monitoring data has indicated that the dechlorination of CDCE and VC occurred via abiotic processes driven by the ZVI and microbial processes simulated by the presence of guar gum and the *Dehaloccoides* culture. However, no CHC degradation was observed in side-gradient and up-gradient monitoring wells located outside the zone of ZVI emplacement in which dissolved carbon increased as a result of guar gum migration. The CHC monitoring data in the wells located in the ZVI-zone showed continuous decreasing trends in concentrations until low µg/L values were reached and then maintained. This demonstrated that: (i) the system has not yet reached steady state at some locations, (ii) the back-diffusion mass flux of CHC from the overlying clay has been decreasing with time; and (iii) the remedial capacity of the ZVI amended aquifer zone has remained high within the monitoring period.

48954 Sulfidation disproportionately influences the removal of chlorinated ethenes by zero-valent iron nanoparticles Brumovský

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ABSTRACT

Sulfidation has been recently recognized as a very promising approach to improve selectivity and longevity of zero-valent iron nanoparticles (nZVI) for groundwater remediation. While the reactivity of sulfidated nZVI (S-nZVI) with trichloroethene (TCE) has been already investigated in several studies, e.g., [1-4], available data on the reactivity of S-nZVI with other chlorinated ethenes such as tetrachloroethene (PCE) or cis-dichloroethene (cis-DCE) are scarce. As these chemicals often occur concurrently at contaminated sites, a better knowledge of the S-nZVI performance for various chlorinated ethenes is essential.

The aim of this study was to investigate the reactivity and selectivity of S-nZVI particles with PCE, TCE and cis-DCE. S-nZVI was synthesized from commercial nZVI treated in suspension with sodium sulfide at different concentrations, resulting in particles with a core-shell structure where the core consisted predominantly of zero-valent iron and the shell contained mostly amorphous iron sulfides. The particles were thoroughly characterized using XRD, XPS, HRTEM including EDX elemental mapping and Mössbauer spectroscopy. Particle reactivity was assessed in batch experiments with both single- and mixed-contaminations.

Sulfidation was found to affect disproportionately the degradation of various chlorinated ethenes. Up to 12-fold increase in TCE removal rate was observed for S-nZVI with S/Fe ratio 0.0195. In contrary, cisDCE removal was not affected by sulfidation and PCE removal was even slightly inhibited. This behavior is hypothesized to be driven by contaminant reactive sorption to different surface sites. Regardless of the type of chlorinated ethene tested, S-nZVI particles consistently displayed substantially slower corrosion in water. This study shows that S-nZVI particles hold great promise for the remediation of TCE, while their applicability for PCE and cis-DCE removal is limited.

Acknowledgements

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Kirsten Rügge ; Morten Dreyer ; Lærke Brabæk ; Torben Højbjerg Jørgensen ; Dimin Fan ; *James Wang; Neal Durant* ; *Maria Tropp Hag ; Nina Tuxen*

Background/Objectives. There is a large demand for sustainable remediation techniques to ensure clean water, which is UN's goal no. 6, and the objective of this project is to develop a method that can be used at sites all over the world. The synergy between zerovalent iron (ZVI) and biological reductive dechlorination has long been recognized and applied as an effective remediation strategy at chlorinated solvent (cVOC) sites. Pre-design microcosm and column test reactors with five different ZVI-products were prepared using site groundwater and aquifer materials to identify the optimal ZVI-product for a pilot scale PRB. Provect-IR® with bioaugmentation with KB-1® culture achieved the most complete treatment in the bench test and, consequently, was selected for the pilot test at a chlorinated solvent site. Provect-IR® contains a natural anti-methanogen compound to inhibit methane production and associated electron donor wastage. Methane production could be problematic in urban areas.

Approach/Activities. Contact between injectate and contamination is essential. Therefore, an injection test was conducted at the site to identify the most effective method for injecting the ZVI-carbon composite as well as to identify the radius of influence (ROI) for designing a pilot scale PRB. Three different methods were tested. DPT with a Geoprobe rig showed the best injection effectivity, however no even distribution was obtained with any of the injection methods tested.

Subsequently, a pilot scale PRB was installed through 7 DPT injection points arranged in 2 rows of offcenter points at the site. The Provect-IR® design dose was 1% by weight of soil and KB-1® dechlorinating culture (4 L per injection point) was added. Installation of the PRB was followed by a detailed documentation of the distribution of ZVI by means of soil core sampling and analyses (magnetic susceptibility, visible iron, and laboratory iron analysis), and geophysics (DCIP). To allow PRB performance monitoring, three transects of monitoring wells were installed. Baseline monitoring confirmed expected iron reducing conditions, significant concentrations of TCE and cDCE, and minor concentrations of VC. Only trace concentrations of ethene and ethane were observed, showing a lack of complete degradation. The ongoing performance monitoring program including chemical as well as microbial analysis and Compound Specific Isotope Analysis (CSIA) to document and quantify biotic and abiotic degradation has included quarterly groundwater sampling to establish cVOC degradation trends and calculate cVOC mass removal in the plume. Moreover, DCIP has been applied to describe the ongoing processes in the groundwater. Monitoring has been applied for now 16 months after injection.

Results/Lesson Learned. Complete degradation to ethene/ethane has been observed in areas with sufficient distribution of Provect-IR® and KB-1® culture, and the method looks promising for plume remediation. However, in areas with the highest concentrations of cVOCs (up to 25.000 µg/L), unfortunately less Provect-IR® and KB-1® culture is present. After a detailed documentation 9 months after injection, reinjection was decided. The reinjection took place in December 2020, 15 months after injection. A detailed documentation of the reinjection and the remediation effect has been performed by means of EC and MIP profiling, DCIP, groundwater analysis of new level specific water samples and samples from monitoring wells. Results are currently being evaluated.

49192 Evaluation of 5 years operation of a funnel and ZVI gate system for a containment of a VOC's and Chromium VI contamination Julien Matha

Julien Matha, Thierry Gisbert (Arcadis France), **Wouter Gevaerts** (Arcadis Europe);

Context / Objectives. A contamination of chlorinated solvents (PCE, TCE, Cis DCE and VC) and Chromium is present in soil and groundwater underneath and outside an automotive production plant in France. Based on these findings and in compliance with local regulations a remediation workplan has been developed (including feasibility studies) in order to select the best remedy approach to consider for this site. In the end a Funnel and Gate (F&G) remedial system using Zero Valent Iron (ZVI) as reagent has been selected. This system consists of 3 gates and bentonite barrier of about 220 m.

Approach / Activities. The F&G system has been implemented to stop / "confine" the spread of the contamination downstream the site boundaries. This system was designed between 2012 and 2013 based on laboratory tests and on data collected during previous investigations. The goal was to define the characteristics of the slurry wall (geotechnical & hydrogeological), of the filter gates (hydraulics), and in particular to evaluate the treatment capacity of the ZVI (laboratory testing : column tests). It was finally implemented in 2014 and has been the subject of a performance monitoring program ever since. From the end of 2015 on, a decrease in the efficiency of the system was noticed. Prior to the decision to engage the first O&M task consisting in replacing the reagent load some tests were conducted in the field to verify the consistency between the design data and the real situation. In 2019 the ZVI in the gates has been changed, and tests have been carried out on the replaced ZVI (chemical analysis, mineralogical analysis, x-ray diffractometry, scanning electron microscope). Before replacement, also hydraulic test have been carried out on the gates. Based on those activities, the way the gates are filled with ZVI is adapted.

Presentation. In the presentation, we will discuss the evolution of the concentrations over the gates, as well as the results of the hydraulic tests, and the chemical and mineralogical analyses that have been carried out.

Session 4a3 PFAS: solutions for impacted waste water, session 1

Chair: Coen de Jong

48625 Field pilot tests of a novel material for the in situ remediation of a PFAS contaminated groundwater aquifer Bosch

Topic 5.1. New low-carbon solutions for emerging contaminants

Presenter: Julian Bosch, Intrapore GmbH, Essen, Germany. Phone +49 201 8589580, Co-Authors: Johannes Bruns (Intrapore); Sarah Sühnholz, Anett Georgi, Katrin Mackenzie (Helmholtz-Zentrum für Umweltforschung - UFZ, Leipzig)

The oil and water-repellent properties of the perfluorinated and polyfluorinated surfactants (PFAS) ensure that they are widely used in many every day and industrial goods. The use in fire extinguishing agents is of particular environmental relevance. The extensive use of this group of putatively carcinogenic substances resulted in widespread groundwater contamination in need of remediation. PFAS do not occur in nature and are not broken down microbiologically. They are also extremely mobile in the soil and groundwater.

If the PFCs have moved into the groundwater via the unsaturated soil zone, then there are currently hardly any possibilities to limit the spread of this contamination on a sustainable, basis. One goal of the German-Ministry (BMBF) funded project CONTASORB was the development and field testing of novel materials for the in-situ treatment of PFAS-contaminated groundwater areas. In-situ sorption barriers based on injectable colloidal activated carbon can stop fast-moving PFAS plumes in an effective and sustained manner, but a proper material formulation, particle size, surface charge and surface are required, among others, to yield a high adsorption capacity and thus a high operational performance. Such a novel formulation has been developed by Helmholtz-Zentrum für Umweltforschung - UFZ, Leipzig, Germany.

To test this novel material in a real-world environment, a large-scale pilot application was carried out. At a former NATO airport in North Rhine-Westphalia, Germany, fire extinguishing exercises with PFAS-containing foams were carried out for decades. The pollutants infiltrated into the groundwater, which led to the formation of a plume, with total PFAS plume concentrations of up to 1.200 ng/L. The novel in-situ material, a specialized, high-surface, activated colloidal carbon (ACC) (Intraplex® B) was injected perpendicular to the main direction of the pollutant outflow, via direct push injections, leading to the establishment of a stable adsorptive zone.

The monitoring results after almost 2 years showed a complete, rebound-free retention of the pollutant load downstream of the area of the adsorptive zone. This demonstrated the high operational performance of Intraplex® B. For the conditions in this pilot study, depending on the chain length of the PFAS, barrier life time starts from a few years for short chain PFOS, but can reach many decades for PFOA.

Overall, results derived from this study suggest that ACC sorption barriers can be used for effective clean-up of PFAS contaminated groundwater. R factor proves to present a good agreement with observed retardation of PFAS within an ACC sorption barrier and give a good first impression of the great potential of in-situ ACC barriers, especially for long chain-chain PFAS. This implicates a superior economic feasibility, with costs of 0.05 € per cubic meter of cleaned groundwater, which is one order of magnitude below comparable pump & treat costs. In addition, this in-situ approach requires very little energy during implementation, and no energy during operations, making it a climatefriendly groundwater remediation technology.

48932 Electrosorption of perfluoroalkyl acids on activated carbon: accumulation of the compounds and on-site regeneration of activated carbon Saeidi

Navid Saeidi, Frank-Dieter Kopinke, Anett Georgi

Helmholtz Centre for Environmental Research – UFZ, Department of Environmental Engineering, D-04318 Leipzig, Germany

In this study electrosorption was investigated as an innovative approach for removal of perfluoroalkyl acids (PFAAs) from contaminated water. External electrical potentials were used for controlling adsorption of perfluorooctanoic acid (PFOA) and perfluorobutanoic acid (PFBA) on microporous activated carbon felts (ACFs). Plotting adsorption affinities as single point adsorption coefficients K_d of PFOA and PFBA versus carbon electrode potentials results in bellshaped curves with maxima located at potentials > E_{PZC} of the ACFs. K_d values for electrosorption of environmentally relevant PFOA concentrations vary between 650,000 L/kg at +500 mV and 14,800 L/kg at -1000 mV (vs. Ag/AgCl), i.e. a difference by a factor of 44. This factor is about 100 in case of PFBA. These large differences in adsorption coefficients allow to remove the compounds from a high volume of water by electroadsorption and release them into a low volume concentrate by means of electrodesorption. An estimation of the concentration factor in a PFOA electroadsorption/-desorption unit was calculated as 130 for the conditions given above. It is lower for milder potential swings, e.g. 71 for +500 mV/-100 mV and 41 for no potential/-100 mV. These high concentration factors illustrate the potential of electrosorption as pre-concentration step for combination with subsequent PFAA chemical destruction, e.g. by electrooxidation. Electroadsorption of PFOA at +500 mV and electrodesorption at -1000 mV showed a significant performance decline over 5 cycles. Selection of milder potentials based on E_{PZC} of the ACF (electrodesorption at -100 mV < E_{PZC} = +75mV < electroadsorption at +300 mV) resulted in only small losses of performance after 10 sorption cycles (1000 h). An almost stable performance of the electrosorption cell was achieved without external potential for adsorption and -100 mV for electrodesorption.

The weak impact of competitive inorganic ions on electrosorption of PFAAs and an only small effect of variable pH values indicate that this concept is applicable for remediation of various sources of water contaminated with both short- and long-chain PFAAs. In addition, it is a promising approach for on-site regeneration of activated carbon saturated with PFAAs.

49005 Surface Active Foam Fractionation (SAFF): Effective PFAS removal from water using only air Hinrichsen

Presenter:	Helena Hinrichsen, Envytech Solutions
AquaConSoil Topic	Sustainable Remediation Technologies in Context of the EGD and Energy Transition
Abstract Title:	Surface Active Foam Fractionation (SAFF): Effective PFAS removal from water using only air

Abstract:

PFAS are arguably the most significant emerging contaminant in the world today and a new innovative technique is showing us that the solution to this problem may be easier, cheaper and more sustainable than we thought.

OPEC Systems, a small Australian environmental engineering company and Envytech, their Scandinavian technology partner, have been working in recent years to develop a PFAS separation and concentration process based entirely on the surface active power of rising air bubbles in a water column. SAFF or Surface Active Foam Fractionation, is almost certainly the most sustainable PFAS remediation solution ever developed, in that it is entirely reliant on pure air to do the heavy lifting to remove more than 99% of C6 chemistry and above including PFOS, PFOA and PFHxS.

OPEC have been successfully operating a 250,000 litre/day PFAS water treatment plant in Queensland Australia for the past 2 years for the Australian Department of Defence without a single exceedance for the sites criteria PFAS compounds (PFOS, PFOA and PFHxS) down to the LOR (1ppt). The SAFF system incorporates 3 distinct fractionation processes: Primary, Secondary and Tertiary Fractionation. The primary stage very effectively separates the majority of the PFAS compounds from the contaminated aqueous solution whilst the secondary and tertiary stages concentrate the harvested fractionate to miniscule volumes. Average concentration factors of greater than three million times have been achieved at the Queensland site and new design geometries are achieving CF's ten million times. After treating 50,000 million litres the SAFF plant has produced a miniscule 15 litres of PFAS hyper-concentrate in over 2 years of operaiton.

On the back of the SAFF's Australian success, in January '21 a containerised SAFF system, the first of 7 units to be supplied into Sweden this year, was built and shipped to treat a PFAS contaminated landfill leachate site near Stockholm. The SAFF40 plant, as the 40' containerised unit is known, is presently treating over 200,000 litres of complex leachate wastewater per day.

Envytech and OPEC have now conducted PFAS removal efficiency tests on over 20 kinds of contaminated water samples from around the world. This data, which will be summarised for the presentation, combined with laboratory validation using a benchtop 'Mini-SAFF' system, have helped to create a highly accurate predictability model which allows individual sites to quantify the removal efficiencies they can expect for their unique water chemistry and PFAS signature.

The SAFF is automated, simple to operate and designed for autonomous on-site operation. Using no consumables and producing virtually no waste the primary OPEX input for SAFF is power and the system can treat $1m^3$ of contaminated water using less than 2.0kw of power making it very efficient and low cost.

This talk will introduce the safest, most effective and sustainable PFAS remediation technologies to arise from the emerging contaminants water treatment space for decades.

49960 Six Pilot-Scale Studies Evaluating the In-Situ Treatment of PFAS in Groundwater InSitu Remediation Services Limited

Rick McGregor*, Gareth Leonard**, Marcello Carboni**

* In Situ Remediation Solutions Limited (IRSL), Canada

** Regenesis

Corresponding author: Rick McGregor

Background/Objectives.

There is considerable interest in developing an in situ remediation approach to target per- and polyfluoroalkyl substances (PFAS) compounds in groundwater. Potential techniques have been trialled at laboratory scale but many have not previously received testing in the field. This presentation discusses a series of field-scale pilot studies that have been completed to evaluate six of these potential in situ remediation approaches. The studies were completed within a mixed PFAS and BTEX plume at a large petroleum hydrocarbon facility located in the Middle East.

Various PFAS compounds were detected within the pre-treatment with concentrations ranging up to 18,000 ng/L. The groundwater was also impacted with gasoline-range petroleum hydrocarbons along with various additives including MTBE and TBA. The aquifer comprised a fine sand with a discreet high-K, coarse sand layer within the target treatment zone.

Approach/Activities.

Six pilot-scale permeable reactive zones (PRZs) were created in the aquifer situated in a slightly saline, sulfate-iron reducing environment.

The pilot-scale field studies comprised the use of two chemical oxidants: hydrogen peroxide and sodium persulfate; as well as four adsorbents: Powdered Activated Carbon (PAC), Colloidal Activated Carbon (CAC), Ion-Exchange Resin (IER) and Biochar.

Results/Lessons Learned.

The site conditions, applications and results will be shown within the presentation. Comparisons will be made of reagent distribution across the injection depth, showing that CAC and sodium persulfate distributed most uniformly. Discussion will be made of disproportionate amounts of PAC and Biochar entering the monitoring well packing and how this may affect groundwater analysis. The efficacy of the various treatments will be shown, discussing why chemical oxidation appears ineffective for PFAS, that PAC, IER and Biochar show initial reductions in concentrations, followed by contaminant break-through and that CAC shows sustained treatment, with all PFAS constituents remaining at 'non-detect' for 550 days of monitoring.

This presentation will further detail the successful CAC remedial approach, in which the aquifer surface is coated with a 1-2µm layer of activated carbon, which adsorbs PFAS from the groundwater. By deploying this method at site boundaries or near to contaminant sources, the route of exposure to down-gradient receptors is eliminated. This approach has been completed on 16 sites worldwide, with over 120 other sites having been evaluated for treatment. Questions of longevity, competitive sorption, sorption capacity and treatment of short-chain PFAS will be explored, with long term data shown.

AquaConsoil topics to which the presentation links:

- Sustainable remediation technologies
- New low carbon solutions for emerging contamination

49950 A study on PFAS in consumer products, recycling processes, dust and sludge MSc. Tessa Pancras

Tessa Pancras, Hans Slenders, Arcadis the Netherlands

For the ministry of Infrastructure and Water Management, Arcadis has executed an extensive study on the presence of PFAS in consumer products.

About 130 samples of household/consumer products, dust, processes, recycling and waste have been tested using a three-step approach, with increasing detail; (1) screening the samples for extractable organic fluorine (EOF), (2) target analysis for 42 individual PFAS and (3) a total oxidizable precursor (TOP) analysis on a selection of samples to gain insight in the presence of PFAS-precursors. Finally, an assessment of the amount of products used in the Netherlands and the concentrations that were measured in this study, led to an estimate of the relevance of the different categories in their contribution in the release of PFAS to the environment.

Almost all of the collected samples contain organic fluorine and/or PFAS. The type of products that stand out the most are several types of stain and water repellents, used for clothing, shoes, carpets, floor tiles, bathroom protectors and for glass.
The concentrations vary greatly between and within the sampled categories. The contribution and relevance of a product or waste category for the release of PFAS in the environment does not only depend on the concentration, but also on the amount of product used and the type of use. The relevance of a product category is estimated based upon the PFAS load that might end up in the environment.

All samples tested were selected based on the exposure routes and release pathways to humans and the environment. Dust samples have been taken as a screening tool in several industries, offices and households, and indicate the widespread use of PFAS. In dust, the concentrations are often relatively high, up to several thousands µg/kg. The origin of the dust is usually not clear, but might be explained by wear of clothing and carpets. In several industries PFAS levels in dust are even higher indicating that PFAS are used in the production process. Dust, together with sewage sludge, seem to be a PFAS sink, which is probably caused by wear and waste of PFAS containing products.

An interesting finding is the large difference between EOF levels and the PFAS-target levels for many products, and more specifically several types of water and stain repellents. These levels indicate the presence of PFAS precursors, which was confirmed by the TOP-analysis. The water and stain repellents therefore pose a significant source of PFAS to the environment. Other interesting findings are the detection of very short PFCA's in paper recycling pulp and paper used for fireworks, and the presence of extractable PFAS-target compounds in fluoroelastomers.

50025 PFASs in Landfill Leachate and Wastewater – Prevalence, Context and Solutions Hurst Jonathan Miles

First Author: Jonathan Miles Co-Author: Jake Hurst, Johnsie Lang, Wim Plaiser

Affiliation: Arcadis UK Ltd (Jake Hurst, Jonathan Miles), Arcadis US (Johnsie Lang), Arcadis Nederland BV (Wim Plaisier)

Aquaconsoil Topic: 4 Integrated Management of Contaminated Land (4a & 4b) and/or 5 Sustainable remediation technologies in context of the EGD and energy transition (5a and 5c)

Title: PFASs in Landfill Leachate and Wastewater – Prevalence, Context and Solutions

This presentation begins by summarises the output of a global literature review of the prevalence of Per- and Polyfluoroalkyl Substances (PFAS) and other Persistent Organic Pollutants (POPs) in landfill leachate undertaken by Arcadis for the UK Department of Environment Food and Rural Affairs (Defra).

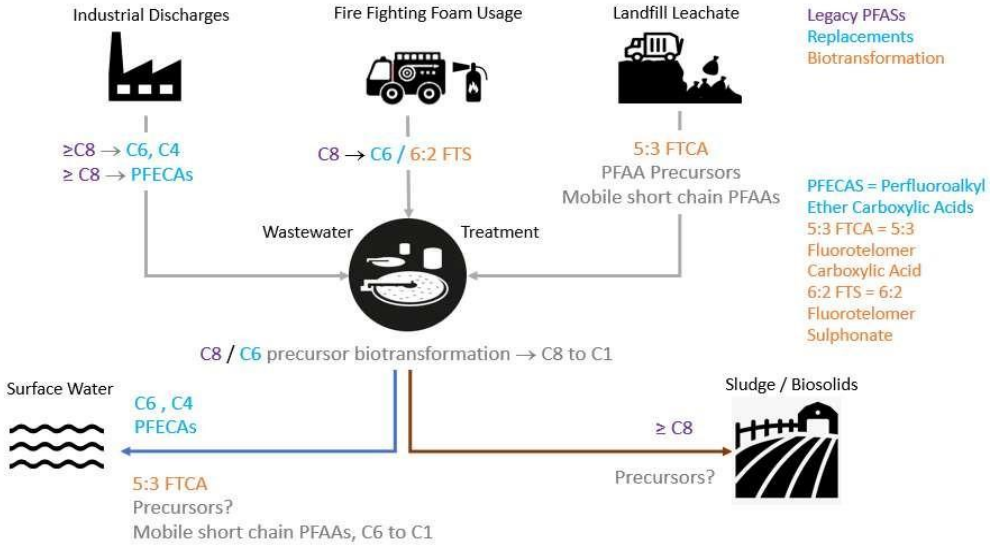
> Take home message: PFASs are the most prevalence class of POPs in landfill leachate and most significant in terms of mobility.

This output is then put within the wider context of PFASs wastewater management such as increasing regulatory activity, biosolids management, PFAS alternatives and differing inputs to wastewater treatment plants (WWTPs).

> Take home message: There is increased focus on WWTPs and industrial PFAS source sites which requires a holistic approach considering treatment and discharge restrictions.

Finally, an overview of the challenges and solutions for addressing PFAS in wastewater is provided highlighting Arcadis research and project work on emerging technologies including foam fractionation, novel sorbents, drainage cleaning & management and E-beam.

> Take home message: PFASs provide challenges for traditional wastewater treatment but there are a range of emerging technologies being developed and deployed



Thomas Held, Arcadis Germany GmbH, Darmstadt

It has already been pointed out many times that the neglect of precursors underestimates the extent of the contamination. For example, several PFAS-containing firefighting foams do not show any perfluorinated carboxylic and sulfonic acids in conventional analysis. Only after treatment of the samples with the TOP assay (*Total Oxidizable Precursor*) can the perfluorinated carboxylic and sulfonic acids be detected analytically. In the presentation, data from our own investigations along with a review of the literature are presented.

Recent data indicate that the precursor problem is much more serious than previously thought. Precursors (by definition polyfluorinated PFASs) can be anionic, cationic, or zwitterionic. Positively charged PFASs bind to soil much better than negatively charged compounds because of the inherent negative soil surface charge. Literature studies with PFOA and analogous cat- and zwitterionic PFAS of comparable molecular size have shown that the binding strength of these PFAS can be orders of magnitude higher compared to the analogous anionic compound. Moreover, the sorption isotherms of the cat- and zwitterionic PFASs (Langmuir-like) differed from those of the anions (linear), suggesting different binding mechanisms.

Studies of real contaminated soils have shown that the cat- and zwitterionic PFASs can account for a substantial percentage (> 90 %) of the total contamination. In commercial analysis, they are insufficiently extracted with the solvents used, so that the sum parameters (extractable organic-bound fluorine (EOF) and TOP) also underestimate the total contaminant mass.

The behavior of cat- and zwitterionic PFASs leads to a poorer elution of these compounds into the groundwater. In this respect, soil-bound precursors are found preferentially near the surface in higher concentrations. There they can remain for many years. For instance, accumulation of PFBA and other short-chain PFAS in grass at a contaminated site with an age of more than 20 years has resulted in ongoing microbial release of PFBA from precursors, which is then taken up into the grass. If PFBA had originally entered the soil along with the other PFAS compounds, today this compound would have already been fully flushed from the upper soil horizon by precipitation several years prior. It is not entirely unlikely that the PFBA-releasing precursors were first taken up into the plant where the subsequent release occurred. On the other hand, with the help of the TOP assay, it could already be shown that precursors are also taken up in plants.

Precursors are only slowly released into the water phase. The question arises whether the transport into the groundwater is so strongly retarded due to the strong sorption that the time is sufficient to completely transform the cat- and zwitterionic PFAS by microbial activity. First degradation experiments with aerobic unsaturated soil columns have shown that the biotransformation is also very slow. Analyzed were only the final products of the biotransformation, the perfluorinated PFAS, not any metabolites. The extent to which known metabolites accumulate or to which extent the metabolites are fixed in the soil as bound residues (a process that has already been demonstrated using ^{14}C-labeled PFAS) cannot yet be quantified or evaluated.

It is indisputable that precursors enter groundwater and surface water. AOF (adsorbable organic bound fluorine) studies have shown that precursors are transported very far for a very long time in aerobic rivers, i.e., in an optimal environment for precursor biotransformation. However, the AOF is sensitive to cross-contamination with fluorinated agrochemicals; this is not the case with the TOP assay.

TOP studies on aerobic groundwater samples have shown that precursor biotransformation is also very slow in this environment. It was possible to calculate the precursor biotransformation with groundwater samples taken and analyzed along the PFAS plume. The results were used in a contaminant transport model to incorporate the “new formation” of perfluorinated PFASs along the contaminant plume as an additional process. There is also the question of whether fluorotelomer alcohols (FTOH) appear as free compounds during precursor degradation. Because of their volatility, this class of compounds could

outgas and enter the atmosphere or even indoor environments. The results from the degradation test in the soil column indicate that such a release does indeed occur. On the other hand, studies of soil air (near the surface) showed no evidence of accumulation of FTOH. At least, the transport of FTOH is described as a serious dispersion pathway in the literature.

Abstract Submission for a Session (60min + 15min discussion)

Main Presenter: Jake Hurst Co-Presenters: Wim Plaisier, Jeff McDonough, Jack O Shaughnessy, Peter Storch, Hans Huizinga. Affiliation: Arcadis UK Ltd (Jake Hurst, Jack O Shaughnessy), Arcadis Nederland B.V (Wim Plaisier), Arcadis US (Jeff McDonough), Arcadis Australia (Peter Storch), Kenbri Fire Fighting (Hans Huizinga)

Aquaconsoil Red Line: Multidisciplinary support for a clean, effective transition from PFAS firefighting foams to fluorine free alternatives occurring globally across multiple sectors reflecting changing European regulations and using novel technologies. Aquaconsoil Topic: 5 Sustainable remediation technologies in context of the EGD and energy transition (5a and 5c) also elements of Topic 3 reflecting a new service connecting fire safety, engineering and environmental disciplines Aquaconsoil Category: 3 - New initiatives/project ideas

Evidence linking PFASs to human health risks and ecological harm is growing. This, along with discoveries of PFAS in drinking water supplies across the globe, is accelerating media attention on PFAS' ability to persist indefinitely in the environment and easily travel some distance in groundwater. Restrictions under the Stockholm convention are increasing alongside European REACH proposal which look to restrict a wider range of PFAS, potentially even a class wide restriction for use in fire fighting foams by 2025. PFASs are the key ingredient in fluorine based firefighting foams used for flammable or combustible liquid fires. Firefighting training areas and facilities that have engineered fire suppression systems at airports, refineries, industrial facilities and military bases have been using these foams for drills and training since the mid 1960s. Many site operators are now rethinking their fire management strategy.

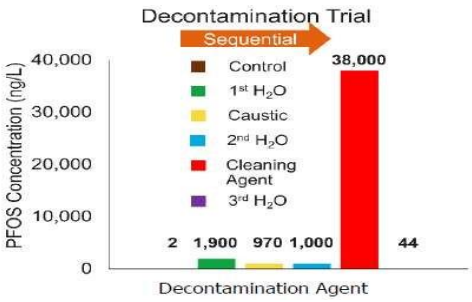
Some foams containing PFASs are being replaced with shorter chain C6 PFASs, but there are increasing concerns and environmental regulations regarding these foams. New, fluorine-free firefighting (F3) foams and modern foam delivery technologies offer equivalent extinguishment performance for the vast majority of fires without the health and environmental risks. There is already wide-scale application of F3 foams across multiple sectors such as aviation and oil and gas with some applications (e.g. large scale gasoline storage) where further F3 foam development is underway.

Effective foam transition programs help clients manage the lifecycle of liability related to fire suppression and firefighting. Transition plans to eliminate PFASs include decontamination of foam delivery infrastructure (e.g. pipework, tanks, and fire trucks), disposal of foams, equipment and infrastructure upgrades/replacement, and training. Transitioning foams also involves combining environmental management with fire protection engineering, fire safety strategies and fire risk assessments to provide a robust, multidisciplinary assurance process. Without appropriate support and clean out there is a risk of contaminating new fluorine free foams with residual PFAS, inappropriate selection of foams, ineffective management of the upgrades and transition process and costly waste disposal.

There are a number of novel and pragmatic solutions being deployed. For example, Arcadis is sealing concrete pads associated with firefighting training facilities, developing on-site destructive treatments for PFASs in foam concentrates and using innovative water treatment solutions to comprehensively remove PFASs.

Following discussion of the topics outlined above, the session will then explore case studies from across Europe and worldwide where Arcadis' Foam Transition services have been employed including aviation fire system upgrades, hangar system foam transition, fire tender clean out and environmental management of past and future fire training activities.

Main message: A clean, effective transition to PFAS-free firefighting foams requires a holistic, multidisciplinary approach involving novel clean -out and treatment technologies.


Decontamination Trial
Sequential
PFOS Concentration (ng/L)
40,000
30,000
20,000
10,000
0
Control
1st H2O
Caustic
2nd H2O
Cleaning Agent
3rd H2O
2
1,900
970
1,000
38,000
44
Decontamination Agent

48615 "Zero energy soil remediation: recovery of free product using solar and wind energy" Verhaagen

Presenter: Mr Paul Verhaagen. HMVT

In the presentation we would like to present results from a zero energy in-situ remediation using solar and wind energy. During the in-situ remediation significant amounts of free product (hydrocarbons) were removed. This has proven that a zero energy soil remediation approach can clean the soil in a sustainable manner.

Of more interest, and a major aim of the presentation is to present design issues, not only from a technical (energy) perspective, but also from a remediation approach perspective.

To start with the latter, in our conventional way of thinking a remediation process starts and follows a continuous linear path to the end. However, if we want to use solar and wind energy, we have to accept that a remediation is not a continuous process. Very simple: more remediation during the day / summer and less remediation during the night / winter. Is this a problem when making a remediation approach? Well, in most projects this is not a problem. In some cases it is even a positive issue as the alteration between active and non-active periods helps the remediation progress. In the few cases where remediation is highly urgent, an in-situ remediation approach is not likely at all. So, from a remediation approach perspective, zero energy soil remediation is a viable option to consider.

From a technical perspective, the design requires some 'new thinking' not only on energy production but also on how energy is made available for the remediation. Most of us when they think about solar or wind energy, they think about the production of electricity. However, for most in-situ remediations, this is noy always the best. An alternative is to use the solar panels to make pressurized air. This pressurized air is then used on the site for operating various pumps to recover product but also for air sparging. A major advantage of this approach is the easy storage of pressurized air in tanks.

Finally, solar energy operated remediation are totally 'of the grid' solutions. This means that even the most remote contaminated locations can now be remediated in a sustainable manner.

For the audience there are the following 'take home messages':

- A zero energy in-situ soil remediation is for most cases a viable remediation approach;
- There are nowadays many solutions that make sustainable remediations possible. Due to intelligent design and new energy technologies, not only biological processes qualify as sustainable;
- It all starts with some new thinking.. not only from a technical perspective. Also when exploring remediation options.

48896 Electrokinetic-enhanced bioremediation: applications in physically heterogeneous settings Richard Gill

Abstract Submission for Presentation in Regular Thematic Session

Author: Dr Richard Gill

Soil and Groundwater Scientist, Shell Global Solutions B.V.

Abstract:

This talk focuses on the coupling of two remediation technologies: electrokinetics and in situ bioremediation (EK-BIO), to overcome the mass transfer limitations presented by physically heterogeneous settings that can limit conventional remediation technologies. While bioremediation is commonly applied, electrokinetics (EK) less so. EK is the application of direct current to the subsurface to initiate certain transport processes independent of hydraulic conductivity. Where bioremediation is limited due to the influence of physical heterogeneity, EK transport processes could be applied to initiate an additional flux of limiting solutes across K boundaries. The research highlighted in this talk relates to laboratory and desk-based studies that have advanced the current state of knowledge for EK-BIO applications at both the fundamental level and field-scale respectively. The laboratory studies support the development of a conceptual framework describing the influence of physical heterogeneity on EK-BIO applications and the desk study compares the technology against others using sustainability criteria.

Take Home Message: EK could be an effective tool to enhance bioremediation in physically heterogeneous settings.

49349 Electrokinetic bioremediation of chlorinated solvents in groundwater: novel insights from multiphysics process-based models and real-time machine learning simulations

Riccardo Sprocati[1], *John Flyvbjerg*[2], *Nina Tuxen*[2], *Massimo Rolle*[1]

[1]Department of Environmental Engineering, Technical University of Denmark, Miljøvej, Building 115, 2800 Kgs. Lyngby, Denmark

[2]Centre for Regional Development, Capital Region of Denmark, Kongens Vænge 2, 3400 Hillerød, Denmark

The success of in-situ groundwater remediation typically relies on effective hydraulic removal of the contaminants and/or hydraulic delivery of reactants or nutrients to promote contaminant degradation. The effectiveness of these techniques is hampered by the presence of low-permeability porous media, in which hydraulic flushing is not feasible and mass transfer mechanisms are controlled by slow diffusive processes. To overcome this limitation, technologies based on electrokinetics (EK) are used to establish an electric field in the subsurface which significantly accelerates the transport of amendments also in poorly accessible low-permeability porous media.

In the first part of this work, we show recent advances in the development of multiphysics processbased models for electrokinetic remediation. We consider the case of electrokinetic bioremediation (EK-Bio) which is a promising technology in which the electric field can be used to deliver both amendments (lactate) and specialized degraders (KB-1) to promote reductive dehalogenation of the organic contaminants. Using the code NP-Phreeqc-EK [1], we setup a model of EK-Bio with the same geometry of a pilot implementation carried out in Skuldelev (Denmark) and we describe the coupled physical, electrostatic, chemical and biological processes occurring in the system during treatment [2]. The model developed accounts for electrokinetic transport, charge interactions, mass-transfer limitations, degradation kinetics and geochemical reactions.

In the second part of this work we propose a machine learning surrogate modeling framework for EK-Bio which is trained on the outputs of the multidimensional multiphysics process-based model. We use an artificial neural network as approximation function and we demonstrate that the surrogate model is able to interpret the complex dynamics of EK-Bio while allowing computationally efficient model exploration, sensitivity analyses and uncertainty quantification. The results of this study indicate that machine learning models can be excellent tools to lower the technical barriers in the simulation of complex environmental processes and increase the trust in novel technologies that are currently considered very complex to predict due to the strong interplay between several physical and biogeochemical subsurface processes.

[1] Sprocati, R., Masi, M., Muniruzzaman, M., & Rolle, M. (2019). Modeling electrokinetic transport and biogeochemical reactions in porous media: A multidimensional Nernst–Planck–Poisson approach with PHREEQC coupling. *Advances in Water Resources*, 127, 134-147.

[2] Sprocati, R., Flyvbjerg, J., Tuxen, N., & Rolle, M. (2020). Process-based modeling of electrokineticenhanced bioremediation of chlorinated ethenes. *Journal of Hazardous Materials*, 397, 122787.

50985 Assessment of the role of densification on displacement of DNAPL in highly permeable porous media using polymer solution Amir Hossein Moahammadi Alamooti

Amir Hossein Moahammadi Alamooti [1,2,3], Stéfan Colombano [1], Sagyn Omirbekov [1,2], Azita Ahmadi-Sénichault [2], David Cazaux[4], Benoit Paris[5], Antoine Joubert[6], Hossein Davarzani [1]

1 BRGM (French Geological Survey)
2 Institut de Mécanique et Ingénierie de Bordeaux (I2M), Arts et Métiers Institute of Technology, CNRS, Talence, 33405, France
3 Agence de la transition écologique (ADEME), Angers, France
4 Inovyn, Tavaux, France
5 Intera, Limonest, France
6 Serpol, Vénissieux, France

Standard oral presentation. Proposed session:
5 Sustainable remediation technologies in context of the EGD and energy transition
5a) New low-carbon solutions for conventional and emerging contamination

Aim of the presentation

This presentation aims at providing the audience with recent results from research on the remediation of soils contaminated by Dense Non-Aqueous Phase Liquids (DNAPL). Despite the fact that these products were mainly used several decades ago, due to their persistence and toxicity, they nevertheless remain highly problematic contaminants and a threat to many aquifers in Europe and globally. The main focus of the presentation is on the engineering of polymer solution densities aimed at optimizing the displacement of DNAPLs present as a discontinuous trapped phase in the porosity of the saturated zone below the groundwater table.

Specific methods addressed

We evaluated various polymer solutions (guar gum, xanthan gum, and carboxymethyl cellulose; CMC) to find the most stable ones capable of suspending barite ($BaSO_4$) in different concentrations to cover a wide range of densities (from 0.6 up to 1.15 times the density of DNAPL). A centimetric-scale 2D sandbox was used to design an experimental procedure with similar permeabilities and fluid configurations as in a real site where there is a layer of DNAPL below the water table. To evaluate the efficiency of the displacement of the DNAPL by the densified polymer solution, the solution was injected through the DNAPL at the bottom of 2D sandbox at a fixed injection rate. The injection was monitored using an advanced imaging technique and interpreted using mass balance techniques and modelling.

Main takeaway messages

Results showed that the denser the polymer solution, the more significant was the lateral movement of DNAPL. In contrast, when polymer solutions with a lower density were used, the gravity forces caused a more vertical displacement. The analysis of displacement efficiency shows that when the density of polymer-barite solution is close to the density of DNAPL, the mobilization of trapped DNAPL is improved by up to 150% compared to using polymer solutions without barite. Our new formulation of the polymer solution can result in a significant improvement in remediation processes of soils contaminated with DNAPL, as it is a safe and stable mobilization technique. A proposed model of two-phase flow displacement, based on Darcy's law and continuity equations, provides a good reproduction of the measured fluid-fluid interface (based on image analysis), as well as the displacement efficiency (mass balance data).

Chair: Frank Volkering

49611 Influence of surfactant on dnapl mobilization

J. Dijk, M. De Camillis, R. De Waele, M. Slooijer

Corresponding author: m.decamillis

Background/Objectives. An industrial site in the port of Tarragona (Spain) is contaminated with mainly chlorinated ethenes, chlorinated methanes and chlorinated ethanes. High concentrations (DNAPL) of mainly tetrachloroethene (PCE) and chloroform are present, as well as degradation products.

Since the site is situated close to the sea, the groundwater is brackish to salt with an electrical conductivity (EC) up to 25,000 µS/cm and sulphate concentrations up to 1,600 mg/l. Given the nature of the contamination and aquifer, anaerobic reductive dichlorination (ERD) was identified as the most promising in-situ bioremedation solution.

In addition, the effect of a surfactant to enhance the mobilization of the residual DNAPL was investigated. The focus of the investigation was on the residual DNAPL that remained probably trapped in the pore space in the form of small droplets.

Approach/Activities. The remediation consists of groundwater circulation system via extraction and infiltration wells and dosing of an electron donor to stimulate the process of ERD. Besides regular monitoring, molecular analyses (qPCR and NGS) were performed to have a better understanding of the microorganisms and degradation pathways involved under these specific conditions.

At the site, surfactant tests were performed to investigate the influence of the surfactant on the soil permeability and DNAPL mobilization. Push-pull test and field test were carried out by using 5% surfactant solution. The push-pull test was followed up by monitoring concentrations and performing molecular analysis. The field test was implemented by adding the surfactant solution to the groundwater circulation system.

Results/Lessons learned. Concentrations as high as 100,000 µg/l of PCE, 41,000 µg/l of VC and 340,000 µg/l of Chloroform were found on site. After about six months, degradation products had increased in concentrations significantly and after about 12 months, ethene increased dramatically from below detection limit up to 26,000 µg/l. Molecular analyses of groundwater confirmed that there is a strong increase in the amount of bacteria and enzymes involved in dichlorination. Also the gene encoding for chloroform reductive dehalogenase (cfrA) increased dramatically from below detection limit up to 8.9E+7 copies/l. As result of partial sequenced DNA (ORVIdecode), it was found that the dominant genus of the bacterial community consisted of *Dehalococcoides (27%)* of which 70% was closely related to *Dehalococcoides mccartyi*.

The surfactant tests provided useful results. The flow rate was measured during the push-pull test and it increased as consequence of the surfactant infiltration. A concentration increases of PCE, as well as the cDCE and VC, was detected. Molecular analysis performed revealed an increase of viable cells from the beginning of the test. These results indicate that DNAPL droplets were mobilized and dechlorinated bacteria were stimulated. The field test confirmed the outcomes of the push-pull test. In particular, the mobilization and bioavailability which enhanced the biodegradation of the present contamination. Moreover, an improvement of the system performance was observed due to the infiltration rate

improvement for several weeks. In addition, the results obtained suggested that the infiltration of the extracted water did not spread outside of the infiltration area.

49102 Surfactant Enhanced Extraction of NAPL, Globule, and Sorbed Phase Contamination Resolving Limitations To Contaminant Availability

George A. Ivey

(Ivey International Inc., Unit 7, 19122 - 27th Avenue, Surrey, BC Canada V3S 5T1)

Background/Objectives. This applied presentation will explain hydro-geo-chemical fundamentals of hydrophobic organic chemical (HOC) behavior, including petroleum hydrocarbons, chlorinated solvents, PFAS, and Pesticides, in saturated and unsaturated regimes, from their general physical chemistry characteristics to detailed phase partitioning and sorption (i.e. absorb and adsorb), and interfacial tension, and how these kinetically limit the '*Availability*' of contamination for remediation. Contaminant sorption and reduced availability can be significantly reduced with integration of surfactant enhanced extraction (SEE), to enhance contaminant phasedesorption (i.e. of vapour, liquids, and solids) and significantly increase their '*Availability'* for enhanced in-situ Physical, Biological and/or Chemical remediation.

Approach/Activities SEE remediation site case studies, are presented that each evolved from pilot to full scale applications, to provide integration details and the client's evidence based findings and the statistically measurable benefits realized at each site, using SEE as part of site specific physical (MPE), biological (MNA) and/or chemical (ISCO/ISCR) treatment strategies that expedited vapour, soil and groundwater remediation to achieve the applicable regulatory and/or risk assessment based clean-up objectives.

The presentation will be technically underpinned by established scientific principles, well supported by site data, figures, tables, and three dimensional computer animation models, for improved audience interaction.

Results/Lessons Learned:

SEE remediation can result in enhancing availability of NAPL, globule (ganglia), and sorbed phase contamination for physical, biological and chemical remediation, within combined remediation technology applications to realize synergistic benefits. Benefits also included significant project life-cycle sustainable cost savings to achieve regulatory and/or risk based site clean-up objectives.

49637 Surfactant-Supported In-Situ Oxidation for the Remediation of DNAPL-Groundwater contaminations Benjamin Herzog; PhD Lorenzo David

Topic 5: Sustainable remediation technologies in context of the EGD and energy transition

Presenters:

- Benjamin Herzog, Norbert Klaas; Research Facility for Subsurface Remediation (VEGAS), University of Stuttgart
- David Lorenzo, Aurora Santos; INPROQUIMA (Department of Chemical and Materials Engineering), University Complutense of Madrid

Groundwater and soil contamination caused by industrial activities are pervasive environmental and public health problems. DNAPLs, in particular, are usually difficult to handle due to their deeper penetration into the subsurface and pose a particular challenge for the sustainable and efficient treatment of contaminated sites.

Various in-situ remediation methods such as In-Situ Chemical Oxidation (ISCO) have been developed for the remediation of such groundwater contaminations. Remediation with ISCO involves the injection of oxidants into the affected aquifer areas with the intention to chemically transform contaminant compounds into less harmless species. However, these oxidative reactions take place in the aqueous phase and thus only the contaminants dissolved in the groundwater are being degraded. Therefore, a rebound often occurs after an ISCO remediation, i.e. the concentration of pollutants in the groundwater increases again after some time due to remaining DNAPL in the aquifer.

To avoid rebound and to increase the efficiency of ISCO applications, the use of plant-based and biodegradable surfactants in combination with oxidizing agents is being investigated as part of the EU research project "Life-SURFING". The use of surfactants is intended to increase the solubility of the contaminants in the aqueous phase, making them more accessible to the oxidant. In addition, the surfactants are able to desorb adhering organic compounds from the soil matrix, which can lead to a complete removal of contaminants from the pore spaces. In the EU project, the group INPROQUIMA (Department of Chemical and Materials Engineering at the University Complutense of Madrid) is conducting research on a field case in northern Spain, where a fractured aquifer is contaminated by a DNAPL mixture containing hexachlorocyclohexanes and other chlorinated liquid wastes from lindane production. A broader application of the Surfactant-Supported In-Situ Chemical Oxidation ("S-ISCO") is being addressed by the Research Facility for Subsurface Remediation (VEGAS) at the University of Stuttgart. Here, the transferability of the technology to other hydrogeological situations and a broader spectrum of contaminants is being investigated based on laboratory experiments of medium to large scale.

By presenting recent findings and progress regarding the S-ISCO technology, this talk will give insight into the ongoing development and research on an innovative remediation technology. The LifeSURFING project and this presentation are to motivate stakeholders to include new and innovative combinations of established and well known methods such as ISCO to increase the efficiency of treatments, shorten remediation time and save costs.

49779 Novel iron oxide nanoparticles for in situ and ex situ treatment of persistent pollutants
Mohammadian
Topic 5.1. New Low-Carbon solutions for conventional and emerging contamination

Abstract:

Removal of toxic pollutants such as heavy metals and cyanides from groundwater and industrial wastewater requires installation of multi-step treatment plants, investments in the million-euro range and use of reagents (sorbents, flocculants) that themselves could be toxic to personnel or the environment.

This work presents the capability of novel iron oxide nanoparticles (ColFerroX®) as a sustainable, scalable solution for *in situ* and *ex situ* removal of heavy metals, chromium, and cyanides from contaminated waste- and groundwater. Iron oxides are non-toxic and pose no danger to the environment or to the personnel. The minute size of these particles offers much higher (>10 times) sorption sites for pollutants compared to other conventional sorbents. These nanoparticles can adsorb mixtures of various heavy meals (As, Zn, Pb, Cu, etc.) and hence no multi-step pH-adjustments and/or different sorbents are needed for removal of complex waste waters. They can easily be removed from e.g. industrial wastewater by flocculation, after sorption of pollutants.

In a further application, the small size of the iron oxide nanoparticles (~500 nm) enables injection of *in situ* permeable sorption barriers into aquifers and, hence, avoiding installation of large-scale pump and treat systems.

Here, we demonstrate the functioning of ColFerroX® nanoparticles in industrial-scale remediation actions for both *in situ* and *ex situ* applications. First, we performed lab-scale customization of the ColFerroX® suspension to the specific geochemical problem. Then, we present the upscaling process and show the results of pilot applications for one groundwater remediation and one industrial wastewater treatment process introducing ColFerroX® nanoparticles as promising, efficient, and cost-effective product for treatment of contaminated waste- and groundwater.

Session 4a7 Mitigation migration risk

Chair: Kirsten Rugge

48483 Subaqueous sediment remediation with a permeable active geocomposite in Sydney/Australia Niewerth

Stefan Niewerth[1], Gus Martins[2]

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At Kendall Bay in Sydney/Australia, the New South Wales Environment Protection Authority (NSW-EPA) issued a sediment remediation declaration for a significantly contaminated area adjacent to a former gasworks facility. Today, the disused industrial site has become a modern residential neighborhood. Therefore, not only the area on land was redeveloped, but also the sediments in the bay.

It was determined that remediation was required where the sediments contain total polyaromatic hydrocarbon (PAH) concentrations greater than 25 mg/kg on average and Total Recoverable Hydrocarbon (TRH) of more than 4000 mg/kg on average. To remediate the highly contaminated sediments a subaqueous cap with an active geocomposite was built. As an alternative to dredging and dewatering the contaminated sediments, so-called “sediment caps” can be built. Materials that adsorb organic pollutants are installed over the contaminated sediments. Percolation of the pollutants with the groundwater discharge into surface waters is thus prevented. With small amounts of an adsorbent, such as activated carbon or organophilic clay, permeable horizontal contaminant barriers can be designed to ensure encapsulation of the organic compounds. In addition, the stern odour of the organic pollutants is bound. With the help of flux simulations, the required amount of the adsorbent can be determined. In Kendall Bay only small quantities of activated carbon of 3.400 g/m² was needed to create a save cap with a service life time of several decades.

For installation, the geocomposite was attached to the shoreline and was unrolled with the help of a barge assisted by divers. A steel frame was used to sink the material, ensuring controlled ballasting for mechanical protection. A thin sand layer on top of the active geocomposite protect the geotextiles against stone drops and UV radiation. In addition, new benthic organisms may colonize in the clean sand. The sediment capping was successfully completed between July and August 2020.

Sediment capping provides several advantages when compared to, e.g. dredging and dewatering or other technical solutions. It is less energy intensive and does not require disposal of the contaminated soil. The decreasing landfill volume in many European countries or an already low landfill density in remote regions are factors for high costs. Moreover, it reduces exposure and related risks, minimizing impacts to living organism in the water body.

The conference paper and the oral presentation will cover the key aspects of designing and constructing a sediment cap with active geocomposites. Examples of sediment remediation projects from the U.S. and Australia are used to introduce the concept of horizontal active permeable barriers in marine environments.

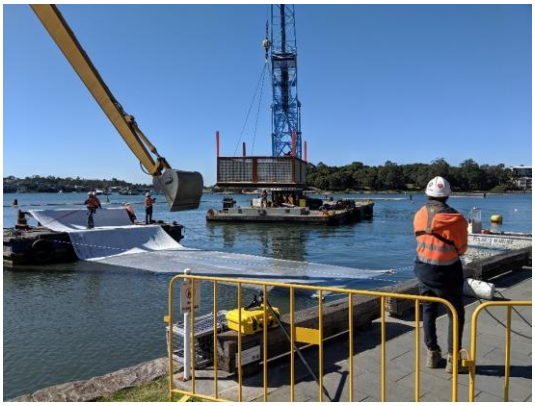


Fig. 1. Installation of the active geocomposite.

47679 Reactive mat on river bed passively catches groundwater contaminants Praamstra
This project links to Topic 5.1: New low-carbon solutions for conventional and emerging contaminants

Presenter: Tobias (T.F.) Praamstra, TAUW bv, Soil & Groundwater Experts

Partners: Bert van Goidsenhoven (OVAM), Pieterjan Waeyaert (Envisan, JdN), Erik Bosmans (iFLUX), Lisanne Keijzer (TTE consultants), Martijn Naert (Witteveen+Bos)

Keywords: reactive mat; sustainability; contamination; remediation; groundwater; surface water; green adsorbents

Within the framework of the Interreg project RESANAT (Residual contamination remediation with nature-based techniques), a cooperation has arisen between several parties from Flanders and the Netherlands. The objective of RESANAT is the development of affordable remediation techniques, with a low footprint, in a natural environment. RESANAT focuses on difficult to remove soil & groundwater contamination, financially or technically, on brownfield sites that lead to risks for the living environment and restricting redevelopment. In addition to pilots based on phytoremediation in Zeebrugge (BE) and biostimulation in 's Gravenmoer (NL), a full-scale field trial is being carried out in Ghent (BE) with a reactive mat ('Natural Catch') in a surface water threatened by soil pollution.

Because of the industrial production of tar and carbon black in the past, the soil next to the canal the Lieve in Ghent has become polluted with aliphatic and mono- and poly-aromatic hydrocarbons, in particular benzene, C6-C10 (light fraction of mineral oil) and some PAH. These substances were part of the production process. The shallow groundwater contamination migrates to the canal, affects the quality of its surface water and causes an ecological risk. After removal of the heavily contaminated sediment in 2019 as part of water management (climate adaptation), the discharge and drainage capacity of the canal has increased and its adsorption capacity for pollutants has decreased. The result was a further increase in pollutant concentrations in the canal up to 300 times the environmental quality standard for surface water. The remediation technique to tackle this consists of a permeable reactive mat on the water bed. The functioning of this mat is based on three nature based pillars:

1. The natural drainage capacity of the Lieve as the driving force
2. The use of an adsorption material of natural origin (‘green adsorbent’)
3. A biologically active interface on the upper side of the mat.

A consortium of six project partners from Belgium and the Netherlands is working on this full-scale field trial: OVAM, TAUW, Envisan, iFLUX, TTE Consultants and Witteveen+Bos.

The concept of the reactive mat did not come out of the blue. As early as the year 2000 IWACO performed a laboratory test on the capacity of locally available coffee bean hulls for the adsorption of for the adsorption of pesticides from groundwater in Sao Paulo, Brazil. Around 2010 Witteveen+Bos and TAUW developed a first prototype of the Natural Catch that was applied in the field at the former landfill site in Zeeland, the Netherlands; by constructing a draining ditch with sieved peat at the bottom, the concentration of aromatics and chlorinated hydrocarbons could be reduced by 93 to 100 percent. Since then, several laboratory studies have been carried out into the adsorption capacity of green adsorbents

for various persistent pollutants (including medicines). Several designs have been made by TAUW, for example for an industrial canal into which HCH migrates via seepage. At the same time, some foreign companies worked on prefabricated reactive mats with organoclay and activated carbon (e.g. the Reactive Core Mat®). However, these prefabricated mats are expensive and have a higher carbon footprint as a result of the use of high-grade adsorption materials that are produced specifically for this application.

In 2018, OVAM took the initiative for the Interreg project RESANAT, which then actually started as of May 2019. Within RESANAT, there was an opportunity to further develop the construction of the reactive mat and to apply the design in the field on the basis of a green adsorbent. Based on an initial literature study, a first selection was made of potentially suitable green adsorbents. Apart from the natural origin, such a material must meet the following requirements: it must be reasonably inert physically and chemically, have a reasonable adsorption capacity and a good water permeability, be attractively priced and preferably available in the region.
The consortium also carried out a study into the site-specific conditions at the location of the Lieve, near the former industrial site. First of all, along the banks of the Lieve over a stretch of approximately 150 meters measurements were carried out with EnISSA-OIP and -MIP to a depth of 8 m -mv, in which not only the contamination situation but also the soil structure was determined. Based on these results, fixed monitoring wells were installed and samples of groundwater and surface water were taken and analyzed (before and after removal of the sediment). In addition, mass fluxes were determined of the inflow of contamination into the surface water with iFlux samplers (horizontal) and Sediment Bed Passive Flux Meters (vertical). This has led to an illuminating insight into the pollution loads that the canal receives daily (locally up to 100 mg/m^2 water bed per day), the distribution of influxes over the canal stretch and the influence of degradation and dilution downstream. In the end, it turned out that over a canal section of 110 meters and a surface of 660 m^2, measures had to be taken to protect the surface water quality.

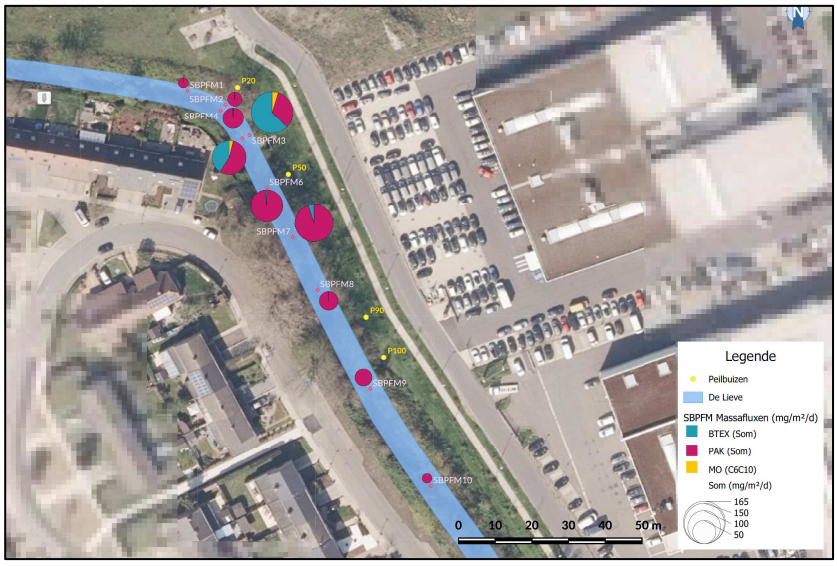


Figure 1. Canal the Lieve in Ghent and influxes of contamination

By performing batch tests at the TAUW test laboratory with different adsorption materials and contaminated groundwater, it became clear which materials were suitable for use in the field based on adsorption capacity, physical stability and permeability. The following materials proved to be the best, in ascending order of adsorption capacity: shredded pine bark, white peat and biochar. For the test in the Lieve, it was ultimately decided to apply biochar on the section with the highest influx and white peat on the section with a lower influx. Based on the adsorption tests and calculations, TAUW expects that at the current influx the adsorption material will last 10 to15 years, at an adsorption efficiency of 90 to 97% for the critical contaminants phenanthrene, pyrene and acenaphthene. The thickness of the mat was a hard boundary condition: from the point of view of water management (surface water flow) it could not exceed 30 cm. It is expected that in reality the purification yield is higher because microbial degradation also occurs at the interface between mat and surface water (anaerobic-aerobic). An initial qPCR test, a technique that is familiar to everyone today from the COVID tests, it appears that more than 3 months after the construction of the reactive mat, activity is present on the mat of a number of specific bacteria that are able to break down phenols, BTEX, PAH and alkanes with the help of oxygen.

Figure 2. Green adsorbents with potential

Finally, the design of the reactive mat construction has been worked on in close consultation between the producer of the required geotextile fabric, the contractor and the environmental advisor, supported by a student from TU Twente. The design procedure was complex because of the many product requirements. Aspects that play a role are the weight of the mat (dry and wet), the lifting capacity of the equipment, the tendency of the adsorbent material to float, type and quantity of ballast, the method of filling the geotextile sheet, the retractability, the durability of the material, the anchoring, the homogeneous distribution and the prevention of short-circuiting. Many designs have been passed in review.

Ultimately, it was decided to use mat elements of approximately 5 meters long and 6 meters wide. Each element consists of a double fabric with several compartments, similar to a down-filled winter jacket. Most of the compartments are filled with adsorbents, and a few are filled with ballast material to counteract for buoyancy. The transition between the mat elements is provided with impermeable foil strips to prevent short-circuiting of contaminated groundwater between the elements. In addition to the

simplicity of filling, lifting and installation, the advantage of working with elements is that they can easily be replaced, once they are loaded with contaminants, or removed when they are not necessary anymore.

Figure 3. Reactive mat in the Lieve after construction

In September 2020, contractor Envisan filled the geotextile elements on the bank of the Lieve with adsorbents and ballast. The elements were then lifted with a crane into the canal and anchored to the bank. At the time of installation, the water level was low. It was therefore possible to ensure a tight connection of the mats by sight. From October onwards, the Lieve continued to fill with water.
Until May 2021, the construction has physically held up well and the first part of the mission has thus been accomplished. The second part of our mission, until the end of 2022, consists of measuring, analyzing and assessing the quality of the surface water, the influx of contamination and the presence of specific micro-organisms. The first results look promising: specific micro-degraders are present on the mat and the surface water quality has improved to a level below threshold values for benzene and C6-C10, while the concentrations of critical PAH-components are reduced to 85% (acenaphtene) to 95% (e.g. phenanthrene and pyrene).

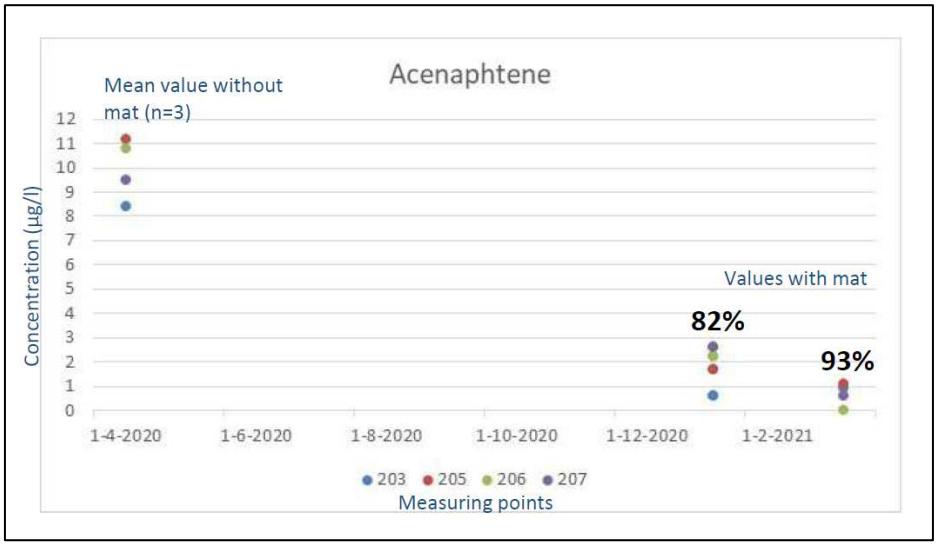


Figure 4 Concentration acenaphtene in surface water the Lieve with and without reactive mat

Another part of the RESANAT program which will be carried out this year concerns determining the carbon footprint and costs of this remediation variant. After all, in addition to the remediation effect, the reactive mat is expected to perform well on other sustainability indicators.

Scope and potential

The reactive mat is intended to catch relatively persistent micro-pollutants. Pollutants that are easy to biodegrade and/or contaminants in very high concentrations (including free product) can better be tackled with other techniques. For these situations, the adsorption capacity of a reactive mat is too limited, easily degradable substrates can even damage the adsorbent and the mat would have to be replaced too soon, which would be detrimental to the sustainability of such a technique.

The application of the reactive mat as in Ghent is intended for draining surface waters in the vicinity of soils with persistent soil and groundwater pollution. In addition to application in surface waters near current and former industrial sites, the reactive mat can also be applied as a medium to long term solution in existing or constructed ditch systems around intensively cultivated agricultural land with pesticides and phosphates and in ring canals around (historical) landfills with a chemical content.

The content of the reactive mat, i.e. the type and quantity of adsorbents, must be adapted to the type and flux of the contamination. For example, a higher flux requires a higher quality material with a higher adsorption capacity. For a non-organic pollutant (non-hydrophobic) there is the possibility of using non-organic adsorbents, such as in the case of phosphate and heavy metals. Based on the experiences and results in Ghent, we hope to further develop this technique in the coming years. The primary goal is to make a sustainable contribution to improving the quality of surface waters in Europe. The secondary objective is to cover environmentally-related liabilities associated with these types of sites in an affordable way to ensure the use and redevelopment of sites.

Acknowledgements:
Without the financial and organizational support of Interreg, Dutch Ministry of Economy and OVAM this project had not been possible, nor without the scientific knowledge of our consortium (SDG 17).

50026 Sheen Management via Oleophilic Bio-Barrier (OBB) – Technology Overview and Case Studies

Shannon Dunn

Abstract Submission for a Session (60min + 15min discussion)

Main Presenter: Shannon Dunn. Supporting Presenters: Adam Bethel , Chris Piddington, Jake Hurst Affiliation: Arcadis US Ltd (Shannon Dunn) and Arcadis UK Ltd (Adam Bethell, Chris Piddington, Jake Hurst)

Aquaconsoil Red Line: Smart, sustainable technology helping to ensure a healthy soil-sediment-water (SSW) system. Aquaconsoil Topic: 5 Sustainable remediation technologies in context of the EGD and energy transition (5a and 5c). Aquaconsoil Category: 3 - New initiatives/project ideas

Title: Sheen Management via Oleophilic Bio-Barrier (OBB) – Technology Overview and Case Studies

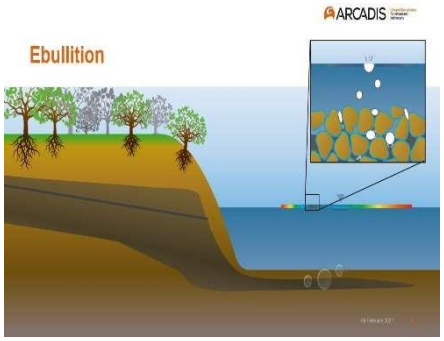
This session describes a novel, nature-based technology providing long term, sustainable management of hydrocarbon sheens at the groundwater – surface water interface which complements source zone management works. Sheens on surface water can cause visual impact and negative perceptions although actual environmental risks may be low, so this proportionate, cost effective solution encourages action from industrial partners and other problem holders.

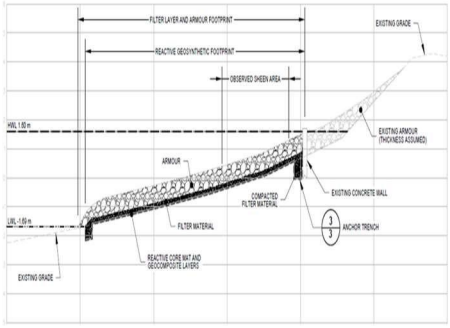
This session will start by providing an introduction to sheens and sheen transport mechanisms including seepage, drainage, tidal influence as well as wicking and ebullition. An overview of the range of sheen mitigation approaches will then be provided to give balance and context helping attendees to consider the most appropriate approach for their sites.

The Oleophilic Bio-Barrier (OBB) technology will then be explained in terms of the Non-Aqueous Phase Liquid (NAPL) wetting and enhanced depletion mechanisms involved, the lines of evidence supporting these mechanisms and materials employed. OBB is different from traditional adsorption based approaches in that it actively supports and enhances aerobic biodegradation by microbial communities on its surface – prolonging its life and degrading the NAPL collected. This section will also include operational considerations including site applicability, data requirements and options for deployment.

The final part of the presentation will provide a case study of the first full scale European implementation of the OBB technology and show the range of scales over which the technology is suitable from a large, tidal estuary to a small river. These case studies will explain the stages of assessment and implementation, logistics and challenges as well as the improvements to visual amenity and mitigation of sheen occurrence achieved.

Main message: The OBB represents a sustainable, cost effective and technically robust, approach to managing hydrocarbon sheens across a range of sites and scales.





49168 Contaminated Soil Capping – Risk-Based Approach for the Redevelopment of the Pharmaceutical Site under the Specific Site Conditions: Case study

Petr Kozubek [1,2]

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[2] *Charles University, Prague, Czech Republic*

The subject site is the pharmaceutical plant located in Prague, the capital of the Czech Republic heavily impacted by cocktail of volatile organic compounds (toluene, chlorobenzene and trichloroethene dominate, the presence of DNAPL of chlorinated solvents is apparent). From the geological point of view, the site bedrock is formed by Ordovician clayey shales overlain with the thin clay layer and top soil layer formed by fill material.
The central portion of the plant historically housing the chemical production (since 1940s) and forming the main hotspot of the plant subsurface contamination was designated for the redevelopment to the green relaxing area.
The following site specific conditions were necessary to take into account when selecting the variant of the remedial action for the planned redevelopment:

- The subject area is located in the central part of the plant daily passing by the majority of the plant staff (over 500 employees);
- The contamination is formed by highly volatile compounds with specific bad odour;
- The unacceptable human health risk via vapours inhalation by passing employees was estimated for no action variant.
- The pipeline bridge branches carrying utilities essential for the site manufacturing processes closely surround the subject area. The bridge is based on heavy concrete foots. There was a concern of the foots stability in case of deep excavation;
- The sensitive pharmaceutical manufacturing area with an air-conditioning system oriented to the subject area is located nearby. There was a concern of the suction of the impacted air in case of an open excavation;
- Given the specific geological site settings (weathered clayey shales) the extent of high level soil contamination is sharply bordered in both horizontal and vertical directions, respectively;
- Low aquifer permeability together with the location of the subject area at the watershed divide results in the limited potential for groundwater contamination spreading off;

Based on the feasibility study comparing several remedial approaches the variant of the contaminated soil capping specifically adjusted to the site conditions was selected. The remedial action was performed between November 2019 and April 2020. The temporary roofing covering entire subject area equipped with an air-conditioning system was constructed as the first step of the action (to eliminate the risk of the contamination emanation for both, the individual employees and sensitive pharmaceutical manufacturing process, respectively). The action was based on the removal of the top soil horizon formed by the fill material with relatively low contamination. The surface of underlying highly contaminated clayey soil was capped with a liner system. The capture system for recharged stormwater was installed at the bottom of the excavation on the liner and the excavation was backfilled with drainage layer and above lying soil layer suitable for planting of grass and ornamental shrubs.

The risk-based approach used under the specific site conditions resulted in the quick redevelopment of the heavily contaminated part of the industrial plant to the green relaxing area. Even though the contamination has remained on-site the risks for both the human health and for the enlargement of the contamination plume were reduced under relatively low financial expenditures.

4b) Advances in measuring and monitoring and the data expansion of contamination

Session 4b1 Innovative approaches for assessing the evolution of contamination

Chair: Hilde Passsier

50987 Application of natural source zone depletion (nszd) to a site impacted by petroleum hydrocarbons using multiple lines of evidence Verginelli

Iason Verginelli[1], Anna De Fina[2], Laura Locchi[2], Luna Maldi[2], Jean Pierre Davit[2], Renato Baciocchi[1]

[1] Department of Civil Engineering and Computer Science Engineering, University of Rome Tor Vergata, Italy.

[2] Golder Associates, Italy.

Natural source zone depletion (NSZD) is becoming a key aspect to be evaluated for the management of petroleum hydrocarbon sites impacted by light non aqueous phase liquids (LNAPL). NSZD is the term used to describe the combination of naturally occurring processes that can progressively reduce the mass of LNAPL in the source zone as a result of sorption of LNAPL constituents onto subsurface solids, dissolution into pore water, volatilization into the vadose zone and biodegradation within the LNAPL body. In recent years, different methods for the quantification of NSZD have been developed and applied, especially in the United States, in order to provide a benchmark for active remedy. In this work we present the results of a 3-year NSZD study carried out at a site impacted by petroleum hydrocarbons. In the considered site, an undetected crude oil spill from a storage tank occurred, generating a long plume of LNAPL and hydrocarbons in groundwater that extended beyond the site boundaries. Immediately after the detection of the spill, piezometers equipped for the recovery of LNAPL were installed to remove the free product and to contain the downstream propagation of the contamination. NSZD was investigated to assess the attenuation phenomena occurring at the site and to support the management of the LNAPL. To this aim, various measurement campaigns were conducted applying different methods to collect multiple lines of evidence on ongoing processes and ensure a greater robustness to the study. Furthermore, the field campaigns were conducted in different periods of the year, to evaluate the variability of the attenuation rates over time and with respect to the seasonality. The different lines of evidence showed the occurrence of NSZD in the areas affected by the presence of LNAPL. Namely, the CO_2 fluxes detected with the dynamic closed chambers (DCC) were statically higher in the contaminated areas compared to the ones detected in the background areas. By stoichiometrically converting these CO_2 fluxes corrected for the background values (i.e. by applying the so called “Background Method”) into degradation rates, we obtained NSZD rates consistent with those reported in other recent studies available in the literature. These estimates were consolidated through the analysis of radiocarbon (^{14}C) in selected soil gas samples which highlighted the presence of CO_2 resulting from the degradation of petroleum hydrocarbons. Furthermore, the analysis of the headspace of some piezometers highlighted the presence of high concentrations of methane, suggesting the occurrence of methanogenesis processes in the source zone.

On the other hand, from the analysis of the vertical concentration profiles in the soil gas probes, evidence of oxidation of methane and other VOCs in the unsaturated surface soil was observed. Finally, the NSZD rates measured in the saturated zone, by means of mass balance of electron acceptors and by-product formation (i.e. assimilative capacity), were significantly lower compared to those observed in the vadose zone (less than 1%), in line with the recent findings reported in the literature. This study represents the first of this kind carried out by an Italian team and hopefully may represent a starting

point for a wider application of this approach in Europe.

Keywords: NSZD; natural attenuation; LNAPL; petroleum hydrocarbons.

48491 New experimentations about the effect of groundwater fluctuations on the multiphase mobilization of LNAPL contaminants: assessment and monitoring. Cavelan

Amélie Cavelan [1*], Stéfan Colombano [2], Hossein Davarzani [2], Jacques Deparis [2], Catherine Lorgeoux [3], Anne-Julie Tinet [3], Constantin Oltean [3], Noële Enjelvin [4], Fabrice Golfier [3], Pierre Faure [1]

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[2] BRGM, France
[3] Université de Lorraine, CNRS, GeoRessources, France
[4] Université de Lorraine, INRAE, LSE, GISFI, France
*Presenter : Amélie Cavelan

While light-non-aqueous phase liquids (LNAPLs) are one of the most important sources of soil pollution worldwide, their remediation remains complex and not always successful. At contaminated sites, significant fluctuations of the soil bio/geochemical properties (metabolismstypes, redox) and significant spatial-temporal variations of the pollutant saturation occur, depending on the LNAPL phase (pure phase floating above the groundwater, dissolved plume, residual droplets). Hence, the real pollutant soil saturation often differs from the LNAPL thickness measured in monitoring wells, and gaps exist between results from modeling and site monitoring. Furthermore, the multiple imbibition/drainage cycles caused by seasonal or pump-induced groundwater level variations also affect the three-phase fluids distribution (gas/water/LNAPL), favoring the LNAPL release to the air and water. The relation between the groundwater variation dynamic and the LNAPL mobilization mechanisms need, to be further understood, especially in the climate change context where increased groundwater fluctuations are expected (changes in precipitation and recharge patterns, increasing groundwater use). For this purpose, a new project based on an original experimental system was developed at the GISFI (Scientist Group on brownfield sites) station, Homécourt, France. This work is based on a multi-scale approach (laboratory and controlled in situ) with an original experimental device (2m3 lysimetric columns), combining indirect (electrical conductivity), in-situ (pH, temperature, RedOx, electrical permittivity), and direct measurements in monitoring wells. This device allows the assessment of the LNAPL release (pure, dissolved, and gaseous phases) under a ‘current’ (based on regional climate records) and ‘extreme’ (based on the most extreme IPCC climate predictions) precipitation and groundwater fluctuation patterns. The remobilized hydrocarbons will be collected via gas collection chambers (gaseous phase) and suction cups (dissolved phase) as the groundwater table fluctuates and will be regularly analyzed (GC-MS, µGC). This work aims to introduce an intermediate scale between laboratory experiments (centimetric columns, 2D tanks) and the real complexity of contaminated sites, to (i) evaluate and compare different monitoring methods (ii) allow a better characterization and prediction of the LNAPL dynamics in a three-phase system (LNAPL/water/gas), (iii) identify and combine key processes and integrate them into existing numerical models. This project will make it possible to strengthen the recommendations concerning the characterization and monitoring programs for hydrocarbons polluted sites. Preliminary results will be presented to illustrate the capacity of this new instrumental system.
This work is partly funded by the DEEPSURF project "Lorraine Université d’Excellence", ANR-15- IDEX-04-LUE" and is included in the scientific program of the GISFI research consortium (Groupement d'Intérêt Scientifique sur les Friches Industrielles - http://www.gisfi.univ-lorraine.fr)

Béatrice Ducastel – Total SA

Abstract

Soil and Groundwater' is one of the primary environmental compartments of interest for better characterization, monitoring and reduction of environmental impacts for low-carbon and sustainable energy production and distribution. Over the last few years, the ORCAD Project (Online and Realtime Characterization of Aquifer Dynamic) aimed at better understanding the dynamics of groundwater flow and mass flux of dissolved species below our industrial sites. A demonstration was performed at the industrial scale in 2020 to validate the prior lab (2016 to 2018) and pilot scale tests (2018 to 2019). This third scale of testing illustrated the utility of the approach for a real-world case of contaminant plume monitoring. The industrial demonstration consisted of a transect of 10 boreholes instrumented with 2probes PVP stands (Point Velocity Probe), each equipped with micro-sampling ports, in direct contact with the unconsolidated shallow aquifer. This transect of probes was oriented perpendicular to the local groundwater flow direction and contaminant plume to validate the innovative mass flux assessment system. Onsite analyses has been performed by portative GC-MS to reduce volatilization of light species and obtain mass flux values after several hours. This demonstration is one of the first to show a high-resolution assessment of contaminant mass flux through a heterogeneous shallow aquifer, based on detailed 3-D point measurements of both velocity and concentration data. Local preferential pathways could be assessed laterally and with depth in this shallow aquifer. This promising approach reveals a new way of groundwater aquifer characterization and monitoring with a better understanding of dissolved species dynamic and a clear reduction of uncertainties for mass discharge assessment and further costs of site management.

Julio A. Zimbron, Ph.D. (E-Flux, Fort Collins, CO, USA)

The term natural source zone depletion (NSZD) is used to describe the transformation of LNAPL into dead-end inorganic products. Although the biodegradability of petroleum has been acknowledged for a long time, this more recently minted term reflects the importance of NSZDrelated data to inform the conceptual site model (CSM) for LNAPL-contaminated sites, as described in the updated 2018 LNAPL ITRC Guidance Document. A new paradigm for LNAPL contaminated sites is derived from the fact that the main biodegradation by-products, methane and carbon dioxide, are mostly expressed in the vadose (unsaturated) zone, rather than in the groundwater, as had been previously understood.

This presentation will include an overview of biogeochemical processes related to NSZD, and examples of methods for data collection that are easy to implement, and yet are key to manage LNAPL contaminated sites. These include: a) mapping the lateral extent of LNAPL sources based on vapor-based surveys of biogas profiles (methane and carbon dioxide) at dedicated points or existing monitoring wells, b) methods to quantify the in-situ biodegradation (NSZD) rates of LNAPL, and c) comparison of field-measured NSZD rates with active remediation technologies. These examples consistently illustrate the benefits of understanding NSZD processes in managing remediation projects in a rational and cost-effective manner, and assessing the risk associated with LNAPL sites.

Session 4b2 Transport and biodegradation of organic contaminants

Chair: Renator Baciocchi

50229 Characterization and carbon and chlorine isotope fractionation pattern of a novel trichloromethane respiring bacterium belonging to the genus Dehalobacter Soder Walz

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An anaerobic enrichment culture was obtained from groundwater contaminated with several chlorinated pollutants in an industrial zone of Barcelona. After the application of dilution-to-extinction techniques in liquid and semisolid medium, the microbial composition was assessed by 16S rRNA gene amplicon sequencing, and showed that the consortium was mainly composed by three gram-negative genera: *Dehalobacter* (20%), *Desulfovibrio* (20%), and *Proteiniphilum* (57%). The 16S rRNA gene sequence of this *Dehalobacter* presented a high similarity (>99%) with *Dehalobacter restrictus* strain PER-K23 16S gene, although they used different electron acceptors for growth. In our enrichment, trichloromethane (TCM) was completely transformed to dichloromethane and 1,1,2-trichloroethane was completely transformed to 1,2-dichloroethane and vinyl chloride at a ratio of 1:2.3. Other halogenated compounds such as 1,1,1-trichloroethane, 1,1-dichloroethane and tribromomethane were incompletely transformed. Carbon and chlorine isotopic fractionation was assessed during TCM degradation in three different systems: respiring cells, resting cells and cell free extracts. TCM degradation in these three systems resulted in small carbon (εC from −2.7 ‰ to −4.1 ‰) and chlorine (εCl from −0.9 ‰ to −1.2 ‰) isotopic fractionation. A characteristic dual C-Cl isotope fractionation pattern was observed for the three systems, and as there were no statistically significant differences between the dual isotope slopes, data from the three systems were merged to derive a combined $\Lambda^{C/Cl}$ value of 2.75 ± 0.27. In addition, this dual slope value differs from other two reported *Dehalobacter* strains capable of respiring TCM. These findings support the feasibility of isotopic analysis as a tool to assess bioremediation of TCM under anaerobic environments and leaves questions about the reaction mechanism of TCM within this genus.

49214 Longtime monitoring of biogeochemical changes in situ remediation of chlorinated solvents Åkesson

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Background

A cleaning facility in Alingsås, SW Sweden, had an accidental spill of chlorinated solvents in the 1970s. The site has been subjected to an *in situ* remediation pilot test with two different enhancing media, Zero Valent Iron (ZVI) and injection of microbial consortium (SDC-9™). Both media were injected into the unconsolidated sediment aquifer as an active barrier downstream the source zone and perpendicular to the plume. During two years, we have followed the trends of biogeochemical changes due to the treatment by concentrations of tetrachloroethene (PCE) and degradation products, physical and chemical properties of the groundwater, Compound-Specific Isotope Analysis (CSIA) of $^{13}C/^{12}C$, and sequencing of microbial DNA.

Aim

Our aim was to evaluate the biogeochemical changes in the two different areas, indirect the two different injectants, with the ambition to determine which injectant is most apposite for the sitespecific conditions, if possible.

Results

The treatment lead in both areas to anoxic and reducing conditions, critical for degradation. The area treated with ZVI had fluctuating tetrachloroethene (PCE) concentrations, as well as the concentrations of metabolites. The area treated by SDC-9™ have dissolved organic carbon and sulfate concentrations changed to a range favorable for the microbes, with optimal pH values, which all have remained favorable throughout the monitoring. For both areas, the first two degradation steps from PCE happened rapidly and stalled by the dichloroethene as the major metabolite at the end of the monitoring period. Both vinyl chloride and ethene have been detected, proving a further degradation process. During the two years, the dominating microbes have changed, and show increases of groups related to biodegradation of chlorinated solvents. The untreated source zone is still feeding the system with PCE.

Conclusions

Both methods showed promising results and would be suitable as a full-scale remediation. The area with ZVI injection had a faster degradation to start with more fluxes in concentrations onwards. The area treated with SDC-9™, had a delayed effect with a more stable progress. The patterns between the two areas are difficult to distinguish due to the system's heterogeneities and dynamics.

Jeremy Birnstingl, Ph.D. (Regenesis Ltd., Bath UK)

Samuel Rosolina, Ph.D. (Microbial Insights, Knoxville, TN, USA) Matthew Burns, B.S. (WSP, Boston, MA, USA)

Background/Objectives. The migration of organic contaminants in groundwater can be mitigated through injection of activated carbon reagents into the subsurface. The approach offers significant design flexibility in strategies ranging from source area containment to barrier configurations. Contaminant flux retardation within the treatment zone may be supplemented with biodegradation. This can extend the time to breakthrough owing to bioregeneration of the sorption sites on the carbon. The barrier longevity may be extended indefinitely if the degradation rate is greater than the rate of mass loading. An understanding of the in-barrier degradation rate is therefore important for performance calibration and management.

In situ monitoring of contaminant degradation is typically achieved through groundwater sampling. Ambient rate may be estimated from concentration trends and advection rates (assisted by models) as the system is dominated by dissolved-phase flux. Within barrier zones however, the contaminant mass is predominantly in the sorbed phase. Contaminant concentrations in the dissolved phase may be close to or below detection limits. The consequent challenge of 'clean' water in the barriers limits options for performance monitoring through groundwater sampling. Qualitative indications of on-going degradation may be secured using microbial diagnostic tools, but quantitative estimation of rate - critical for performance prediction and monitoring - remains elusive.

Approach/Activities. A methodology is presented that employs *in situ* microcosms and isotope analytical tools for estimation of sorbed-phase biodegradation rate in activated carbon barriers. Interference from abiotic factors, including on-going sorption or desorption, are differentiated from biotic changes using control microcosms, and compound-specific isotope analysis (CSIA). Additional 'lines-of-evidence' context is secured through microbial diagnostic tools. Case study data (Quebec, Missouri, Arkanas, and Kentucky) are reviewed and contrasted, and the sorbed-phase bio rates achieved are compared with data from conventional (i.e. dissolved-phase) ERD projects.

Results/Lessons Learned. Biodegradation of sorbed-phase VOC mass is indicated through CSIA and microbial diagnostic lines of evidence. This further supports the understanding that biodegradation is not restricted to the dissolved-phase. Sorbed-phase degradation rate estimates and isotopic enrichment factors are contrasted with those of other available sources: the ambient dissolved phase, laboratory estimates, and published values. This relatively simple approach is an important first step in refining conceptual site modelling for sites that employ activated carbon-based treatments. Ideally, the results of this study will be leveraged for use in more predictive analyses in conjunction with plume modelling software. Its full potential therefore rests on an adequate understanding of the limits of confidence in the data it provides.

50262 What Your Bugs are Trying to Tell You- Illuminating Subsurface Conditions by using Microbial Communities as Biosensors Philip Dennis

Philip Dennis (SiREM) Ximena Druar, Melody Vachon, Taylor Aris and Jennifer Wilkinson

Specific microorganisms live within set limits of temperature, pH, salinity, dissolved oxygen, nutrients, toxicity and other variables responding to their environment by increasing under ideal conditions or declining under adverse conditions. Therefore, the composition of microbial communities provides a window to view subsurface conditions. Our ability to use microorganisms as "biosensors" is increasingly practical as cost-effective characterization of microbial communities becomes routine. Microbial community molecular characterization, performed for decades using methods such as cloning combined with Sanger sequencing, was expensive and time consuming. The advent of next generation sequencing (NGS) technologies has revolutionized our ability to characterize microbial communities at much lower cost. The use of NGS is now used to understand the capabilities of microbial communities, such as the ability to degrade specific contaminants of concern. A helpful variation in the way we look at microbial composition data is to view microbes as biosensors that allow us to better understand the environments in which microbes live, this can be approached in several ways.

1) Microbial diversity is easily determined by NGS and is informative of the overall compatibility of conditions with microbial colonization, with lower diversity often signaling more challenging geochemistry or even toxicity.

2) The detection of a high number of microbes with a particular metabolic function can help determine the dominant conditions in the subsurface (e.g., aerobic, nitrate, sulfate reducing, etc.). Also due to the tenacity of living microbes and the stability of microbial DNA in the subsurface, NGS also has the potential to provide indications of previous transient conditions, such as infiltration of nutrients, aerobic groundwater or toxicity.

3) Microorganisms are adept at finding niches, such as interfaces, where conditions are not reflected in "bulk" parameters. For example, the pH of groundwater samples, may not be indicative of the full range of pH conditions in an aquifer when solids are considered. In addition to measuring dominant community members, the sensitivity of NGS methods allows detection of microbes that may be present in relatively low abundance in microniches, while at the same time providing clues to the heterogeneity of the subsurface environment.

4) Detections of obligate degraders of particular compounds can be particularly useful including obligate degraders of hydrocarbons, chlorinated solvents and polycyclic aromatic hydrocarbons which can provide clues regarding the presence of particular compounds that are, or were, present at a site. These contaminants may not always be apparent in groundwater analytical measurements due to low concentrations or partitioning into solids.

This presentation will review traditional site groundwater parameters from contaminated sites in relation to microbial community profiles to better understand the additional insights NGS can provide. Subsurface conditions such as contaminant presence, distribution, toxicity, subsurface niches and the resultant increases in our understanding of the potential range of biodegradation pathways possible, particularly for natural attenuation, will be discussed.

Session 4b3 Digital tools for site characterization and assessment

Chair: Laurent Bakker

48927 The GroundWater Spatiotemporal Data Analysis Tool (GWSDAT): What are the latest developments? Wayne Jones; Luc Rock

Jones, W.R.^, Miller, C.#, Low, M.#, Alexander, C.#, Bowman, A.#, Rock, L.*

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The GroundWater Spatiotemporal Data Analysis Tool (GWSDAT) was developed "*to provide a simple to use, but statistically powerful decision support tool to environmental engineers and practitioners who routinely report on the status of numerous groundwater monitoring sites*." (Jones et al, 2014). GWSDAT makes use of a spatiotemporal model for data analysis, which has benefits compared to a discrete timebased spatial model (McLean et al., 2019):

- Significantly smaller sample sizes can be used while retaining estimation accuracy.
- Spatiotemporal modelling methods result in clearer more accurate plume estimations.

Over ten years, GWSDAT has been used successfully in analyzing, visualizing and communicating historical groundwater data for constituents of potential concern (e.g. benzene), across the globe. A number of case studies can be viewed at http://gwsdat.net/case-studies/. The output from GWSDAT todate has focused on the following key items (Jones et al., 2014):

- Spatial concentration maps for select parameters over time
- Plume diagnostics, such as mass, area, average concentration, in the case of a defined plume boundary.

A need to further enhance GWSDAT's functionality has been identified (McLean et al., 2019), e.g. integration of monitoring network optimization tools. The aim of this presentation is to share the development of a new functionality within GWSDAT called the 'well redundancy analysis'. In addition, an overview of enhancements to the latest GWSDAT version (3.10) of GWSDAT will be provided. The 'Well Redundancy Analysis' functionality allows the user to very conveniently drop a well, or a combination of wells, from the analysis and investigate the resultant impact. The primary intent of this tool is to understand which wells may have the most influence and also provide supporting evidence that the conclusions of the analysis would not be significantly different with the omission of some select wells. Hence, it will allow the user to identify potential optimization measures with regards to monitoring well network sampling locations.

References:

- Jones et al., 2014, A software tool for the spatiotemporal analysis and reporting of groundwater monitoring data, Environmental Modelling & Software, 55: 242-249.
- McLean et al. 2019, Statistical Modelling of Groundwater Contamination Monitoring Data: A Comparison of Spatial and Spatiotemporal Methods, Science of The Total Environment 652: 1339–46.

50031 Application of digital technologies for site walkovers Brent Brinkman

Abstract Submission for a Regular Online Session, Oral Presentation (15min + 5min discussion)

First Author: Brent Brinkman. Co-Author: Jonathan Coulson, Roy Dennis, Mark Webb, Denny Schanze

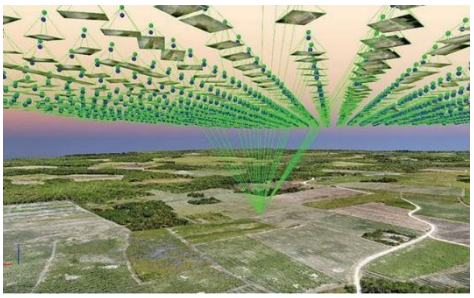
Affiliation: Arcadis UK Ltd and Arcadis Nederland B.V.

The Covid pandemic has placed necessary restrictions on travel to and from site, limiting attendance to only essential workers. This has led to an increase in the use of technology to provide the benefits of site understanding that the 'on site' experience brings to the wider project and client teams. With an increased focus on sustainability and the aim to reduce the carbon footprint associated with site work, these tools should become an essential part of our future toolkit.

This session will explore some of the available tools and provide real site examples of the use of these technologies and the benefits that have been realised including the application of 360 photography applications, the enhancement of mobile phone photography through software to provide point cloud data, laser scanning and drone applications.

The examples will highlight initial benefits through enhanced site visualisation and the follow-on benefits that can be realised throughout the project lifecycle.

Take home message: There are a variety of site imaging tools available that can now be easily applied to improve site understanding and provide benefits in carbon footprint reduction associated with travel.



Abstract Submission for a Regular Online Session, Oral Presentation (15min + 5min discussion)

First Author: Shreyata Sohni. Co-Author: Jonathan Coulson, Mark Webb.

Affiliation: Arcadis UK Ltd

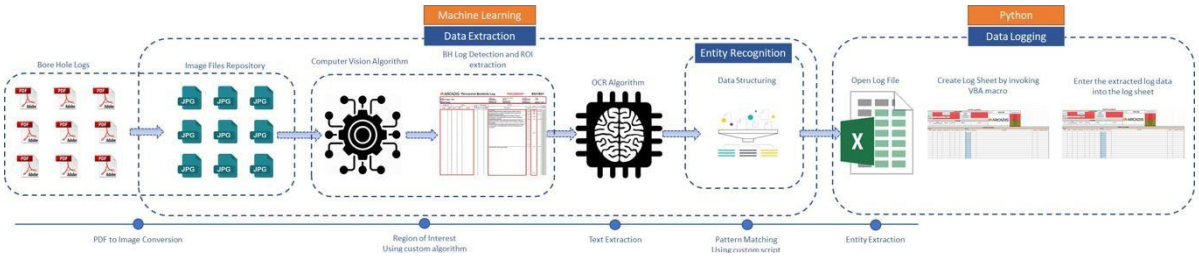
Title: Applications of Machine Learning to release value from historical data

There is valuable information contained with historical datasets that, when combined with new data can release valuable insights to support site conceptualisation and trend evaluation. However, historical site information data is often only available in hard copy or pdf format. This creates challenges in historical data review and integration with new digital datasets in a time efficient manner.

The use of machine learning can be a valuable tool to efficiently extract key information from historical information and convert into a format where it can be incorporated into digital models. This allows historical data to be readily visualised and utilised for analysis alongside new data for site conceptualisation.

The session will provide an overview of machine learning, running through a typical process and the use of data conversion and algorithms to apply machine learning to common environmental data sources. Example use cases will be summarised including borehole log and laboratory data extraction with an illustration of the benefits in time saved through use.

Take home message: Machine learning can prove valuable and cost effective in allowing historical data to be extracted and combined within digital data sets for whole site modelling.



49243 Camera surveillance for the "Smart Supervision" Jasper Schmeits

- Name presenter: Jasper Schmeits – innovation manager TAUW group

- Main message of the presentation:

The idea of using cameras for surveillance has become more interesting and necessary due to the COVID-19 pandemic. Digital meetings are very common due to the obligation of working from home. In a short period of time it became normal to do our work as consultants remotely and this has inspired us to extent this remote working experience to supervision. Supervision of work traditionally requires presence at the remediation location, to check if the contractor works as planned, to adjust strategy in case of unexpected circumstances, to take samples in the excavation pit and to control the safety on the worksite.

On the remediation project of a landfill in Woltersum (Groningen), safety of the employees is of the highest importance. Due to different kinds of industrial waste in the landfill all kinds of toxic and volatile components are released. Minimization of the presence of the supervisor in the remediation area is therefore important. Limiting the number of visits to the worksite will also increase the sustainability of the work of the supervisor. Normally at these sites cameras are used to secure the equipment/materials against intruders – during the night. The same cameras can also be used to get live recordings which the supervisor can use doing his work. With the use of cameras the supervisor can check when it is essential to go to site. To enter the contaminated area several safety measures are needed. The supervisor can do this to finalize critical situations or take samples of the ground for verification.

Primarily the smart surveillance system would be used to give the supervisor ability to view the worksite remotely and to provide him/her with information to minimalize his/her presence at the remediation location; there are a lot of more opportunities if the output is used as data.

The main advantages are:

- Providing authorities with input on the progress of the remediation o Important to consider privacy laws

  o Important to combine with BRL6000 regulations
- Mapping the camera-footage as recording of the excavation – basis voor evaluationreport - Insight in usage on other type of works:

o Cables and piping: temporary excavations – mapping situation o Ability to combine different kind of supervison works

- Using the output as data – within the project we hope to get insight in opportunities:

o "live" 3D point cloud of excavation, o Machine Learning for

- detection of "critical" activities
- recognition of sensory pollutants
- mapping of transport vehicles
- Aim of the presentation

To provide an overview of the experience of what has been discovered during the project Woltersum/Groningen and to give insight in further opportunities. For TAUW this is a pilot project where we have enough time to experiment with some available camera surveillance systems on the market. The supervisors involved were given the opportunity to determine whether these systems would provide added value to their daily work. The next step is to use this experience on other kinds of remediation work.

- What is your take home message? What's in it for the audience?

Digital Transformation provides us with a lot of new opportunities. The use of cameras is not new in itself, but clever analysis of the data and integration of this information in the work flow of the supervisor provide new opportunities. Digital Transformation is not about making supervision unnecessary, but to apply available technology to improve the quality and efficiency of our way of working.

- Think about how to engage your audience in a digital setting. Tips & Tricks will be shared. This is a digital solution – so the presentation will be prepared in such a way that is applicable in the field of supervision. We want to emphasize the added value of using cameras for remote working – and we will provide the audience with an experience-based-solution, visiting a real remediation site.

Session 4b4 Modelling and Monitoring for the management of contaminated sites

Chair: Wouter Gevaerts

50072 Validation of Combined Geophysical and Geochemical Screening Tools to Locate and Delineate Subsoil DNAPL Hotspots in Multi-Layer Soil Profiles. *Lucía Arévalo-Lomas*

Authors: Arévalo-Lomas L., Barrio-Parra F., Biosca B., Izquierdo-Díaz M., Lorenzo, D., Medina R., Santos A., De Miguel E., Díaz-Curiel J.

Name of the presenter: Lucía Arévalo Lomas

Affiliation of the presenter: Prospecting & Environment Laboratory (PROMEDIAM), Universidad Politécnica de Madrid

Abstract:

The detection and accurate delineation of subsurface accumulations of Dense Non-Aqueous Phase Liquids (DNAPLs) with standard characterization techniques is a particularly challenging problem because of their gravity-driven migration mechanisms and their resulting heterogeneous spatial distribution. The development and application of high resolution and relatively inexpensive screening methodologies aimed at locating DNAPL hotspots can optimize subsequent drilling and analytical campaigns, both in terms of cost and of probability of success in the detection of the contaminant.

The case-study here presented was carried out at a site in which the soil profile presents four distinct stratigraphic layers and is affected at different depths (because of different migration mechanisms from the source) by a complex, denser-than-water mixture of chlorinated compounds. The plume of contaminants is threatening a near-by important surface water course. A combination of 11 Electrical Resistivity profiles (ERT) and 350 sub-surficial measurements of ^{222}Rn activity in soil air were carried out on a 15700 m^2 area.

The separate interpretation of geophysical and geochemical anomalies resulted in the erroneous classification of several zones as potentially contaminated. The main confounding factors responsible for this misclassification were the limited effective diffusion length of Rn in soil air and the problem of equivalence for the geophysical techniques. On the contrary, when the spatial information from both sets of techniques was overlapped, the resulting representation successfully identified the pollution hotspots at different depths and their migration pathways These predictions were borne out by the analytical results of soil cores collected from several newly drilled boreholes at the site.

In conclusion, the results of this study demonstrate that the combined application of geophysical and geochemical non-intrusive screening methods is a promising approach to obtain semiquantitative, almost real-time, 3D spatial information that allows to identify and delineate DNAPL pollution hotspots.

Acknowledgements

This study was funded through the CAREDENSE (CTM 2016-77151-C2-1-R and CTM 2016-77151C2-2-R) research grant of the Spanish Ministry of Economy, Industry and Competitiveness.

5.2 – ADVANCES IN MEASURING AND MONITORING AND THE DATA EXPANSION OF CONTAMINATION

Modelling the thermal desorption soil treatment

Ysaline Depasse[1*], Aline Jordens[1], Katia Pacella[1], Hatem Saadaoui[1] & Jan Haemers[1]

[1] Haemers Technologies, Brussels, Belgium

Keywords: Thermal desorption, soil remediation, Fluent, simulation, modelling.

HAEMERS Technologies© is a leading company in soil remediation industry with more than 25 years of experience in this field and a commitment to being at the forefront of technology. To do this, Haemers Technologies has turned its activities towards research and development to improve its own technology.

The SMART Burners™ technology developed by HAEMERS Technologies© is a thermal conduction desorption method developed in-house and patented. It consists of a system of burners placed on the top of heating pipes inserted in the contaminated soil. The hot gases, produced by the combustion of fuel, circulate through the length of the pipes. In this way, the soil is heated by conduction until a certain temperature is reached, allowing the pollutant to volatilise (typically between 200 and 250°C for hydrocarbons). The contaminated vapours generated in the soil are extracted by suction and recovered to be treated. In the case of hydrocarbon pollution, the contaminated gases can be re-injected into the burner as an energy source. This method, named "reburn", allows a significant reduction in the burner's gas consumption.

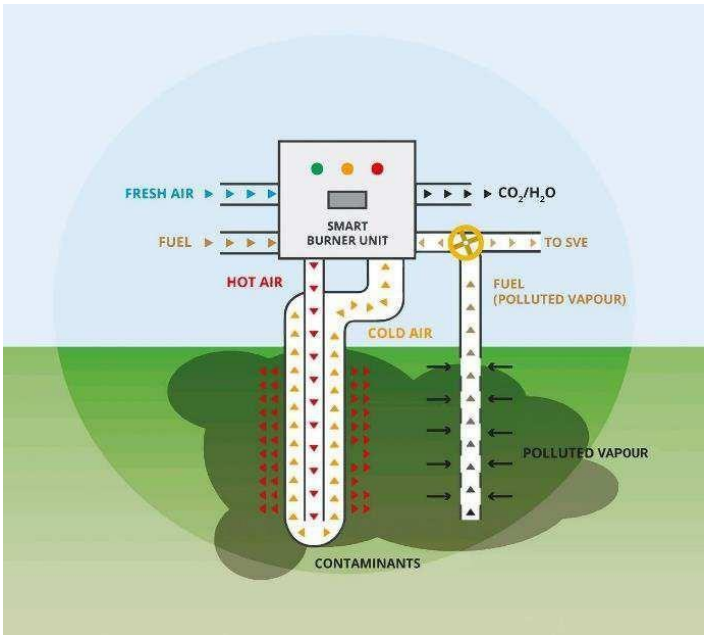


Figure 1. Schematic diagram of the Smart Burner

The research and development projects within HAEMERS Technologies© are perfectly in line with the company's strategy to improve the competitive position of the technology in the soil remediation market. The R&D department has a key role to play and is working on several projects to maximise the energy efficiency of the technology, thereby minimising the treatment time and therefore the cost.

One of the projects within the R&D department called **RSIM**, consists of modelling the thermal treatment of soil using ANSYS FLUENT software. Previously, only very basic tools were used to understand the transport phenomena in the soils to be treated and it was therefore not possible to accurately determine

the process control parameters. This led to the use of large safety factors to ensure that the remediation objectives were met. However, these safety margins are a source of high energy and time losses that undermine the competitiveness of the technology. Modelling is therefore essential to gain a better understanding of the phenomena that take place in the soil during thermal treatment. Modelling downstream of a worksite also helps to optimise the design and provide operational data to the site teams to control the treatment in the most optimal way according to the site conditions.

This large-scale project is divided into several stages to achieve its goals. In broad terms, the modelling will first take into account the soil properties due to the presence of moisture and pollutants in the soil and to understand and quantify the physico-chemical phenomena such as evaporation and pyrolysis of the pollutants that occur during the treatment. In the second step, the modelling will turn to our treatment facilities by simulating the combustion that occurs in a Smart Burner and by simulating the phenomena that occur in a vapour treatment unit.

In this report, the first major advance of the project is outlined. This is the consideration of the properties of a soil to be treated as a function of its initial moisture content.

The first thing that was done was to analyse what the ANSYS FLUENT tool can do. Indeed, some materials are already predefined in the program, so maybe a wet soil too? It was necessary to analyse the equation models that the tool makes available to the user, such as the energy, turbulence, and momentum equations, etc.

In fact, the simulation software, ANSYS FLUENT, used makes it possible to consider soil properties that vary with temperature, vary over time or are simply a constant value. However, during our numerous projects, we have been able to observe that the thermal properties of the soil vary as a function of humidity as shown in Figure 2, which are measurements taken at a construction site.

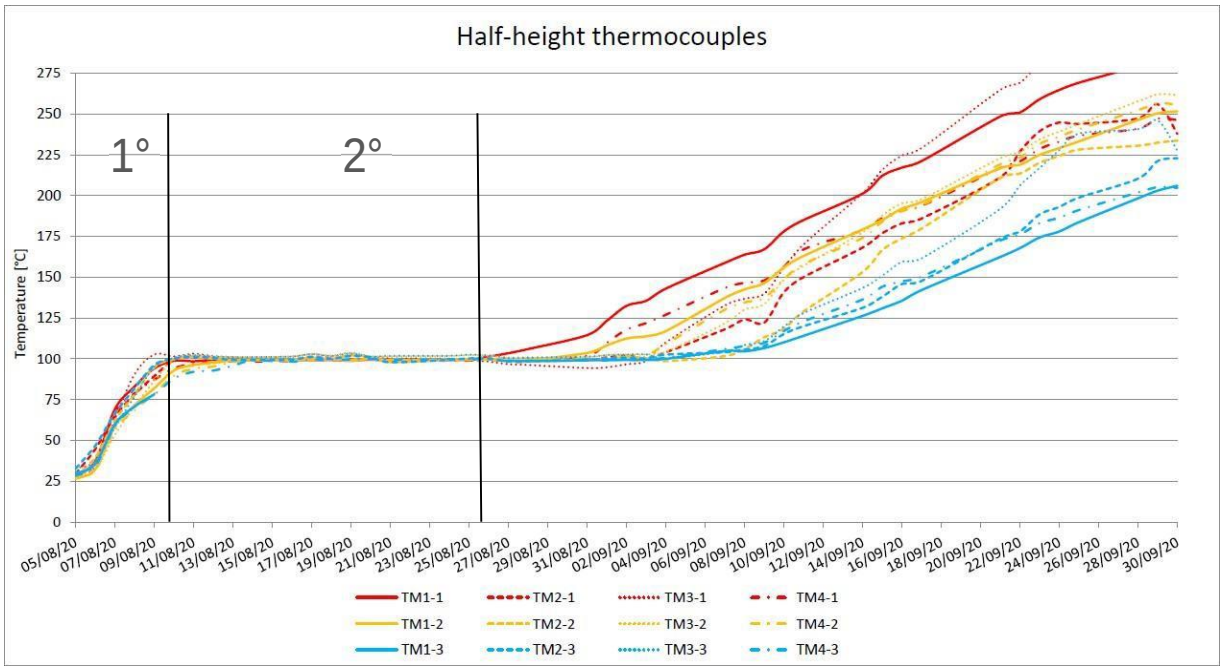


Figure 2. Typical curve obtained on a worksite

ANSYS FLUENT allows this factor to be considered but requires the resolution of several equation models considering the phases change of water and therefore requires too many time-consuming calculations. It was decided to develop a formula, written in the C programming language, for these properties that considers the variation in humidity over time under the effect of the heat created by the heating elements. This formula initially considers a porous medium consisting of a type of soil initially containing a certain percentage of water. It also considers numerically the energy consumed by the evaporation of this quantity of water. Thanks to this proprietary formula, employing the “used defined function (UDF)” option in FLUENT, a simple model can be used which only solves the energy equation developed below.

$$\frac{\partial}{\partial t}(\rho E) + \nabla.(\vec{v}(\rho E + p)) = \nabla.\left(k_{eff}\nabla T - \sum_{j} h_{j}\vec{J}_{j} + (\tau_{eff}.\vec{v})\right) + S_{h}$$

Equation 1: Energy equation

Once this formula developed, its robustness had to be verified by comparing the results obtained by modelling with those measured on site. Temperature is a parameter that can be measured on site over time and is a major parameter of thermal technologies. Therefore, the on-site tests focused on this parameter: thermocouples (temperature sensors) were inserted (TG4, TG5 and TG6 on Figure) into the ground every 15 cm from a heating tube (H5-6 on Figure) to the coldest point (centre of the triangle formed by this heating tube (T10 on Figure)) and two surrounding tubes (H5-7 and H6-5 on Figure). In the simulation, this area was drawn in 2D and the position of the thermocouples was recorded in the software so that the layout of the site and the simulation are identical. The initial soil moisture content was unknown; hence it was set at 30% (w/w) by default.

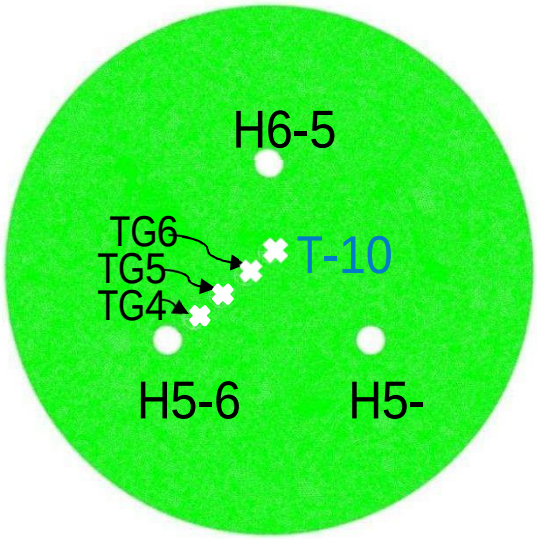


Figure 3. Layout of the comparison test

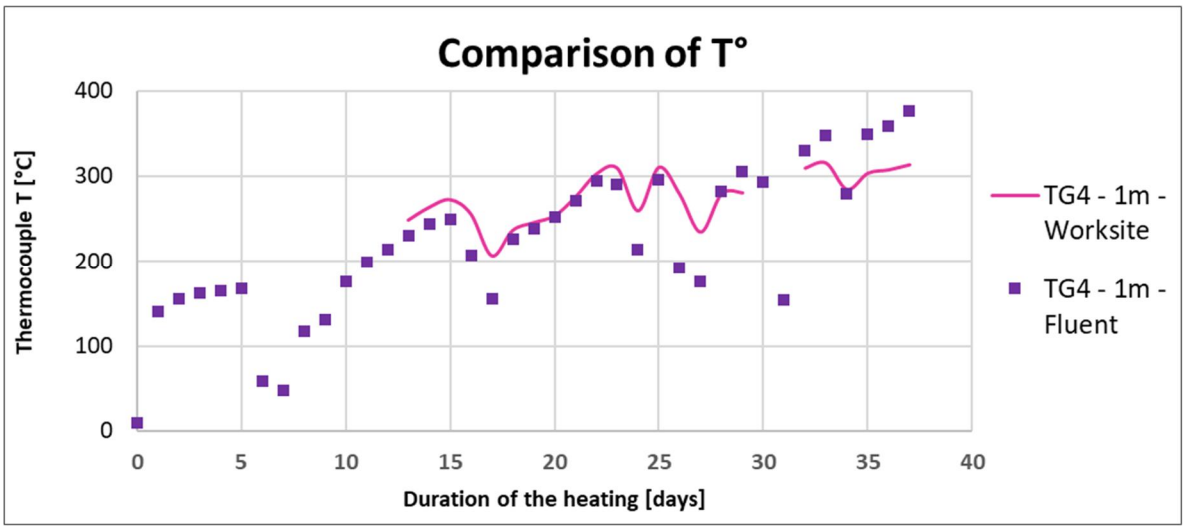


Figure 4. Comparison of temperature measurements at 1m depth at point TG4

By juxtaposing the measured temperature curves on the worksite over time with those obtained numerically by the simulation, several observations were made.

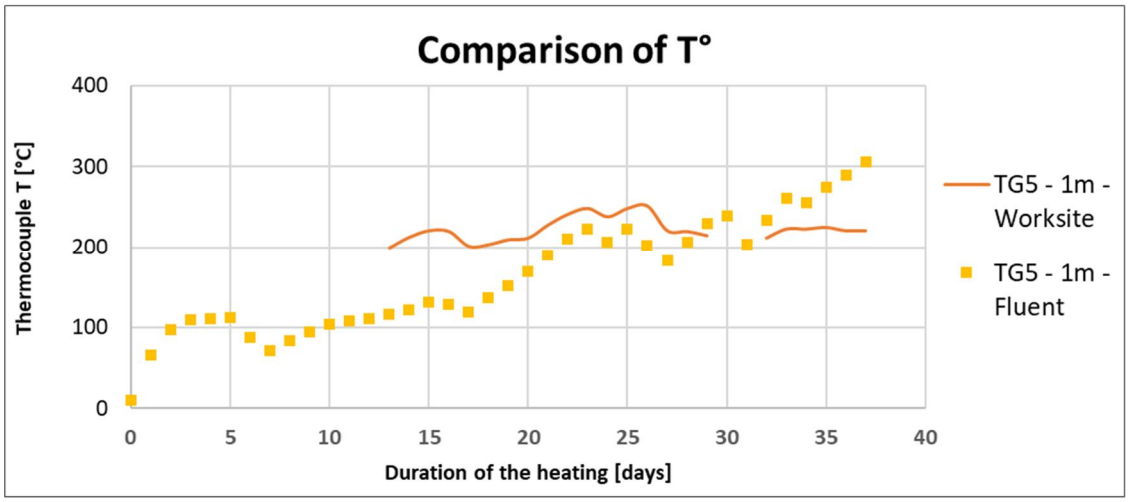


Figure 3. Comparison of temperature measurements at 1 m depth at point TG4

First, the formula developed is functional: the general behaviour of the curve is similar to that observed on the worksite as shown in the Figure 5 and Figure 6.

Second, the soil heterogeneity is difficult to exploit by simulation but could highlight problems on the worksite such as a poorly operated lowering of the water table.

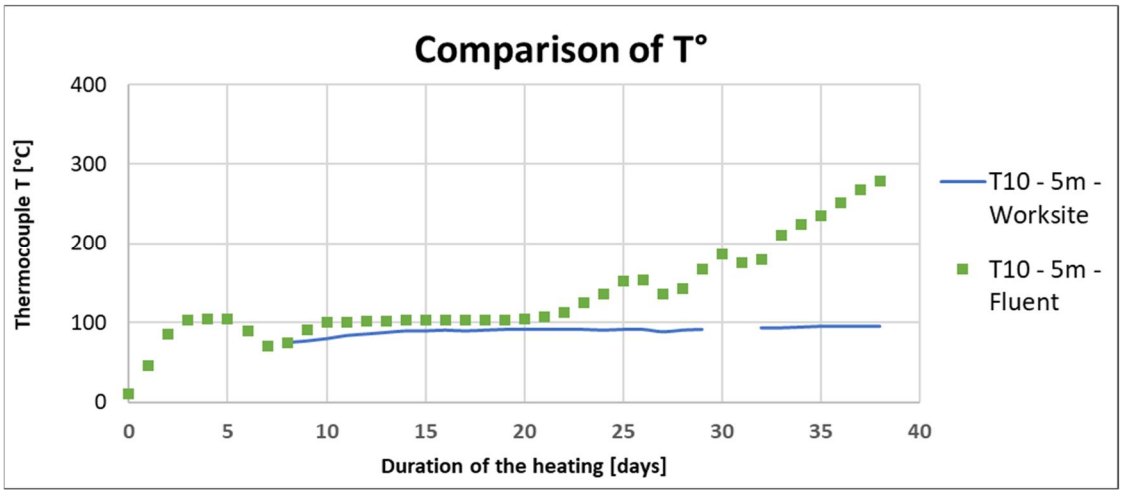


Figure 4. Comparison of temperature measurements at 1 m depth at point TG5

Indeed, as shown in the figure 4, the temperature has never been able to exceed 100°C due to a perpetual inflow of water due to the known presence of a water table at this depth.

Finally, it appears that what was the coldest point on this zone - going from the heating tube to the centre of the triangle - was not necessarily the coldest point. As a matter of fact, the simulation revealed the influence of the two other surrounding tubes on this central point.

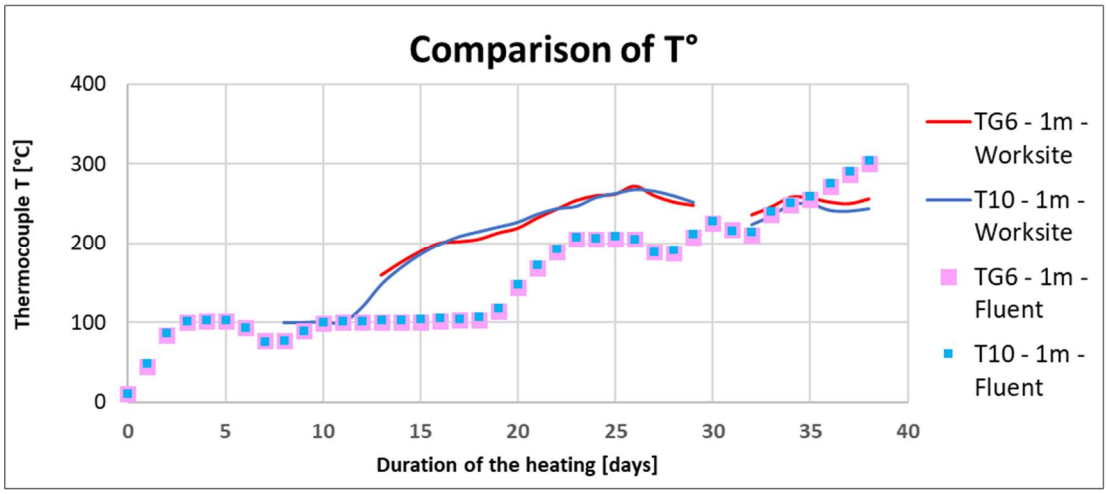


Figure 7. Comparison of temperature measurements at 1 m depth at point TG6 and the cold point T10

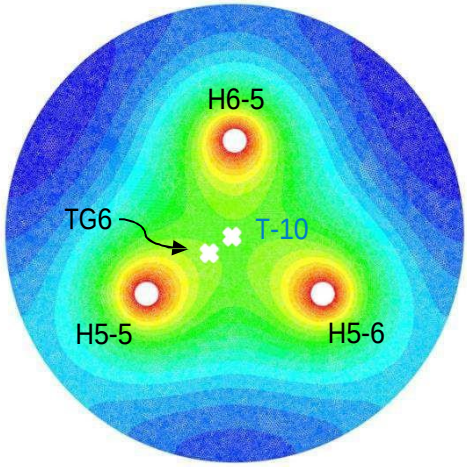


Figure 5. Thermography of the simulation area at 38 days of treatment

This comparison study also provided an understanding of heat transfer in the soil. When the temperatureprofile between a hot point (wall tubes temperature) and the corresponding cold point is known, it is possible to carry out a thermography at a given time. Site measurements showed that the temperaturecurve tends towards a parabolic profile. It could be observed that this profile became stable in time. These observations have also been obtained by modelling, meaning that for each future site, simulationcould be used to provide the profile equation between the different hot and cold points, and therefore generate thermography as close as possible to reality.

Only a 2D model has been tested here, in the future we will work on 3D models considering any soil properties that may exist such as the effect of groundwater on the treatment. We will also take into account the temperature profile that may exist along our heating tubes by modelling the combustion thatoccurs downstream.

In the future, it will be possible to combine Fluent with the monitoring tool to have the most realistic thermographies possible. Indeed, only the temperature of certain cold spots is measured on site, so themonitoring tool extends its measurements to the other surrounding spots in an arbitrary way.

49992 Advantages of Passive Sampling as a Decision-Making Tool and its Application to Contaminated Groundwater Upwelling Pautler

Brent G. Pautler (SiREM, Guelph, ON, Canada);

Jeff Roberts (SiREM, Guelph, ON, Canada);

Michael Healey (SiREM, Guelph, ON, Canada);

Jason Conder (Geosyntec Consultants, Huntington Beach, CA, USA);

Passive sampling devices (PSDs) present many advantages over conventional sampling methods for quantifying the availability of hydrophobic organic compounds (HOC) and inorganic compounds in sediment, soil, surface water and storm water in terms of cost and data quality. PSDs provide data to estimate contaminant bioavailability and toxicity to environmental receptors that are more accurate than conventional grab or mechanically extracted samples, as PSDs quantify freely dissolved contaminant concentrations (C_{free}) as opposed to total mass including sorbed fractions. Measuring only bioavailable contaminants with PSDs provides a better measure of actual toxicity and mobility for environmental receptors and decreases toxicity overestimation compared to conventional sampling methods (e.g., core collection, porewater extraction).

PSDs have been used in the laboratory and the field for decision making in site investigation and remediation, including techniques and advancements that simplify and improve ease of sampling, increase data quality and lower costs. PSDs can be deployed directly *in-situ* to capture the influence of groundwater flux, changes in field conditions and the heterogeneity of a site on the freely dissolved concentrations of the compounds of interest.

In a recent case study, PSDs were used to assess groundwater upwelling of parent and alkylated polycyclic aromatic hydrocarbons (PAH) concentrations in sediments and surface water at a site adjacent to a former wood preserving facility. The use of C_{free} results indicated distinguishable groundwater discharge zones at the site, and that if corrective action were required for the sediments, it would be of limited spatial extent reducing remediation costs. This case study, in addition to abundant laboratory data, illustrates how good site management practices and efficiencies can be realized by using passive sampling at contaminated sediment sites.

50284 Evaluation of High Resolution Methods for VOC Contaminant and Flux Distributions in Igneous / Metamorphic Rock Settings Davidsson

Oral presentations (15 min + 5 min of discussion)

Lars Davidsson (Technical Director, WSP Environmental, Halmstad, Sweden)

Aim of the presentation

This presentation will focus on intensive field characterization efforts at a former metals fabricating facility in Sweden with chlorinated solvent contamination, where the underlying bedrock is granite with extremely low matrix porosity. Initial investigations using conventional wells showed high levels of chlorinated solvents in overburden and shallow fractured bedrock. Two deeper bedrock holes also showed high levels of contamination, although results were likely influenced by open hole cross-connection. Comprehensive field investigations, using the 'Discrete Fracture Network – Matrix' (DFN-

M) field approach established by Parker and colleagues (G360 Institute, University of Guelph, Canada), were subsequently conducted in two boreholes at the site, one within the presumed source area and one downgradient to characterize the contaminant mass distributions and groundwater / contaminant flux within the fracture-dominated flow system. Continuous rock coring with high resolution subsampling adjacent to fractures and in the matrix off fractures was conducted to assess contaminant mass distribution, minimizing possibility for biased results from cross-contamination created with open borehole conditions. Other techniques included FLUTe FACT™ for contaminant flux profiles, in which two deployments were conducted: one immediately after drilling in Spring 2017 and another nearly 2.5 years later in Fall 2019, far removed from drilling disturbance with the boreholes sealed in the interim. Other geophysical and hydrophysical logging techniques included Active Line Source (ALS) and Active Distributed Temperature Sensing (A-DTS) in lined boreholes and transducers deployed behind liners to assess the ambient groundwater flow system. These multiple borehole datasets were collectively used to design six-port multilevel systems using the new FLUTe Cased Hole Sampler (CHS), where the informed placement of ports and seals reduces blending across hydrologic units and provides improved spatio-temporal resolution of hydraulic head and groundwater sampling.

Conclusion – Take home message

The various high-resolution datasets provide exceptional insights into the contaminant mass distributions in the context of a highly variable fracture network. This presentation will discuss results from these techniques, potential for bias such as effects of open hole cross-connection and best practices. It will also discuss how these techniques, when applied in a complementary manner, contributed to an improved site conceptual model and decision making, which will contribute to the most optimized remedy, making the carbon footprint as small as possible.

Session Success stories

48951 Advanox: an efficient and modern method for groundwater treatment Thege Clara

Type: Presentation in a regular online session, oral presentation (15 min + 5 min discussion)

Topic: 2 c. Balancing groundwater quality and quantity

Project: Advanox: an efficient and modern method for groundwater treatment

Presenters: Clara Thege – Van Remmen UV Technology

Marco van den Brand – HMVT

Background

Micropollutants are present in all forms of water and is growing issue with multiple reported and suspected effects on ecosystem, environmental, and human health. Water, especially groundwater, and soil go hand in hand where they readily exchange nutrients and pollutants. Micropollutants such as pharmaceuticals and pesticides infiltrate the soil and groundwater from several sources including agricultural run-off, surface water, and treated wastewater. Some drinking water extraction areas are already under threat, and with the ever increasing water scarcity, emerging (micro)pollutants will only make the threat grow.

Part of the solution

There are several parts to the solution where front-of-pipe and no-pipe solutions deal with the use of alternative, more biodegradable, and simply less of pesticides, pharmaceuticals, and other persistent compounds. Traditional treatment techniques have a difficult time removing micropollutants which per design are difficult to break down, and we need to look to advanced remediation techniques. The Advanced Oxidation Process UV-C and hydrogen peroxide, Advanox™, is a technology that is very well equipped for groundwater treatment. Furthermore it can reach >95% removal efficiency, provides disinfection, and produces less and fewer by-products than other techniques.

HMVT and Van Remmen UV Technology have joined forces to do this as efficiently as possible. HMVT has 30 years of experience in design, realization, and management of groundwater extraction and remediation systems. Van Remmen UV Technology is a specialist in design and realization of water treatment with the help of UV/H_2O_2.

Presentation

The aim of the presentation is to discuss the urgency and threat of the already present and emerging pollutants in relation to clean groundwater supplies, and to present a demonstrated solution. The presentation will show the results from UV/H_2O_2 a groundwater treatment research project performed in Switzerland, as well as to have a look at the performance of UV/H_2O_2 on a wider range of micropollutants on relevant water qualities. It will also compare UV/H_2O_2 on a technical and financial level to alternative remediation techniques.

Take home messages from the presentation will be:

- Groundwater basins and drinking water extraction areas are under threat of micropollutants such as pesticides and pharmaceuticals.
- Groundwater remediation with UV/H_2O_2 is effective and efficient, demonstrating >95% removal of target compounds, with no harmful residues.
- UV/H_2O_2 is competitive on a technical and financial level with other treatment techniques.

48809 Application of klozur® cr for the treatment of hydrocarbons, btex and mtbe in a former petrol station in Italy Alberto LEOMBRUNI

Alberto Leombruni[1], Mike Mueller[2]

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AquaConSoil Topic: Upgrading contaminated and degraded land

Summary

Klozur® CR is a combined remedy treatment technology consisting of Klozur® SP (sodium persulfate) and PermeOx® Ultra (extended release calcium peroxide). Klozur CR is a single, all-in-one formulated oproduct that can be readily applied to either source areas or plumes impacted with a wide range of contaminants, e.g. TPHs co-mingled with CVOCs. Klozur CR destroys contaminants in both soil and groundwater by promoting three modes of action: activated persulfate chemical oxidation, aerobic bioremediation, and anaerobic oxidation.

This thermodynamically powerful reagent provides self-activating sodium persulfate oxidation technology, utilizing the alkalinity generated by the calcium peroxide component. High pH, or alkaline, activated persulfate is capable of destroying a wide range of contaminants, including PAHs, BTEX, TPHs, phenols, chlorinated solvents, chlorobenzenes, haloalkanes, pesticides, energetics, and many others. Following the initial chemical oxidation phase, Klozur CR will continue to release oxygen (used as an electron receptor for aerobic bioremediation) for up to a year. This as a result of the slow hydration of the engineered calcium peroxide. Diffusion and transport of oxygen downgradient will support contaminant reductions in plume areas, treating the contaminants of concern (COCs). As a result of the persulfate oxidation with organic compounds, generated sulfate ions can be utilized by sulfate reducing bacteria as an electron acceptor under anaerobic conditions to degrade COCs via a process called anaerobic oxidation.

This technology was successfully applied at a densely populated urban area site in the northern Italy. The site was characterized by historical contamination of various toxic compounds. The site, a dismantled former petrol station, was impacted by the storage of fuels which has resulted in the groundwater contamination, including hydrocarbons (C<12 ~ 2000 µg/L), benzene (~ 500 µg/L), ethylbenzene (~ 380 µg/L) and MtBE (~ 13000 µg/L).

Two injection campaigns were carried out 15 months apart, and a total of 4800 kg of Klozur CR (in a 25% aqueous solution) was injected onsite. Following 18 months after the first application, the concentrations of contaminants had reached and maintained concentrations below the remediation goals in all monitoring piezometers in the treatment area. TPHs were reduced by greater than 80 percent, while MtBE was reduced by greater than 90 percent. Monitoring data confirmed sustained elevation of oxidation-reduction potential (ORP) and dissolved oxygen (DO) as necessary subsurface conditions to support treatment.

49840 Sodium Persulfate with Integrated Activator Destroys >99% of Trichlorethylene in 5 Weeks at a Manufacturing Facility in The Netherlands Mueller Mike

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AquaConSoil Topic: Upgrading contaminated and degraded land

Background/Objectives. For several years, a manufacturing facility was in operation near Uden, Holland. Soil and groundwater have been impacted with chlorinated hydrocarbons. Following demolition of the buildings in 2005, Site Investigations (SI) revealed high levels of contamination. In the groundwater aquifer, concentrations of more than 16000 µg/l of trichlorethylene (TCE) were measured, indicating the presence of a source zone (SZ). The impacted SZ is 270 m^2 and contaminated in the saturated zone from 3 to 7 meters below ground level. For the planned redevelopment of the site into a residential area, local regulatory authorities mandated remediation of the contaminations to stringent clean-up target levels.

Approach/Activities. Following SI, the first step was excavation of contaminated soils to the top of the groundwater level, then backfilling with certificated clean soils. As end-use by the developer was construction of residential housing, rapid remedial results were required. As elements of the Remedial Options Appraisal (ROA) process, the technological solution required high reliability, cost-effective implementation and quick results as key objectives. The Klozur® One ISCO technology was selected primarily because it met all ROA objectives. The blend of sodium persulfate (SP) with built-in activation chemistry provided powerful oxidation capacity as a “ready to use” product suitable for this highly contaminated treatment area. A total of 9225 kgs was required, delivered in 25 kg bags from a nearby warehouse, helping to keep the logistics carbon footprint low. As SP requires careful handling, the contractor took all necessary safety measures for storage and handling. From the storage facility the product was transported to an onsite mixing facility. Subsurface injections were made per batch. A typical batch contained 4 m^3 of clean water into which a specified amount of Klozur One was added. From the mixing unit, the proper solution is transferred into the injection tank. As each batch of injectable solution is mixed together, it is then applied to the subsurface through a network of injection wells. In total, the contractor injected though 40 points at 3 different subsurface levels, in a grid pattern with a center-to-center distance of 2 meters. With this grid, it was possible to engineer contact across the entire source area. At spots with higher concentrations of contaminant, more solution was applied with a higher concentration of activated SP. At each injection point, between 2775 and 4500 liters of solution were applied. Through use of a manifold system, 4 to 6 wells were worked simultaneously, using overpressure to prevent blow-out at the surface. In total, the field works lasted 9 days to inject 155 m^3 injection fluid of self-activated SP.

Results/Lessons Learned. Prior to start of injections there an investigation of the TCE concentrations was performed. Monitoring activities during and after the injections including measurements of pH, oxygen, redox and electrical conductivity. Following the SP injections, a notable decrease in pH and increase in electrical conductivity was visible. The contractor used Klozur Field Test Kits to determine an indication of the amount of active SP still available. After four weeks, most of the active SP was consumed, allowing the monitoring wells to be used for groundwater quality. In total, monitoring was conducted through 10 wells and in all of them the TCE concentration was decreased to below remediation targets. Four weeks later, an independent verification by the engineering consultants confirmed the positive results. They also concluded that there was no active SP left and that the TCE was sufficiently removed. In total the ISCO process removed 99,6% of the contamination, resulting in site closure.

50106 In Situ Thermal Remediation Lithological Efficiency: Application of Electrical Resistance Heating in Sandstone Bedrock Amy Wagner

Amy Wagner P.E. , Gorm Heron, Ph.D, Emily Crownover, Ph.D

(TRS Group)

TOPIC: Integrated management of contaminated land, 4c) Updating contaminated and degraded land
AIM OF PRESENTATION: This presentation will focus on lessons learned on energy application at three sandstone in situ thermal remediation projects to achieve more sustainable systems TAKE HOME MESSAGE: Importance of in situ thermal remediation technique selection on power application for sustainable remediation in rock lithologies.

In situ thermal remediation (ISTR) of crystalline bedrock can be challenging due to power delivery limitations. Application of thermal conduction heating (TCH) has been proven successful in bedrock formations such as sandstone, mudstone and granite; however, heater wells are limited to a power input of 250-300 Watts per foot (0.82-0.98 W/cm) of heater, thus requiring months of heating to achieve steaming conditions. The application of electrical resistance heating (ERH) in bedrock formations has been viewed as less efficient than TCH for rocks with low porosity and water content, due to their high electrical resistivity. This presentation will describe how ERH can efficiently remediate sandstone formations, in some cases, with heat up rates two to three times faster than TCH with similar heater and electrode spacings.

Data from three ERH sites in sandstone formations were evaluated for power application per length of electrode, achieved subsurface temperatures, and overall remedial results. The data was analyzed over the course of the project to ensure that any effects from decreased moisture in the subsurface were captured. This presentation will focus on data comparison of ERH vs TCH systems operated in sandstone lithologies and the possible energy savings achieved when ERH favors TCH.

Results from the three sandstone sites indicate ERH sustained a power application of 500-1000 W/ft (1.64 – 3.28 W/cm) in sandstone bedrock with highly uniform heating in the subsurface. The target zones heated from ambient to boiling temperatures in as few as 60 days. Over the course of the project average power delivery did not significantly decrease, indicating the sandstone remained sufficiently hydrated for ERH. Compared to the TCH power limitation of 250-300 W/ft, ERH achieves significantly higher power delivery in sandstone. Higher power application allows for fewer electrodes than heater wells, faster heat-up rates, and decreased energy required to reach remedial goals.

The presentation will end with an analysis of bedrock properties and implications for electrical resistivity and project energy savings when ERH is applied. What is the minimum porosity and a minimum water content needed for ERH to be effective? What rock properties indicate that TCH would be a more energy efficient choice? What data informs ISTR method selection?

From 1945 through 1983 "processing" of used chlorinated hydrocarbons took place on the subject site (former garage shop). A six yearlong pump & treat remediation ceased in 2006. Due to continuously high groundwater concentrations of PCE/TCE of up to 200,000 µg/L remediation was necessary. A variety of methods were evaluated including thermal but the winner from a costbenefit viewpoint was ISCO using RiskCom's i-SAV© technology as the preferred emplacement method.

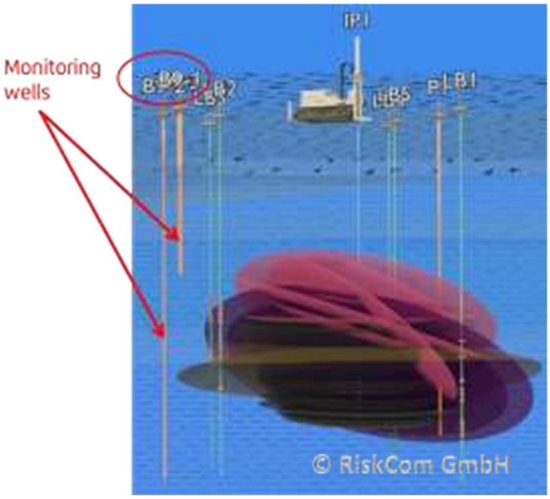
The site is underlain by fill and Quaternary loess to a depth of 4 m below ground surface (bgs), which is overlaying a clayey silt layer followed by some silty clay layer of weathered marlstone to a depth of 7.5 m containing some perched water which is followed by the more competent, naturally fissured marlstone (Lias β).

Due to the low permeability soil at the site hydraulic fracturing as injection technique i-SAV© was selected for the subsurface contamination below the main road, which was the pre-selected location for the pilot test. For the pilot test only one injection borehole was drilled. Remediation reagents were injected with pressures between 10-20 bars in the main contaminated area between 6.2 m and 10.5 m depth using a direct push system in one-off campaign. A total of 2.53 t of solid reagents ($Na_2S_2O_8$, persulfate,"PS" and $KMnO_4$, permangnate "PM") were injected.

The vertical distance between the emplaced fracs was mainly 0.15 m. Spatial monitoring of the artificially generated fracs was done using tiltmeters which were placed on the road's surface. A live evaluation of generated tiltmeter data allowed the on-site determination of each frac with respect to its extent, and 3D orientation (dip and strike).

Over the entire depth of injection approximately 70% of the fracs show dip angles of less than 20° and only 30% of the fracs dip < 45°. Consequently, mainly horizontal injection layers were generated. The average thickness of the fracs was estimated to about 12 mm. The aspect ratio is ¾ indicating that in line with the acting geotechnical stresses, ellipses instead of circles were formed. The calculated radius of influence was proven by the results of the sampling of the liner bores (see picture below), which were spatially placed at the tip of the planned injection coverage.

Measurements of the groundwater potential at three groundwater monitoring wells located around the injection borehole, indicated that existing fissures were (re)activated and thereby filled with reagents. This was also proven from real-time monitoring of the injection pressure data.



It could also be shown, that the generation of the 25 fracs increased the permeability at the area affected by the pilot test, which means that the groundwater flow locally (horizontally and vertically) became faster, which in turn positively influenced the distribution of the emplaced reagent afterwards. Analytically it could be proven that at least 25% of the injected $KMnO_4$ was still available in the subsoil two months after the injection. Gas generation in the monitoring wells showed that persulfate and or permanagnate was still active more than 15 months afetre injection took place.

After nearly two years of monitoring it could be shown that a one-time injection of the remedial agents was enough to reach the remediation goals in the pilot test area.

The CO_2 footprint for the remediation of 163 kg CHC was calculated 1) excluding the production of permanganate and 2) including the production of permanganate. The results showed that during the i-SAV© remediation only 15,3 kg CO_2 per kg CHC were produced whereas 88 kg CO_2 per kg CHC were generated when the CO_2 mass produced during the manufacturing process of the permanganate is included in the calculation. This shows that the CO_2 footprint of the i-SAV© remediation technology is low compared to other remediation technology (e.g. theraml remediation) and the overall CO_2 footprint depends on the CO_2 mass produced during the manufacturing process of the remnediation reagent.

49828 In-Situ Stabilization Carbon Dioxide Footprint Reduction using Klozur Persulfate Brant SMITH

Brant Smith[1], Mike Mueller[2]
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AquaConSoil Topic: New low-carbon solutions for conventional and emerging contamination

Summary

The carbon dioxide footprint associated with the remediation of contaminated sites is an important aspect to consider when selecting a remedial approach.

Two established treatment technologies include *In Situ* Chemical Oxidation (ISCO) and *In Situ* Solidification and Stabilization (ISS). ISCO is a contaminant destruction or mass reduction technology, whereas ISS using binders such as Portland cement (PC) is primarily used to reduce mass flux. Portland cement production is energy intensive and has a relatively high CO_2 footprint that has been estimated to account for 5 percent of the global CO_2 emissions. These two technologies can be synergistically combined in a single application process commonly referred to as ISCO-ISS. The data has shown that this combination can decrease the overall CO_2 footprint of ISS while achieving remedial objectives.

A review of the CO_2 footprint for the manufacturing of persulfate based on hydroelectric power as a renewable energy source, compared to equivalent regional grid power, was conducted for PeroxyChem's Klozur® persulfate. On a parallel track, reducing the CO_2 footprint of ISS by augmenting PC with a material such as blast furnace slag (BFS), sodium persulfate or a combination of materials was evaluated. Bench tests have been conducted demonstrating that the addition of sodium persulfate can decrease the amount of binder required to achieve the remedial goals often targeted by ISS.

An evaluation of the CO_2 footprint for the large-scale manufacturing production of persulfates using hydroelectric power will be presented. The evaluation of adding BFS to PC to decrease CO_2 impacts will also be presented along with data on key performance criteria including unconsolidated strength and hydraulic conductivity. Data will be provided illustrating how the amount of binder required to achieve the same remedial goals can be decreased by more than 50 percent by adding sodium persulfate to the process. This decrease in binder required results in a significantly lower potential CO_2 footprint for ISS applications, whilst also resulting in a combined remedy that involves both the destruction and solidification of the contaminants.

In summary, ISS-ISCO can be both environmentally and socially beneficial remedial initiative. That contributes towards the realization of a circular economy by maximizing the inherent value in materials, products and by-products through all production stages; reducing material and energy costs.

50208 Full scale pilot test of a new UV/H2O2-remediation technique "RemUVe®" for removal of chlorinated solvents and pesticides to reduced usage of GAC on remediation facilities Martin Bymose; Ronny Rahbek

Authors: Ronny Rahbek, Insatech; Mathias Schouw, Insatech; Martin Bymose, DGE Miljø & Ingeniørfirma.

Background:

Pesticides in the ground water in Denmark have in recent years become an increasingly crucial problem for the danish regions. The findings of "new" pesticides such as desphenyl chloridazon and N, N-
dimethylsulfamide (DMS) means that pump & treat facilities will have a major increase in use of activated carbon. Many of these facilities are operated by the 5 danish regions.

Aim:

The purpose of the full-scale pilot test conducted together with the Danish Capital Region on their P&T facility "Grusgraven" in 2020 is to demonstrate that with the new UV-technology "RemUVe" it is possible to reduce the content of DMS and chlorinated solvents in the water but also reduce the operating costs for existing and future P&T plants and reduce the consumption of activated carbon.

Method:

The method is an advanced oxidation process created by a combination of energy from UV light and the addition of very small amounts of hydrogen peroxide. We have developed a mobile plant that can be used on existing wells or remediation facilities. The UV system has a unique reflection technique that lowers the energy consumption compared to traditional UV systems.

Full Scale pilot test on "Grusgraven"

On Grusgraven the pumping rate is about 20 m3/h. A part of the water stream, about 5 m3/h, went through the mobile RemUVe® system. On day one there is a mapping with multiple settings of UV energy and H_2O_2 dosing to find the best combination of UV energy and H_2O_2 dose to treat the water. Treatment goal was to reduce the content of DMS with 80% and thereby reach a level just below the groundwater criteria at 0,1 ug/l. In the process the chlorinated solvents were reduced between 85 and 99%.

Based on the mapping the RemUVe® system was set on continuous operation for 6 weeks with weekly monitoring of the treatment. The results are very promising, and calculations shows that with the obtained reduction on the content of Chlorinated Solvents and DMS there is a potential lifetime expand on the GAC- filters from 6 months to 4-5 years.

Take home message:

RemUVe® water treatment can effectively reduce the use of active carbon and remove a very wide array of contaminants with high efficiency UV and H_2O_2 based treatment.

RemUVe® use electricity to operate, but green energy production in Denmark and Europe are growing and already today the energy usage of operating the RemUVe® system is less than er than energy used to regenerate the active carbon.