AquaConSoil

11 - 15 september 2023 | Prague

Topic 3 – abstracts posters

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The complete programme and session overview can be found on our website at: https://aquaconsoil.com/aquaconsoil-2023/scientific-programme/

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Session 3 poster / Abstract title: Using Sustainable Soil Amendments for Accelerated Bioremediation of 4-6 ring PAHs in Hydrocarbon Contaminated Wetlands.

ID: 11

Key words: Wetlands, Polycyclic aromatic hydrocarbons (PAHs), Oxygenation, Nutrients, Biodegradation, Microaerobic

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Session: 3 poster

Abstract

Wetlands are located on coastal routes for oil and gas exploration, production, and transportation, this makes wetlands vulnerable to pollution by oil spills. Some of the endemic microorganisms in wetlands can utilise hydrocarbons as an energy source but the process is often slow as the natural state of wetland environments is generally unfavourable for biodegradation of hydrocarbons. Wetlands are often microaerobic, oxygen deficient, and negatively affected by tidal waves that lead to nutrient wash out.
This study aims to introduce bioavailable nutrients in form of nitrates and improve oxygen concentrations in saturated wetland environments with the intent to improve the capacity of the endemic microorganisms to produce enzymes for accelerated metabolism of 4-6 ring PAHs.
Sediments were spiked with crude oil in a potted experiment which was run for 90 days and analysed on day 0, 7, 45 and 90. The experiment design consisted of a control, a treatment with an addition of poultry droppings, a second treatment were straw was added and a third treatment with a combination of poultry droppings and straw. 5 replicates were taken to ensure accuracy in data analysis.
Findings from experimental analysis showed that addition of straw and poultry droppings can lead to increased oxygenation and accelerated biodegradation of HMW hydrocarbons in saturated wetland environments. This was evident as a positive redox potential was measured in both treatments containing straw with respective values of 455mV in straw and 166.46mV in poultry droppings and straw which is indicative of an oxidizing environment. Statistical analysis of the total PAHs showed a significant effect between the days ($p = 0.000$). The treatment with straw and poultry droppings had the overall highest percentage degradation (84.3%) of total PAHs across all treatments and control from day 0 to day 90. PAH degradation in poultry droppings was 55.3%, 43.6% in straw and 35.5 % in the control. Repeated measure ANOVA of the 4-6 ring PAHs showed a significant effect between the

treatments ($p=0.0001$) and the days ($p=0.0102$). Straw and poultry droppings led to 84.2% degradation of 4-6 ring PAHs between day 0 and day 90, 28.6% in straw and 57.1% for poultry droppings and 27.5% in the control. The complimentary physical qualities of straw and nutrient potential of poultry droppings led to more efficient bioremediation than in the treatments where amendments were used separately. Hence, for more efficient bioremediation, a combination of complimentary soil amendments should be used.

Session 3 poster / Abstract title: Reactive multibarrier for the abatement of chlorinated compounds: lab and pilot studies

ID: 122

Key words: chlorinated solvents, reactive barrier, ZVI, GAC

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Session: 3 poster

Abstract

In this study we present the design and pilot scale implementation of an in-situ reactive multibarrier for the abatement of chlorinated solvents. The impacted area falls into one of the 42 Italian contaminated sites of national importance (Sito di interesse nazionale – SIN). The groundwater in the site is contaminated by chlorinated organic compounds and metals, such as 1,2-dichloroethane (1,2-DCA), tetrachlorethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloroethylene (1,2-DCE), vinyl chloride (VC) and arsenic. The conceptual model of the area indicates the presence of a plume of dissolved contamination characterized by a width of about 150 m and an extension of over 300 m along the flow direction. Among the contaminants, 1,2-DCA is the most critical since it is present in high concentrations (tens of mg/L in groundwater) and is highly recalcitrant to treatments involving reductive dehalogenation, including both abiotic and biological approaches.
The groundwater remediation plan involves the installation of a reactive multibarrier composed of: i) an impermeable wall to intercept the plume and prevent the downstream migration of the contaminants; ii) a pumping system installed upstream the barrier for groundwater extraction; iii) a multistage treatment system for the removal of pollutants; iv) an infiltration system installed downstream the barrier to release the treated water back into the aquifer. The multistage treatment system is in turn composed of two reactive filters installed

in series and respectively filled with: i) millimetric zerovalent iron (ZVI) for the removal of arsenic and chlorinated aliphatic hydrocarbons that can be treated by abiotic reductive dehalogenation; ii) granular activated carbon (GAC) for the removal by adsorption of 1,2-DCA (non-degradable with ZVI) and residual organic contaminants.
In this study, groundwater treatability tests were carried out in the laboratory to optimize the site-specific design and sizing of the reactive filters. First, batch tests were performed to compare different types of ZVI and GAC and to select the most effective reactive materials. Then, column tests were carried out to verify the effectiveness of the treatment chain in flow conditions. The test results confirmed the effectiveness of the multibarrier under the tested conditions. The ZVI filter ensured a 99,9% removal of many chlorinated solvents, such as PCE and TCE, and a complete abatement of the arsenic, while a 60% degradation was observed for 1,2-DCE and VC. As expected, 1,2-DCA proved to be recalcitrant to treatment with ZVI. Full removal of all residual contaminants, including 1,2-DCA, was instead observed upon GAC filtration. Overall, the treated groundwater at column outlet was found to be fully compliant with the concentration limits set for water release into the aquifer. Mathematical models were finally applied to interpret the experimental results and obtain quantitative parameters useful to design the large-scale multibarrier, i.e. the kinetic constants of contaminant removal in the ZVI filter, the expected longevity of the reactive materials, as well as the volumes of reagent necessary to meet the target concentrations for each contaminant.
Based on the information obtained from laboratory tests, a pilot scale multibarrier was installed on-site to verify the performance of the filtration chain in field conditions. The pilot system, which included only the extraction and filtration sections (no impermeable wall and infiltration system), was sized to treat a total flowrate of 2 m3/day. The preliminary results of the pilot test, which is still ongoing, confirmed the potentiality of the reactive multibarrier to effectively remediate groundwater in site-specific conditions.

Session 3 poster / Abstract title: DNAPL Remediation through injection of densified polymer by sodium iodide: balancing gravity and buoyancy forces

ID: 124

Key words: DNAPL remediation, xanthan, sodium iodide, densification, two-phase flow

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Session: 3 poster

Abstract

Purpose of study
DNAPLs such as chlorinated solvents are considered toxic hazardous materials that can cause serious problems for human health. Many conventional in situ remediation methods like pump-and-treat cannot efficiently remove DNAPL from the contaminated zones. Injection of polymer solutions as a promising method can improve the removal of DNAPL by mobility control. Despite their good performance in the improvement of the displacement of the pollutant in a confined system, in the case of non-confined highly permeable contaminated soils, the non-zero balance of buoyancy and gravity forces can influence their efficiency. Densifying the polymer solution by adding particles such as barite can increase the recovery efficiency, but high clogging can lead to increased injection pressure. In this work, the polymer solution is densified by adding a soluble salt to nullify gravity and buoyancy forces in DNAPL remediation.
Methodology
Xanthan gum solution as a non-Newtonian biopolymer has been selected for the removal of DNAPL. Sodium iodide, widely used as a tracer in aquifers, was used as a densifier. DNAPL with density of 1.66 g/mL used in this study was a multicomponent chlorinated solvent. The rheological behavior of the polymer solutions was characterized using a rheometer. 1D-column experiments were used for the evaluation of the rheological behavior of the polymer solutions in porous media, and for two-phase flow experiments as well. A decimetric-scale 2D tank was used to evaluate the efficiency of the injection of different solutions in the remediation of DNAPL. The displacement process was tracked through the mass balance and an imaging technique. The injection was carried out through a port located at the bottom of the tank, below the DNAPL zone.

Summary of findings/results

The xanthan solutions with and without the densifier exhibit similar shear-thinning rheological behavior, but the viscosity is slightly reduced when salt is present in the polymer. Three solutions were chosen for injection into DNAPL-saturated soil: a salted solution (i.e. NaI solution) and a mixture of xanthan salt with densities equal to that of DNAPL for both, and a pure xanthan solution with a density equal to unity. The solutions were injected individually through decimetric 1D columns filled with DNAPL-saturated soil. The results showed that regardless of density, the recovery efficiency for the solutions containing xanthan was similar and around 89%, while the pure salted solution had a recovery efficiency of around 74%. To evaluate the performance of these solutions in an open system, they were individually injected through the DNAPL-saturated zone in a 2D tank. When the pure xanthan solution was injected, most of it was displaced vertically, resulting in an aspect ratio (ratio of the vertical to lateral displacement) of 6.7. However, when the densified polymer solution was injected, it invaded the contaminated zone more radially, sweeping a greater zone and resulting in an aspect ratio of 0.57. When the pure salted solution was injected, it reached most of the contaminated zone, but the presence of fingers of contamination was still noticeable. This is likely due to the low viscosity of the brine solution.

Conclusion

Densification of the polymer solution with salt improves the recovery efficiency of DNAPL by balancing gravity and buoyancy forces. Moreover, our results show that to have a better understanding of the performance of polymer solutions in real contaminated sites, it is necessary to perform experiments in an open system.

Significance / contributions of study

Removing DNAPLs from contaminated zones is essential. While polymer solutions can improve displacement efficiency, their performance in real-field conditions should be thoroughly evaluated. Densifying the polymer solution with salt not only improves recovery efficiency but also increases the radius of influence while keeping injection pressure relatively low.

Session 3 poster / Abstract title: Progressing Modeling of PFAS Bioavailability to Support Water Permitting and Effluent Monitoring Regulations

ID: 126

Key words: PFAS, bioavailability, partitioning

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Session: 3 poster

Abstract

The unique chemical properties of per- and poly-fluoroalkyl substances (PFASs) present a challenge for developing regulatory guidelines to protect organisms in the environment. While long-chain perfluorinated alkyl acids (PFAAs) are bioaccumulative and frequently detected in biota and humans, their bioavailability and biological uptake are more complicated than other hydrophobic contaminants, such as polycyclic aromatic hydrocarbons (PAHs) or polychlorinated biphenyls (PCBs). Where PAHs and PCBs bind predominantly to storage lipids, PFAAs have the potential to interact strongly with proteins such as serum albumin, fatty acid binding proteins, and phospholipid membranes as well as storage lipids. This challenge is further compounded by the fact that only a fraction of the PFAS structures identified or inferred in environmental samples can be reliably quantified with standard analytical methods. As such our understanding of PFAS bioavailability and environmental risk is incomplete and based on experiments and modelling from a limited domain of PFAS chemistry.

This poster outlines the framework for developing a reliable methodology for estimating biological uptake of PFAS based on Protein-Water (PW), Membrane-Water (MW), and

Octanol-Water (OW) partition coefficients. These enhanced methods can better estimate PFAS bioavailability and provide practical guidance for regulatory monitoring and permitting of PFAS while minimizing vertebrate and in vivo testing.

Traditional bioaccumulation models which solely rely on partitioning to storage lipids and are based on octanol-water partition coefficients (KOW), do not accurately predict observed PFAA bioaccumulation. Such models do not consider other biologically relevant partitioning of PFAS. Therefore, there is a need to develop novel bioaccumulation models, or incorporate better predictors of biological partitioning to develop PFAS regulations protective of the environment. These models may include KOW, as well as protein-water (KPW) and membrane-water (KMW) partition coefficients.

There is ongoing research to empirically measure KPW and KMW values for target PFAS. One particular tool, biomimetic chromatography, has the ability to predict KPW or KMW from the retention time on specialized high-performance liquid chromatography (HPLC) columns. When coupled with high-resolution mass spectrometry (HRMS), biomimetic chromatography offers the ability to predict KPW and KMW values for suspect or non-target PFAS. Coupled with Quantitative structure-activity relationship (QSAR) modeling, measurements of biologically relevant partition coefficients will provide a more comprehensive understanding of the bioavailability of a larger domain of PFAS chemistries.

Session 3 poster / Abstract title: Nitrate reduction in domestic wastewater using on-site tertiary treatment with bioremediation

ID: 130

Key words: bioremediation, nitrate, pollution, wastewater, nitrogen

Submitter: Fred Wu

Organization: Advanced Bacterial Sciences

Co-authors: Dr. Fred Wu, Advanced Bacterial Sciences, Biogeochemist

Session: 3 poster

Abstract

Domestic septic tanks (DSTs) can adequately reduce dissolved organic nitrogen and ammonium levels in wastewater via mineralisation and nitrification. However, many systems still lack the efficiency to reduce nitrate during the treatment processes, which is caused by the lack of a functional denitrifying community and unfavourable biochemical conditions for denitrification. This results in high levels of nitrate and total nitrogen (up to 150 mg N/L in the UK) in DST discharge. Between three to five hundred thousand properties are currently served by DSTs in the UK. Consequently, DSTs can be significant sources of nitrogen pollution to adjacent waters.

To efficiently reduce nitrate in domestic wastewater, Advanced Bacterial Sciences (ABS) has developed a bioremediation product, which involves a non-pathogenic, denitrification-focused bacterial consortium and a specific blend of organic carbon substrates to serve as tertiary treatment of DSTs. The nitrate removal efficiency of this product was tested with synthetic wastewater in microcosm trials and a scaled-up mesocosm trial under field conditions. In the mesocosm trial, multiple nitrate additions were performed, resulting in increased nitrate concentrations ranging between 12 and 198 mg N/L immediately after the additions. Wastewater samples were then collected at 6, 12, 24, 48 and 168 hours after each addition. The results showed the product can achieve 90-100% nitrate reduction within 12 hours (0-5 mg N/L) after nitrate additions. Further planned pilot trials will investigate the product's nitrate and total nitrogen removal efficiency when implemented in a commercial tertiary tank receiving secondary-treated domestic wastewater.

Given the UK government has designated 55% of its land as Nitrate Vulnerable Zones (NVZs) and is implementing the Nutrient Neutrality scheme in some NVZs which prohibits new housing developments without purchase of nitrate credits or offset of nitrogen loading from the new developments, the potential applications of this bioremediation product in DSTs and other on-site wastewater treatment systems can provide a cost-effective mitigation strategy to the persistent and heightening problem of nitrogen pollution in surface

waters.

Session 3 poster / Abstract title: Enhanced rhizodegradation of soils impacted with PAH, HC and PCB due to biochar, mycorrhizes addition and electrokinetic application

ID: 131

Key words: rhizodegradation, PAH, electrokinetic, biochar, mycorrhize

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Organization: SERPOL

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Session: 3 poster

Abstract

Purpose of study:
In the frame of EiClaR Project (H2020), one of the research objectives is to develop a combined process to enhanced in-situ rhizodegradation in soils impacted with organics to treat large impacted area sites at a very low cost. This group of technologies combines electrokinetically stimulated in situ redox reactions with phytoremediation to provide low input remediation of hydrocarbons, including some persistent compounds in parallel with immobilisation of trace elements (primarily arsenic). The use of “sacrificial” iron electrodes is also included to immobilise some trace elements with iron oxide complexes. The electrokinetic system is based on the use of pulsed voltage and frequent polarity changes. This method fractures longer hydrocarbon chains, thus increasing their bioavailability. This study will show how these reactions can help improve the rhizodegradation processes and arsenic immobilization. Mycorrhizal fungal and biochar amendments are also being considered to support plant establishment and to provide lignase-based bioremediation to target recalcitrant compounds such as PAHs.

Methodology:
Soils from two contaminated sites in France were collected. An experimental plan was prepared for the implementation of on-site and in situ experiments. For the on-site experiments, electrokinetic process are applied i) in a biopile configuration without plants (HC and PCB) and ii) as landfarming using plants in order to evaluate the synergetic effects between electrokinetics and rhizodegradation of organic contaminants (PAH and HC). Biochar and mycorhizes addition will also be evaluated. For in situ experiments, electrokinetics, biochar and mycorhizes addition with plants or without plants are implemented at a brownfield site. This experimental plan is also tested in parallel at lab scale

in order to better understand the mechanisms involved in PAHs degradation and metals/As immobilization.

Results:
First laboratory experiments have demonstrated the increase of PAH degradation and the decrease of arsenic mobility due to the application of electrokinetic treatment. Laboratory and field pilots including plant, mycorhizes, biochar and electrokinetics conditions will be performed between February and March so results will be available at the conference date in September.

Session 3 poster / Abstract title: Mobilization and dissolution of LNAPL by using polymer-based alcohol emulsions in contaminated aquifers.

ID: 138

Key words: Soil remediation, porous media, biopolymer, alcohol, LNAPL

Submitter: Bexultan Sabyrbay

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Session: 3 poster

Abstract

Environmental pollution, notably soil pollution, is one of the urgent problems at present. Light refined petroleum products (gasoline, diesel, engine oil, etc.) which represent light non-aqueous phase liquids (LNAPL) are among the most dangerous environmental pollutants. Penetration of LNAPL into the soil or groundwater makes it unsuitable for plant, animal, and microorganism life. Therefore, the search for effective ways to dispose of hydrocarbon pollution is of great importance. One of the most widely known LNAPL remediation methods is Pump-and-treat (PT), which is considered inefficient due to long operation, and low recovery efficiency (around 60%). Injecting non-Newtonian fluids such as polymers presents a significant industrial application interest for in situ remediation of contaminated soil, especially for aquifers with significantly high permeability and strong heterogeneity. Nevertheless, there is some limitation to using high-viscosity fluids. For instance, the injection of a high-viscosity polymer solution during soil remediation can harm the environment by increasing the injection pressure, leading to aquifer erosion or soil uplift. Hence, developing eco-friendly, sufficiently viscous, and biodegradable fluid is highly in demand.

The main goal of this study is to improve the removal of LNAPL (here diesel fuel) with a new polymer-based formulation that promotes its dissolution or mobilization. The use of viscous polymer solutions can contribute to stable oil displacement in heterogeneous porous media and simultaneously carry active matters (surfactants, co-solvents) to hard-to-reach low-permeability media.

To embody the goal, the remediation of diesel was tested in one-dimensional 30 cm long silica-based sand-pack columns. Biopolymer “xanthan gum” was used due to its rheological

and biodegradability properties. Primary flushing by xanthan gum with a concentration of 0.1% w/w, promoted stable displacement in saturated porous media and allowed the recovery of up to 80% of diesel fuel. Further, the polymer solution was formulated with the addition of alcohol solvents to improve sweeping performance. Therefore, fifteen types of biodegradable homologous alcohols (from ethanol to n-octanol) were applied for batch experiments to formulate polymer-based alcohol mixtures. These homologous alcohols are known to exhibit different partitioning behavior upon contact with diesel fuel. Environmentally friendly surfactant sodium dodecyl sulfate (SDS) was used to stabilize a mixture of alcohol and polymer solution. To obtain a stable formulation, batch experiments were carried out at various surfactant concentrations and various volume fractions of polymer solution, alcohol, and diesel fuel.

Batch experiments were carried out in small polypropylene vials to test the mechanisms of alcohol partitioning in the presence of diesel fuel. According to the results of batch experiments, ethanol, 1-propanol, and 2-propanol exhibit a mechanism of diesel dissolution into an aqueous phase, which leads to a decrease in the volume of diesel fuel. Homologous alcohols from n-butanol to n-octanol promoted partitioning into the organic phase. As a result, swelling of the volume of diesel fuel was observed, which is typical for the mobilization mechanism. However, only 1-pentanol, 1-hexanol, 1-heptanol, 1-octanol, and 2-octanol among mobilization alcohols showed stable emulsions when mixed with a xanthan-SDS solution.

Further, the rheological behaviors of xanthan-SDS-alcohol mixtures were characterized through a rheometer. The preliminary results showed that they exhibit non-Newtonian shear-thinning behavior. Rheological experiments are still ongoing to select the best formulation regarding viscosity properties. Thus, the final polymer-based alcohol emulsion will be used for the secondary flushing (after polymer flushing) in a 1D column to remove residual diesel.

Session 3 poster / Abstract title: Enhanced delivery of reactive sulfide reagents in porous media by biopolymer solutions for in situ remediation of mercury-contaminated soils

ID: 143

Key words: Mercury, stabilization, in situ remediation, soil heterogeneity, biopolymer

Submitter: Dorian Davarzani

Organization: BRGM

Co-authors: Dorian Davarzani, Marcio Nascimento, Zeinab Derikvand, Stéphanie Betelu, Daniel Hubé, Stéfan Colombano (BRGM, Orléans France)

Session: 3 poster

Abstract

Mercury is released from both natural (rock erosion, volcanic eruptions) and anthropogenic sources. Currently, humans are primarily responsible for mercury pollution, through power plants, industrial processes, or the extraction of certain mercury ores. In soils, mercury remediation can be technically challenging and costly, depending on the subsurface mercury distribution, the types of mercury species, and the regulatory requirements. The chemical stabilization approach uses sulfur-containing compounds to react with elemental mercury (Hg 0) in contaminated soil to form mercury sulfide (HgS) which is a stable and insoluble compound. However, it can be challenging to deliver in situ the reactive compounds using traditional Newtonian fluids in heterogeneous soils. Here, we show how injecting biopolymer can improve the delivery of sulfide micro-particles and reagents. The main objective is therefore to develop a biopolymer and sulfide-based solution to stabilize the elemental mercury but also to study the feasibility of injecting in situ such a solution into polluted soil. The delivery of sulfide micro-particles is experimentally studied in order to develop a biopolymer solution capable of transporting pyrite (FeS2) particles in polluted soils. Two biopolymers were tested for their known non-Newtonian behavior (xanthan gum and carboxymethyl cellulose). Then, the experiments were carried out in a graduated cylinder to study the stability of biopolymers in solutions with and without micro-particles of pyrite (FeS2). The biopolymers have been characterized in order to obtain more information about their rheological behavior using a rheometer. Xanthan gum was chosen as the non-Newtonian fluid for its capacity to maintain the particles in suspension, and its strong non-Newtonian behavior. Different combinations of the xanthan biopolymer, micro-particle of pyrite, and a sulfide-containing reagent (thiosulfate, xanthate, and sodium sulfide) mixtures were tested in small glass vials for their capacities to stabilize mercury. We placed a small drop of Hg0 at the bottom of the vial and mixed it with the prepared solutions. Finally, a 1D column (30 cm long and diameter of 4 cm) packed with dry sand (0.7-1 mm) was used to

study the potential of the solutions to deliver the micro-particles.
The batch tests show that the solutions with xanthate, sodium sulfide, and thiosulfate are capable of stabilizing mercury with or without a biopolymer-based solution. This statement is based only on significant changes in the color of these solutions. To draw more conclusions, chemical analyses are under investigation to quantify the reaction. We found that the addition of pyrite particles and sulfide-based reagents reduces the bulk viscosity of the mixture while maintaining still good shear-thinning behavior. The column experiments show that the xanthan biopolymer is suitable for injecting the mixture of pyrite particles and the sulfide-containing reagent into the soil. On the contrary, conventional water injection is not suitable to deliver the pyrite micro-particles. Viscous fingerings were observed for the solution with 2 g/L of xanthan despite the effectiveness of the injection. At three pore volumes of injection, the relative density of the solution at the column outlet was 60%. By increasing the concentration of polymer up to 4 g/L, a stable displacement front was observed. At the end of the injection, we were able to find 85% of the relative density of the solution initially injected at the outlet of the column.
This study found a method to deliver a solution that can stabilize the elemental mercury in polluted soils using a non-Newtonian liquid loaded with micro-particles and a reactive sulfide compound.

Session 3 poster / Abstract title: Who wants to skim forever?

ID: 148

Key words: LNAPL, historical, recoverability, aftercare, NSZD

Submitter: Laura Simone

Organization: Arcadis Germany GmbH

Co-authors: Imke Hesse MSc., Arcadis Germany GmbH, environmental consultant

Session: 3 poster

Abstract

LNAPL (Light Non-Aqueous Phase Liquids) recovery measures are often operated for decades and become increasingly inefficient until they finally reach their technical limits. However, the pollutant concentrations in the soil and groundwater at this point are usually still elevated and LNAPL still present. Therefore, the end of active remediation is often opposed by the Regulators. But is remediation till complete LNAPL-removal really the best option? This question was critically addressed in a German remediation project.
During a bombing raid in 1945, production facilities and tanks on the site of a former lubricant plant were destroyed. As a result, several hundred tonnes of LNAPL were released into the ground. The LNAPL have been recovered via hydraulically assisted skimming since 1995, although a formal remediation plan was first prepared in 2007. According to the plan, the existing remedial measures were to be further operated, but with technical upgrades, which were carried out in 2009-2010. In 2004 and 2014, the amount of LNAPL in the subsurface of the site was estimated using the calculation tool published by the American Petroleum Institute (API).
Extensive optimisation tests were carried out during the remediation (including changes in pumping rates, discontinuous operation, skimming with and without hydraulic support). In 2017, six additional skimming wells, equipped with best available technologies were constructed in the centre of the LNAPL body.
Despite all this, the LNAPL recovery could not match remediation goals, based on the estimated oil quantities in the subsurface, because the theoretically recoverable LNAPL represents only a minimal fraction of the total LNAPL body, decreasing over time. The LNAPL quantity that can be extracted with an economically and technically reasonable effort is even smaller. Moreover, the API calculation tool is not suitable in this case, as this is based on LNAPL saturation assumptions that are not applicable at this site.
Therefore, Arcadis proposed an alternative approach based on the most recent advances in LNAPL-science to set new, realistic remediation goals and to verify that the active remediation could be ended safely to transition to a passive course of action (Monitored Natural Attenuation, MNA including Natural Source Zone Depletion, NSZD). LNAPL saturation profiles extrapolated from new Liner-drillings and enhanced mapping thanks to

new monitoring wells confirmed that the previous model based LNAPL inventories were largely overestimated. Instead of the API-tool calculations, LNAPL transmissivity was used to evaluate the LNAPL recoverability. An evaluation of the operational data of the LNAPL skimming and further testing (bail-down tests and LNAPL tracer tests) confirmed that even at the most recently constructed wells in the middle of the LNAPL body the LNAPL transmissivity was very low. This indicated that an improvement in the efficiency of LNAPL recovery was no longer achievable at a proportionate cost. The LNAPL tracer test also proved that the remaining LNAPL was not migrating. Furthermore, preliminary investigations using fossil fuel traps showed that the NSZD potential at the site is currently at least as high as the active LNAPL recovery rate via skimming. Instead of a set of target values, a combination of different criteria with a staged approach in which threshold exceedances trigger actions was proposed as new remediation goal.
The Regulators accepted the proposed remediation goals based on these lines of evidence, approved the shut-down of the skimming system and transition to aftercare (MNA including NSZD), started in 2022. Not only were the costs cut up to 6-fold, but the emissions and energy consumption were drastically reduced in the transition, whereas the estimated duration for complete LNAPL removal was not significantly increased and no new risks arose for the environment and the community. An overall more sustainable solution was hence achieved.

Abstract title: 'Demonstration and evaluation of sustainable on-site remediation technologies for PFAS-contaminated groundwater - the LIFE SOuRCE project

ID: 157

Presentation type: Poster presentation

Key words: PFAS, groundwater remediation, Surface Active Foam Fractionation, phytoremediation, Boron Doped Diamond electrode

Submitter: Dan Berggren Kleja

Organization: Swedish Geotechnical Institute

Topic: 3. Sustainable remediation, emerging contaminants and prevention towards zero pollution

Sub-topic: b. Novel technologies to treat emerging contaminants, such as chlorinated solvents, halogenated compounds, antibiotics and antimicrobial resistance, Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS), pesticides, etc.

Comment by submitter (if any): nan

Abstract

"Purpose of study

LIFE SOuRCE is a European project, funded by the EU through the LIFE Programme, focusing on the demonstration and evaluation of sustainable on-site remediation technologies for PFAS contaminated groundwater. PFAS (per- and polyfluoroalkyl substances) are a group persistent anthropogenic chemicals that pose risks to human health and the environment. The production and use of PFAS has resulted in contamination of drinking water supplies worldwide. Hence, there is an urgent need to find economical and sustainable technologies that can be used to remediate PFAS-contaminated water. Here we present four remediation technologies that can be combined into efficient treatment trains for removal of PFAS from groundwater.

Methodology

The treatment trains, proposed by LIFE SOuRCE, are based on four on-site PFAS remediation technologies, which can be combined in a modular way, to optimize the removal

and cost efficiency for PFAS removal based on local groundwater composition and site characteristics:

1. Surface Active Foam Fractionation (SAFF), which utilizes the physiochemical properties of PFAS compounds to attach to air bubbles.

2. Phytoremediation (PHYTO) can be used as a polishing step of SAFF treated water, since the SAFF method might be less efficient for short-chain PFAS (<C7). Plants can extract and accumulate PFAS, in particular the short-chain ones.

3. Anion EXchange filter (AEX) is an alternative polishing step of SAFF treated water. Water is passing a column with anion exchange resin and the negatively charged PFAS are retained. The AEX resin can be regenerated on-site.

4. Electrochemical Oxidation (EO), using boron doped diamond electrodes, can be used to degrade PFAS, either enriched in the foam produced by the SAFF method or eluted from the anion exchange resin. The method is versatile and can be used on-site.

Within LIFE SOuRCE two treatment trains consisting of 1) SAFF, EO and PHYTO and 2) SAFF, EO and AEX are being tested for groundwater remediation on two demo sites; one in Sweden, the landfill Hovgården, operated by Uppsala Water and Waste AB, and one in Spain, where aqueous firefighting foam (AFFF) products have been used.

Summary of findings/results

The project started in September 2021 and will run for four years. During 2022, bench scale testing was conducted to i) check the removal efficiency of short and long chain PFAS using SAFF, ii) select suitable resins and optimize the resin volume for AEX-treatment of groundwater collected from the Spanish site, iii) test different plant species (willow, hemp and tufted sedge) and substrates to optimize PFAS removal with PHYTO and iv) to optimize electric consumption of the EO-technology.

The results are now being evaluated to optimize our large-scale pilots at our demo-sites. The pilots will be monitored, so that removal efficiencies, costs, and impacts like emissions, can be compared to more conventional treatment methods using granular activated carbon (GAC).

Conclusions

Results and conclusions are disseminated continuously throughout the project time at the project website: https://life-source.se/. Here you can find more information about the different treatment technologies, together with news from the LIFE SOuRCE team.

Significance / contributions of study

At present, GAC is the most common technology for on-site PFAS remediation but treating large volumes of water with GAC is relatively expensive and possibly insufficient for reduction of the short-chain PFAS. LIFE SOuRCE will offer alternative technologies, when combined, aiming to remove both long-chain PFAS (> 99 %) and short-chain PFAS (> 95 %) to meet the new EU Drinking Water Directive targets of 0.1 µg/L for sum 20 PFAS and 0.5 µg/L for total PFAS, within affordable costs of around 0.1 €/m³ groundwater treated.

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Session 3 poster / Abstract title: Application of iron bionanoparticles prepared from food waste for PCB removal.

ID: 160

Key words: green synthesis; degradation of PCBs; iron bioparticles; food waste.

Submitter: Marcela Tlčíková

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Session: 3 poster

Abstract

This experiment was financially supported by the UK/168/2023 student grant.

Industrial activities abandoned contaminated territory of old factories and mining sites are source of pollution for our environment. For such reasons, it is very important to clean industrial and municipal waste water and decontaminate soil and groundwater. In the presented contribution, PCBs are removed by an integrated (hybrid) approach. The iron bioparticles are sequentially applied (physico-chemical reduction of higher chlorinated PCBs and adsorption) and then bacterial strains (biological degradation of lower chlorinated intermediates) are added. Bioparticles are prepared by the so-called green synthesis, which describes the precipitation of polyphenols with di- or trivalent iron into complex structures. In the work, we also focus on the concept of sustainability in terms of the use of waste food residues (grape pomace), which will be used for the green synthesis of iron bioparticles and subsequently applied in experiments for PCB removal. The content of total polyphenols and flavonoids in samples of grape berries of the Merlot and Blaufränkisch varieties and their pomace as food waste was studied. Spectrophotometric analysis of total phenolic substances determined the content of polyphenols (337,94 ± 50,77 mg. l-1) and flavonoids (271,51 ± 2,51 mg. l-1) in ethanol extract from Blaufränkisch pomace. By determining the content of polyphenols in the samples, we found that even with a lower content, it is possible to synthesize iron bioparticles and use them for degradation experiments. The iron bioparticles formed from each of the four grape matrices were used in the first step for degradation experiments of polychlorinated biphenyls from the commercial mixture Delor 103 by physico-chemical approach (abiotic). Abiotic degradation for 7 days reached a percentage of PCB degradation of 48% using bioparticles from Blaufränkisch variety pomace. The same approach for 14 days of PCB elimination reached a maximum of 63%, also with iron bioparticles from Blaufränkisch pomace. In the process of biodegradation

(biotic) approach, two bacterial strains isolated from the area contaminated with PCBs (from Chemko Strážske) were used, namely Ochrobactrum anthropi and Stenotrophomonas maltophilia. Both bacterial strains achieved PCB degradation efficiencies of 62% and 63%, respectively. By combining the previous methodologies, we get to the process of integrated sequential approach. After 7 days of abiotic approach of PCBs without access to oxygen, the bacterial strain was added for another 14 days under aerated conditions. The highest percentage of degradation was found in the combination of iron bioparticles from Merlot pomace with the O. anthropi strain (73%) and with the S. maltophilia strain (70%). To use iron bioparticles for environmental decontamination, it is necessary to carry out toxicological tests on biota. The method of auxanograms by the action of bionanoparticles from Merlot grape pomace on the O. anthropi strain did not show possible toxicity. By monitoring the phytotoxicity on germination of Sinapis alba by the action of iron bioparticles from Merlot pomace, an inhibitory effect was revealed from the concentration of 50 g.l-1 and higher. Bioparticles accumulated on the root and thus prevented the passage of nutrients and water into the plant tissue. The content of polyphenols and flavonoids in food waste from grape pomace of the Merlot and Blaufränkisch varieties was shown to be sufficient for the successful green synthesis of iron bioparticles. Iron bioparticles demonstrated the ability to eliminate PCBs in an artificially contaminated water medium. The achieved results indicate that the hybrid method (combination of physico-chemical and biological) application of iron bioparticles and the subsequent addition of bacteria is a more effective method for PCB degradation than the use of bioparticles or bacteria alone.

Session 3 poster / Abstract title: Effects of in-situ remediation with sulfidized nanoscale zero-valent iron on the metal(loid) bioavailability in two soils from a former heavily industrialized region of CZ

ID: 180

Key words: nanoremediation, SnZVI, bioavailability, metal(loid)s

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Organization: Czech University of Life Sciences Prague

Co-authors: nan

Session: 3 poster

Abstract

In recent years, the use of nanomaterials (substances with one dimension under 100 nm) has been investigated as novel technique for soil and groundwater remediation. Among the nanomaterials, iron-based nanomaterials have received increasing attention as a new promising technique to remediate soil contaminations by immobilizing contaminants through various processes.
If their potential is to be fully exploited, especially in the case of novel iron-based nanomaterials, such as sulfidized nanoscale zero-valent iron (SnZVI), then field and laboratory assessments are required to establish their efficacy, longevity, and potential deleterious effects (e.g., toxicity).
In this study, the pilot test of metal(loid)s in-situ immobilization in contaminated soils was carried out via a small-scale field experiment situated on two sampling localities – brownfield soil (BFS) and contaminated alluvial soil (CAS), both contaminated predominantly with As (ca. 300 ppm), Cd (30-40 ppm), Pb (5000-8000 ppm), and Zn (4000-5000 ppm). Each locality comprises eight sampling sites with four treatments (in duplicate). The following treatments were applied to the topsoil: control (soil without any amendments), 1 wt.% of SnZVI, 1 wt.% of SnZVI in combination with 3 wt.% of thermally stabilized sewage sludge (SnZVI-TSS), and iron grit (1 wt.%) as macroscale and commercially available alternative. Seasonal soil samples, soil solution (pore waters) and naturally occurring plants, were periodically collected for various analyses, such as pH, Eh, and electrical conductivity of soil solution, soil microbial activity, metal(loid) bioavailability using extractions with different extracting agents, or DGT technique.
Despite considerable inter-site variability in pH and organic matter content, there was a generalised trend of the amendments to raise pH, which in the case of CAS decreased back to control values after 6 months. The bioavailable fraction of the metal(loid)s was determined using demineralized water as an extractant. In the case of As in BFS, all applied

amendments seem effective in decreasing its concentration in water extracts even after six months from the application. In comparison, As is generally less mobile with decreasing pH. Therefore, it was found less mobile in CAS samples regardless of the treatment. All amendments decreased the water-extractable concentrations of Cd and Zn in both localities. However, as the pH of CAS samples started to decline to its original values, the extractability of both metals began to increase again. Moreover, the addition of SnZVI-TSS even promoted increased Cd and Zn leaching. Concerning Pb, it is already regarded as one of the most immobile metals. Still, SnZVI and SnZVI-TSS have slightly better immobilizing efficiency than iron grit.

In conclusion, SnZVI-TSS has the best initial performance for immobilizing metal(loid)s. However, from a longer-term perspective, iron grit seems to be the most reliable option for immobilizing metal(loid)s. The experimental work continues to confirm the trends already observed.

Session 3 poster / Abstract title: APPLICATION OF BACTERIAL REMEDIATION PRODUCTS IN AN OIL-WATER INTERCEPTOR AT A MOTORWAY DEPOT IN THE UK

ID: 186

Key words: hydrocarbon, oil water interceptor, bacteria products, motorway

Submitter: Bastian Saputra

Organization: Advanced Bacterial Sciences (ABS) Ltd

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Session: 3 poster

Abstract

Oil-Water Interceptors (OWIs) act as a separation point, preventing hydrocarbon pollution due to oil spillage from vehicles, run-off water, or washing areas in motorway depot from entering the sewer network and/or natural watercourses. OWIs need to be regularly maintained in order to ensure the water discharging meets Environmental Quality Standards (EQS) as set by the Environment Agency or the water purveyor. The current practice is generally to empty the OWIs using suction into a truck and transport it for disposal as hazardous waste. This is an expensive and time-consuming process as well as creating an additional carbon footprint from the use of fuel necessary for the transportation.
ABS conducted a field application of our bacteria remediation product (Carbonzap) to digest the hydrocarbon sludge inside the OWI at a Motorway Depot in Bolton, England. The aims of this project were to determine the efficacy of the product in treating hydrocarbons in OWI, to monitor the impact on microbial communities, and to determine the potential risk to receiving waters from residual hydrocarbons and heavy metals after the product dosing.
Following the six weeks of dosing, it was found that the bacterial product degraded hydrocarbons in the OWI as indicated by the reduction in sludge level (60%) and Total Petroleum Hydrocarbons (TPHs) (81.43%). TPH reduction in the OWI resulted in lower concentration of hydrocarbons being discharged into receiving water. The product application did not result in a release of heavy metals into the OWI or the receiving water. Metagenomic analysis of microbial communities indicated that the product application caused the Firmicutes to become the most dominant in the OWI. This microbial phylum is beneficial as its increase was followed by an improvement in hydrocarbon biodegradation. The product application in the OWI did not significantly change the microbial communities in the receiving water.
ABS has demonstrated the ability of the product in digesting interceptor sludge in-situ with a

very low risk for the environment. The use of this product within the maintenance program for OWIs can significantly reduce the frequency of sludge transportation or disposal and potentially reduce the budget for OWI maintenance. The product could be effectively be used in tank decommissioning, spill clean up and soil remediation.

Session 3 poster / Abstract title: BIOREMEDIATION OF HEXAVALENT CHROMIUM USING BACTERIA ISOLATES AND AN ABSORBENT MATERIAL

ID: 187

Key words: Hexavalent chromium, bacteria, adsorbent

Submitter: Bastian Saputra

Organization: Advanced Bacterial Sciences (ABS) Ltd

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Session: 3 poster

Abstract

Hexavalent chromium (Cr (VI)) compounds are used in many industrial processes including corrosion resistance, pigments, leather tanning, steel plating, etc. However, contamination of Cr VI residues from manufacturing or past chromite ore disposal to receiving streams or groundwater could exhibit mutagenic and carcinogenic effects on living organisms. Remediation of Cr VI using physical, or chemical technologies is commonly used for in-situ applications because of simple and rapid treatment. Nonetheless, some disadvantages come from high economic or energy costs and create additional problems such as nutrient loss or secondary pollution.

A promising bioremediation strategy is the use of bacteria that can remove Cr VI through biosorption and biotransformation by reducing Cr VI to a less toxic form (Cr III) enzymatically. Chromate-reducing bacteria have been widely studied but their application in the real contaminated environment remains limited mainly because of microbial loss and growth inhibition in highly polluted conditions. Therefore, microbial immobilisation could be used as a solution to reduce microbial loss and improve bioremediation efficiency.

ABS exploits the performance of chromate-reducing bacteria in combination with an absorbent from a sustainable material. This project aims to develop a product based on bacteria-absorbent aggregates that can be used to remediate Cr VI in contaminated water. Water samples were collected from a chromium-contaminated stream in Glasgow with the Cr VI concentration range from 5-7 mg/L. The bacteria consortium was isolated from the water and selected based on their ability to reduce Chromium VI. A lab-scale experiment showed that the bacteria consortium decreased Cr VI concentration by 82.52% in the contaminated water following the 24-hours incubation period. A batch absorption test using 2.5 w/v of absorbent material resulted in the removal of Cr VI by 99.9% after 16 hours of incubation time. Current experiments focus on immobilisation of the bacteria consortium on

the absorbent material and testing the Cr VI reduction on a pilot scale using a column experiment. Future work will test the product application to remediate the contaminated water in the field.

The application of this product is expected to decrease the Cr VI concentrations and improve the water quality. Furthermore, the product deployment could be expanded to remove Cr VI in contaminated sediment and soils. The strategy of combining chromate-reducing bacteria with the absorbent material offers an economic and environment-friendly solution to remediate chromium contamination.

Session 3 poster / Abstract title: BIOCHAR- AND PGR-ASSISTED PHYTOREMEDIATION OF COMPLEX CONTAMINATED SEDIMENTS WITH PAULOWNIA TOMENTOSA

ID: 194

Key words: phytoremediation, complex contamination, HCH isomers, Paulownia tomentosa, biochar

Submitter: Aigerim Mamirova

Organization: Jan Evangelista Purkyne University

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Session: 3 poster

Abstract

Optimisation of phytoremediation applied to complex contaminated sites is among the important tasks in sustainable remediation and movement toward zero pollution. Paulownia tomentosa (Thunb.) Steud produces consistent biomass of 50 t DM ha-1 yr-1 under non-optimised growth conditions, has the ability to accumulate trace elements (TEs) and organochlorine pesticides [1], and therefore, has been considered a promising candidate for remediation of soil and sediments.
Sediments utilised in the experiment were collected in Hajek, Czech Republic (GPS 50°17’31.5” N 12°53’35.2” E), being complex contaminated with TEs and HCH isomers, i.e., the concentrations of Cr, Mn, Cu, Zn, Sr, and Pb in sediments exceeded the maximum permissible concentrations (MPC) by up to 3.88 times, the concentration of HCH isomers was 1,023 ± 56.8 µg kg-1, being 10 times higher MPC. Phytoremediation was optimised by the application of plant growth regulators (PGRs; Charkor and Stimpo) and biochar, due to their proven ability to improve phytoremediation and biomass production of the well-known phytoagent, Miscanthus × giganteus [2–4]. Charkor is a complex mixture of 2,6-dimethylpyridine-N-oxide, Emistim C, and phytohormone analogue 1-naphthyl acetic acid. Stimpo is a complex substance of micromycete Cylindrocarpon obtusiusculum metabolites, Emistim C, and Aversectin C, an actinomycete Streptomyces avermytilis metabolite. Biochar was produced by Agmeco s.r.o. by pyrolyzing sewage sludge from the municipal wastewater treatment plant (Brno, Czech Republic). The application rates of Charkor, Stimpo, and

biochar were 0.25, 0.50, and 5%, respectively. Plant height, stem diameter, leaf length, width, and quantity, dry weight (DW) of leaves, stems, and roots were evaluated to access biomass productivity. Research data was processed with two-way ANOVA (factors: PGRs and biochar) followed by Tukey HSD pairwise comparison.

During the first year of phytoremediation, the biomass metrics essentially decreased following PGRs treatment but increased in the presence of biochar. The results of the study revealed that Charkor and Stimpo significantly reduced plant height, stem diameter, leaves DW, and stem DW by 30.4 and 28.9, 33.3 and 54.8, 61.8 and 77.1, 72.2 and 82.4%, respectively, while incorporating biochar to the system with the above-mentioned PGRs cancelled out their effects on the plant by either matching the control or being even higher. Solely applied biochar improved almost all the parameters measured (except stem diameter and leaves quantity) by up to 196%. The analysis of leaf length and width as well as roots DW showed that these parameters were not affected by PGRs but by biochar, increasing the parameter by 76.1, 73.5, and 350%, respectively.

The application of biochar in a dose of 5% thus showed a clearly positive influence on the development of P. tomentosa in complex contaminated sediments, which can probably be explained by the increased tolerance of the plant to the contaminants. The application of PGRs, on the other hand, had a negative effect on plant bioparameters, possibly due to the increased permeability of the cell membrane in the roots, which aims to improve nutrient uptake but also increases the uptake of contaminants.

Study findings substantially contribute to developing novel technologies to treat emerging contaminants toward zero pollution.

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Session 3 poster / Abstract title: PILOT TESTING OF HCH AND CBs REMOVAL BY WETLAND TECHNOLOGY

ID: 197

Key words: wetland technology, bioremediation, pesticides, POPs

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Session: 3 poster

Abstract

Uncontrolled migration of pesticides in groundwater poses a serious threat to drinking water resources. One of the most toxic pesticides produced in Europe since the 1940s until the 1980s was lindane, or γ-HCH. Both lindane and its post-production wastes were often disposed of inappropriately, resulting in uncontrolled migration of these compounds into the soil and water environment. In Poland, it has been estimated that 35,000 tonnes of HCH waste is still present, of which the largest amount is stored in Jaworzno. The site most contaminated with lindane and other HCH isomers is located in Jaworzno in southern Poland where the Chemical Plant "Organika-Azot" produced lindane from 1965 till 1982. The contaminants found in Jaworzno are dominated by HCH isomers and chlorobenzens, but important fact is also the presence of other persistent organic pollutants such as chlorophenols, dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, dichlorodiphenyltrichloroethane, chloroethenes and chloromethane. The LIFEPOPWAT project proposes Wetland+ technology suitable for remediation of such complicated mixture of persistent organic pollutants. The present paper reports HCH removal efficiencies for a five-stage Wetland+ technology in a pilot scale. The pilot installation consists of the following modules: sedimentation, zero-valent iron (ZVI), biosorption, aerobic wetland, infiltration wetland. The removal process is based on combination of various methods such as chemical oxidation of contaminants, physical treatment methods through sorption processes as well as biological treatment methods using plant biomass and coexisting microorganisms. The pilot Wetland + system is located between trenches R2 and R3 which are the part of the network of dewatering trenches constructed on the bottom of former sand pit “Rudna Góra” which is currently partially filled in by HCH waste. Trench R3 is collecting heavily contaminated water where the concentration of sum of HCH in 2020 was ca. 79 µg/L and trench R2 is collected less contaminated water with the concentration of HCH was ca. 1µg/L.

The pilot Wetland + system operates on the mixture of water from trenches R2 and R3 so that contamination level is within the operation window of the technology. In the article the results from first months of operation of the Wetland+ installation are presented. The results document the process of optimizing the functioning of the system, including the selection of the flow rate and pollutant load. The article presents also the comparison of the efficiency of HCH and CBs removal on each installation modules. The results obtained and presented in this paper could be useful for further design of full-scale Wetland+ technology on sites contaminated by similar persistent organic pollutants.

Session 3 poster / Abstract title: Column tests of microbial dechlorination supported by substrate application and DC field

ID: 209

Key words: bioremediation, microbial dechlorination, DC field

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Session: 3 poster

Abstract

The aim of this study was to create columns simulating subsoil conditions and to test the influence of the fermentable substrate and the DC field application on the microbial dechlorination of chlorinated ethenes (ClE). Electrokinetic and electrolytic processes are involved when applying a DC field. These processes fundamentally affect the change in the physicochemical parameters of the underground environment (mainly pH and ORP change). They can thus significantly influence the ongoing biological decomposition of ClE. Understanding these processes and their adequate support in field application can increase the effectiveness of remediation techniques.

For this purpose, a column test methodology was developed, which uses two parallel columns with separate inputs and a shared output. Thus the cathodic and anodic processes can be studied separately without influencing each other. DC was supplied to the columns through steel electrodes placed in the input parts of the columns. The columns were filled with a substrate that simulated an underground environment, and natural ClE-contaminated groundwater was pumped through them.

The results show that the most efficient microbial dechlorination occurred in the cathode column when an intermediate potential of 60 V was applied. The observed ClE degradation is attributed to hydrogenolysis and also to β-elimination as acetylene was produced. Thus, abiotic processes contributed to ClE decomposition in addition to microbial dechlorination processes. A further increase in potential up to 120 V has already led to a decrease in the activity of MOs capable of dechlorination of PCE and TCE. However, abiotic degradation via β-elimination was still intensive in the cathode column.

The microbial dechlorination of ClE was mainly due to the increase in the abundance of sulfate reductants and iron reductants after the DC application. The conditions in the cathode column favoured a reduction type of microbial metabolism, so the sulphate and iron-reducing bacteria used ClE as alternative electron acceptors in this column. On the contrary,

the fermentation of glycerol to products, which were used by methanogenic microorganisms, took place mainly in the anode column. This led to higher methane production and a smaller production of ClE decomposition intermediates in this column. The above shows a higher activity of ClE-degrading bacteria in the cathode column, while methanogenic microorganisms prevailed in the anode column.

Column tests of microbial dechlorination supported by the application of fermentable substrate and a DC field demonstrated that appropriate conditions setting can lead to the high efficiency of such remediation technique. Higher intensity of microbial dechlorination processes as well as abiotic degradation of ClE, was observed in the cathode column. However, some promotion of biological dechlorination of ClE also occurred in the anode column.

The authors acknowledge the assistance provided by the European Union's Horizon 2020 research and innovation programme under grant agreement N°965945 and The Technology Agency of the Czech Republic, project No. FW03010071.

Session 3 poster / Abstract title: IMPACT OF SUBSTRATE ADSORPTION BEHAVIOUR FOR EMERGING POLLUTANTS IN CONSTRUCTED WETLANDS

ID: 215

Key words: Emerging pollutants; Pharmaceutical and personal care products; Constructed wetlands; Adsorption; Substrates.

Submitter: Yana Prados

Organization: Czech University of Life Sciences Prague

Co-authors: Thesis supervisor: doc. Dr.-Ing. Zhongbing Chen Department of Applied Ecology

Session: 3 poster

Abstract

Abstracts
Emerging pollutants (EPs) have become a considerable concern for human health and all biota, thereby endangering the health and lives of the whole environmental system. For example, pharmaceutically active compounds, including over-the-counter medications, have more frequently been found throughout water bodies around the world. Moreover, a pandemic caused by the SARSCoV-2 virus has entailed increasing the use of various chemicals and compounds, including Pharmaceuticals and Personal Care Products. Therefore, the risk of environmental damage has received extensive attention in recent years.
This research aims to investigate, evaluate, and compare the role of two different substrates, sand and perlite, within the waste products removal process regarding the adsorption capability of EPs, including ibuprofen (IBU) and diclofenac (DCF) in constructed wetlands (CWs).
The comparative results showed that perlite provides a superior condition for plant growth versus sand and indicates that the size difference of the plant shoots and roots length is 20% and 16%, respectively, in favor of perlite. In addition, the removal efficiencies of TOC, PO43-, and NH4+ have shown the best sorption results using perlite increased treatment process by 5%, 25%, and 42%, respectively, compared to sand. Furthermore, the influence of perlite also contributed to higher IBU and DCF removal efficiency. It was 88.57% and 63.48% for perlite, which is higher than the adsorption ability of sand by 23 and 27%, respectively. Besides, the perlite significantly boosts the contents of IBU in the rhizosphere soil and raises the presence of DCF in plant roots. Moreover, the contents of IBU and DCF metabolites (2-OH IBU and 4′-OH DCF) in the plant roots were also higher.
It can be concluded that perlite may be contributing to the high removal efficiency of

emerging pollutants, including pharmaceuticals. Thus, the characteristics of this substrate are promising due to its effectiveness in emerging pollutants removal. This paper considers the components, pathways, and impact of pollutants on the ecosystem. The presumed mutual influence and co-dependency of the elements of nature can shed new light on the existing problem and may contribute to solving it.

Objectives

Large-scale production and consumption create a heavy load on conventional WWTPs, which are not designed for many pollutants, including medicals that appear in large amounts in the water. Additionally, the COVID-19 pandemic raised the release of a considerable amount of medicine in the sewage system. Thus, an urgent need arose to use CWs in terms of efficiency, economy, and ecologically friendly application.

As noted above, NSAIDs' removal method in CWs, including IBU and DCF and sorption efficiency of given absorbent, are still not thoroughly studied. Their further fate is still not well understood. Therefore, the primary purpose of this research was:

-To investigate and compare the adsorption behaviour of the chosen substrate: sand and perlite for selected EPs in VSSF CWs.

-To analyze and estimate their role and purification ability in CWs for removing EPs, including pharmaceuticals IBU and DCF.

The research may provide data and knowledge about the purification process. In addition, the obtained data can be helpful at improving methods of elimination of EPs in CWs and mitigating their impact on aquatic and human life. Conclusively, the study can shed light on issues related to the impact of EPs on the ecosystem to contribute to future researchers. Initially had planned to study both the adsorption and desorption capacity of sand and perlite. Unfortunately, due to the unpredictable situation of the COVID-19 epidemic in the Czech Republic, the desorption capacity of given substrates couldn’t be achieved.

Method and materials

The experimental section of the thesis is based on the small-scale experimental sub-surface vertical constructed wetlands, which were established and used on the

Session 3 poster / Abstract title: Large-scale on-site bioremediation and VOC emission control at a former landfill site near Brussels (Vilvoorde, Belgium)

ID: 244

Key words: BETX, Emissions, Bioremediation, on-site re-use, landfill

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Organization: DEME Environmental

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Session: 3 poster

Abstract

In Vilvoorde near Brussels (Belgium), an old brownfield site contained a mixed contamination of BETX, heavy metals, chlorinated hydrocarbons and petroleum hydrocarbons caused by former landfilling activities. Prior to the redevelopment of this site a large scale remediation was undertaken to eliminate the human health and environmental risks posed by the contamination.
A joint venture of DEME Environmental, Envisan (Jan de Nul Group) and Sarpi Remediaton (Veolia), named CATS, was appointed the remediation works which took place from August 2020 till December 2022. The joint venture name refers to the original name of the site; Cat-site. The remediation works comprised of selective excavation of the about 200 000 tonnes of contaminated soil and waste, on-site separation and treatment to finally backfill the treated soils, without any import of clean soils from external sources.
A clear aim was set by the client, MG Real Estate and Regulator (OVAM) to minimise off-site disposal by maximising on-site bioremediation of the contaminated soils after waste separation. This objective was set in view of lowering the carbon footprint of the remediation through elimination of transport. In addition a particular challenge for this project was preventing high benzene concentrations to be emitted to the surrounding area during the works. In the soils concentrations up to 27 000 mg/kg were detected in localised hotspots. These resulted in a significant potential for benzene emissions during excavation and installation of the on-site biopiles.
Prior to the start of the works, detailed design of the excavation plan was supported by pilot-scale emission monitoring on-site to characterise the emission sources and determine the efficiencies of several control measures. During the full-scale excavation works, weather predictions were used to plan excavation works and adjust where necessary. Extensive emission monitoring was further undertaken using both active and passive measurement systems to control and demonstrate compliance with air quality standards. In addition a

number of emission control measures were successfully applied to limit the VOC emissions and safeguard the air quality on-site and at the industrial and residential areas surrounding the site.
The contaminated soil was treated by aerobic biological degradation in a specific biopile design. The oxygen was distributed through an air extraction system, that also eliminated the VOC emissions. Extracted air was treated on-site by catalytic oxidation and biofiltration. In order to optimise the bioremediation system, the treated air was partially reinjected into the biopiles while keeping the biopiles at a negative pressure.
A total of about 20 biopiles were installed on-site throughout the course of the project. The system was capable of reducing the initial benzene concentrations above 1000 mg/kg to meet the treatment target of 2.64 mg/kg benzene with an average remediation time of 223 days.

Session 3 poster / Abstract title: Effect of PAC (PAH Polar-PAC) availability on aquatic organisms' ecotoxicity

ID: 245

Key words: PAC (PAH Polar-PAC), availability, aquatic organisms, ecotoxicity

Submitter: Imane AABBAR

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Session: 3 poster

Abstract

Historically contaminated sites have gained attention in recent decades. Some of them, e.g., former coking plants, are contaminated by polycyclic aromatic compounds (PACs), including 16 US-EPA PAHs and polar-PACs (O/N/S-PACs) which can induce potential risk for aquatic organisms[1]. Several studies reported that PAC (bio)availability can be limited in such sites, due to aging phenomenon [2,3], explaining the low impact on soil biota of some heavily contaminated soils . Consequently, bioavailability is a major factor to consider in the risk evaluation associated to PAC-contaminated soil and PAC transfer to the aqueous phase [2, 3] but is scarcely taken into account

The objective of this work is to evaluate the influence of the PAC availability on PAC transfer from soil to the aqueous phase and its consequences on toxicity towards model aquatic organisms. Two soils (HOM and THI) were sampled on former coking plants. Aliquote of both soils were heated at 100 °C under inert atmosphere for one week in order to increase PAC availability by 10-30% for HOM and THI respectively [4]. Batch leaching tests were carried out according to the ISO 18772 (2008) procedure, PACs were quantified in the leachates by GC-MS after solid phase extraction. Simultaneously, ecotoxicity tests were performed through limit assays using standard acute bioassays. Rotifers and daphnie mobility and reproduction rate, respectively, as well as the growth inhibition of algae were evaluated.

Results showed that leachates from raw soils have identical physico-chemical properties , except ionic strength that was ten times higher in THI than in HOM leachate. The PAC content was higher in HOM than in THI leachate, with polar PAC concentrations of 37300

and 6150 ng/L and PAH concentrations of 95 510 and16 030 ng/L for HOM and THI, respectively.Both leachates exhibited a similar PAH distribution. The results show a preferencial release of low-molecular-weight PAHs and polar PACs, especially O-PAC, mainly by dissolution, while higher-molecular-weight PAHs are released in association with colloids. An Important toxic effect of growth inhibition (85%) was observed on algae for both leachates. No toxic effects were observed in daphnie mobility and only THI leachate induced a slight decrease on rotifer reproduction (25%).

The pre-heating treatment increased PAC content in leachates by 35% and 74% for HOM and THI, turning them into 105678 and 48094 ng/L for 16 PAHs and into 98100 and 39300 ng/L for polar PAC, respectively. As a result ,the leachates from preheated soils were more toxic than those from raw soils. Algae growth inhibition was observed to be 8% higher for both soils' pre-heated leachates. As for raw soil leachate, THI presented no toxic effects on daphnia mobility, and it exhibited a similar degree of toxicity on rotifer reproduction. On daphnia, however, HOM demonstrated 95% mobility inhibition and presented a toxic effect on rotifer reproduction (37%).

This study showed that soils with similar chemical composition but contrasting levels of PAC availability release higher amounts of PACs into the aqueous phase, contributing to important ecotoxic responses in aquatic organisms.These results pointed out the importance of considering the contamination availability parameter in risk assessment and not only the total contaminant concentration.

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Session 3 poster / Abstract title: Contaminants in Saprolite: Analysis of Research Gaps and Future Research Directions

ID: 258

Key words: Contaminant transport; Emerging contaminants; Persistent contaminants; Vadose zone; Saprolite

Submitter: Gemma Shaw

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Co-authors: Dr. Daniel Evans, Cranfield University, soil scientist; Prof. Frederic Coulon, Cranfield University, environmental chemist and microbiologist; Prof. Wilfred Otten, Cranfield University, soil biophysicist; Dr. Darren Beriro, British Geological Survey, geoscientist

Session: 3 poster

Abstract

Saprolite is a transitional zone of highly weathered rock between soil and unweathered bedrock. Pedogenic processes transform saprolite into soil.

Contaminants may enter saprolite from overlying contaminated soils, agricultural spreading, waste burial, contaminated surface water, or other pathways and sources. It is important to understand how they behave in the weathered profile so that their transport and fate can be accurately predicted. This could inform risk assessments, remediation strategies, and approaches to the management of emerging contaminants in the environment. From a sustainable remediation perspective, improving the targeting of remediation could reduce the resources, energy, and carbon emissions required to achieve the remediation goals.

This research is particularly timely in the context of persistent, emerging contaminants, including but not limited to: microplastics, pharmaceuticals, pesticides, and PFAS. Additionally, Climate Change may impact contaminant fate and transport in this context, due for example to its potential effects on unsaturated zone hydrology and water table fluctuations.

Saprolite is chemically highly weathered but retains structural features of the parent rock. This often includes some form of fracture network. Saprolite varies significantly in thickness and properties between different locations and geologies. It has distinct properties compared to the soil and unweathered bedrock at the same location, due to isovolumetric weathering processes, its position in hydraulic cycles, and the mineralogical changes associated with weathering. It is not a uniform material, with different researchers sometimes attributing specific roles to different depth zones within the saprolite. Examples include storm-flow rapid

transport higher up in the saprolite, or the presence of a more impermeable layer at the base. Therefore, it would be expected that contaminants would interact with, and behave somewhat differently in, this zone compared to in the soil or unweathered bedrock.

The role of saprolite in the transport, storage and potential re-release of contaminants has implications for the health and quality of future soils, crops, and water. For example, storage and concentration of persistent contamination may in future migrate upwards, or the soil may be eroded such that the contamination is accessed by crop roots. In the context of groundwater, thick and ubiquitous saprolite is often considered to be a protective layer for the groundwater below, for example acting to filter out colloidal contamination before it reaches the major aquifer. For persistent contamination, this could raise concerns of possible contaminant build-up in saprolite, remobilisation from saprolite, or potential rhizosphere interactions.

However, there does not appear to be clear consensus about contaminant transport and fate in saprolite, and more studies are required, particularly for persistent, emerging contaminants. Currently, many of the available papers are based on a single site. Furthermore, the boundaries of the saprolite zone are not precisely defined. There are currently gaps in knowledge about the roles saprolite plays in contaminant fate and transport. This research aims to identify and address some of those gaps.

This research aims to review the current evidence on the presence and behaviour of contaminants in saprolite and use this to inform digital mapping of saprolite and contamination risks, fieldwork sampling of saprolite contamination, mesocosm experiments and modelling. This will enable the identification and quantification of both natural processes and risks.

This poster presents the findings from the first research phase - a systematic literature review. The review addresses the question: What is the state-of-the-art of knowledge on the presence and behaviour of contaminants in saprolite? It reviews the research on contamination in saprolite and identifies research gaps to be addressed.

Session 3 poster / Abstract title: Impact of substrate adsorption behavior for emerging pollutants in constructed wetlands

ID: 26

Key words: Emerging pollutants; Pharmaceutical and personal care products; Constructed wetlands; Adsorption; Substrates

Submitter: Yana Prados

Organization: Czech University of Life Sciences Prague

Co-authors: doc. Dr.-Ing. Zhongbing Chen

Session: 3 poster

Abstract

Emerging pollutants (EPs) have become a considerable concern for human health and all biota, thereby endangering the health and lives of the whole environmental system. Pharmaceutically active compounds, including over-the-counter medications, have more frequently been found throughout the water bodies around the world. Moreover, a pandemic caused by the SARS-CoV-2 virus has entailed increasing the use of various chemicals and compounds, including Pharmaceuticals and Personal Care Products. Therefore, the risk of environmental damage has received extensive attention in recent years.
This research aims to investigate, evaluate, and compare the role of two different substrates, sand, and perlite, within the waste products removal process regarding the adsorption capability of EPs, including ibuprofen (IBU) and diclofenac (DCF) in constructed wetlands (CWs).
The comparative results showed that perlite provides a superior condition for plant growth versus sand and indicates that the size difference of the plant shoots and roots length is 20% and 16%, respectively, in favor of perlite. In addition, the removal efficiencies of TOC, PO_4^{3-} and NH_4^+ have shown the best sorption results using perlite increased treatment process by 5%, 25%, and 42%, respectively, compared to sand. Furthermore, the influence of perlite also contributed to higher IBU and DCF removal efficiency. It was 88.57% and 63.48% for perlite, which is higher than the adsorption ability of sand by 23 and 27%, respectively. Besides, the perlite significantly boosts the contents of IBU in the rhizosphere soil and raises the presence of DCF in plant roots. Moreover, the contents of IBU and DCF metabolites (2-OH IBU and 4′-OH DCF) in the plant roots also was higher.
It can be concluded that perlite may be contributing to the high removal efficiency of emerging pollutants, including pharmaceuticals. Thus, the characteristics of this substrate are promising due to its effectiveness in emerging pollutants removal. This paper considers the components, pathways, and impact of pollutants on the ecosystem. The presumed

mutual influence and co-dependency of the elements of nature can shed new light on the existing problem and may contribute to solving it.

Session 3 poster / Abstract title: Simulation of As and Sb mobility in rhizosphere-based solution from contaminated soils amended with Fe chips.

ID: 260

Key words: leaching, iron waste, metalloids, citric acid

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Session: 3 poster

Abstract

This work was financially supported by the project APVV-21-0212.

The addition of amendments to contaminated soils might immobilize metalloids or release them into the environment. A similar effect was also observed in the case of organic acids that occur naturally in soil and rhizosphere. The aim of our study was to monitor the effect of Fe chips addition to soils and the effect of citric acid on the mobility of As and Sb in co-contaminated soils during a one-month column experiment.
Soils with different properties, and As and Sb contents were sampled from three different sites located at the abandoned Sb deposit nearby Pezinok (Slovakia). A sieved air-dried soil sample with(out) Fe chips addition (2 wt. %) was transferred into glass columns. The contents of the columns were slowly saturated with demineralized water from the bottom up. The samples were left to equilibrate in the column for a week. After, the samples were leached with a solution of 1mM citric acid or demineralized water in weekly intervals. A total of 4 leaching cycles were carried out. At the end of each cycle, total Sb/As concentrations in the filtered leachates were measured by ICP-OES.
The soil samples were generally rich in As and Sb with the highest bulk concentrations of As (14 379 mg/kg) and Sb (15 066 mg/kg) in tailing material (PK-B), followed by a sample taken right below the tailing deposit (PK-C: As=1 252 mg/kg, Sb=788 mg/kg) and the soil sample influenced mainly by mine water discharges (359 mg As/kg, 19 mg Sb/kg; PK-A). The efficiency of Fe chips on the As/Sb immobilization varied considerably depending on the soil sample type, the leaching cycle, and the leaching solution.
A significant effect of Fe chips on the immobilization of metalloids in the studied soils was observed only in the case of As in PK-A soil sample. The total leachability of As from the

non-amended PK-A soil was 33% regardless of the leaching solution used. The addition of Fe chips resulted in a decrease of the As leachability by 10%. In other soil samples, the leached amounts of As and Sb were very low and the influence of the treatments was negligible. Nevertheless, after adding Fe chips to PK-A soil sample, mobility of Sb slightly increased in demineralized water and also in citric acid leachates. Similar behaviour was observed for As in amended PK-B soil sample in demineralized water leachate. Moderately elevated concentrations of As were also found in the citric acid leachates from amended and non-amended PK-C samples.

To summarize, the soil type and the actual level of As/Sb contamination seem to be crucial aspects when assessing the soil amendment remediation efficiency. Iron based materials are often considered as effective immobilizing agents of metalloids in contaminated soils. However, the results of our experiment showed that this statement cannot be fully generalized. Arsenic and Sb behave differently in contrasting soils, so the effect of Fe-based amendments can also be different. Further research in the application of such soil amendments in different soil types under various environmental conditions is therefore required.

Session 3 poster / Abstract title: Soil Vapor, Groundwater, and Condensate Treatment for High-Temperature Thermal Remediation Sites: Design Considerations and a Case Study

ID: 264

Key words: high temperature, treatment process

Submitter: David Rountree

Organization: McMillan-McGee Corp.

Co-authors: nan

Session: 3 poster

Abstract

Background/Objectives: High-temperature thermal remediation can be defined as those projects having a target temperature above the boiling point of water. These projects typically rely on electric or gas-fired thermal conductive heating (TCH) technologies that target high-molecular weight compounds. This can include compounds such as polynuclear aromatic hydrocarbons, (PAHs), polychlorinated biphenyls (PCBs), pesticides (e.g., Dichlorodiphenyltrichloroethane (DDT)) and associated precursor chemicals, and potentially per/polyfluoroalkyl substances (PFAS), per/polyfluorocarboxylic acids (PFCAs), and per/polyfluorosulfonic acids (PFSAs).

The above grade treatment system needs to be designed to process: (i) high temperature extracted vapors and non-condensable gases; (ii) extracted groundwater, condensate, and non-aqueous phase liquids (NAPLs); precipitated solids; and (iv) potential breakdown products from the high temperature treatment of these contaminants. As such, a detailed analysis of the contaminants of concern is the first step to identify potential challenges and properly informing the design of the treatment system.

These unique operating conditions and design challenges that need to be considered might include:

1. High-temperature process vapors;
2. Contaminants that are solid at room temperature;
3. Contaminants that decompose rather than boil;
4. Formation of unknown breakdown products;
5. High destruction temperatures;
6. Low emissions standards; and,
7. Acid production during decomposition.

These challenges constrain the selection of treatment technologies, and lead to trade-offs that have to be considered when selecting treatment technologies. The constraints on the selection of treatment technologies often require a trade-off between effectiveness, efficiency, and cost. For example, a technology that is highly effective in removing contaminants may be too expensive to implement, leading to a need to consider a less effective but more cost-effective option. Similarly, a technology that is very efficient in its operations may have a higher upfront cost that could be prohibitively expensive. Therefore, when selecting a treatment technology, it is important to carefully consider the cost implications of the trade-offs involved and weigh them against the desired outcomes of the project.

Case Study: The above factors were examined during the design process for the BT Kemi soil vapor, groundwater, and condensate system. Various process treatment steps and configurations were examined before settling on a treatment system design. These competing systems will be examined, along with the decision process resulting in the selected design.

The specific design characteristics of the selected treatment system will be reviewed, including:

1. Heat transfer and process fluid cooling;
2. Acid neutralization;
3. Acid adsorption;
4. Liquid treatment;
5. Vapor conditioning; and,
6. Vapor treatment.

The actual system procurement, construction, and operational results will be reported. Lessons learned and implications for future sites will be summarized

Session 3 poster / Abstract title: Sustainable remediation under limiting formal conditions – case study of the Polish legislation

ID: 267

Key words: sustainable remediation in Poland; brownfield remediation; legal uncertainties; environmental legislation issues

Submitter: Tomasz Powroźnik

Organization: Arcadis

Co-authors: nan

Session: 3 poster

Abstract

In Poland, legal regulations regarding sustainable remediation are still at the stage of development (the first legal regulations regarding risk analysis are from 2014). As the sustainable remediation is still in its infancy, some of its constituent parts still require legal clarification or structured guidelines on which the authority could rely.
Polish land contamination legislation has several peculiarities which must be considered while developing a sustainable remediation project. The most notable are:
• groundwater quality is not formally a subject of remediation process,
• no detailed requirements for risk analysis and lack of methodological guidelines on which the official could rely to ensure quality of the risk model,
• contaminated soil (recognised as waste upon extraction) often cannot be remediated using ex-situ onsite methods (considered to be waste processing by the law).
The above ambiguities and deficiencies in current legislation determine that in the case of complex remediation projects requiring a sustainable approach to remediation (complex in terms of the type of contamination, geological structure, hydrogeological conditions, volume of the contaminated material), in particular projects related to brownfields, remediation proceedings might present a challenge.
In Poland there are numerous brownfields, including industrial areas as well as the sites where post-industrial, post-mining and post-metallurgical materials have been deposited. Such areas are connected with most major cities, albeit the best example is the Upper Silesian Industrial Region, i.e., a region of 3,000 km2 where much of the country's industrial and mining production was historically located.
Areas of this type are usually connected by the prevalence of contaminated anthropogenic soils, as well as large lateral and vertical spread of contamination. Due to the extremely high costs of remediation based on the fixed soil quality standards (removal of all soils exceeding these standards, the most straightforward method for the official to interpret), this situation motivates investors to conduct more detailed environmental investigation and to carry out

remediation focused on a risk-based approach.
In the realities of the country, Arcadis Poland can be considered a precursor in the implementation of remediation projects regarding brownfield areas which are based on sustainable remediation. Over the years, a methodology has been developed to overcome various formal and human obstacles in order to ensure maximum environmental benefits, eliminate threats to human health and ensure a reasonable financial framework.
In the experience of Arcadis Poland, one of the most important factors enabling the rationalization of the remediation process is establishing a thread of understanding between the project developer and the official in order to build trust on the part of the Environmental Agency. The main problems encountered so far are legal restrictions, reluctance to accept solutions not precisely defined by the law, caution against new methods of remediation as well as lack of knowledge and experience with numerical risk modelling. Several case studies with diverse characteristics and varied formal and administrative issues necessary to solve will be discussed during presentation.
In summary, the presentation will show that even in countries where land contamination framework is still evolving, sustainable remediation can be attempted. It is also intended to indicate the problems that a consultant may face when starting a project in a region with lower awareness regarding sustainable remediation.

Session 3 poster / Abstract title: Bioremediation systems exploiting synergies for improved removal of mixed pollutants

ID: 269

Key words: Bioremediation; Mixed contamination; Genome-scale metabolic models; Phytoremediation; Bio-electrochemical systems

Submitter: Rocío Barros

Organization: University of Burgos-ICCRAM

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Session: 3 poster

Abstract

BIOSYSMO is a 48-month EU-action that will develop a computationally-assisted framework for designing and optimizing synergistic biosystems combining the required pathways and traits to achieve the most efficient degradation and sequestration of pollutant mixtures. These biosystems will comprise combinations of bacteria, fungi and plants containing the natural or engineered pathways required for pollutants management and identified based on a computationally-assisted analysis. BIOSYSMO will take advantage of the high natural microbial diversity by screening samples from metal polluted sites and locations affected by diffuse pollution to identify natural microorganisms already present and able to alter pollutant availability. The search will be expanded to microorganisms previously identified and characterized by applying data mining tools to genomic and metagenomic data available in public repositories. The construction and optimization of synergistic biosystems will combine approaches based on 1) enhancing plant- microbe (bacteria, fungi) interactions to achieving combinations with improved pollutant uptake and/or degradation; 2) engineering bacteria, for improved degradation and bioaugmentation, and plants (poplar tree), for improved microbial colonization and pollutant uptake; 3) constructing artificial micro-structured consortia into aggregates and biofilms, containing all the required pathways for pollutant removal; and 4) applying bioelectrochemical systems (BES) as stand-alone or in hybrid systems. 5) biostimulating the native microbial communities to exploit natural traits that improve contaminant removal.. The different key players will be identified and combined to formulate

innovative biosystems with the assistance of genome-scale metabolic (GEM) models for elucidating and simulating the key metabolic pathways. The constructed biosystems will be applied in conventional (phytoremediation, biopile, biostimulation/bioaugmentation) and innovative (BES, hybrid BES-phytoremediation) bioremediation approaches optimized for the treatment of mixtures of pollutants in soil, sediments and waters.

Session 3 poster / Abstract title: Transport and reactivity of green rust and biochar for reductive dechlorination of chlorinated solvents

ID: 275

Key words: Chlorinated solvents, Particle transport, Reductive dechlorination, Biochar, Iron hydroxides

Submitter: Theis van Beek Pedersen

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Session: 3 poster

Abstract

-Purpose of study
Composite materials, consisting of green rust (layered Fe(II) and Fe(III) hydroxides, GR) and biochar (BC), are promising materials for the dechlorination of trichloroethylene (TCE), but knowledge on their injectivity and reactivity in the subsurface does not exist. Successful remediation of contamination though injection of reactive agents requires fundamental understanding of their transport properties. Thus, the purpose of this study was to investigate the particle transport of the composite materials through saturated, sand-packed columns and subsequently, their reactivity. By varying the flow rates and initial particle concentrations, we aimed to generate transport data for a one-dimensional system that can be used in the development of a three-dimensional model. When validated through larger scale experiments, such a model would be a valuable tool for the engineering of full-scale remediations. Finally, the transformation and reactivity of GR and BC towards TCE were tested under sediment-bound conditions to calibrate a geochemical model for reactions.
-Methodology
The suspensions of sulphate bearing GR and BC were added an organic polymer to minimize aggregation of the particles and improve mobility. The injection of the suspension was performed at three flow rates and at three initial particle concentrations, and the breakthrough and retention of GR and BC were determined. Afterwards, the longevity and reactivity of the retained GR and BC was assessed by flushing the column with a synthetic groundwater that episodically contained TCE.

-Summary of findings/results

In the transport experiments, the GR and BC composite was generally retained more strongly with decreasing injection rates and/or decreasing concentration. Depending on conditions, the particle concentration at the outlet decreased by 15 to 60 % relative to the initial concentrations. Concomitantly, the amount of pore volumes injected before breakthrough increased. Transport behavior was very similar for the two components, GR and BC, suggesting the formation of hetero aggregates, which remained intact during transport. This intimate association is likely critical for composite reactivity after injection. Sediment analysis revealed larger concentrations of retained GR and BC in the first fourth of the column and an even distribution of particles in the rest of the column. Geochemical modeling indicated that the major transformation products of GR were magnetite, carbonate GR (substitution of SO_4 for CO_3 in the GR interlayers) and siderite. Degradation of TCE inside the column led to the formation of acetylene and ethene as the main degradation products, amounting to 21 % within 22.5 hours for the fresh composite. After flushing with 15 pore volumes synthetic groundwater, TCE degradation was halved, most likely reflecting the slower reacting carbonate GR.

-Significance / contributions of study

The present study has been an important part of the project, GreenCat, which aims to develop a green solution to handling the widespread soil and groundwater contamination due to chlorinated ethylenes. In this study, methods were developed to detect and optimize the transport and distribution of the particular composite material. The results indicated that injection of the composite materials into the subsurface is possible and that its reactivity is retained. The data generated in this study will be used to create a 3-dimensional numerical model for particle injection and reactivity, which can be used as a tool for planning full-scale remediations.

Session 3 poster / Abstract title: The Incorporation of Sustainable Remediation During the Closure and Remediation of an Agrochemical Manufacturing Facility

ID: 277

Key words: Sustainable Remediation Incorporation process management

Submitter: David Manning

Organization: ERM

Co-authors: nan

Session: 3 poster

Abstract

Embedding sustainability into management of land contamination is known as “sustainable remediation” but its application is not restricted to the remedial options appraisal stage alone. This case study will describe the practice of incorporating sustainable remediation into the process of site closure and remediation of a former agrochemical manufacturing facility in the UK. The process followed UK LCRM guidance and the structure of the SuRF UK framework. A key consideration at the outset was the client’s sustainability policies. With the agreement of clear project objectives (technical and business) and boundaries sustainability was then considered during the remedial options appraisal process, as part of the contractor procurement and was carried forward into the remediation implementation phase by adopting a number of sustainable management practices (SMPS). A semi quantitative multicriteria analysis (MCA) was used in the remedial options appraisal and this was supplemented by a carbon footprint assessment of the preferred technical options. A number of SMPs were identified and carried through to the remediation implementation phase. This paper will provide a broad overview of each of the phases undertaken above highlighting the benefits and limitations of the approach together with practical lessons learned. The paper will conclude with recommendations for future implementation.

Session 3 poster / Abstract title: Efficient and sustainable removal of cadmium from contaminated farmland soil by novel magnetic mercapto-functionalized attapulgite beads

ID: 290

Key words: Farmland soil, Magnetic alginate beads, Cadmium, Mercapto-attapulgite, Magnetic separation

Submitter: Yongming Luo

Organization: Institute of Soil Science, Chinese Academy of Sciences

Co-authors: Dr. Guoming Liu, Institute of Soil Science, Chinese Academy of Sciences, post doctor; Dr. Chen Tu, Institute of Soil Science, Chinese Academy of Sciences, Associate Prof.

Session: 3 poster

Abstract

Purpose: Farmland soils contaminated with Cd complex pose a serious threat to human health and the ecological environment. Remediation of contaminated farmland soils by reduction/removal of heavy metal from soil is more challenging than the current commonly used immobilization methods. To address this challenge, we propose the use of novel magnetic mercapto-functionalized attapulgite beads (MFBs) to remove cadmium (Cd) from the contaminated farmland soil by magnetic retrieval.
Methods: MFBs were prepared via a rapid and cost-effective one-step gelation method with mercapto-functionalized attapulgite and magnetic Fe3O4 matrix. MFBs were used to treat 26 Cd-contaminated farmland soils collected from different regions of China. The MFBs was mixed with soil and water, and the Cd-loaded MFBs in the soil are separated by magnets after the reaction. The change of Cd concentration in the soil after the reaction was measured.
Results: The good magnetic properties of MFBs can realize facile separation from flooded soil and thus magnetically remove adsorbed Cd. The removal efficiency of acid extracted Cd reached 54.7 (19.2 – 79.8)% by a single treatment in 26 Cd-contaminated farmland soils. MFBs mainly removed the exchangeable and reducible Cd from the farmland soils. Under low soil pH and organic matter content conditions, soil Cd, especially its labile fraction was more favorably adsorbed by MFBs. Chemical precipitation, surface complexation and electrostatic attraction were three main mechanisms for Cd removal by functional groups (e.g, –OH, –COO- and–SH) on MFB surfaces. MFBs had good recovery and recycle ability and maintained a high removal efficiency of 85.5% after five regeneration cycles.
Conclusion and Significance: Cd removal from farmland soil by magnetic retrieval of Cd-laden MFBs offers the advantages of short remediation time, simple preparation, easy

retrieval and reusable. MFBs and have promising and environmentally friendly filed application for Cd removal from farmland soil.

Session 3 poster / Abstract title: The evolution of two remediation methods: Combined In Situ Stabilization (ISS) and In Situ Chemical Oxidation (ISCO)

ID: 299

Key words: Source Remediation, Soil Mixing, ISCO, Stabilization, MGPs

Submitter: Brant Smith

Organization: Evonik Corporation

Co-authors: Dr. Brant Smith, Evonik Corporation, scientist

Session: 3 poster

Abstract

Background / Objectives: In situ stabilization (ISS) and in situ chemical oxidation (ISCO) are well-established remediation technologies that have been used to treat contaminated sites since the late 1990s. ISS reduces the spread and leachability of contaminants by reducing the soil's hydraulic conductivity and binding some contaminants while providing the desired soil stability. Potential disadvantages of ISS as a remediation method are that the contamination is left in place maintaining environmental liability and that the addition of binders can cause soils to swell (increase in volume), which requires treatment or disposal. Alternatively, ISCO works by reacting with and breaking down organic pollutants and attacks in the first stage more mobile and easily soluble compounds but can be costly at very high contamination levels combined with strict remedial goals. In recent years, a combination of these two technologies has increased in popularity for heavily contaminated sites, after showing a more complete and cost-effective solution as opposed to applying either technology alone. Bench and field data will be presented from three full-scale applications targeting different contaminant groups.

Approach / Activities: ISCO/ISS has been evaluated in a series of bench and pilot-scale tests where varying dose combinations of sodium persulfate with different binders were analyzed based on its effect on soil stability, hydraulic conductivity and leaching. This presentation will provide a history of the development of the two technologies, review scientific theory and discuss the limitations of each technology. Data from bench scale experiments and field applications will be presented to illustrate how both concentration and stabilization goals can be achieved more effectively in a combined application.

Results / Lessons Learned: Data show that addition of the oxidizing agent sodium persulfate can make an ISS application more efficient by reducing the total amount of additives (binder + oxidizing agent) to reach stability and leach targets. This in turn reduces the mass of soil

that is displaced and the need for further handling and disposal of excess soil masses. A combined ISCO / ISS strategy can thus result in significant cost and energy savings. Addition of sodium persulfate has also resulted in lower hydraulic conductivity and higher strength compared to soils treated with cement only at a similar dose of cement. Data from field trials will illustrate a reduction in the concentration of more mobile substances such as benzene, naphthalene, and other lighter petroleum products to below the action targets for soil, while remaining heavier hydrocarbons were bound with the addition of binders and achieved the targets for reduced leachability.

Session 3 poster / Abstract title: The Remediation of a Large-scale Diluted Chlorinated Solvent Plume using Whey as the Sustainable Carbon Source

ID: 30

Key words: Chlorinated Solvent, full-scale remediation, enhanced reductive dechlorination, whey, qPCR

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Session: 3 poster

Abstract

Purpose of the study
A large-scale chlorinated ethene plume is present in the aquifer used for the extraction of drinking water in the vicinity of the village of Olšany near Prostějov. The contamination plume presently extends over an area of approx. 500 x 3000 m and its front line is approaching a water source that supplies drinking water to almost 100,000 inhabitants at an approximate average speed of 150 m/year. The contamination originated in an upstream factory that was remediated around 15 years ago. However, the groundwater contamination extended downstream to a significant distance from the original source. The aquifer is situated in highly-permeable gravel river sediments and has a thickness of between 20 and 40 m. Prior to the commencement of the current remediation work, the frontline of the contamination was approx. 4.5 km from the drinking water extraction wells, and the concentration maxima of the chlorinated ethenes in the plume were as follows: PCE 140 µg/l, TCE 162 µg/l, and cis-1,2 DCE 220 µg/l. No VC or ethene were found to be present.
Methodology
The enhanced reductive dechlorination (ERD) method that employs a dairy waste product, whey, as the sole organic carbon and nutrient source for autochthonous bacteria was chosen for the remediation of the groundwater. 5 lines perpendicular to the groundwater flow were determined at the site, along which a total of 282 injection wells were built. The wells are approx. 10 m apart and the lines are between 300 and 800 m apart. A further 41 monitoring wells were built about 20 to 50 m from the injection lines for the monitoring of the effect of the whey injections. Whey was injected into the wells at regular two-month intervals so as to establish the optimal conditions for the microbial reduction of the chlorinated ethenes into the final degradation products (ethane). The first phase of remediation involved the injection of 1 440 m3 of whey.

Summary of the findings/results

Remediation work based on the regular injection of whey resulted in the establishment of effective degradation processes and the creation of “biological reactive barriers” in which significant decreases in the concentrations of the various chlorinated ethenes and the associated formation of degradation products (ethane) were recorded. The average PCE and TCE concentrations decreased by more than 78% in the monitoring wells after 2.5 years of whey injection. In the case of DCE, an average drop in concentrations of 54% was recorded in the injection wells and 43% in the monitoring wells, while the VC and ethene concentrations increased in some of the injection wells, which, together with the detection of Dehalococcoides sp. via qPCR, served to prove the occurrence of biological anaerobic dechlorination. VC and ethene were not detected in the other wells even though the cis-1,2 DCE concentration dropped significantly. We assumed that aerobic co-metabolic methanotrophic bacteria were responsible for the cis-1,2 DCE degradation in these wells due to the high concentration of methane; the presence of these bacteria was subsequently confirmed by the qPCR analysis.

Conclusion

It was possible to create an effective “biological reactive barrier” in the areas of the injection lines along which the gradually inflowing contaminated water was treated continuously via both anaerobic and aerobic biodegradation processes, thus preventing the further spread of chlorinated ethene contamination towards the drinking water source.

Significance/contributions of the study

The results of the remediation intervention procedure confirmed the potential for the use of waste whey as the sole carbon and nutrient source for the treatment of a large-scale diluted chlorinated ethene plume so as to attain low residual concentrations applying a sustainable approach.

Session 3 poster / Abstract title: Reducing salinity's effects on bioremediation of oil-contaminated soil using bioamendments.

ID: 300

Key words: biochar; spent mushroom compost; bioamendment; hydrocarbon; microbial community; non-saline and saline soil

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Organization: Cranfield University

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Session: 3 poster

Abstract

This study examined the efficacy of three bioamendments (rice husk biochar (RHB), wheat straw biochar (WSB), and spent mushroom compost (SMC)) to promote the degradation of crude oil in saline soil by microorganisms. A microcosm experiment was conducted using two types of soil: saline (1% NaCl) and non-saline. Both types of soil were amended with 2.5% or 5% of the bioamendments or left unamended as a control. The microcosms were incubated for 120 days at 20°C, and the initial concentration of total petroleum hydrocarbons (TPH) was measured (5871±361mg/kg and 3471±138mg/kg for the Non-saline and Saline soils respectively). The results showed that biodegradation of TPH in non-saline soil was approximately four times higher than in saline soil. Among the five treatments, the greatest biodegradation was observed in the non-saline soil for the alkanes in the RHB-SMC (15%) and SMC (16%) treatments, and for the polycyclic aromatic hydrocarbons (PAH) in the WSB-SMC (27%) and RHB (49%) treatments. In saline soil, RHB and WSB had the most significant effect on biodegradation. The actinomycetes and fungi microbial groups demonstrated higher tolerance to soil salinity, particularly in the RHB and WSB treatments. The production of CO2, a measure of microbial activity, was highest in the RHB-SMC (56%) and WSB-SMC (60%) treatments in non-saline soil and in the RHB (50%) treatment in saline soil. Overall, the bioamendments were able to partially overcome the inhibitory effect of soil salinity on crude oil biodegradation, with RHB and WSB being the most effective.

Session 3 poster / Abstract title: Remediation of metal(loid) polluted soils using sustainable sucrose foams impregnated with goethite nanoparticles to reduce pollutants accumulation in plants

ID: 301

Key words: immobilization, sustainable technology; sucrose foams; metal(loid)s

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Session: 3 poster

Abstract

Soil stabilization is a widely used technology to reduce the availability and mobility of metal(loid)s in polluted soils. The technique falls within the framework of nature-based solutions (NBS) that aim to treat soil in-situ while preserving natural ecosystems and their physicochemical and biological characteristics. This study evaluated the capacity of carbon foams, made from sustainable precursors such as sucrose, also impregnated with goethite nanoparticles, to reduce As and metals availability in polluted mining and industrial sites.
To test the effectiveness of the sucrose foams for metal(loid)s immobilization, pot experiments were conducted for 4 months using untreated and treated soils with Brassica juncea L. as an indicator plant. The selected dose of sucrose foam, with and without goethite nanoparticles impregnation, was 10% according to previous experiments. Following amendment application, soils were incubated for one week at 70% water holding capacity prior to planting. Brassica juncea L. was pre-germinated in seedbeds until the plants had two fully expanded leaves, and then they were transferred to the pots. At the end of the experiment, plant height and fresh biomass were measured and samples of both roots and aerial part were collected for metal(loid)s analysis.
The new amendment based on sucrose foam was effective in immobilizing As and metals in the studied soils, with improved results when impregnated with goethite nanoparticles. The use of this amendment did not result in increased Fe mobility, changes in soil pH and electrical conductivity, or phytotoxicity, assessed by germination tests.

Session 3 poster / Abstract title: In-situ bioestimulation of ethyl acetate and volatile fatty acids (VFA) in industrially polluted groundwater

ID: 302

Key words: Biostimulation, ethyl acetate, native microbial populations, volatile fatty acids (VFA)

Submitter: Diego Corcho

Organization: Envirotecnics Global Service SL

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Session: 3 poster

Abstract

1. Purpose of study

Historical leakages from 3 underground storage tanks (UST) of a manufacturing of flexible packaging for food market facility located in the north of Spain, have resulted in ethyl acetate. An acetate plume was formed in the aquifer, with extended off-site towards the south and was detected in a downstream borehole.

High concentrations of ethyl acetate (range 2,900-8,100 mg/L), acetic acid (5.290 mg/l), butyric acid (1.590 mg/l) and ethanol (5,7 mg/l) were detected in the groundwater of the impacted area (200 m2). The site was equipped with 9 monitoring wells and the groundwater detected between 22 and 25 meters below ground surface (bgs).

2. Methodology

Lab studies were performed with groundwater samples from the site (Pz-6 and Pz-9) in order to determine the potential of autochthonous microbial population to degrade ethyl acetate and volatile fatty acids (VFA).

The field work was conducted at the highly contaminated section of the plume, approximately in a 200 square meters area. Aeration by an oxygen release compound devise and supplementation with a solution with urea and K2HPO4 was performed in 5 monitoring wells distributed in the affected area (Pz-1, Pz-6, Pz-7, Pz-8, Pz-9,) to keep optimal conditions.

An extensive set of data was obtained through groundwater sampling and analyses during 180 days of: contaminant concentrations (ethyl acetate, ethanol, and volatile fatty acids), DQO, nutrients (NO3, NO2, NH4, PO4) electron acceptors, MPN total heterotrophs, MNP acetate degraders, pH, temperature, redox potential, electric conductivity and dissolved oxygen.

3. Summary of findings/results

Groundwater samples for the industrial site (Pz-6 and Pz-9) showed high concentrations of COD, ethyl acetate and a VFA mixture. Sample P6 being the one that contains the highest content of organic compounds. Groundwater samples showed deficits of nitrogen and phosphorus (non detectable) that were supplemented to balance the C:N:P ratio in order to ensure microbiological processes, due to the high content of organic compounds.
The field work under aerobic conditions and nutrients amendment (urea and diphosphate) lead to a significant decrease in Pz-6 well, in the ethyl acetate concentration from 1.600 mg/l at the beginning of the biostimulation to under detection level (1,0 mg/l) after 75 days..
In parallel with the reduction of the contamination levels in the aquifer, heterotrophs bacteria and ethyl acetate degraders in Pz-9 and specially in Pz-6, with an increase of heterotrophs from 5,10x10+5 (T=0) to 6,8x10+6 MPN/mL (T=180 days) and ethyl acetate degraders from 4,1x10+2 (T=0) to 6,8x10+5 MPN/mL (T=180 days), with a maximum percentage of degraders al 120 days (73%).

4. Conclusion

Initial laboratory studies showed the presence in the aquifer of indigenous microbial populations capable of degrading ethyl acetate and VFA under aerobic conditions.
Monitoring of the field work after 75 days indicated ethyl acetate and degradation product (ethanol) significant concentration decrease when optimal nutritional and aerobic conditions were maintained.
The degradation of contaminants were coupled with an increase in microbial population the numbers of heterotroph bacteria (> 106 MPN/mL) and ethyl acetate degrading bacteria (> 105 MPN/mL) in the monitoring wells Pz-6 and Pz-9, proving the removal of contaminants in the groundwater due to the biostimulacion process.

5. Significance / contributions of study

The use of an aerobic biostimulation strategy has allowed the removal of ethyl acetate and other VFA present in the aquifer from an industrial site dedicated to the manufacture of flexible packaging for the food industry. The initial determination of the degrading capability of native groundwater aerobic microbial populations, and the development of an analysis method for quantifying degrading populations have been key in the study to demonstrate the in-stu biotic role on ethyl acetate removal.

Session 3 poster / Abstract title: Waste-derived amendments for sustainable remediation of metal(loid)-contaminated soils

ID: 310

Key words: Immobilisation; Iron scrap; Sewage sludge; Antimony; Arsenic

Submitter: Martina Vitkova

Organization: Czech University of Life Sciences Prague

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Session: 3 poster

Abstract

The use of waste-derived soil amendments for contaminated sites remediation contributes to sustainable development and circular economy, since waste materials are reused to improve the soil environment and prevent further contamination. Yet, much is unknown about the waste material behaviour and transformations under varying environmental conditions. Therefore, the aim of this study was to investigate different waste-derived soil amendments and assess their suitability to immobilise various risk metal(loid)s in different soil types while maintaining safe environmental conditions.
Four different waste materials were used: iron chips, iron mud, pyrolysed sewage sludge, and compost. Iron-based amendments are well-known to efficiently immobilise As, while organic amendments are typically efficient for Pb and generally improve soil quality. Therefore, not only single amendments but also combinations of Fe-based and organic materials were tested. In total, nine treatments were applied including a control (no amendment). Three contrasting soils with different properties and types of risk element contamination (Zn Pb; As Sb; Cr) were incubated with each treatment (2 wt.%) under constant conditions (70% water holding capacity). After the incubation period of one month, a set of standard and advanced extraction methods were performed to determine the changes in As, Cr, Pb, Sb, and Zn availabilities, including the diffusive gradients in thin films (DGT) technique. Moreover, the incubated solids were investigated using SEM/EDS to visualise the amendments and determine metal(loid) associations.
The first results confirmed high efficiency for As immobilisation when Fe-based amendment was present both alone and in combination with compost or pyrolysed sludge. The Fe chips were very efficient also for Sb, while higher availability of Sb was determined in soils amended with compost and pyrolysed sludge. Similarly, significant differences among the

treatments were observed for different metals. Iron mud showed to be the most efficient for Pb immobilisation both alone and in combination with the organic materials, while Zn availability decreased significantly only when the soil was amended by the combination of Fe- and organic-based materials. The behaviour of Cr was mainly influenced by the Fe treatments, showing Fe chips to decrease its available concentration, while Fe mud to increase it.

To conclude, each of the amendments confirmed its high potential in metal(loid) immobilisation in heavily contaminated soils. However, each material showed to be suitable for a different type of contamination. Particularly, the immobilisation efficiency of the amendments strongly depends on the properties of the risk element and its affinity to iron or organic matter. Therefore, further investigation is necessary to assess waste material suitability for multi-element contaminated sites. Nevertheless, the use of soil amendments derived from waste represents a promising and sustainable solution not only for environment-friendly and cost-effective soil remediation but also for waste management.

Session 3 poster / Abstract title: A field pilot study demonstrating sustainable and successful remediation of mercury-contaminated soil and groundwater sources using a novel amendment technology known as MercLok™ P-640.

ID: 311

Key words: Mercury, in-situ, elemental, methylmercury, vapor

Submitter: Jon Miller

Organization: Albemarle Corp.

Co-authors: Kim Pingree, PhD, Albemarle Corporation, Research and Technology Program Manager; Dr. Peter Martus, AECOM Germany, Head of Department

Session: 3 poster

Abstract

MercLok P-640, a novel soil amendment, has been developed by Albemarle to sustainably address soil and groundwater impacts from mercury contamination. The product is a powder-based amendment for the in-situ remediation of mercury-contaminated mining, chlor-alkali, manufacturing, and munitions sites. Using MercLok P-640, rapid sequestration of mercury and long-term stability was validated in bench and field studies in a wide range of soils and subsurface conditions. Multiple species of mercury such as ionic, elemental, and methylmercury were present in the studies and MercLok P-640 showed a high level of efficacy to capture and sequester all species tested.

To validate the product on a large application scale, a mercury-contaminated legacy munitions site in Europe was identified for a field-scale in-situ pilot study. An initial on-site investigation was performed to collect a range of contaminated soil and groundwater samples for evaluation. Laboratory tests were performed including, but not limited to, mercury speciation, leachability, and sequential extraction testing to optimize both amendment loading rates and chosen area of the pilot study at the site. The laboratory test results showed a reduction of greater than 99% in leachable mercury from the treated soil at the highest dosage.

The laboratory results were utilized to design and implement a multi-faceted pilot study. Objectives of the pilot were to 1) further demonstrate field-scale efficacy at a munitions site containing high levels of elemental mercury in the soil; and 2) determine methods for applying the amendment into the subsurface. The application techniques of shallow soil mixing (SSM) and direct-push injection (DPI) were selected to provide amendment contact with the mercury-contaminated media.

MercLok P-640 was applied to a portion of highly contaminated soil in a 9 square meter area to a depth of 3 meters below ground surface (bgs) using a SSM technique.

Within the pilot study area, DPI was utilized to emplace the amendment as a slurry into the unsaturated soil from 1-meter bgs to 3 meters bgs. DPI was also used to emplace the amendment into the groundwater saturated soil zone up to 9 meters bgs to form a permeable reactive barrier (PRB) for the reduction of mercury in the groundwater. Baseline conditions were established before installation of the pilot and a performance monitoring program was initiated to collect data from the pilot study areas. The performance monitoring program included a significant number of parameters to provide robust data-driven insights on leachability and groundwater concentration reductions, durability of the in-situ treatments, as well as evidence to support full-scale remediation activities at the site.

Several lessons were learned from the bench studies and active pilot-scale project, such as gaining a greater understanding of various delivery methods, the performance consistencies across varying soil conditions located on-site, the influence of loading rates on performance, and the resultant efficacy for elemental mercury and methylmercury.

Results of the pilot study showed greater than 99% reduction of mercury in groundwater, 87% reduction in leachable mercury from soil, and greater than 93% reduction in mercury gas escaping from the elemental mercury contaminated hotspot.

Mercury in the groundwater and mercury soil gas continues to be monitored. After one year, the groundwater results still indicate greater than 99% reduction in mercury and a greater than 93% reduction in mercury soil gas.

Session 3 poster / Abstract title: Sustainable remediation and sequestration of mercury-contaminated mining calcines using a novel amendment technology known as MercLok™ P-640

ID: 312

Key words: Mercury, mining, calcines, remediation, amendment

Submitter: Jon Miller

Organization: Albemarle Corporation

Co-authors: Kim Pingree, PhD, Albemarle Corp, Baton Rouge, Research and Technology Program Manager; Daniel Griffin, Albemarle Corp., New Business Development Manager

Session: 3 poster

Abstract

Albemarle conducted a pilot study for in-situ mercury stabilization using MercLok™ P-640 at an abandoned mercury mine site in California. Characterization of the study site found exposed calcines in three distinct areas, all with mercury content and leachability above regulatory thresholds for hazardous waste classification.

MercLok P-640 is a new remediation product intended to capture multiple species of mercury, preventing it from leaching or diffusing into groundwater and surface water. For the five-month pilot study in 2021, layers of unamended (controls) and MercLok P-640-amended calcines were arranged in sixteen, 13-gallon, open-top bucket “reactors” representing two alternative applications and various dosages. Rainwater entered the reactors to allow natural leaching of mercury. Leachate was sampled monthly and analyzed for total, dissolved, and methylmercury, plus other metals, minerals, and field measurements. The calcine solids were also analyzed at the beginning and end of the exposure/leaching period for total and leachable mercury and other metals.

Results demonstrate MercLok P-640 reduced up to 99% of leachable mercury and 75% of methylmercury. This sequestration efficacy was reproduced in rainwater leachate and in acid-based leaching tests. MercLok P-640 reduced the leachability of mercury to below hazardous solid waste classification limits and leachate concentrations below water quality criteria. The results suggest that MercLok P-640 could offer a sustainable remediation approach to safely allow calcines to be treated in-place at legacy mercury mines.

Session 3 poster / Abstract title: Updated risk analysis of the unipetrol litvínov landfill areas

ID: 313

Key words: Risk Assessment, contamination, ammonia source-sink investigation, risk analysis, groundwater, surface water

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Session: 3 poster

Abstract

The updated Risk Analysis (RA) focused on landfilling areas located directly eastward of petrochemical facility Chempark ORLEN Unipetrol RPA, s.r.o. in Litvínov (CZE) and comprising of multiple ash dumps, two lime-sludge landfills, and solid waste and liquid waste (lagoons) landfills. History of the site is dated back to 1939, when the Nazi founded the petrochemical facility for coal hydrogenation. Landfilling of the terrain continued until 1980's, serving the needs of ever growing chemical industry.
Two major Risk-recipients represent medium sized creek, running in N-S-SW direction and draining water from the entire area to Bílina River (tributary of Elbe River), and large effluent-lacking Lake Most created by flooding of former surface coal mine, directly southward from target area.
Overall hydraulic conditions of the area are greatly affected by past and recent anthropogenic activity, including long history of deep coal mining (many mining works unmapped or unrecognizable), mine-water pumping, surface coal mining, soil heap dumping, tailings dams' construction, water streams diverting, and drainage systems operation.
Target area has been studied thoroughly since 1994 by multiple reconnaissance studies for full or partial risk analyses, which have defined following contaminants of interest: Ammonia-nitrogen (Namon), petroleum hydrocarbons, aromatic hydrocarbons, phenols, arsenic (As), fluorides (F-), and sodium (Na).
Present updated RA has two main objectives: 1) To assess the option of extending time-frame for complete remediation of the area, as defined by Czech Environmental Inspectorate (CEI). 2) To verify effectiveness of all applied and projected remediation efforts with respect to reaching remediation limits derived by riskiness of particular sites in the area and to recommend eventual adjustments in methodology and/or defined remediation limits.

Session 3 poster / Abstract title: Arsenic immobilisation in magnetite in highly contaminated soil

ID: 314

Key words: arsenic, green rust, highly polluted soil, mineral transformations, remediation longevity

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Session: 3 poster

Abstract

Arsenic in form of arsenate or arsenite binds strongly to particle surfaces of metal oxides, such as iron(III) and aluminum oxides, and thus these metal oxides are often used for arsenic bonding in contaminated soil and for water cleaning. However, arsenic sorption to these metal oxides is partly reversible, and change in pH, reducing conditions and the presence of metal complexing humic compounds may cause arsenic release to the solution phase. Incorporation of arsenic into magnetite may provide a more stable and long-lasting bonding of arsenic due to arsenic substitution into the magnetite structure, and because magnetite is relatively resistant to change in environmental conditions. Magnetite can form via both microbial and abiotic pathways. Here we test two abiotic pathways: i) from iron(II) solution that is neutralized with alkali after introduction into arsenic contaminated soil followed by oxidation under alkaline conditions, and ii) from layered iron(II)-iron(III) hydroxides (green rust, GR) that is introduced to the arsenic contaminated soil followed by oxidation. Green rust is a layered double hydroxide that has anion exchange properties and hence can bind anions like arsenate and arsenite. In both of the above pathways we hypothesize that arsenic in the contaminated soil is sorbed to the in-situ produced or directly injected GR phase which then upon slow oxidation (here by adding nitrate) transforms to magnetite while simultaneously locking arsenic inside the magnetite structure. We have tested these two immobilization pathways on soils contaminated with arsenic, chromium and copper at a previous Danish wood impregnation site. The total arsenic content in the fine sandy soil/sediment reaches up to 2000 mg/kg with pore water arsenic concentrations of approximately 2 mg/L. The mass of arsenic in the contaminated soil at the site is estimated to approximately 14 tones. Our tests are performed on sediments with ~300 mg As/kg.

Following immobilization treatment, the soils will be exposed to variable conditions of low and high pH, presence of strong metal complexing ligands (citric acid), shifting reducing and oxidation conditions to test for the stability of arsenic immobilization by magnetite. This are ongoing experiments, and results from all stages will be presented and discussed in terms of their effectiveness and implementation feasibility at field scale.

Session 3 poster / Abstract title: Impact of ZVI nanoparticles on lettuce biomass ant its rhizosphere microbial communities in two different soil types

ID: 322

Key words: nZVI, lettuce, microorganisms, rhizosphere, soil type

Submitter: Pilar García-Gonzalo

Organization: IMIDRA

Co-authors: Dr. Pilar García-Gonzalo, IMIDRA, microbiologist

Session: 3 poster

Abstract

Nanoscale zero valent iron (nZVI) has been considered a promising tool for the remediation of water and soils polluted with metals, metalloids, anions or organic pollutants. Previous studies have concluded that the addition of nZVI to polluted soils with metals or metalloids reduces their availability, decreasing their toxicity and therefore allowing a better development of the plants. However, the effect of nZVI in unpolluted soils is not totally known and can be different due to the presence of pollutants which can mask other effects caused by nZVI. Considering that bacteria and fungi are present in the rhizosphere of plants, the antimicrobial effects from nZVI exposure may have significant implications for the host plant health. Rhizosphere-based studies examining the implications of nanoparticles exposure on both the microbes present and the supporting host plant are scarce. This study evaluated the impact of nZVI on lettuce plants and the bacteria and fungi in the plant rhizosphere in two agricultural soils with different characteristics.

The experimental soils, acidic and alkaline, were collected from agricultural plots, and treated with ZVI nanoparticles ((NANOFER 25S, NANO IRON, Czech Republic) according to the following treatments: 0% nZVI (control), 0.5% nZVI and 5% nZVI. Five plots per treatment were used. Seedling of lettuce were transplanted and after 30 days plants were harvest, oven dried and then weighed. Soil samples for microbial community analysis were taken from the rhizosphere, and bulk soil samples were collected to determine physico-chemical soil properties. To assess microbial activity and functional diversity, samples from the rhizosphere were used to determine enzyme activities involved in soil C, N, P and S cycling, and community-level physiological profiling (CLPP) with Biolog EcoPlates . The bacterial and fungal genetic diversity was analysed using PCR-DGGE (denature gradient gel electrophoresis). Total DNA was extracted from rhizosphere soil, and bacterial 16S rRNA and fungal 18S rRNA gene fragments were amplified with universal primers.

Regarding plant response, no significant differences were observed in the dry biomass among treatments in alkaline soil. A major effect was observed in plants from acidic soil, since the biomass extremely increased at 0.5 % of nZVI treatment. An enhanced microbial activity was observed after nZVI amendments. Arylsulfatase and acid phosphatase increased in both soils at 0.5 % and 5% of nZVI. Urease activity in alkaline soil and □-glucosidase activity in acidic soil were higher in nZVI-exposed soils. However, depending on soil type, contrasting results were observed regarding functional diversity. Shannon and richness diversity indices of CLPP were negatively impacted after nZVI treatments in alkaline soil, whereas in acidic soil an increase of diversity was observed at 0.5% nZVI dose. In relation to PCR-DGGE genetic profiles, bacterial richness significantly increased in alkaline soil, and fungal communities showed higher diversity indices after nZVI treatments in both types of soils. Canonical correspondence analysis between microbial communities structure and environmental factors reveals that available Fe played a key role in the genetic structure of bacterial and fungal communities in acidic nZVI amended soils.

Our results indicate that the effects of nZVI on lettuce growth and rhizosphere microbial communities are soil-dependent. In acidic soil, microbial communities apparently are altered in a way that benefits lettuce growth, mainly mediated by shifts in these communities. Available Fe was the main driver of changes in rhizosphere microbial communities in acidic soil. Microorganisms in the rhizosphere seem to play an important role when evaluating the impact of nZVI exposure. Consequently, knowledge of nZVI effects driven by rhizosphere processes might maximize the potentials of nZVI applications.

Session 3 poster / Abstract title: How Does Climate Change Impact Thermal Remediation?

ID: 327

Key words: Thermal, Climate Resilience, Sustainable Remediation

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Organization: ERM

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Session: 3 poster

Abstract

Thermal remediation is a rapid technology where the operational phase is usually completed within 6 to 9 months. This means that it is more resilient than longer running remedial technologies, such as pump and treat that will often run for decades, as process equipment is only deployed to a site for a short period of time. Despite this, the effects of extreme weather driven by climate change increasingly need to be considered in the design of thermal remediation systems, as highlighted in this paper.

Traditionally, thermal remediation Hazard Identification (HAZID) studies have focused upon effects and mitigations where these projects are carried out in colder climates and freezing conditions may occur. For example treatment systems can experience issues with liquid freezing in equipment and causing liquid and vapor flow processes throughout the operational system to seize. Best practices including weatherproofing, heat tracing and/or scheduling operations during warmer periods can offset issues resulting from these conditions.

However, due to an increase in hotter or wetter conditions, these factors also need to be included within the HAZID and mitigations provided for events that in the past would have been seen as unlikely occurrences. An example of this is at an ERM Steam Enhanced Extraction site, located in California, US. This system was implemented to recover significant volumes of Light Non-Aqueous Phase Liquid and an unexpected and unmitigated strong rainfall event caused many issues throughout the treatment system and boiler components, leading to shutdown. Best practices and lessons learned have directly aided in mitigating loss of subsurface heating, delays in LNAPL mass removal, and delays in energy delivery goals.

Extreme weather conditions may also influence the choice of selecting a thermal remedy

and the design and timeframe of operating such a system. For example, long term drought conditions result in the depletion of groundwater reservoirs due to decreasing groundwater levels. To effectively remediate an impacted area where wells are at risk of becoming dry makes thermal remediation an especially attractive technology for both vadose and saturated zone treatment, with more rapid heating being achieved in unsaturated conditions.

Overall, thermal remediation technologies can work around seasonal and problematic weather conditions as a short-term remedial technique compared to some remedial techniques that span years or decades, although consideration of many types of climate conditions needs to be more robustly factored into the design and mitigation measures. Lessons learned from these weather-related issues will help to establish the resilience, fast pace, and economical benefit of thermal remediation technology and establish an increased need for thermal remediation technologies for future remedial sites.

It should also be noted that whilst thermal technology aligns with resilience and mitigation of climate effects, in the context of climate change, the carbon footprint still needs to be carefully considered and the remediation decarbonised to the extent possible. Such measures can also be included within the design to enable sustainable operation, for example reuse of water or biofuels to power process equipment.

Session 3 poster / Abstract title: Full-scale Application in Italy of a Combined ISCR and ERD Technology for the treatment of an Aerobic Aquifer Impacted with Tetrachloromethane and Chloroform

ID: 33

Key words: groundwater, bioremediation, chlorinated solvents, dechlorination, Microemulsion

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Session: 3 poster

Abstract

Background/Objectives.
The site is in a highly industrialized area of northern Italy, where groundwater is contaminated with tetrachloromethane (>10 ppb), chloroform (>10 ppb), hexavalent chromium and, to a lesser extent, PCE and TCE (1 ppb). The EHC® Liquid technology deploys in situ chemical reduction (ISCR) mechanisms for treatment of impacted groundwater. It is comprised of two ingredients which are easily combined and diluted for injection: ii) ELS™ Microemulsion; a controlled-release food-grade carbon in the form of lecithin, and ii) EHC® Liquid Reagent Mix; an organo-iron compound. The addition of organic carbon in a saturated zone is widely known to promote conventional enzymatic reductive dechlorination reactions. As bacteria ferment the ELS Microemulsion component, they release a variety of volatile fatty acids (VFAs) such as lactic, propionic and butyric, which diffuse from the site of fermentation into the groundwater plume, and serve as electron donors for other bacteria, including dehalogenators. Lecithin itself is primarily composed of phospholipids, with both hydrophilic and hydrophobic properties in the molecular structure. Further, phospholipids support remediation by providing essential nutrients (carbon, nitrogen, phosphorus) to bacteria. Synergistically, the soluble organo-iron component is comprised of a ferrous iron (Fe^{2+}) that can form a variety of iron minerals (e.g. magnetite, pyrite) capable of reducing contaminants as they oxidize further to the ferric (Fe^{3+}) state via one electron transfer. The ferric ion can then be “recycled” back to ferrous, as long as other electrons from supplied carbon and indigenous carbon are available.

Approach/Activities.
In the intervention area and its downstream sector, 10 standard Pump Treat wells were located, designed to accelerate the removal of various contaminants. However, the presence

of active pumps inside, or in the immediate vicinity, of the EHC Liquid injection zones could have compromised their effectiveness. This as a function of the increase in groundwater speed and potential removal of the injected emulsion. For this reason, a strategy has been planned to remodel the onsite well flow rates by reducing them to below threshold values, thus protecting effectiveness of the ERD treatment. Through use of mathematical modelling, optimal flow rates were defined to keep natural seepage velocity 300 m/year in the ERD treatment area, whilst still allowing P of groundwater in a wide downstream area, and effectively capturing flow from the injections area. Application of the remedial reagents was performed via direct injection through 28 fixed Manchette tubes distributed in the source area. The injection campaign required 306 kg of ELS Concentrate per point, plus 70 kg of organo-iron powder, for a total injection volume of 96 m3 of EHC Liquid emulsion, in 10% solution.

Results/Lessons Learned.
Fifteen months after injection of EHC Liquid into the main source area, concentrations of CT and CF contaminants were rapidly reduced compared to pre-treatment levels. Requisite remedial target values were reached in all main monitoring piezometers in the area. Main field parameters in the ISCR ERD treatment areas included: i) increase of Mn Fe(II) in solution as anaerobic cometabolites, ii) decrease of DO (mg/L) and sulphate (mg/L) – competing electron acceptors pH stable in the neutral range, and iii) negative Redox around -150 mV.

Session 3 poster / Abstract title: Opportunities and Challenges in the design, construction and operation of the first Steam Enhanced Thermal remediation project in South Africa

ID: 343

Key words: Africa, Thermal Remediation, Localised Approach, Skills Transfer, Remote Operation

Submitter: Theo Ferreira

Organization: GeoRem International

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Session: 3 poster

Abstract

Thermal Remediation has gained global appeal as a method to enable high intensity remediation to allow industrial sites to be restored to a condition suitable for more sensitive land use within shorter periods of time than conventional approaches. GeoRem recently undertook the mechanical and process design, construction and operation of the first Steam Enhanced recovery project in South Africa. During this implementation, several engineering challenges were encountered and addressed throughout the project. The implementation was undertaken during various stages of global COVID lockdowns, which required innovative and localised approaches due to local and international travel and shipping delays.

The client required an approach to inject a specified volume of steam in an injection grid, while extracting groundwater and vapour through a multiphase extraction system. The nature of the site required that all the injection and extraction wells, as well as the entire system, be installed in a semi-basement. Management of residual heat and the effect of higher temperatures in the extracted vapour and groundwater, required a system to extract and re-use energy in an efficient way, while managing ambient working temperatures in a closed building environment.

Close cooperation and effective communication between the client, consultant and contractor allowed for fast problem solving and management of change during the process. Due to very variable site conditions and equipment supply constraints, designs had to be adjusted and modified to accommodate these factors while maintaining system integrity and safety. Remote operation capabilities allowed the system to operate and be monitored 24/7

throughout the operational period.

During the project lifecycle, a very localised approach was followed, with the entire system being designed and constructed in South-Africa using existing capabilities and other industries. This reduced the reliance on external suppliers and allowed the maintenance team to repair or modify any component of the system as was necessary during the implementation. Skills with regard to the engineering and operation of such a project were successfully and sustainably transferred from Europe to Africa. Remediation was implemented successfully, and the system has now been decommissioned and is currently in the verification stage of the project.

Session 3 poster / Abstract title: The fate of hexachlorocyclohexanes in aerobic wetland plants

ID: 346

Key words: Hexachlorocyclohexanes, pesticides, wetland, phytoremediation

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Session: 3 poster

Abstract

Background: Brownfield redevelopment is a critical requirement if we are to build homes and industrial sites without encroaching on greenland. No matter if former gas stations or refineries, chemical plants or dry-cleaning facilities, regulatory compliance or proceedings with remedial scenarios, choosing the right technology is the key to address the particular issue of each individual site.

Methods/Activities: Volatile contaminants such as fuels or solvents are detected by the Membrane Interface Probe. Along with Hydraulic Profiling, it provides in only one push a high-resolution structuring of the underground to determine contamination, hydraulic, lithology and geotechnical parameters. Fugro coupled the standard system with a high end lab analyser in order to develop a field equipment able to provide additionally the composition of the contaminant cocktail and the concentration of each individual compound.

Results: Besides the typical MIP signals, being able to identify individual compounds and deliver their concentrations in high vertical resolution proved to be a quick, very reliable and inexpensive pre-screening field method. This continuous and rapid survey allows a high-end analysis directly from the screening phase of a site, no matter of hot spots, different source areas or degradation paths. A comparison to the results from conventional soil and groundwater sampling confirmed the results.

Conclusion: This study method further-development illustrates the usefulness of reliable initial screening methods for effective site investigation especially at large contaminated sites. The large-scale application of low-invasive initially screening can be valuable in directing and focusing the subsequent, more expensive methods of soil and groundwater sampling. Moreover, it delivers a significant added value for a success promising design of

remediation strategies and shortens the overall decision chain with associated budget savings.

Session 3 poster / Abstract title: Sodium Persulfate with Integrated Activator Destroys >99% of Trichlorethylene in 5 Weeks at a Manufacturing Facility in Holland

ID: 36

Key words: ISCO, Activated Sodium Persulfate, Trichlorethylene, Groundwater

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Session: 3 poster

Abstract

Background/Objectives. For several years, a manufacturing facility was in operation near Uden, Holland. Soil and groundwater had been impacted with chlorinated hydrocarbons. Following demolition of the buildings in 2005, Site Investigations (SI) revealed high levels of contamination and risk to nearby receptors. In the groundwater aquifer, concentrations of more than 16,000 µg/l of trichlorethylene (TCE) were measured, indicating the presence of a source zone (SZ). The impacted SZ was 270 m2 and contaminated in the saturated zone from 3 to 7 meters below ground level. For planned redevelopment of the site into a residential area, local regulatory authorities mandated remediation of the contamination 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. End-use by the site owner was construction of high-density residential housing, thus rapid remedial results were required. Key objectives of the Remedial Options Appraisal (ROA) process included selection of a technological solution that provided i) high reliability, ii) cost-effective implementation and ii) rapid monitoring results. The Klozur® One ISCO technology was selected primarily because it met all ROA objectives. This fully soluble blend of sodium persulfate (SP) with built-in activation chemistry provided powerful oxidation capacity as a “ready to use” product suitable for highly contaminated treatment areas. The formulation also has built in pH buffer to help maintain near neutral pH, and multiple activation methods (i.e. iron chelate and manganese) combined into the single blend. A total of 9,225 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 prepared onsite and made per batch. A typical batch contained 4 m3 of clean water, into which a specified

amount of Klozur One was added. From the mixing unit, the proper solution is transferred into an 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 all-important contact across the entire source area. At zones with higher concentrations of contaminant, more solution was applied with a higher concentration of activated SP. At each injection point, between 2,775 and 4,500 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 m3 injection fluid of self-activated SP.

Results/Lessons Learned.
Prior to start of the injections, a fresh evaluation of the actual TCE concentrations was performed. Monitoring activities during and after the application included 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 Field Test Kits to determine 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 reconfirmed the positive results. They also concluded that there was no active SP left and that the TCE wa

Session 3 poster / Abstract title: Poster presentation

ID: 375

Key words: lead contamination, shooting range, skeet shooting range, trap shooting range

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Session: 3 poster

Abstract

The Tajimi general shooting center (trap, skeet, rifle and pistol) in Japan, which area is 68,000 m2, had been suffered from Pb contamination for more than 30 years. During the service, large amounts of Pb shot had been discharged at the whole area of the shooting range. As a result of Pb shot stimulation, the soil and the river in this area were severely contaminated by Pb with 5330mg/kg (1N-HCl soluble) and 0.276mg/l (water soluble), respectively. The center has formally been closed in October 2001 according to the extensive studies on lead impact on environment of soil and water. More than 2.76mg/L was recorded in water sampled at the Kinzoh-Valley river which flows from the shooting range. This was 270 times of the Japan Environment Standard 0.01mg/L. The paper aims to describe the temporal change of lead contamination at the range of shot and rifle guns after closing the service in 2001.

Session 3 poster / Abstract title: Preliminary designs of utility models to carry out mycoremediation studies of soils contaminated by total petroleum hydrocarbons

ID: 379

Key words: Soil, organic pollutants, ligninolytic fungi, bioremediation, mesocosm

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Session: 3 poster

Abstract

Although mycoremediation is a technology that has been widely studied at the laboratory and some experiences at the pilot scale can be found, there is currently a paucity of information available on its scaling up for subsequent commercialization. MySOIL (LIFE EU) project aims to push forward the use of an emerging on site/ex-situ bioremediation technology based on novel biopiling structures inoculated with specific fungal inoculum (mycoremediation). The advantage of this biotechnology is that it has the benefits of bioremediation treatments, including low economic, social, and environmental costs, and it also increases the removal efficiencies up to other traditional physicochemical technologies. MySOIL project is being developed by a consortium from 5 European countries (Spain, France, Italy, Belgium, and Germany) working together to evaluate the efficiency of the mycoremediation technology in different soils and climates across Europe. MySOIL partners have designed, constructed, and are operating pilot fungal biopiles at 3 different sites: in Huelva (Spain), Rouen (France), and Borgo Faiti (Italy). The diversity among the sites in terms of edaphic characteristics, climatic conditions, TPH fractions, and pollutant loads, is providing indications amenable to be extended to a wide variety of TPH contamination scenarios across Europe. During the operation, soil characteristics (physicochemical parameters, microbiological activity, climate sensors), pollutant concentrations (TPH, aliphatic and aromatics), and ecotoxicity are being monitored.

In this contribution, results from the Spanish site biotreatability tests and a previous model in

mesocosm conditions will be shown. The fungal contribution in mycoremediation comes from spent mushroom substrates (SMS) of four different fungi (Agaricus bisporus, Pleurotus eryngii, Pleurotus ostreatus and Lentinula edodes). They showed significant higher removal of TPHs than the non-inoculated soil demonstrating the usefulness of these wastes in the remediation of petroleum hydrocarbon contaminated soil obtained from accidental oil spills in a refinery. A. bisporus and P. eryngii clearly colonized the contaminated soil. However, the mere colonization of the soil did not assure high removal of TPHs. The interaction of the inherent microbiota of the SMS with the autochthonous soil microbiota is an important factor in the TPHs biodegradation. The SMS of A. bisporus was the most effective SMS for the bioremediation of petroleum hydrocarbon contaminated soils. However, the SMS of L. edodes reached high degradation of the heaviest aliphatic chains (>C35) and the aromatic chains >C12-C16. SMS of P. ostreatus was the most effective for the degradation of the aliphatic chains >C10-C12 and aromatic chains C10-C12. P. eryngii SMS was only useful for the biodegradation of the light aliphatic chains >C10-C12. After these results obtained in biotreatability tests, the technology scaling for the mesocosm is being performed by a utility model designed for the improvement of mycoremediation conditions which will allow the optimization of the process and the detailed monitoring of its evolution.

Session 3 poster / Abstract title: Transition from active remediation to natural source zone depletion (NSZD) at a LNAPL-impacted site, supported by sustainable remediation appraisal

ID: 38

Key words: Sustainable remediation, NSZD, LNAPL, remediation, remediation closure

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Session: 3 poster

Abstract

Natural source zone depletion (NSZD), the combination of naturally occurring processes that reduce the mass or toxicity of light non-aqueous phase liquid (LNAPL) in the subsurface, is increasingly being considered as a risk-management option at impacted sites. NSZD can be applied in isolation or in combination with active remediation techniques, depending on site-specific risk management requirements.

The importance of NSZD in remediation strategies has been investigated over the past decade in scientific literature, and subsequently measurement guidance documents have been produced for remediation practitioners. Over a similar time period, there has also been increasing awareness that active remediation of LNAPL impacted sites reaches practical limits and that long-term active treatment without significant risk reduction may not be a sustainable remediation strategy.

While NSZD is currently gaining acceptance as a LNAPL remediation option, there are very few publicly available case studies where the remediation focus has successfully transitioned from active LNAPL recovery to passive but monitored NSZD. A case study for such a transition is presented here for a petroleum impacted site in northwest Europe. Through application of local sustainable remediation principles consistent with ISO / SuRF-UK sustainable remediation frameworks and tools, regulatory approval for closeout of active remediation has been achieved for over half of a large modular groundwater treatment system. In 2021, this was subject to a review by an independent third party selected by the regulator. It was established that there were no objections to ending active remediation in this area, based on a combination of the following factors:

- Groundwater and land development restrictions had been established. A residual risk assessment indicated established that current environmental conditions in former active remediation area are compatible with a future industrial or tertiary use in line with the local land zoning and planning regulations, and did not pose a risk to the wider environment.

- Monitoring had demonstrated that the LNAPL plume was reducing in size and there was with only a limited dissolved phase hydrocarbon plume beyond the LNAPL footprint.
- In the final year of active remediation, approximately three times more hydrocarbon was depleted by NSZD than recovered by extraction with total fluid pumps (12,000 L/ha/a for NSZD; 3,800 L/ha/a for active LNAPL recovery). Decline curve analysis indicated that this active recovery would continue to decrease. With one further year of operation, it was estimated that the rate of NSZD would have been seven times greater than active recovery, increasing to 17 times greater with a subsequent second year of additional operation.
- It was estimated that twice the quantity of CO_2 equivalent emissions were produced by active recovery in comparison with the same amount of LNAPL degraded by NSZD.
- In additional to bulk LNAPL removal, LNAPL chemical compositional analysis demonstrated a preferential loss of lighter fractions during bulk LNAPL degradation, with a notable decrease in benzene and TEX concentrations (some of the main contaminants of concern), have reduced in LNAPL. LNAPL compositional change analysis indicates that benzene has a shorter degradation half-life and is depleted more rapidly than the bulk LNAPL.
- Following cessation of active remediation, NSZD will continue to act to deplete the hydrocarbon mass.

In the remaining areas of ongoing active remediation, sustainability indicators and metrics, and NSZD assessment criteria suggest that active mass recovery remains an efficient and appropriate remediation technique. Total fluids extraction will continue in these areas until it is more sustainable to manage risks in another manner. No one metric has or will be adopted. It is recommended that numerous lines of evidence be used to identify an appropriate endpoint for active remediation, at which

Session 3 poster / Abstract title: Sustainable and energy-saving TPH groundwater remediation by SEE (TUBA method) at a former tank farm site

ID: 382

Key words: in-situ thermal remediation (ISTR), steam enhanced extraction (SEE, TUBA method), total petroleum hydrocarbons (TPH), sustainable tidally influenced groundwater remediation, energy-saving mega site remediation

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Organization: reconsite GmbH

Co-authors: Dr.-Ing. Uwe Hiester, reconsite GmbH; Alexander Ruppmann (M.Eng.), reconsite GmbH

Session: 3 poster

Abstract

1 Purpose of study

During World War 2, the Hamburg harbour petroleum tank farm had been destroyed. As a result, hundreds of tons of total petroleum hydrocarbons (TPH) and other pollutants were released. These hazard substances seeped into the ground and significantly polluted the soil and the tidally influenced groundwater.

To enable brownfield redevelopment of this highly contaminated area, soil and groundwater were remediated in an area of roughly 10,000 m² up to a depth of up to 12 m below the ground level (bgl). To remove TPH from the tidally influenced groundwater in a sustainable manner, the largest steam enhanced extraction (SEE) with additional air-co-injection (TUBA method) in Europe had been applied.

2 Methodology

The steam boiler capacity had been designed to generate up to 10,000 kg steam/h. A mixture of steam and air had been injected into the tidally influenced groundwater (saturated zone). To monitor and optimize the remediation progress, heating of soil and groundwater had been measured and evaluated. Tidally effects had been seen in groundwater temperature.

The evaporated pollutants were captured via 150 soil vapor extraction (SVE) wells in total. The extracted soil vapour had been cooled down and dried. Condensate had been separated and passed on to the water treatment plant. The contaminated soil vapour was purified using a recuperative thermal oxidation system (RTO). In this process, TPH and other pollutants were converted autotherm into H2O and CO2 at temperatures of up to 900 °C before being released into the atmosphere.

During the first two months of the remediation, light non-aqueous phase (LNAPL, oil phase)

was extracted with belt skimmers. Afterwards, belt skimmers were replaced by temperature resistant groundwater pumps. The contaminated groundwater, was treated in a water treatment plant and reinfiltrated next to the treatment target zone (TTZ).

3 Summary of findings/results

The remediation process was completed within 17 months by recovering more than 280 tons of TPH from soil and groundwater. A total of around 10,080 MWh of energy was used for heating, pumping and treatment purposes. Thereby 1,030,000 liters of heating oil were burned to operate the steam generator. The operation of the plants consumed additional 1,075 MWh of electrical power. Due to the calorific value of the pollutant mixture, the hot bed reactor of the RTO was mainly operated autotherm. The energy input per ton of remediated soil was only approx. 55 kWh/t, related to a kilogram of TPH only approx. 36 kWh/kg.

4 Conclusion

This in-situ thermal remediation by SEE (TUBA method) was a highly energy efficient and energy saving groundwater treatment. The contaminant specific energy consumption is more than 20 times lower than the median energy consumption of pump and treat systems (850 kWh/kg).

The in-situ thermal remediation using the TUBA method avoided excavation of over 100,000 m³ of soil, which would have had to be transported to landfills by at least 8,000 trucks. The cost per ton of remediated soil was about 30 €/t for the TUBA remediation. For a classical soil exchange, the costs are estimated at about 130-200 €/t. By avoiding the excavation, there was no risk to uninvolved third parties. Transportation of contaminated soil through Hamburg, construction noise and dust were avoided. The remediation took place without external soil decontamination, with the exception of the drilling material disposal. In addition, no new soil had to be brought in and compacted (conservation of soil as a resource).

5 Significance/ contribution of study

The remediation has shown that in-situ thermal remediation methods are an energy-saving, efficient and sustainable alternative to conventional remediation methods. The remediation project was therefore awarded the Brownfield24 Award 2022.

Session 3 poster / Abstract title: Hexachlorocyclohexane (HCH): Wetland plants bioaccumulation and metabolism.

ID: 388

Key words: phytoremediation; OCPs; hexachlorocyclohexane; wetland plants; Alnus Glutinosa

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Session: 3 poster

Abstract

The issue of environmental hexachlorocyclohexane (HCH) contamination is widely known. Although their use in the agricultural sector has long been banned, currently, there are 299 HCH contaminated sites, including former production and processing companies, unsecured landfills, storage sites and deposits of technical HCH (t-HCH), Lindane or HCH waste in EU countries. Our study aims to evaluate the general performance and remediation potential of selected plant species Typha latifolia, Juncus effusus, Phragmites australis and Alnus glutinosa via laboratory experiments. Simultaneously the rhizosphere microbiome was studied at the genetic level, together with the detection of the genes involved in HCH degradation, which strongly affects plants' OCP uptake and, thus, their phytoremediation potential. This study is focused on monitoring removal efficiency and plant uptake under long-term and repeated exposure to δ-HCH and t-HCH under well-controlled growth chamber conditions. At the same time, this study investigated the metabolism of these plants through non-target analysis to try to identify HCH degradation products that could shed light on HCH metabolism in plant biomass.A total of 60 experimental units were set up for each selected treatment for δ-HCH and t-HCH. These 60 pots were divided into five groups - four planted groups and one unplanted group. Every group consisted of 12 pots split into four triplicates. The individual triplicates were exposed to three different pesticide concentrations (20, 200, 1000 µg.l-1) with one control triplicate for three months. The plant biomass was weighed at the end of the experiments.GS/MS/MS was used to analyze HCH and related metabolites. LC/HRMS performed a non-targeted analysis. Detection of the HCH transformation functional genes performed by qPCR method. DNA sequencing and whole microbial community profiling were accessed by sequencing the V4 region of the bacterial

16S rDNA gene and ITS2 fungal genes. Despite the high variability of data and artificial growth chamber conditions, our study provides essential conclusions regarding species-dependent HCH phytoextraction differences. Alder is the most effective specie for HCH elimination from water and solid substrate, with plant species order being Alder > Juncus > Typha > Phragmittes. We suppose installing alder shrubs/coppice culture with regularly disturbed rooting can be the best option for HCH-contaminated water treatment. Juncus seedlings also performed well, especially at low and medium HCH loads. At high HCH loads, Typha reached the same efficiency as Juncus. Phragmites only showed results comparable to Typha at small and medium loads. It performed worst of the studied species at high loads. All species showed better phytoexctractability toward δ-HCH isomer (max. 50-70 %) than t-HCH of the same load (40-50 %). α-HCH and δ-HCH were detected in above-ground parts of the plants, while β-HCH remains in roots. 1,3-DiClB was found as an HCH transformation product in most plants, without any indication of its appearance's exact location (substrate/roots/stem). Concentration in leaves is correlated to concentration in the soil, which can be helpful for phytoscreening technics. The bacterial and fungal consortia abundance was not significantly different between treated and control samples. Similarly, there was not a significant difference between soil and rhizosphere microorganisms. Overall, lin genes were found in all samples, with higher relative quantities in soil than in the rhizosphere, especially in treated samples. We suppose the degradation of the δ-HCH isomer occurs by the upstream pathway. To conclude, all the plants could uptake HCH isomers, with the highest quantities detected in roots and the lowest in leaves. This study's results provide better insights into examined plants' performance in HCH-contaminated substrate and its microbial community profile.

Session 3 poster / Abstract title: A pilot study at a DDT-contaminated tree nursery in Sweden: effectiveness of gentle remediation options (GRO) to reduce risks

ID: 389

Key words: ontaminated sites; Gentle remediation options (GRO); DDT

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Session: 3 poster

Abstract

Purpose of study: to present the results of a pilot study application of gentle remediation options (GRO) – i.e., nature-based risk management strategies/technologies that use plants, bacteria and fungi for effective risk management and improving soil functions – at a historically DDT-contaminated forest nursery in southern Sweden. The presentation will focus on the effectiveness of the tested GRO to reduce risks to human health and the environment.

Methodology: A pilot-scale field experiment was established at the Kolleberga site in Ljungbyhed (Southern Sweden) according to a randomized block design of test plots, with 4 different types of plants, with or without biochar addition to the soil, each strategy in triplicate (in total 24 plots). The four different plants are aimed at different phytoremediation strategies: 1) phytoextraction (pumpkin), 2) phytostabilisation (Salix, grass-mixture), and 3) phytodegradation (nitrogen-fixing plants, such as clover and alfalfa). The following parameters are measured: total content of DDT in soil, bioavailable part of DDT in soil using POM, uptake of DDT in biomass (plants and earthworms).

Summary of findings/results: In terms of stabilisation, the results from the first two growth seasons indicate that biochar have a significant impact on the uptake of DDT in biomass. In terms of phytoextraction, the uptake of DDT in pumpkin was lower than expected. Using biochar, produced at high pyrolysis temperature, gives rise to soil quality effects that counteract phytoextraction strategies. In terms of phytodegradation, results are not yet

available.

Conclusion: Preliminary results indicate that biochar for stabilisation of DDT can reduce the risks to the environment but leaves the site with DDT-concentrations as before, albeit not bioavailable to the same extent. Phytoextraction is expected to require long time horizons to reduce the concentration of DDT to below recommended guideline values.

Significance/contributions of study: Land and soil values at these DDT contaminated sites are typically high, and remediation by traditional excavation is expected to destroy existing nature values as the natural soils (typically glaciofluvial or fluvial well-sorted sands) are not possible to recreate. In addition, these areas are large, and traditional remediation by excavation will be costly, not least in terms of transportation, waste production and loss of valuable soil resources. The results from this pilot study will provide valuable input into the ongoing work to manage DDT contaminated forest nurseries in Sweden and beyond by more sustainable and low-impact remediation technologies.

Session 3 poster / Abstract title: Frac-In-Ox: The Development and Pilot Testing of Technology for the Combined Direct Push and Fracturing of Contaminated Soil with the Injection of Strong Oxidising Agents

ID: 39

Key words: in-situ remediation, chemical oxidants, groundwater remediation, direct push hydraulic fracturing, in-situ injection

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Session: 3 poster

Abstract

• Purpose of the study
So-called Frac-In-Ox technology, which combines direct-push drilling with pneumatic fracturing and the subsequent hydraulic emplacement of strong oxidation agents in the subsurface has been developed as part of the Frac-In-Ox project. This technology is suitable for the treatment of poorly permeable or heterogeneous sites that have been contaminated with organic contaminants and that are treatable applying in-situ chemical oxidation (ISCO). The technology enables the injection of highly-concentrated and, thus, highly-corrosive solutions of strong oxidation agents.
• Methodology
Standard direct injection is performed by inserting a hollow rod into the soil using a direct-push drilling unit. The end of the rod is equipped with injection nozzles, which are closed while inserting the rod in order to prevent clogging. Once the injection depth has been reached, the injection nozzles are opened and a predetermined volume of fluid is injected into the surrounding soil. Once completed, the injection nozzles are closed and the rod is pushed into the deeper horizons. This allows for the performance of several injections at different depths in a single push location. The Frac-In-Ox process involves the injection of air under high pressure and high flow into low-permeability soils thus resulting in their pneumatic fracturing and the formation of a network of cracks into which the suspension, which, inter alia, contains sand, is subsequently injected. The sand in the suspension acts as a proppant for the filling and stabilisation of the cracks. The suspension may also contain calcium peroxide that acts both as an oxidising agent and a source for the slow release of oxygen. The stabilised fractures thus created are later flushed with solutions of strong

oxidising agents based on sodium/potassium persulphate.

- Summary of the findings/results

Frac-In technology was verified via a field pilot test conducted at the Březinka site where the groundwater was contaminated with a mixture of solvents, predominantly 1,2-DCA, chloroform and dichloromethane. As part of the pilot test, two different mixtures of remediation agents were injected using 16 injection probes at the site. The first mixture was based on the use of guar gum as a thickening agent to carry sand into the created fractures, while the second involved the use of hydrophilic fumed silica and calcium peroxide. Surveys of the pilot site using the so-called Hydraulic Profiling Tool (HPT) performed at the site prior to and following the Frac-In-Ox injections provided information on the changes in the hydraulic properties. The results indicated a significant increase in the hydraulic permeability of the aquifer. The monitoring of the groundwater quality both before and after the pilot testing served to prove the good distribution of the injected remediation agents and their long-lasting presence in the groundwater. A mean decrease of 62% in the sum of the volatile organic compound concentration was observed via the monitoring of boreholes 4 months following the injection campaign.

- Conclusion

Frac-In-Ox technology provides a suitable solution for the remediation of sites with unconfined poorly permeable sediments that have been contaminated with oxidable organic contaminants that are often difficult to remediate using traditional remediation technologies.

- Significance/contributions of the study

The use of Frac-In-Ox technology results in significant cost savings via the shortening of the time required for remediation, a decrease in the volume of the reagents used and the extent of the drilling, and a reduction in other operational and maintenance costs.

Session 3 poster / Abstract title: Methodical aspects of column experiments for organic compounds based on imidacloprid studies

ID: 398

Key words: methodology, column experiments, organic compunds, neonicotinoids, imidacloprid

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Co-authors: nan

Session: 3 poster

Abstract

Purpose of study
Although nowadays column experiments are commonly used, there are still no detailed guidelines or procedures for their performance. As a result, the comparison of the obtained results from column experiments performed by different scientists is difficult, and sometimes even impossible. Hence, this article presents methodical aspects of column experiments, performed to investigate transport parameters of organic compounds, based on the example of studies with imidacloprid. The studies included an important stage of planning experiments, taking into account the factors affecting the uncertainty of the obtained results.

Methodology
The following factors affecting the uncertainty of the obtained results were taken into account: the materials of the components of the stand and their reactivity to the tested substances, the preparation of soil samples, injection solutions (preparation and stability), tracer injection method, as well as the storage and transport of the samples to the laboratory. Another important factor related to the uncertainty of analytical determinations is the parameters of the method used to analyse the test compounds. They can be estimated at the stage of method validation/verification.
In the example presented in this work, column experiments were performed to determine the transport parameters of neonicotinoid's pesticide imidacloprid in several artificial soils representing the aquifer, characterized by varied content of silty and clay fractions as well as organic matter. The CXTFIT–STANMOD software was used to determine the transport parameter based on the deterministic equilibrium of the convection–dispersion equation, solving the inverse problem.
The experiment consisted of a few stages. Firstly, test stands were designed. Then, pilot experiments of column studies with the use of a conservative tracer (chloride, Cl–) for three different soils prepared in the laboratory were conducted. The purpose of this stage was to

verify whether the prepared stand meets the assumed criteria and allows for obtaining reliable test results. Finally, the reproducibility of the experiments was assessed by conducting imidacloprid migration studies simultaneously in two identical columns at two different concentration levels.

Summary of findings/results

Based on the obtained results, it was found that the prepared stand meets the assumed criteria and enables obtaining reliable and comparable test results. The repeatability of the methodology of preparing and performing column experiments was also successfully confirmed. For both the lower and higher concentration levels, in both replicates very similar values of the R–factors were observed — 2.84 and 2.83 as well as 2.62 and 2.68, respectively — which means a difference of less than 3%.

Conclusion and significance/contributions of the study

Considering the risk posed by organic contaminants such as imidacloprid to the environment, it is important to know the migration ability of these compounds in the soil–water system. The use of column experiments is an essential element for the correct assessment of their fate in the environment. Hence, a lot of emphases was placed on the appropriate methodology of performing column experiments, taking into account factors that can affect the uncertainty of the research results.

Session 3 poster / Abstract title: Biodegradation of Chloracetanilide Herbicide by the Immobilized Microbial Consortium in Continuous Biofilm Reactor

ID: 405

Key words: Biodegradation, biofilm, continuous reactor, microbial consortium, pesticides

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Session: 3 poster

Abstract

Purpose of study
The three most used herbicide groups in the Czech Republic (chloracetanilides, triazines and glyphosate) are also the compounds found in the highest concentration in surface water, ground water etc. Sorption in soils and sediments is an important factor influencing the migration and bioavailability of these herbicides, while microbial degradation is the most important factor in determining their overall fate in the environment. While moving through soil, parent compounds of mentioned herbicides are biodegraded by microorganisms, the most efficient decomposers in nature. Even if the microbial degradation is working well in a water or soil environment, there are many other new, arising compounds whose persistence in the environment is significantly higher than that of the parent compound. Degrades can end up in surface water by washing out from agricultural fields and can remain there for decades depending on their chemical properties and natural conditions. Metabolic products, especially of the chloroacetanilide group of pesticides, often end up in the drinking water of consumers. These findings lead to a constant need to search for new methods for removing these undesirable substances from water or soil. Our company participate in several research projects focused mainly on the decontamination of waters polluted by chloracetanilide pesticides and their metabolites.

Methodology
The chosen experimental set-up includes biodegradation by an immobilized mixed population of microorganisms capable of degrading alachlor, acetochlor, metolachlor, metozachlor and their metabolites as an exclusive source of energy and carbon. Microbial consortium, used in this study consists of two bacterial strains Brevundimonas diminuta and Microbacterium testaceum and two yeast strains Cyberlindnera suaveolens and Barnettozyma californica. These taxons were isolated previously from the soil and water samples contaminated with acetochlor and other herbicides through the selective enrichment

technique.
The biodegradation of synthetic or real samples of contaminated water containing acetochlor and other herbicides was studied in a special type of aerobic innovative membrane reactor in continuous mode. The membrane in the form of hollow fibres is at the same time a surface for the biofilm formation of degrading microorganisms and at the same time separator of the output water stream from the present microorganisms. The inlet into the bioreactor is supplied from a feed tank with the help of a peristaltic pump, and the effluent is discharged out of the bioreactor into a collection tank. All the experiments were carried out at ambient room temperature. The active reactor volume was approximately 2l.

Summary of findings/results
Biofilm formation and the type of microorganisms on the surface of hollow fibres was monitored by the scanning electron microscope and by the molecular-genetic determination of biofilm composition.
The packed-bed bioreactor was operated in continuous mode for several months. The feed flow rate, acetochlor concentration and hydraulic retention time (HRT) varied over the course of experiment to determine the effect of these parameters on biodegradation efficiency. The concentration of acetochlor and other chloroacetanilides was in the range of lower mg/l units. The system reached elimination capacity from 80 to 96 % at HRTc24 hod

Conclusion
Biological systems can be a beneficial alternative to the currently prevailing physical-chemical methods of removing pollutants from the group of pesticides.

Session 3 poster / Abstract title: Pilot tests as a way to introduce new technologies in Sweden

ID: 42

Key words: Pilot-tests, New Technologies

Submitter: Per Johansson

Organization: WSP Sweden

Co-authors: nan

Session: 3 poster

Abstract

Background/Objectives
Even if the Swedish environmental law is very much alike regulations in similar countries, the application of the Environmental Protection Agency's guidelines is often conservative, and presumed safe methods are preferred. Regarding remediation of contaminated land, this gives that aggressive methods like excavation and transport to landfill are often used, resulting in both substantial costs and high CO2-emissions.
When more modern methods are introduced, it is often necessary to convince both clients and regulatory authorities. Pilot test have shown to be a successful way, but a foreign supplier of technology also needs a local partner.
Approach/Activities
Many pilot tests performed in Sweden have opened opportunities to introduce new advanced technologies that had not been used in the country before. The small scale and therefore low economic risk have made both clients and regulatory authorities more willingly to accept untried technologies. Concrete examples of methods introduced such as skimming, hot air sparging and injection of chemical and biological compounds will be presented. Often, the techniques have been adapted to Swedish conditions regarding outdoor temperature, local geology and legal issues. The projects have in most cases been the result of a cooperation between a local Swedish consultant or contractor and an international supplier of technology.
Results/Lessons learned
The results have generally been good, but adoptions have been necessary. For example, very low winter temperatures caused ice plugs from condensed water even if just petrol product were recovered. This made it necessary with heating of the pipework, with the challenges it brought given the inflammable product.
A successful pilot test results in one of the following:
1. None of the tested method(s) prove to be effective. Other methods must be applied for further remedial actions.

2. The tested method(s) prove effective and the remediation can continue, in a larger scale if needed.
3. The tested method(s) prove so effective that no further remedial actions are needed.

Should a physical method give the first result, a possible assessment is that the contamination is less mobile than expected. This in turn can indicate that remediation is less needed or can be postponed. The second and third results show that the remediation can continue.

Using pilot tests, a number of advanced technologies has successfully been introduced in Sweden. To continue that, WSP Sweden is happy to welcome contact with foreign suppliers of advanced remediation technologies.

Session 3 poster / Abstract title: The performance of intensive green roofs for the treatment of greywater: effect of biochar and mycorrhiza inoculum

ID: 426

Key words: greywater, micropollutants, nature-based solutions, biochar, green roofs

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Session: 3 poster

Abstract

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Session 3 poster / Abstract title: Sustainable PFAS remediation: comparing the environmental impact of long-term in situ sequestration to pump and treat

ID: 48

Key words: PFAS, sustainability, CAC, remediation, P

Submitter: Gareth Leonard

Organization: REGENESIS

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Session: 3 poster

Abstract

Purpose: Comparing the environmental impact of a long-term in situ sequestration solution vs. a pump and treat system for the remediation of Per- and Polyfluoroalkyl substances (PFAS).

Methodology: Methods of PFAS remediation include Enhanced Attenuation (EA) of the source-plume system. One method of EA employs the in situ emplacement of Colloidal Activated Carbon (CAC) liquid into PFAS-impacted groundwater and coating the aquifer material in a thin layer of activated carbon. The PFAS influx is adsorbed by the CAC to provide a significant and long-term reduction in downgradient concentrations. Following installation, treatment through sequestration is designed to last decades and can be maintained through occasional re-application or may be sufficient if source treatment/removal is also completed. This approach has been used on over forty sites in the US, Canada, Europe, Scandinavia and the Middle East.

With the increasing interest in the sustainability of remedial approaches from problem holders, regulators and engineering firms, it was determined that a study should be completed into the environmental impact of this long-term EA method. Comparison was then made to the default groundwater remediation approach of water extraction and filtration to remove PFAS.

A Life Cycle Analysis (LCA) study was completed on the CAC susbtrate to gain an overall view of the environmental impacts into manufacturing, shipping and application of the product. The LCA boundary encompassed ‘cradle to grave’, i.e. it considered upstream sourcing of the material, core processes including activation and milling and also the downstream processes of transport and injection. The LCA was undertaken according to ISO14044/ISO14025 by using GaBi Professional software in order to meet EN15804

standards to create an Environmental Product Declaration (EPD).

Following this, a site was chosen on which CAC had been applied to remediate PFAS contamination. This comprised a commercial airport at which AFFF use had created a PFAS plume that was egressing the site and impacting an adjacent Site of Specific Scientific Interest (SSSI) and river. The CAC Injectable Permeable Reactive Barrier (IPRB) had been applied along a 110m length at the site boundary, immediately downgradient of the fire training area. The IPRB design was then analysed to determine the environmental impact. A 'pump and treat' system was then designed that could provide an alternative groundwater treatment along the same length, to achieve similar parameters over the same treatment period. A comparison was then made between the two approaches using GaBi Professional software, SiteWise green remediation tool and RemS remediation emissions excel tool. The comparisons included greenhouse gas emissions, acidification, photochemical ozone formation, hazardous waste, slag/ashes and energy use. The cost and site disturbance were also considered within the study.

Findings: The results of the LCA and a comparison of the remediation approaches will be presented.

Conclusion: Conclusions will be drawn on the relative sustainability and environmental impact of each process.

Significance: This study will provide important information on the environmental impact of different methods for remediating PFAS contamination in groundwater, which will be useful for practitioners seeking to provide long-term mitigation of risk to human health and the environment while also considering sustainability.

Session 3 poster / Abstract title: Enhanced Dynamic Skimming - A new and highly effective approach to skimming LNAPL

ID: 53

Key words: Dynamic skimming, LNAPL,

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Organization: Haemers Technologies

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Session: 3 poster

Abstract

Dynaskim® solution

Actual dynamic solutions for recovering LNAPL have multiple general disadvantages such as a high sensitivity to viscosity and clogging, high electrical consumption, unsuitable to groundwater level variations, high effluent water production, incapability to recover very thin layers, risk of secondary pollution, emulsion production, no central storage of recovered product and high maintenance.

The DYNASKIM® solution avoids these various disadvantages because it allows for the dynamic and effective vacuum suction of the hydrocarbon free phase at any depth. It creates an imbalance between the level of the free phase inside the pumping well and the level present in the soil located around the well. This imbalance allows for the forced recharge of the well by a free phase of pollutant, which is immediately pumped and eliminated.

Skimming is carried out using pump cycles. During each cycle, the floating liquid is pumped sequentially and independently in each well while monitoring is carried out by a PLC. The frequency of pumping between two cycles depends on 2 factors:

- the time required to recharge the well with the pollutant,
- the time of suction per well, linked to the quantity of free phase present in the well.

Pumping into the wells is achieved using a proprietary float connected to the pumping unit with a flexible hose.

The pumped mixture is then transferred automatically to a settling tank. The product is stored in a tank, awaiting removal by a specialised company. The small quantities of effluent

are then sent to a coalescence separator.

The limitations are that the soil must be sufficiently permeable to allow for the movement of the product and groundwater towards the wells and the NAPL must have a low viscosity to be able to move towards the wells. Although the DYNASKIM® technology allows to pump viscous product, the pumping time will then depend on the forces recharge of the wells.

Enhanced Dynaskim Solution

The DYNASKIM® technology fits perfectly into an overall solution for the remediation of a polluted site, in addition to other complementary techniques (soil excavation, thermal desorption, bio-remediation, chemical oxidation…).

Indeed, the viscosity is inversely proportional to temperature. It means that by increasing temperature, the viscosity of the product will decrease. Heating the soil and groundwater can be done using In Situ Thermal Desorption. By reducing viscosity of the product, the wells will fill up quicker which will allow the dynamic skimming to pump faster the NAPL.

DYNASKIM® guarantees the complete disposal of the thinnest free phase, but also viscous layers in combination with heating. Such performance is unmatched using traditional techniques.

It was already observed on different In Situ Thermal Desorption sites where pumping of the NAPL was also performed, that the heating of the soil increased the performance of the product recuperation. Combining In Situ Thermal Desorption and dynamic skimming can drastically reduce the time of skimming project.

Session 3 poster / Abstract title: A novel sustainability scoring method for soil remediation technologies assessment

ID: 56

Key words: sustainability, scoring, CO2-equivalent, social, environmental, economic

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Session: 3 poster

Abstract

The concept of sustainability is ever more pervasive in all aspects of today's society, and soil remediation should be no exception. Several of the goals set by the United Nations are particularly relevant to soil rehabilitation, such as resilient infrastructure development, safety, resiliency of land management and sustainable consumption.

Unfortunately, the sustainability of a remediation method is too often understood solely as its correspondent greenhouse gases emission. While being a key factor, it is only a limited part of the big picture. Furthermore, several of tools are available for the stakeholders to estimate CO2-equivalent emissions of different technologies but, depending on their scope and assumptions (which are not always disclosed), results can vary significantly.

In order to properly choose the most sustainable technologies depending on project- and pollutant-specific constraints, a sustainability scoring method is proposed. It is based on three main pillars, namely the economic (ECO), environmental (ENV) and socials (SOC) criteria.

The economic criterion is the most straightforward as it relates to the remediation cost. It includes the total cost, degree of uncertainty and change in land value. The social indicator, often the most neglected, relates to the impact of the remediation on society and individuals. It covers safety, education and employment, stakeholder involvement, land use, dust, odours, traffic, and noise generated. Finally, the environmental criterion evaluates the efficiency of remediation, risk of secondary contamination, gas emissions, impact on soil and water characteristics and generated waste.

Each sub-criterion is rated thanks to an evaluation grid, attributing a note ranging from 0 to 10 based on the performance of the given remediation method. When a numbers-based rating is not possible, which is typically the case for some social indicators, a clear description of different scenarios is used to make their objective assessment possible.

After each of the main three pillars have been attributed a score based on the mean score of the topics that they cover, a final scoring method is proposed such that:

Each of the main pillars (ECO, ENV, SOC) is given the same weight.

A poor score in one of the pillars is highly penalizing for the final overall score.

For those reasons, necessary to select truly sustainable technologies, the final sustainability score is the geometrical mean of the three main scores, written as $\sqrt[3]{(ECO \times SOC \times ENV)}$.

To highlight the method and conclude the paper, a small case study is used, where "remediation" using excavation (dig dump) is compared against thermal desorption. While studies relying on CO2-equivalent emissions sometimes favour one method or the other based on their respective scopes and assumptions, the weaknesses of the excavation are properly highlighted using a full sustainability scope.

Abstract title: Evolution of the soil profile at a tailings management facility due to the establishment of vegetation cover and its effects on the mobility of potential contaminant metal(odis)

ID: 85

Presentation type: Oral presentation

Key words: Mine waste management, nature based solutions, rhizoremediation

Submitter: Felipe Sepulveda Olea

Organization: University of Leeds

Topic: 3. Sustainable remediation, emerging contaminants and prevention towards zero pollution

Sub-topic: a. Low carbon emitting technologies for historical large-scale pollutions (e.g. landfills, mine wastes) using sustainable resources and energy

Comment by submitter (if any): Thank you

Abstract

'This study has investigated the evolution of the soil profile at a tailings management facility (lead/zinc), due to the establishment of vegetation cover (grassland species). Changes in the geochemistry of the waste are reported and the effects of root exudates and microorganism activity on the mobility of potential contaminant metal(odis) and elements of economic interest are inferred.

Replicate boreholes were advanced at two locations where grassland species had been established for 1 and 3 years (cores were subdivided at 5 or 10 cm intervals for analysis). Trial pits were also excavated in two 8-years old trial mesocosms with similar vegetation which had under-drainage (excavation undertaken in intervals of 3 to 4 cm). Water leaching tests were performed in all samples, for the measurement of pH, EC, DOC, water leachable metals and water leachable organic acids. In addition, samples were processed for LOI (at 550°C), acid extractible Fe as Fe(II) (redox conditions), pseudo-total metals content, DNA concentration and DNA analysis.

Fresh tailing material consists mainly of carbonates, silicates and trace amounts of pyrite. Gypsum and Fe oxides appear later as alteration products. pH in collected samples was predominantly neutral, ranging from 6.7 to 7.6.

DOC does not increase with age. In 8-years old samples higher concentrations are present in the first 8 cm (9- 30 mg/kg) and in the first 10 cm in 3-years old samples (9- 28 mg/kg, excluding one outlier sample). Lastly, 1-year old samples show concentrations greater than 11 mg/kg up to 20-30 cm depth. LOI results overall indicate a low contents of soil organic carbon, and show a similar pattern to the DOC, with higher concentrations in the first 5 to 10 cm.

In terms of water leachable elements, Ca and S have the highest concentrations (208.4 - 1512.6 mg/kg), and are correlated (R2 of 0.87) in the tailings profile, which could indicate that their presence in solution is controlled by the dissolution of gypsum. Readily exchangeable cations (i.e. Mg and Na) were positively correlated with depth in the tailing profile. Water soluble Cu, on the other hand had a negative correlation with depth, there being higher concentrations of water extractable Cu on surficial layers. The remaining elements showed no trend with depth.

In order of decreasing degree of correlation, the following parameters exhibited a decrease with increasing age: K, % of extractable Fe as Fe (II) (i.e. more oxidising conditions in older samples), Na, Ni, Zn, Pb, Mo. In all cases the difference is primarily between the 8-year-old samples and those collected from the boreholes at the 1 and 3 year old sites, with notably less difference between the latter two. In contrast to the other geochemical parameters, pH increases with age.

DNA was mostly concentrated in the top 2 cm (4 cm in 8-year old samples), descending to values close to the detection limit at depths of 5, 10 and 12 cm in 1, 3 and 8-year old samples, and was mostly below the detection limit beyond that. With age, a tendency for concentrations ranges to rise is observed, with values ranging from <LOD to 334.2 ng/g in 1-year old samples to 413.3 to 10787.3 ng/g in 8-year old samples.

Overall, preliminary results indicate that the influence of root exudates as well as the establishment of soil microbiota is mostly limited to the topmost layer (2-4 cm). While there is some difference in terms of the water soluble metals and other parameters (e.g. pH) in 8-year old samples, these are likely a consequence of the oxidising conditions prevalent in mesocosms, which may be favoured by the free flowing drainage set up. These results can contribute significantly to decision making about the use of vegetation cover as a management approach for industrial, mining and mineral wastes, not only respective to the effects this may have on trace contaminant speciation changes and leaching behaviour, but also in terms of the development of soil ecosystems.'

Session 3 poster / Abstract title: Volatile chlorinated solvents migrating over long distances in sewer systems

ID: 98

Key words: volatile organic compounds, VOCs, indoor air, sewer systems, vapor movement

Submitter: Kaspar Ruegg

Organization: Central Denmark Region

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Session: 3 poster

Abstract

Background
There has been a special focus on chlorinated solvents in indoor air in Denmark for many years. Investigations usually have focused on intrusion pathways from a local soil contamination to buildings in the vicinity.

On many sites we have found that contaminated groundwater from shallow, contaminated aquifers is seeping into sewer systems. Once contaminated water has found its way into sewer systems, vapor containing volatile compounds can move in any direction and pose a potential threat to indoor air in housing far from the source.

Purpose of studies
The purpose of the studies has been to determine the main processes that drive transport of volatile organic compounds (VOC's) in sewers and if possible identify parameters that induce the processes. The studies give an understanding of the driving forces, their magnitudes and therefore a better understanding of how to investigate future sites.

Methodology
Theoretical studies to determine the main processes for transport of vapors in sewers were conducted. Conceptual considerations for the processes and their relative magnitudes were made. In a second step, field studies were conducted, including measurements on the identified processes and on a wide array of parameters.

The investigations were mainly carried out on two locations with shallow aquifers, where sewer systems are situated below the groundwater table.

Summary and findings
The main process inducing movement of volatile compounds is convective transport of vapor

in the sewer pipes. The driving force behind vapor movement is in turn pressure differences over space. The measured pressure differences are for the most on a scale of up to 3-5 Pa. Pressure is oscillating around 0 Pa in a pulsating manner, for the most in the interval of ±0,3 Pa. Usually a net pressure gradient in one of the directions can be detected.

Three parameters were identified as possible drivers for vapor movement:

1. Changes in filling grade of pipes with liquids
2. Temperature differences between surface and sewer
3. Wind velocities in combination with wind direction

Conclusion

The main influx of VOC contaminations (with e.g. chlorinated solvents) to sewers is caused by an influx of contaminated groundwater to the sewers, which can happen on or downstream contaminated sites. The contaminant mass flux is mainly depended on the scale of influx and transport of contaminants in the liquid phase. Once in the liquid phase of public sewers, vapor form VOCs may move in any direction transported with vapor flow in the pipes. Vapor movement in sewage pipes is induced by small net pressure differences in space, and possibly in unexpected directions. Pressure difference vary over time, and may cause seemingly “random” indoor air problems far from the source, at sites with no apparent soil, groundwater or soil vapor contamination.

Presentation: At the conference, a case will be presented, conceptual considerations discussed, results from field investigations showed and the implications discussed.