Consiglio Nazionale delle Ricerche

REMTECH EXPO

HUTTE

Società Italiana di Geologia Ambientale - APS

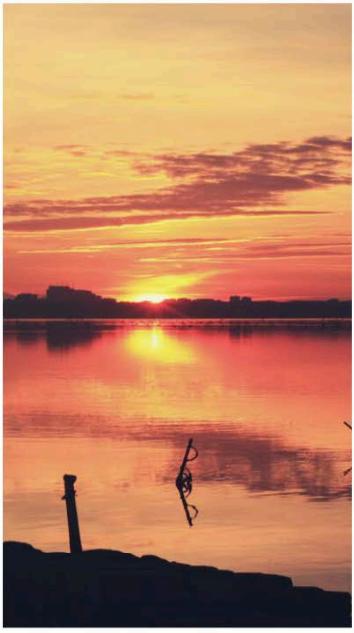
COMMISSARIO UNICO PER LA REALIZZAZIONE DEGLI INTERVENTI NECESSARI ALL'ADEGUAMENTO ALLA NORMATIVA VIGENTE DELLE DISCARICHE ABUSIVE PRESENTI SUL TERRITORIO NAZIONALE

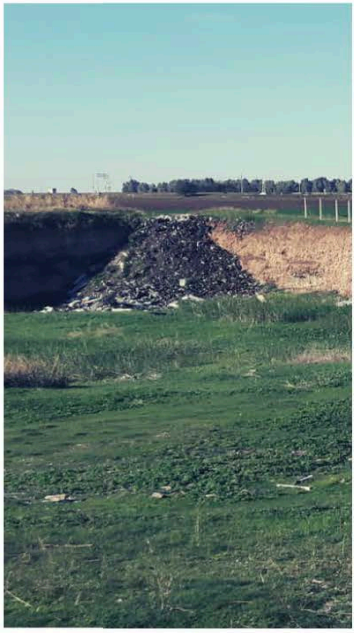
L'INNOVAZIONE NEL COMPARTO DELLE BONIFICHE E LE TRAIETTORIE DI SVILUPPO

LIBRO DEGLI ABSTRACT

A CURA DI VITO FELICE URICCHIO, SILVIA PAPARELLA E MARCO FALCONI

con le prefazioni delle Sottosegretarie al MiTE On. Ilaria Fontana, On. Vannia Gava e Gen. Giuseppe Vadalà





MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

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Prefazioni

In un momento storico, che vive la transizione ecologica come la ricerca di nuovi equilibri nel segno dell'etica e della sostenibilità, l'innovazione assume elemento di centralità per la realizzazione di nuovi modelli di sviluppo che mettano al centro la tutela ambientale, affrontando responsabilmente le tante sfide poste dalle principali minacce che interessano il nostro ecosistema.

L'innovazione, cuore pulsante della transizione, affonda le radici nella conoscenza dello stato dell'ambiente e dei processi che regolano la vita, poiché solo attraverso un'attenta osservazione dei fenomeni è possibile animare una riconfigurazione e una trasformazione culturale che possa incidere a più livelli, coinvolgendo la sfera sociale, economica, sino a quella ambientale e sanitaria.

La transizione deve puntare a rafforzare la resilienza ambientale ma anche e soprattutto delle comunità, che possa cogliere come avvenuto nelle recenti limitazioni dei combustibili fossili, inedite istanze di cambiamento verso percorsi di responsabilizzazione e di condivisione delle risorse.

In tale contesto, il settore del bonifiche, che il presente volume affronta, ci fa comprendere il significato della tutela ambientale, poiché con le attività di caratterizzazione e di analisi di rischio, ci rendiamo conto di come gli impatti perpetrati da politiche e attività antropiche "dissennate" possano interessare più matrici ambientali, mentre con le attività di bonifica tocchiamo con mano quali sforzi e costi economici siano necessari per rimuovere gli effetti della contaminazione, giungendo al parziale ripristino delle situazioni ambientali inziali. Ricordo sempre che favorire le operazioni di messa in sicurezza, bonifica e ripristino di aree storicamente contaminate, significa non solo restituire alla cittadinanza porzioni di territorio altrimenti inutilizzabili, ma contestualmente prendersi cura di vere e proprie ferite, peraltro ancora pericolose per i territori e la salute di chi li vive.

Per tale motivazione dalle attività di bonifica possono nascere e maturare nuove consapevolezze e nuove conoscenze funzionali anche ad orientare nuovi modelli di transizione ecologica, rilocalizzando l'economia, soprattutto la produzione e il consumo, anche valorizzando appieno i principi dell'economia circolare che hanno il grande vantaggio di ridurre le dipendenza dalle risorse dall'estero, ma soprattutto di limitare la produzione di rifiuti che hanno storicamente prodotto significativi impatti sui territori.

Tali percorsi culturali puntano alla promozione di sistemi economici fortemente circolari, ma anche a ripensare ai territori, alle governance, ai legami sociali, alla ricerca di approcci organici per essere resilienti. Tali approcci sono contenuti in importati documenti quali il Piano per la transizione ecologica, la Strategia nazionale per l'economia circolare ed il Programma nazionale per la gestione dei rifiuti: documenti che ci fanno comprendere chiaramente come lo sviluppo a breve termine è insostenibile, che occorre un più ampio respiro che porti ad attuare una concreta transizione culturale, sociale, economica e quindi ambientale con un deciso cambio di paradigma collegato al concetto di solidarietà intergenerazionale.

In tale direzione la transizione ecologica che abbiamo convintamente avviato, richiede l'adozione di metodi e pratiche sostenibili, ma coglie anche emergenze che ci troviamo oggi ad affrontare un'opportunità di sviluppo sostenibile per gettare le fondamenta del mondo che vorremo consegnare alle generazioni future.

AugurandoVi una buona lettura di pillole di sostenibilità che il presente volume contiene, ci auguriamo di proseguire insieme un percorso lastricato di azioni organiche ed integrate, che coinvolgono tutti gli attori sociali, per preparare un terreno culturale per avviare quell'irrinunciabile transizione ecologica, economica e sociale, ma anche inclusiva e interculturale di cui sentiamo un urgente bisogno.

Sottosegretario al MiTE
On. Ilaria Fontana

È ormai evidente che l'economia del nostro Paese, messo a dura prova prima dall'emergenza Covid-19 ed poi dal conflitto tra Russia e Ucraina, ha bisogno di reagire attraverso il rilancio delle attività economiche, URL un rilancio che deve assolutamente essere sostenibile, rispettare l'ambiente e ridurre al minimo l'impatto. Con il Governo guidato da Mario Draghi, il Ministero della Transizione Ecologica ha assunto le competenze istituzionali in materia di sviluppo sostenibile, tutela e valorizzazione dell'ambiente, del territorio e dell'ecosistema ed è stato impegnato a dare risposte concrete alle domande degli operatori, che hanno sempre più bisogno di un quadro di regole chiare e certe. Ecco perché abbiamo considerato una priorità, prima ancora che potessero arrivare i finanziamenti del Piano Nazionale di Ripresa e Resilienza, una poderosa azione di semplificazione dei processi, per accorciare i tempi di realizzazione delle opere e degli interventi. Senza semplificazione e senza mettere a disposizione dei territori le competenze necessarie per presentare progetti e richiedere finanziamenti, lo sforzo di investimento sarebbe stato vano, l'occasione persa.

L'Italia ha reagito e sta reagendo, recuperando i decenni perduti, e con le risorse del Piano Nazionale di Ripresa e Resilienza destinate alla rivoluzione verde e alla transizione ecologica, prevede interventi nei settori quali l'economia circolare e l'agricoltura sostenibile; l'energia rinnovabile, idrogeno, rete e mobilità sostenibile; efficienza energetica e riqualificazione degli edifici; tutela del territorio e della risorsa idrica. Risparmio energetico e idrico sono importantissimi sempre e in questo momento storico, coi prezzi dell'energia alle stelle, questa importanza è sotto agli occhi di tutti.

Per far fronte ai cambiamenti climatici e per realizzare una vera e propria transizione ecologica bisogna continuare ad introdurre sistemi avanzati e integrati di monitoraggio e analisi per migliorare la capacità di prevenzione di fenomeni e impatti, incrementare gli investimenti volti a rendere più robuste le infrastrutture critiche, le reti energetiche e tutte le altre infrastrutture esposte a rischi climatici e idrogeologici,

ma soprattutto bisogna puntare sulla ricerca e sull'innovazione tecnologica.

La tecnologia e la conoscenza sono le migliori alleate dell'ambiente.

L'Italia vanta grandi conoscenze scientifiche e capacità tecniche ed è assolutamente all'avanguardia. La transizione va fatta gradualmente, va programmata e condivisa grazie allo scambio di buone pratiche e alla collaborazione costruttiva tra realtà diverse che operano in questo campo. Per questa ragione, ben vengano le iniziative come RemTech che permettono a istituzioni, tecnici, imprese e cittadini di confrontarsi sul tema che non solo è un tema "del futuro", ma rappresenta esso stesso il "futuro" del pianeta, cioè del luogo dove viviamo e dove vogliamo che crescano i nostri figli.

Sottosegretario al MiTE
On. Vannia Gava

La Transizione Ecologica non è più un concetto innovativo. E' una necessità imposta dalla velocità dello sviluppo e dalla sostenibilità delle risorse del Nostro Pianeta Terra. Le azioni e le politiche, la cd. governance, sono in continuo movimento e in perenne costruzione, perché fare e realizzare significa cambiare in modo "feroce" gli stili di vita e il livello di benessere fin'ora goduto e acquisito dai cittadini del Mondo Occidentale, dell'Europa, dell'Italia. Significa a volte modificare i propri redditi, spostare risorse su nuovi produzioni verdi. In questo nessuno vuole e deve essere lasciato indietro.

Quello che nel 1972, nel giugno di quell'anno, era stato appena teorizzato nel corso della Conferenza di Stoccolma, oggi è realtà di ogni Governo, anzi necessità di continua cooperazione internazionale per un Governo mondiale della Terra, per distribuire a tutti di fronte a possibili catastrofi immanenti le risorse della Terra che via via diventano sempre di meno, per una popolazione tendente ai 8 miliardi di essere umani.

Si cerca oggi nel nostro Paese, nel Mondo di consumare un po' di meno, non abbandonando il benessere conosciuto, riutilizzando e risanando beni e territori, cercando di distribuire meglio le ricchezze mondiali, in presenza di tensioni internazionali da governare.

In questo senso la tecnologia è sempre venuta a soccorrere l'Uomo. Questa volta chiediamo alla tecnologia una nuova e grande impresa. Farci godere ancora del benessere posseduto a minor prezzo ambientale. Sembra un paradigma impossibile ma gli sforzi continui della ricerca su energia, risanamento dei territori, riutilizzo di rifiuti, cura delle risorse naturali è tutta indirizzata in questo senso.

Anche noi, Uomini e Donne, dobbiamo sviluppare capacità di adattamento al cambiamento attraverso il riutilizzo dei beni, la cura del territorio e della cosa pubblica, l'utilizzo più parsimonioso dei beni, acqua, energia, cibo.

La ricerca e il moto continuo dei network, RemTech di Ferrara e di HuTTE, realizzano questo: fare ricerca nei laboratori e poi applicare subito i risultati alla realtà, attraverso i continui consessi, incontri, esperienze, realizzazione di progetti UE, attraverso l'incontro pubblico

- privato per capire reciprocamente e più velocemente, insieme, tecniche, modi di pensare e necessità.

Questa terza pubblicazione degli scritti di decine di ricercatori e di uomini di buona volontà significa questo: amore per il proprio territorio, amore per le generazioni future, amore per il Pianeta Terra.

Quale più alto significato vogliamo dare a questo impegno se non quello di adoperarsi per il bene altrui.

Un plauso quindi agli animatori di questa pubblicazione, al Prof. Vito Uricchio, docente del C.N.R. che della qualità, quantità e disponibilità delle acque ne ha fatto un credo di vita e alla Dott.ssa Geologa Silvia Paparella, Amministratore Delegato di Ferrara Fiere e dell'Hub Tecnologico Ambientale di RemTech, che della trasmissione dell'innovazione tecnologica ne ha fatto missione e passione di vita.

Buon lavoro a tutti noi.

Giuseppe Vadala'

Premessa

Utilizzando la formula degli abstract, con il presente volume abbiamo voluto rappresentare, in forma sintetica e di agevole lettura, buone pratiche, esperienze, esiti della ricerca scientifica e tecnologica, riflessioni sulle più recenti normative, approcci metodologici che possano ispirare attività ed interventi di caratterizzazione, messa in sicurezza e bonifica dei siti contaminati. La forma contratta e fluida, consente una rapida scansione di contenuti di interesse, suscettibili di approfondimento, attraverso il contatto diretto con gli autori, citati nello stesso articolo ed immediatamente contattabili a mezzo mail.

Il presente volume, punta ad amplificare ulteriormente l'utilissimo scambio di informazioni, esperienze ed innovazioni che si materializza ogni anno delle giornate di RemTech Expo, lasciando una aggiuntiva testimonianza scritta, fruibile in formato cartaceo e digitale, da utilizzare quasi come degli appunti delle più recenti novità sul temi della bonifica. L'edizione di RemTech Expo 2022, insieme ai nostri precedenti incontri dell'Hub Tecnologica per la Transizione Ecologica, rappresenta un'occasione preziosa per riflettere su come mettere a fattor comune le differenti espressioni ed esperienze del mondo della ricerca e delle impresa.

Con RemTech e con il presente volume, continuiamo a considerare lo scambio di conoscenza ed il consolidamento della cultura, un motore di crescita, di ricerca e di sviluppo, straordinariamente importante in ogni momento della nostra esistenza, ma particolarmente strategico in questa fase della transizione ecologica, energetica e digitale. E', di fatti, impossibile costruire scenari e riflettere sull'avvenire dell'umanità senza una stretta connessione al mondo dell'innovazione e della tecnologia, convalidato anche da significative esperienze di impresa adattate ai differenti contesti sito-specifici. Negli ultimi due anni abbiamo ancora di più verificato come innovazione e tecnologia siano due elementi che guidano prepotentemente questa fase delle nostre vite e che, se adeguatamente governati, potranno fungere da moltiplicatori di sviluppo sostenibile e da volano di crescita.

In questa direzione appare evidente come conoscenza e la cultura rappresentino un capitale sul quale s'innesta il nostro essere comunità. È un capitale che permette di illuminare il nostro percorso, la nostra transizione e di esserne consapevoli. È una tappa importante, specie quando si offrono alle imprese interessanti prospettive di competitività internazionale che le proiettano verso nuove possibilità imprenditoriali, economiche ed occupazionali.

Come noto, ricerca ed innovazione alimentano filiere organicamente collegate alla tutela dell'ambiente, della salute ed al benessere delle popolazioni. L'osmosi tra ricerca ed impresa, specie se volta a concretizzare uno spunto competitivo, genera valore ed arricchisce sia l'identità tecnologica e morale di un popolo sia il suo benessere generale.

Dalla lettura del volume si intuisce come lo sviluppo sostenibile intrecci questioni e processi complessi e tra loro profondamente interconnessi che intersecano anche la dimensione etica e della solidarietà intergenerazionale. Andando oltre le tecnologie, che rappresentano un fattore centrale per l'efficacia e l'economicità degli interventi, per raggiungere degli obiettivi realmente sostenibili, occorre adottare un nuovo orientamento culturale che sappia sviluppare una nuova idea di mondializzazione fondata sulla sostenibilità, sull'interdipendenza, sull'inclusività, sulla democrazia e sulla giustizia sociale. In tale direzione, il settore delle bonifiche testimonia con particolare incisività il concetto che "tutto è connesso" e le bonifiche vanno interpretate traguardando obiettivi con uno sguardo lungimirante che anteponga il benessere a lungo termine della collettività agli interessi individuali immediati per traghettarci verso un futuro più sostenibile, equo, solidale, inclusivo ed ecologico . Grazie per la vostra attenzione e buona lettura.

Vito Felice Uricchio

La modifica della Costituzione del febbraio scorso, che ha introdotto nella Carta costituzionale il concetto di "generazioni future" e di "ecosistema", qualificando ulteriormente il concetto di "ambiente", ci fa comprendere come l'approccio allo sviluppo mondiale sia profondamente cambiato e come sia inevitabilmente da ricercare un punto di equilibrio di una compiuta sostenibilità, da un punto di vista appunto economico, sociale ed ambientale.

Il risanamento è una vera e propria occasione per l'Europa e per il nostro Paese, di recupero e di rigenerazione sostenibile dei territori. Basti pensare ai 2.8 Milioni di siti potenzialmente inquinati a livello Europeo, ai 700 Mila siti caratterizzati e contaminati o ancora ai 42 Siti di Interesse Nazionale, i 34 Mila Siti di Interesse Regionale, ai siti orfani, ai siti di discarica, alle discariche abusive di competenza del Commissario Unico alle bonifiche.

Il nostro Paese è al contempo un bacino immensamente vasto e competente di conoscenze, di tecniche e di tecnologie innovative. Queste stesse tecnologie che oggi rendono l'approccio alla bonifica sempre più sostenibile e sempre più inclusivo rispetto al panel degli stakeholders coinvolti, diversamente da un approccio tradizionale che basa lo sviluppo progettuale esclusivamente sui pilastri dei costi, della fattibilità tecnica e la conformità normativa.

In Italia le imprese iscritte alla categoria 9 dell'Albo nazionale dei gestori ambientali (bonifiche dei siti contaminati) sono quasi 1.500 che diventano 6.200 tra micro, piccole, medie e grandi imprese che operano nel campo della bonifica di siti e della bonifica dei beni contenenti amianto e che arrivano fino 165 Mila imprese che operano nel campo dei rifiuti e del risanamento. L'osservatorio di RemBook ha messo in evidenza che, per la sola categoria 9, sono stimati 23 Mila addetti, 18 Mila interventi all'anno per un fatturato complessivo di 2,1 Miliardi di euro.

Recuperare il territorio significa non solo restituire il territorio agli usi legittimi ma anche ridare speranza e fiducia a porzioni di territorio compromesse incrementando allo stesso tempo la qualità della vita ed il benessere dei cittadini.

Per fare questo serve compiere un ulteriore sforzo in termini di potenziamento della condivisione, degli strumenti e dei momenti qualificati di condivisione ma anche in termini di formazione e di aggiornamento permanente dei professionisti e dei funzionari delle pubbliche amministrazioni e certamente potenziare il confronto tra pubblico e privato, che necessariamente poggia il primo pilastro sulla fiducia, il rispetto dei ruoli, la capacità di condivisione di strategie e obiettivi comuni.

Tale approccio genera oltremodo una migliore gestione integrata delle attività, delle diverse fasi progettuali e quindi dei risultati, una maggiore efficienza complessiva, la valorizzazione e l'applicazione delle migliori innovazioni tecnologiche, tempi e costi di intervento inferiori, e la conseguente restituzione dei territori ai cittadini ed a future attività di sviluppo.

RemTech Expo e il Comitato di HuTTE condividono che la divulgazione operativa, anche e soprattutto attraverso questo prezioso volume che racchiude i migliori esempi applicativi in materia di risanamento ambientale e territoriale, rappresenti un contributo fondamentale nonchè uno strumento di lavoro centrale per i decisori e le stazioni appaltanti in termini di azioni e potenzialità che possono essere attivate attraverso la cura degli iter amministrativi di gara. L'impegno deve continuare in forma permanente così come la collaborazione, la condivisione e la sinergia tra Pubblico e Privato nelle migliori forme realizzabili e con le migliori forze possibili.

Silvia Paparella

In this publication you will find the abstracts that were presented for Remtech Europe 2022 that represent in a concise and easy-to-read form, good practices, experiences, scientific and technological research outcomes, and methodological approaches that can inspire activities and interventions in the characterization, securing and remediation of contaminated sites. It also appears necessary to take steps to implement interventions-with sustainable approaches in which social, environmental and economic aspects are evaluated in an integrated manner.

The protection, preservation and enhancement of environmental resources are widely recognized priorities, referred to in almost all public, national and international programs. But to deal with an environmental situation that appears very critical both globally and locally, focusing on sustainability has become necessary. There is a need to develop and disseminate environmental knowledge in order to sustainably guide decisions by helping to positively influence the decisions of communities and territories.

The main scope of this event to formulate sustainability-oriented initiatives and to promote sustainable processes of territorial development. And it is only true awareness and participation of stakeholders (public and private) that makes it possible to identify effective solutions to govern environmental issues.

Through his own intelligence, man has created from nothing everything we see around us, something to move quickly, to fly, to protect himself from danger. Not exactly starting from nothing, because through the sharing between master and apprentice, that has been done over time-technological transfer and progress. Even in a subject like environmental remediation, which seeks to solve something for which man has damaged his own health and the planet, which this event is about, sharing is necessary.

We therefore do so with this volume: the exchange of knowledge and the consolidation of culture, an extraordinarily important engine of growth, research and development at every moment of our existence

Indeed, the exchange of information among those working in the field (companies, professionals, consultants, but also local authorities responsible for rendering opinions as part of project approval procedures) is an indispensable element in advancing remediation in Europe and other continents, facilitating the sharing of knowledge, skills and best practices.

The present volume, aims to further amplify the very useful exchange of information, experiences and innovations that materializes each year of the RemTech Europe days, leaving an additional written testimony, usable in paper and digital format, to be used almost like notes of the speeches you will hear during the 5 days of RemTech Europe 2022 in presence or online (19-23 September 2022).

Marco Falconi

Indice

I. Caratterizzazione di siti inquinati

Caratterizzazione dei microbiomi e metagenomica per il biorisanamento di siti contaminati da composti clorurati: casi di studio in sistemi bioelettrochimici

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Le strategie di bonifica per via biologica (biorisanamento) sono efficaci e promettenti per applicazioni di campo. I solventi clorurati si prestano particolarmente a questo approccio in quanto sono biodegradabili da microorganismi specializzati, sia mediante processi anaerobici in presenza di un donatore esterno di elettroni o di un substrato organico fermentabile (declorazione riduttiva), che mediante processi ossidativi mediati da microorganismi aerobici (etenotrofi, metanotrofi) per la rimozione dei solventi basso clorurati. Studiare questi microorganismi consente di definirne le caratteristiche metaboliche/funzionali e le interazioni all'interno di comunità microbiche complesse, ma anche di supportare lo sviluppo di adeguate biotecnologie di bonifica, indirizzandone l'applicazione su campo. A questo scopo, sono stati fatti molti sforzi di ricerca per ottimizzare ed applicare gli approcci "omici" (genomica, metagenomica, trascrittomica) nel monitoraggio dei biomarcatori (specie microbiche, geni funzionali) responsabili dei processi biodegradativi ed investigarne il loro ruolo funzionale, sia nelle fasi preliminari degli interventi di bonifica (caratterizzazione dei siti contaminati, studi di microcosmo), che durante lo sviluppo e l'applicazione di biotecnologie per il biorisanamento, dalla scala di laboratorio alla scala di campo.

Tra le tecnologie innovative e promettenti per il biorisanamento si annoverano i sistemi bioelettrochimici (BES). I BES si basano sull'utilizzo di elettrodi (anodo, catodo) che fungono da accettori o donatori di elettroni per la biodegradazione e/o biotrasformazione degli inquinanti, con vantaggi in termini di rapporto costo/efficacia e

sostenibilità ambientale. Recentemente sono stati sviluppati BES per la rimozione anaerobica/aerobica del PCE mediante l'utilizzo di reattori sequenziali in cui avvengono separatamente la declorazione riduttiva ed ossidativa (Zeppilli et al., 2019, 2021; Di Franca et al., 2022). Sono stati inoltre sviluppati BES per il trattamento simultaneo di co-contaminazione da solventi clorurati e metalli pesanti (TCE/CrVI), condizione frequente nelle acque di falda (Lai et al., 2021; Matturro et al., 2021).

In questa presentazione verranno riportati i risultati delle caratterizzazioni biomolecolari condotte nei sistemi citati, focalizzandosi sull'analisi dei biomarcatori di declorazione e sullo studio della composizione e dinamica dei microbiomi in diverse condizioni testate. Verranno inoltre presentati i risultati di studi di metagenomica da cui sono emerse le caratteristiche metaboliche e funzionali dei principali microorganismi trovati nei BES, evidenziando come, mediante un approccio multidisciplinare sia possibile contribuire all'implementazione delle tecnologie di biorisanamento in situ, con conseguenti applicazioni in scala reale.

Keywords: idrocarburi organoclorurati, microbioma, metagenoma, tecnologie bioelettrochimiche

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L'esperienza del SNPA nel SIN di Porto Torres: stato dell'arte, criticità e prospettive

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Il lavoro proposto nasce nell'ambito delle attività istituzionali che ISPRA ed ARPAS conducono ai sensi dell'art. 252 del d.lgs. 152/2006 ed è frutto dell'intensa collaborazione tecnica tra ISPRA ed ARPAS, in seno al Sistema Nazionale a rete per la Protezione dell'Ambiente (SNPA, ex Legge 132/2016). Oggetto della presentazione è il Sito di Interesse Nazionale "Aree industriali di Porto Torres", perimetrato con Decreto del Ministero dell'Ambiente e della Tutela del Territorio (ora MITE) del 7 febbraio 2003, successivamente riperimetrato con Decreto del MATTM del 03/08/2005. Con Decreto del MATTM del 21/07/2016 è stata poi rettificata la cartografia del 2005 con l'inclusione delle aree a mare. L'estensione complessiva delle aree a terra è pari a 1874 ha, mentre quelle a mare risultano pari a circa 2700 ha. A circa venti anni dalla sua costituzione, nell'ambito del Sistema Nazionale per la Protezione dell'Ambiente, ISPRA ed ARPA Sardegna intendono proporre una prima descrizione organica del quadro ambientale del SIN. A tal fine, è stata effettuata una disamina dei dati disponibili per le matrici ambientali suolo ed acque di falda, derivanti sia dalle attività di caratterizzazione e bonifica delle aree private e delle aree pubbliche che delle attività di validazione da parte dell'Arpa Sardegna. L'unione e la successiva elaborazione di tali dati ha permesso di delineare non solo lo stato dell'arte del Sito di Interesse Nazionale ma anche alcune sue importanti criticità, ambientali ed amministrative. Nell'ottica della centralità che assume il modello concettuale a scala di intero SIN sono state, inoltre, formulate alcune proposte volte ad integrare e, possibilmente migliorare, la gestione del Sito di Interesse Nazionale.

Keywords: Sito di Interesse Nazionale di Porto Torres, contaminazione ambientale, sorgente primaria, suolo e sottosuolo, acque di falda

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La discarica di Contrada Martucci in agro di Conversano (BA). Il supporto tecnico-scientifico di ARPA Puglia per il monitoraggio e la caratterizzazione del sito

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In agro di Conversano è situato, in contrada Martucci, un impianto di discarica costituito da tre lotti, di cui due esauriti per rifiuti solidi urbani (lotti I e III) ed uno destinato a discarica di servizio/soccorso per l'adiacente impianto complesso di trattamento meccanico biologico di rifiuti per la produzione di combustibile solido secondario.
Il sito è stato oggetto di sequestro, di procedimenti penali e specifici accertamenti tesi a valutare la presenza di inquinamento dell'area. Nella Sentenza del Tribunale di Bari n.1021/18 R.G. SENT. il Giudice ha segnalato che "i periti […] hanno evidenziato significative criticità e la conseguente necessità di interventi strutturali e gestionali sul comparto di discarica che garantiscano in futuro la certezza che non vi possano essere quelle perdite di percolato che allo stato si sono presentate solo come possibili o occasionali e comunque non tali ma solo per carenza della relativa prova] da aver provocato modifiche nella falda acquifera".
Si tratta, pertanto, di un sito complesso e oggetto di grande attenzione da parte delle amministrazioni locali e dell'opinione pubblica, in particolare a seguito della pubblicazione del nuovo Piano Regionale per la Gestione dei Rifiuti Urbani (D.C.R. 68/2021), che ha previsto la possibilità della riapertura del lotto II a valle di una serie di attività investigative e geognostiche sul lotto III, di eventuali ulteriori indagini ad esito dei primi accertamenti, dell'attuazione di eventuali misure di prevenzione ai sensi dell'art.240 del d.lgs. n.152/2006 e ss.mm.ii, della chiusura definitiva della discarica esaurita con le conseguenti attività di gestione post-operativa.
Il presente intervento presenta le molteplici attività di supporto tecnico-scientifico svolte da ARPA Puglia ed ancora in corso, con il

coinvolgimento di numerose professionalità, per la verifica dell'eventuale stato di contaminazione in collaborazione con Regione Puglia, Comuni interessati (Conversano, Mola di Bari, Polignano a Mare), CNR IRSA e AGER Puglia. Sono previste la valutazione dei risultati delle indagini geofisiche, le valutazioni tecniche per l'ubicazione e la realizzazione di nuovi piezometri, l'esecuzione dei campionamenti e delle analisi delle matrici ambientali (in particolare acque di falda), la definizione della necessità di ulteriori approfondimenti in relazione agli esiti delle attività svolte, l'effettuazione di sopralluoghi in campo, l'analisi della documentazione progettuale in atti.

Keywords: monitoraggio ambientale, discarica, verifica eventuale stato di contaminazione

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Applicazione per analisi e valutazioni territoriali basata su geodatabase open-source per la comprensione e il contrasto al fenomeno degli abbandoni nel territorio di Brindisi

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L' incontrollato abbandono dei rifiuti nelle aree urbane ed extraurbane provoca fenomeni di degrado e deturpamento del territorio. Un'attività di contrasto al fenomeno si sviluppa con l'individuazione dei siti, mappatura delle aree interessate dagli abbandoni, sensibilizzazione dei cittadini ed una successiva bonifica del sito inquinato con ripristino delle condizioni iniziali.
Lo sviluppo di una applicazione interamente basata su software open-source può fungere da DSS volto alla comprensione dei fenomeni in atto e fornire una risposta agli Amministratori. L'applicazione disegnata ed implementata principalmente attraverso su vfront, OpenStreetMap, Leaflet e PostgreSQL, ed in grado di fornire l'accesso diretto per la segnalazione in tempo reale degli abbandoni sul territorio, svolge anche l'importantissima funzione di coordinamento tra gli attori ai fini della predisposizione di strumenti e analisi, valutazioni territoriali e geospaziali per la comprensione e il contrasto al fenomeno degli abbandoni di rifiuti. La segnalazione dell'abbandono viene effettuata dalle FFOO dello Stato oppure dai funzionari abilitati ed anche da cittadini designati e avviene tramite inserimento di coordinate o perimetrazione delle aree interessate con l'aggiunta delle informazioni inerenti le caratteristiche del rifiuto, tipologia, stato fisico, putrescibilità, emissioni maleodoranti, stato di conservazione, presenza di amianto e altre informazioni utili a completare il quadro conoscitivo. Ogni singola segnalazione confluisce nella mappa complessiva dove è possibile visualizzare la distribuzione spaziale degli abbandoni e tutte le altre informazioni contenute nel sistema informativo territoriale, ad esempio le posizioni delle telecamere. Ulteriori elaborazioni dei dati basati su algoritmi di

machine learning permettono di individuare quali sono le componenti che maggiormente influenzano tali dinamiche, come ad esempio la possibilità di effettuare analisi di prossimità.
Lo scopo dell'applicazione è fornire una valutazione territoriale e geospaziale delle aree dove più spesso avvengono gli abbandoni operando con interventi mirati di prevenzione, bonifica e nuove tecnologie di presidio. L'applicazione è in fase di sperimentazione ed i risultati ottenuti confermano l'utilità per l'analisi territoriale per il contrasto ai fenomeni di degrado per individuare le aree sorgenti di produzione dei rifiuti ed intensificare le attività di indagine ottimizzando costi e tempi di intervento. Il fine è la creazione di una rete di vigilanza ambientale con misure di prevenzione e protezione a tutela dell'ambiente.

Keywords: *valutazione territoriale, abbandono rifiuti, applicazione, Brindisi*

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Uso della spettroscopia vis-NIR per la caratterizzazione di aree agricole potenzialmente contaminate

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La valutazione dello stato di qualità ambientale di aree potenzialmente contaminate destinate alla produzione agro-alimentare ai sensi del Decreto Ministeriale n. 46 del 2019 prevede l'adozione di specifici criteri e metodologie di indagine per la caratterizzazione dei suoli agricoli che, talvolta, richiedono tempi di acquisizione e di elaborazione piuttosto lunghi e costosi.
Nell'ambito di una delle prime applicazioni del D.M. 46/2019 ad un'area vasta potenzialmente contaminata prossima al SIN di Taranto, il CNR-IRSA di Bari ha sperimentato una metodologia di indagine innovativa, più rapida ed economica rispetto alle analisi tradizionali, che prevede l'utilizzo della spettroscopia nel dominio visibile-infrarosso vicino (vis-NIR) per la caratterizzazione dei suoli contaminati. Tale tecnologia, consente di valutare in modo rapido la natura e le proprietà chimiche, fisiche e mineralogiche dei suoli, e il loro stato di contaminazione.
Le misure di riflettanza spettrale, ossia del rapporto tra la radiazione incidente sul suolo e quella da esso riflessa, sono state condotte in laboratorio su 108 campioni compositi di suolo derivanti dalla miscelazione di campioni elementari prelevati in 73 aree-omogenee di indagine, individuate nella fase di caratterizzazione dei territori agricoli in esame secondo l'approccio definito dal D.M. 46/2019. Particolare attenzione è stata data all'analisi dei Policlorobifenili (PCB)

che, in alcuni campioni compositi, hanno mostrato superamenti della CSC normativa (6 ng/kg), con concentrazioni massime comprese tra 11,55 e 94,61 ng/kg.
Recenti studi condotti dal CNR-IRSA hanno infatti dimostrato che elevate concentrazioni di PCB possono influenzare il colore del suolo; pertanto, in suoli fortemente contaminati da PCB, è possibile stimare con buona accuratezza il contenuto di tali contaminanti attraverso una semplice determinazione dei parametri del colore per via spettroradiometrica; inoltre, relazionando statisticamente le misure di riflettanza spettrale ai risultati delle analisi chimiche di laboratorio, si possono calibrare modelli predittivi di alcuni congeneri di PCB applicando metodi statistici multivariati.
Considerate le sue potenzialità, la spettroscopia vis-NIR può rappresentare quindi una valida alternativa alle analisi tradizionali per indagini di suoli potenzialmente contaminati ed essere utilizzata sia per attività di pre-screeening dello stato di contaminazione dei suoli, sia per la caratterizzazione e le successive fasi di monitoraggio.

Keywords: caratterizzazione di aree agricole, D.M. 46/2019, Policlorobifenili

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La Cromatografia Liquida-Spettrometria di Massa e Massa Tandem come strumento per l'analisi dei pesticidi a livelli di tracce (sub µg/l) in corpi idrici superficiali e sotterranei della Regione Puglia

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L'ambiente acquatico, rappresenta una delle risorse ambientali più vulnerabile all'inquinamento fitosanitario. La Direttiva Quadro sulle Acque identifica un quadro di sostanze prioritarie da monitorare nei corpi idrici, introducendo il concetto di Standard di Qualità Ambientale (SQA) (D.lgs.172/2015). Grande importanza riveste la normativa europea sull'acqua potabile che fissa un limite di concentrazione di 0.1 µg/L per ogni pesticida e 0.5 µg/L per la loro somma. Il monitoraggio dei corpi idrici superficiali (Dir. 39/2013/UE, D.M. 56/2009, Dir.2006/118/CE) e sotterranei (D.M. 6/07/2016, D.lgs. 30/2009) necessita di un arduo approccio analitico per il raggiungimento degli SQA. In particolare, si richiedono metodi analitici in grado di raggiungere un Limite di Quantificazione (LOQ) pari o inferiore al 30% dei valori cogenti. I progressi nel campo della Cromatografia Liquida (LC) associata alla Spettrometria di Massa (MS) hanno favorito l'uso diffuso della tecnica nell'analisi dei pesticidi. La tecnologia UHPLC interfacciata ad uno spettrometro di massa a triplo quadrupolo (QqQ) con sorgente ESI (ElectroSpray Ionization) permette una quantificazione simultanea di un numero elevato di pesticidi mediante iniezione diretta del campione. Questa tecnologia risulta la più applicata per lo screening multiresiduale di molti pesticidi in acqua. Il CNR-IRSA mediante l'utilizzo di un UHPLC-MS/MS QqQ, è in grado di determinare una varietà di fitofarmaci a livelli di tracce nei corpi idrici predetti della Puglia. Abbiamo sviluppato la metodica per l'analisi multiresiduale, con iniezione diretta di un pool di 107 analiti, con un notevole risparmio di risorse e di tempo assicurando al contempo un dato robusto e raggiungendo LOQ inferiori rispetto a quelli cogenti.

Contestualmente abbiamo sviluppato single methods robusti per le molecole con proprietà chimiche particolari, raggiungendo anche in questo caso LOQ stringenti. Inoltre è stato possibile analizzare con successo anche molecole, la cui analisi in acqua risulta laboriosa e richiede una preparativa prima dell'analisi strumentale (Glifosato, Etefon). La tecnologia UHPLC-MS QqQ ha permesso di caratterizzare le acque della Regione Puglia secondo un piano di monitoraggio dei residui dei prodotti fitosanitari nei corpi idrici superficiali e sotterranei pugliesi (D.Lgs. n.150/2012 e del D.M. 22/01/2014). I dati analitici elaborati hanno evidenziato la presenza di alcuni pesticidi e il superamento dello SQA di altri, nei corpi idrici superficiali e sotterranei della Puglia.

Keywords: Pesticidi, Corpi Idrici, UHPLC-MS/MS, LOQ

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Tutela delle risorse naturali e territoriali attraverso l'analisi di immagini rilevate da piattaforme aeree per l'identificazione di condotte illecite legate alle attività estrattive

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La caratterizzazione degli illeciti in materia ambientale, in particolare nell'ambito delle attività estrattive, rappresenta una delle principali problematiche per la tutela del territorio. La tutela delle risorse naturali e territoriali si effettua con un monitoraggio del territorio, individuando la presenza di scavi sospetti totalmente o parzialmente abusivi e comportamenti illeciti e lesivi a danno del paesaggio e del patrimonio ambientale. La metodologia d'indagine si applica nella terza regione per numero di siti estrattivi, nello stato con la produzione di materiali lapidei maggiore al mondo. La regione Puglia conta circa 380 cave autorizzate e 2.500 cave dismesse, che inducono da tempo variazioni nella conformazione paesaggistica e nelle condizioni naturali dell'ambiente.

La proposta elaborata adopera tool di interoperabilità per interrogare differenti banche dati, ponendo a sistema le informazioni, per rilevare la presenza di scavi sospetti. L'utilizzo esclusivo di software open-source ha favorito l'implementazione di algoritmi di apprendimento automatico, che attraverso l'analisi di immagini rilevate da piattaforme aeree e satellitari sono in grado di rilevare la profondità del fondo e dei fronti di scavo con un certo margine di errore. Le fotografie aeree, dall'archivio documentale dell'IRSA-CNR e dalla banca dati della Regione Puglia, forniscono indicazioni attendibili in un arco temporale ampio dal 1988 ad oggi. Inoltre, sono state utilizzate anche le immagini radar ad apertura sintetica Sentinel-1 (programma Copernicus) che si sono rilevate un ottimo strumento per effettuare prime valutazioni sullo stato dei luoghi per ogni singolo bacino

estrattivo. La procedura messa a punto consente di minimizzare i costi delle campagne di monitoraggio sul campo che vengono effettuate in minima parte per validare gli algoritmi di classificazione.
I risultati ad oggi conseguiti hanno permesso di effettuare valutazioni di conformità dei bacini estrattivi pugliesi esaminati con i piani e le autorizzazioni regionali attivando i controlli in quelle aree che eccedevano i limiti autorizzativi imposti. Infine, si prevede di produrre mappe contenenti informazioni sull'evoluzione temporale di aree con presunte irregolarità, facilmente fruibili ad enti pubblici ed ai corpi armati dello stato.

Keywords: tutela delle risorse, cave, scavi abusivi, Puglia

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Monitoraggio dei soil gas mediante flux chamber aperta dinamica

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Verrà mostrata la tecnica di campionamento dei soil gas mediante Flux Chamber Aperta Dinamica, mostrando le attività preliminari al campionamento (mappatura sito mediante camera accumulo), progettazione della campagna, definizione della tecnica analitica più idonea in base alle finalità del monitoraggio, esecuzione dell'attività di campionamento e restituzione dei dati.

Keywords: Flux Chamber, Camera accumulo, Soil Gas

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Le più recenti metodologie geofisiche applicate allo studio dei siti inquinati e delle discariche

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Per attuare la bonifica di siti inquinati da discariche autorizzate o abusive, le Amministrazioni territoriali possono prescrivere al proprietario le indagini esplorative solo se sia stata già accertata con sufficiente approssimazione l'ipotesi di inquinamento dell'area.
È necessario caratterizzare gli inquinanti per individuare l'ubicazione e la natura dei rifiuti e la diffusione dell'inquinamento l'intera area, anche se indeterminata e molto ampia.
Le discariche autorizzate e in esercizio da diversi anni hanno dovuto eseguire le prescrizioni del D.P.R. n.915/82, hanno realizzato le opere per la Normalizzazione per il D. Lgs. 22/1997 e l'adeguamento al D. Lgs. 36/2003.
Le discariche autorizzate, ma chiuse prima del D. Lgs. 36/2003, sono sprovviste delle opere per la messa in sicurezza. In alcuni casi, le discariche sono caratterizzate da barriere a bassissima permeabilità realizzate con diaframmi continui di cemento/bentonite oppure diaframmi colonnari (jet-grouting), la cui integrità ed efficacia deve essere verificata e monitorata. Talvolta, lo stato della copertura di una discarica chiusa (capping), dopo alcuni anni può presentare danneggiamenti o lacerazioni, che devono essere individuati e riparati.
Le discariche abusive sono siti ad elevata criticità in quanto non si conosce la storia e la natura degli abbancamenti+. In questi casi, le aree da investigare per verificare la diffusione degli inquinanti e la natura degli stessi possono essere molto ampie o indeterminate, rendendo impossibile l'esecuzione di indagini dirette.
Le prospezioni geofisiche sono indagini indirette utilizzate nel campo dell'esplorazione geologica e per lo studio delle proprietà fisiche della terra, applicabili in aree molto ampie con tempi di acquisizione speditivi.
È d'uopo individuare la migliore metodologia per l'efficacia dell'indagine e di predisporre una accurata campagna di acquisizione per rilevare i dati caratteristici

Le prospezioni geoelettriche, georadar, elettromagnetiche e magnetometriche con drone permettono una caratterizzazione dei siti per ricostruire lo stato dei siti inquinati e determinare l'efficacia di eventuali opere di impermeabilizzazione. Nessun metodologia può essere completamente esaustiva, ma è prodromica per individuare eventuali criticità e ottimizzare la progettazione delle indagini dirette per la caratterizzazione analitica del sito e per la realizzazione di un efficace rete di monitoraggio e controllo.
Keywords: siti inquinati, prospezioni geofisiche

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Le potenzialità dei mitili: da bioindicatori dello stato di salute dell'ambiente a biomateriali nei processi di riqualificazione ambientale

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Negli ultimi anni, l'utilizzo di indicatori biologici ha assunto un ruolo significativo nell'ambito delle valutazioni integrate dello stato di qualità degli ecosistemi acquatici. I bivalvi, in particolare i mitili, sono in grado di riflettere la salute dei corpi idrici come un'istantanea nel tempo, grazie alla loro modalità di alimentazione, ampia distribuzione, reperibilità ed elevata tolleranza agli stress ambientali. Inoltre, sono noti per la loro capacità di accumulare metalli ed inquinanti organici persistenti nei tessuti, risultando degli utili strumenti per il monitoraggio dei trend spaziali e temporali delle concentrazioni dei contaminanti nell'acqua. Recentemente, le potenzialità di un biomonitoraggio attraverso i mitili sono state valutate anche per affrontare le incognite di rischio correlate alla presenza di inquinanti emergenti, come le microplastiche. Questi organismi rappresentano una risorsa in termini di qualità ambientale ma anche di economia circolare. La loro struttura protettiva, ricca di carbonato di calcio ed oligoelementi, sta attirando l'attenzione di numerosi ricercatori. Da prodotto di scarto, le conchiglie dei bivalvi possono essere impiegate in diverse applicazioni su larga scala. In campo agricolo, possono fungere da neutralizzanti di suoli acidi, ed associati ad altre sostanze, migliorarne il grado di fertilità. Tuttavia, nei suoli, la formazione di idrato di silicato di calcio e idrato di alluminato di calcio crea uno strato relativamente impermeabile riducendo la mobilità di metalli pesanti e la disponibilità di assorbimento da parte delle piante. Il sequestro dei metalli a livello della conchiglia viene favorito anche nei sistemi acquatici, conferendo a questa matrice un elevato valore in termini di riqualificazione ambientale. I gusci calcinati sono stati proposti come biofiltri per la rimozione

di altre sostanze come antibiotici, coloranti, fosfati dalle acque reflue domestiche ed industriali, ma anche come validi sostituti di alcune materie prime nel settore dell'edilizia. Molti processi di valorizzazione delle conchiglie sono ancora in fase di sperimentazione ed interessano l'ambito biomedico, cosmetico ed ambientale. Con le opportune valutazioni ed approfondimenti, le potenzialità di questi organismi possono, quindi, preannunciare lo sviluppo di promettenti approcci tecnologici, economici ed ambientali nell'ottica di un'ecologia umana sostenibile.

Keywords: inquinamento acquatico, biomonitoraggio, mitili, economia circolare

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La valutazione della sostenibilità lungo il ciclo di vita nella gestione dei rifiuti a seguito della recente approvazione del 'Programma nazionale per la gestione dei rifiuti'

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Il nuovo Programma Nazionale di Gestione Rifiuti (PNGR) rappresenta lo strumento di indirizzo per Regioni e Province autonome nella pianificazione della gestione dei rifiuti. Il PNGR, previsto dall'articolo 198bis della legge 152 del 2006 ed introdotto con il recepimento del pacchetto europeo per l'economia circolare a settembre 2020, è stato inserito dal governo nel Piano nazionale di ripresa e resilienza (PNRR) come una delle riforme principali della missione sull'economia circolare (M2C1). Il decreto per l'adozione del Programma è stato firmato a fine giugno 2022 (DM 257 del 24 giugno 2022), a seguito della conclusione della procedura di Valutazione Ambientale Strategica (VAS) (DM 230 del 10 giugno 2022), congiuntamente con quello relativo all'adozione della strategia nazionale per l'economia circolare. Segnale che la gestione dei rifiuti è strettamente correlata ad una strategia di riduzione alla fonte in ottica di prevenzione ed ecoprogettazione. Nello specifico, il programma vincolerà a confrontarsi con linee guida volte a garantire il raggiungimento di obiettivi di sostenibilità in materia di gestione rifiuti, tra cui la razionalizzazione e l'ottimizzazione del sistema impiantistico e infrastrutturale. Novità assoluta del PNGR è l'introduzione della metodologia LCA (Life Cycle Assessment) come strumento di indirizzo per la formulazione di strategie per una gestione sostenibile dei rifiuti, per la determinazione dei criteri per la definizione di macroaree e per la valutazione dell'autonomia regionale sulla gestione dei rifiuti. In particolare per i rifiuti organici, da gestire prioritariamente all'interno del territorio regionale al fine di limitarne il più possibile la

movimentazione, le Regioni devono verificare l'autonomia impiantistica e pianificare eventuali impianti necessari alla copertura del fabbisogno, "salvo l'elaborazione di una relazione tecnica supportata da uno studio LCA, finalizzata alla definizione di intese interregionali, che ne dimostri la compatibilità ambientale rispetto a categorie di impatto globale, regionale e locale (inclusi il riscaldamento globale e l'ecotossicità umana)". Nella comunità scientifica, è noto che la LCA, pur quantificando gli impatti ambientali potenziali, non fornisce valori assoluti e deve essere sempre utilizzata per analisi comparative. È pertanto auspicabile che la metodologia LCA sia usata come supporto metodologico, ma che le decisioni conseguenti si basino su studi puntuali effettuati a scala regionale e sottoposti a revisione critica, come richiesto dalle norme (ISO 14040-44). Per poter realizzare Piani Regionali coerenti con il PNGR è necessario quindi che la metodologia che sta alla base della definizione delle priorità e della gerarchia dei rifiuti sia condivisa con la comunità scientifica ed accademica, attraverso l'istituzione di un tavolo tecnico con le principali università e centri di ricerca italiani esperti del settore per la definizione di Linee Guida che ne garantiscano la scientificità e la confrontabilità (ad es. PCR, Product Category Rules, Solid waste collection, treatment and disposal services. The International EPD® System"). Tale tavolo tecnico è stato richiesto dalle osservazioni comprese nel parere CTVA n. 257 del 18 maggio 2022 (DM 230 del 10 giugno 2022) e dalle Regioni che, nella Conferenza Stato-Regioni del 21 giugno che ha sancito l'intesa sul PNGR, hanno evidenziato una serie di criticità, da affrontare nei successivi tavoli tecnici, tra cui il fatto che il PNGR non disciplina il procedimento amministrativo di coordinamento e approvazione di Piani regionali di gestione dei rifiuti che dovessero contemplare l'istituzione di macroaree per la gestione di flussi per il recupero energetico e per la gestione della frazione organica previa verifica con l'LCA.

Keywords: gestione rifiuti, Life Cycle Assessment, macroaree, PNGR

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Documento Strategico per contrastare il fenomeno del littering in Puglia

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La Regione Puglia con la deliberazione della Giunta Regionale n. 946 del 4 luglio 2022, si è dotata di un documento strategico teso a prevenire e contrastare efficacemente i fenomeni di smaltimento dei rifiuti, con un coacervo di azioni di prevenzione e di intervento mirate all'ottimizzazione dell'intero ciclo dei rifiuti, funzionale anche alla riqualificazione dei luoghi oggetto di smaltimento dalle periferie, alle aree rurali, ai margini delle strade, alle aree di particolare pregio naturalistico o lungo le coste. Un documento strategico di ampia collaborazione tra numerosi attori, al fine di amministrare le Istituzioni riservando una cura quotidiana della gestione dei servizi ma anche un'accresciuta capacità di previsione e di lungimiranza.
La Regione Puglia è da tempo fortemente impegnata nella tutela ambientale e paesaggistica del proprio territorio ed ha investito importanti risorse ai fini della vigilanza e controllo, con azioni di contrasto rivolte sia a comportamenti irrispettosi verso l'ambiente di normali cittadini (abbandoni tradizionali, sacchetti di spazzatura, ingombranti, etc…) che a sodalizi criminali impegnati in traffici illeciti nazionali ed internazionali. In particolare per questo ultimo aspetto la Regione Puglia si è resa promotrice di un Accordo di Programma Quadro per Tutela Ambientale che vede il coinvolgimento della Legione Carabinieri "Puglia", del Comando unità per la Tutela Forestale, Ambientale e agroalimentare Carabinieri, del Comando Carabinieri per la Tutela Ambientale e la Transizione Ecologica – Nuclei Operativi Ecologici di Bari e Lecce, della Guardia di Finanza, di Arpa Puglia e del CNR-IRSA, con attività di prevenzione e vigilanza che, integrate ad indagini di elevato rango condotte dalle Forze dell'Ordine, hanno conseguito ottimi risultati anche sul versante della rimozione dei rifiuti presso le aree segnalate.
Tra le priorità del documento strategico il potenziamento del presidio territoriale e della dotazione strumentale per il controllo e

monitoraggio degli abbandoni dei rifiuti, affiancando alla "Cabina di Regia" dell'Accordo Quadro, un "Tavolo Operativo permanente", quale ulteriore elemento di raccordo con la Vigilanza Ambientale regionale, ANCI, UPI, AGER, le Polizie locali, le Guardie Ecologiche Volontarie (GEV) ed i cittadini. Dotazione strumentale che si avvarrà di ulteriori videocamere che si sommeranno alle 1.811 già acquisite e distribuite da AGER ed integrate da microcamere mimetizzabili gestite da algoritmi di intelligenza artificiale in grado di rilevare e notificare situazioni di abbandono, al fine di perseguire gli autori di tali illeciti. Tali rilevazioni saranno integrate da immagini acquisite da mezzi aerei ad ala fissa e rotante, oltre che da droni. Il rafforzamento delle azioni di contrasto, sarà accompagnato dal potenziamento dei servizi utili al conferimento "legale" dei rifiuti da parte dei cittadini, attraverso un'organizzazione flessibile del servizio, opportunamente tarata sulle esigenze degli utenti e sostenuta ad un sistema di informazione permanente. In tale direzione sarà promossa la realizzazione di Carte dei Servizi Comunali e dei Centri Comunali di Raccolta (CCR), con orari e giornate di apertura coerenti con le necessità dei cittadini e che saranno ulteriormente ampliate in località balneari a turistiche, in cui potranno conferire anche cittadini di diversa residenza che avranno accesso ai servizi con CIE e CF. Ulteriore impegno riguarda la gestione del *marine litter*, favorendo la raccolta dei rifiuti portati a terra da pescatori e turisti.

Ultimo punto, non meno importante, riguarda la sensibilizzazione dei cittadini che andrà ad incidere sui comportamenti individuali e collettivi, accrescendo il senso di appartenenza ai territori e promuovendo la partecipazione attiva nella cura dei beni e degli spazi comuni. In particolare l'attività di educazione ambientale che rappresenta la principale leva di cambiamento, per un generale aumento di consapevolezza e di partecipazione da parte di tutta la popolazione, opportunamente amplificata attraverso un inedito sforzo di comunicazione verso la realizzazione di un pieno sviluppo sostenibile. Infatti non c'è piano o programma che possa produrre effetti concreti in assenza di un costruttivo dialogo tra istituzioni con la piena partecipazione dei cittadini: dialogo sostenuto da una solida visione valoriale, ispirata dal rispetto della persona, della natura, della vita.

Keywords: Abbandono rifiuti, smaltimento illecito, prevenzione, droni, videosorveglianza intelligente.

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Determinazione del valore di fondo naturale nei suoli per l'arsenico. Il caso studio del Comune di Livigno

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Il tema del fondo naturale nei suoli è richiamato più volte nella normativa di riferimento nazionale e regionale e l'Agenzia svolge un ruolo determinante nella definizione dei valori di fondo (si vedano ad esempio l'articolo 11 del DPR 120/2017 e l'articolo 242 ter, comma 4 bis, del d.lgs. 152/06).
In Regione Lombardia, sono disponibili conoscenze di dettaglio principalmente per le aree di pianura, ma queste sono per lo più orientate all'uso funzionale e sostenibile della risorsa a scopo agricolo e ad oggi non è disponibile una mappatura delle aree caratterizzate dalla presenza di concentrazioni di fondo naturale per alcuni inquinanti quali arsenico, nichel e cromo.
La presente attività si pone l'obiettivo di individuare una metodologia per la definizione dei valori di fondo naturale nei suoli da applicare in tutte le aree della Lombardia in cui sia rilevante tale problematica, al fine di pervenire ad una mappatura dei valori di fondo naturale e favorire la gestione sostenibile dei materiali da scavo e degli interventi di bonifica. Lo studio è stato sviluppato in conformità alle linee guida n. 8 del 2018 del Sistema Nazionale per la Protezione dell'Ambiente (SNPA).
L'area di studio indagata nel presente progetto è il territorio del Comune di Livigno che è stato scelto sulla base delle conoscenze pregresse a disposizione dell'Agenzia, che indicano la presenza diffusa di arsenico di origine naturale in tutta l'alta Valtellina, e per il fatto che esso potrà essere interessato, nei prossimi anni, da numerosi

interventi di riqualificazione, a seguito della sua designazione come una delle sedi dei Giochi olimpici invernali 2026.
Le concentrazioni di arsenico misurate sono risultate non conformi alle CSC per la destinazione d'uso verde pubblico, privato e residenziale nel 59% dei campioni analizzati; di questi, 9 campioni sono risultati non conformi anche per la destinazione d'uso commerciale e industriale. I risultati analitici confermano quindi la presenza diffusa di arsenico nei suoli in concentrazioni spesso superiori ai limiti di legge, ma, poiché sono stati campionati i suoli in aree naturali e poco rimaneggiate da interventi antropici e nell'area sono assenti sorgenti legate ad attività produttive o depositi incontrollati di rifiuti industriali, è possibile assumere i valori di concentrazione misurati come determinati da fattori naturali.
I dati risultanti sono stati quindi analizzati sia dal punto di vista puramente statistico che integrando le conoscenze pedologiche e geologiche raccolte in campo, per individuare i fattori che hanno contribuito alla distribuzione delle concentrazioni di arsenico misurate e definire un valore rappresentativo del fondo naturale.
In prima approssimazione, si è osservato che le concentrazioni di arsenico misurate all'intorno dell'abitato di Livigno hanno un valore medio superiore (circa 35 mg/kg) e una deviazione standard più elevata di quelle misurate nei campioni di Trepalle (circa 13 mg/kg). L'analisi dei dati fa ipotizzare che tale differenza sia legata principalmente alla litologia del materiale parentale dal quale il suolo si è originato e sia influenzata, in secondo luogo, dai processi di erosione e trasporto sia di tipo fluviale che glaciale. I campioni con concentrazioni di arsenico inferiori, infatti, sono stati prelevati su depositi di natura eluvio-colluviale, la cui genesi è riconducibile all'evoluzione pedogenetica del substrato roccioso costituito da rocce metamorfiche, mentre i campioni con le concentrazioni di arsenico più elevate si concentrano lungo piana di Livigno e sono riconducibili alla Falda tettonica di Languard, costituita principalmente da gneiss, micascisti e quarziti; tra questi campioni, le concentrazioni più elevate sono state misurate nei campioni provenienti da depositi di conoide, mentre quelle inferiori da depositi di piana alluvionale.
Nonostante quanto sopra osservato, si è ritenuto sufficiente proporre, in prima istanza, un unico valore rappresentativo del fondo naturale dell'arsenico nei suoli sull'intero territorio indagato, in quanto non si hanno, ad oggi, elementi sufficienti a discriminare in modo netto aree con concentrazioni di arsenico differenti. Questa scelta è supportata

anche dall'analisi statistica dei dati, in quanto, rappresentando i dati attraverso un QQ plot, si osserva un andamento continuo assimilabile ad una distribuzione normale (coefficiente di correlazione R pari a 0,958), il cui 95° percentile è pari a circa 56 mg/kg, che è stato assunto come valore di fondo per l'area indagata.
Il lavoro è stato consegnato al Comune di Livigno e alle associazioni di categoria corredato di Norme Tecniche di Attuazione, al fine di fornire loro una guida all'utilizzo del valore di fondo determinato che fosse chiara ed esaustiva.

Keywords: Valori di fondo, arsenico, suoli

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Acque ad uso umano e contaminanti ubiquitari: PFAS e Bisfenolo A, dal testo della nuova direttiva ai test di laboratorio

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La nuova Direttiva europea sulle acque ad uso umano 2020/2184 propone un approccio alla sicurezza dell'acqua potabile basato sul rischio, attraverso la valutazione dei vari bacini idrografici, sia nei punti di estrazione che nel sistema distributivo.
Affronta inoltre la questione dei contaminanti emergenti, sostanze scarsamente o per nulla normate in maniera armonizzata in Europa, ma che pongono serie preoccupazioni in termini di sicurezza a causa della loro presenza ubiquitaria e degli studi che ne confermano la pericolosità per la salute.
Tra questi i PFAS e il Bisfenolo A, accomunati, tra i vari aspetti, proprio dal fatto che precedentemente la loro concentrazione nelle acque non era normata, e dalla sfida che pongono in termini di rilevazione analitica.
Non si tratta degli unici contaminanti emergenti posti sotto la lente di ingrandimento: la Decisione di esecuzione (UE) 2022/679 integra il controllo di altri composti che destano preoccupazione (già citate nella suddetta Direttiva Europea): 17-betaestradiolo e nonilfenolo, determinando ulteriore chiara evoluzione normativa a riguardo delle acque destinate al consumo umano.
Attualmente non esiste una legislazione armonizzata che regolamenti la presenza nei PFAS nel packaging alimentare. Esistono due differenti regolamenti per gli alimenti e per le acque ad uso umano. Nell'attuale draft sugli alimenti i limiti arrivano anche a 0,1microgrammi/chilogrammo. Come non pensare che in tutti i comparti (alimentare, acque, packaging) sarà indispensabile ragionare su limiti e molecole, visto che l'origine stessa dei PFAS non intenzionalmente aggiunti in un comparto potrebbe derivare da un altro? – negli alimenti e nel packaging dall'acqua, o, al contrario, negli alimenti dal packaging e dall'acqua, ecc.

Lo standard è un riferimento che consente di basarsi su elementi comuni, che rende comparabile l'analisi, che garantisce dei punti fermi. In mancanza di questo, ci possono essere svantaggi e vantaggi legati alla scelta dei metodi, si devono fare magari, compromessi tra selettività e inclusività.
Per i PFAS, l'approccio con metodo LC-MS/MS, può essere un vantaggio in termini di sensibilità e selettività: questa tecnica può aiutare a rilevare e quantificare con precisione i livelli di PFAS a bassa concentrazione. Ma quali molecole scegliere in un panorama di contaminazione così ampio?
Altre tecniche danno un'indicazione della quantità totale di specie perfluorurate in un campione, ma non del tipo, e possono non tenere conto di alcuni precursori.
In alcuni casi le indicazioni locali hanno indicato la strada al laboratorio: in Veneto viene indicato il metodo ISO 25101:2009, con tecnica HPLC MS/MS che consente di arrivare a rilevare concentrazioni anche di 0,001microgrammi/chilogrammo.
Il laboratorio è un osservatorio privilegiato di fronte a contaminazioni dell'acqua che possono influenzare anche altri comparti, come quello alimentare. E' anche luogo di sperimentazione di metodi e può investire sulla migliore delle tecnologie esistenti per arrivare a limiti di concentrazioni molto basse.
Di fronte a contaminanti che pongono una sfida in termini di metodo di analisi, in cui l'Europa stessa nel legiferare si pone l'obiettivo futuro di condividere un metodo unitario idoneo (es. per il monitoraggio dei contaminanti ubiquitari in acqua), il laboratorio non può che cercare la strada che ritiene più affidabile e, appena individuato il metodo condiviso, orientarsi su quello, al fine di ottenere risultati rappresentativi e comparabili.

Keywords: PFAS, Bisfenolo A, LC-MS/MS

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Modellazione idrogeologica – Case study Acciaierie d'Italia

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L'attività di elaborazione del modello geologico 3D è stata sviluppata nell'ambito del contratto stipulato tra Arcelor Mittal, ora Acciaierie d'Italia (AdI), e Eni Rewind, nel 2020. Eni Rewind è advisor ambientale di Acciaierie d'Italia con lo specifico scopo di definire, a livello complessivo, un percorso che accompagni AdI nell'iter autorizzativo definito dalla 152/06 per la Messa in Sicurezza Operativa del sito.
Tale percorso prevede la realizzazione di una serie di attività di progettazione che, partendo dalla caratterizzazione, attraverso la modellizzazione e lo sviluppo del modello concettuale definitivo del sito e l'elaborazione dell'analisi di rischio, condurranno alla Messa in Sicurezza Operativa. Le attività descritte includono inoltre il supporto ad Acciaierie per tutte le fasi di permitting necessarie nel corso dello sviluppo dell'iter ambientale secondo D.Lgs. 152/06.
Vista la complessità e l'estensione del sito su 1500 ha, e la numerosità dei dati presenti nonché la necessità di aggiornare ed integrare il modello concettuale di sito, come primo passo, è stato sviluppato il modello geologico finalizzato alla descrizione e rappresentazione della sequenza degli orizzonti litologici e delle loro interconnessioni, determinandone caratteristiche e relazioni con il comparto acquifero. Eni Rewind ha pertanto sviluppato un modello geologico in tre dimensioni per rappresentare la geologia dell'area e poter visualizzare in modo chiaro formazioni geologiche, strati di riporto, sviluppo degli acquiferi superficiale e profondo.
Preliminarmente alla modellazione si è proceduto alla raccolta di tutte le informazioni necessarie disponibili, sia con il contributo di Acciaierie d'Italia, sia attraverso la collaborazione con altri enti che in passato hanno lavorato sull'area, e alla digitalizzazione del materiale reperito ed alla relativa organizzazione in specifici database in cui sono state catalogate le informazioni di dettaglio di oltre 3200 punti di indagine ambientale realizzati dal 2005 ad oggi.

Tale base di dati ha consentito quindi di costruire un modello che ha compreso anche aree esterne al perimetro dello stabilimento di Taranto, così da avere maggiore dettaglio anche sulle zone di confine dello stesso; il dominio oggetto di modellazione ha un'estensione totale pari ad oltre 4.000 ha circa, di cui oltre 1.000 ha ricadenti all'interno del SIN (Sito di Interesse Nazionale). Dall'analisi delle stratigrafie, sono stati selezionati quasi 7.400 orizzonti litologici, distribuiti in 7 unità litostratigrafiche differenti, descritte nel dettaglio sino mediamente a 30 metri da piano campagna e in alcuni casi fino a raggiungere i 140 metri di profondità. Le unità stratigrafiche al loro interno comprendono un acquifero superficiale avente estensione limitata e discontinuità spaziale e valori di carico idraulico massimo intorno ai 17-18 metri ed un acquifero profondo, o carbonatico, che raggiunge anche i 60 metri di profondità da p.c.. Il tutto costituisce quindi un complesso sistema altamente eterogeneo, le cui caratteristiche interconnesse fra loro sono state rappresentate negli output del modello stesso. I risultati ottenuti sono stati poi sottoposti ad un ulteriore processo di consolidamento attraverso un confronto con Acciaierie d'Italia che ha messo a disposizione le proprie conoscenze acquisite nel corso di anni di attività di studio sul sito e ha permesso un ulteriore affinamento della modellazione nelle fasi finali del lavoro.

Il risultato ha molteplici potenzialità a partire dai database creati, che oggi sono fruibili non solo a scopi modellistici, ma anche come punto di riferimento per la ricerca delle informazioni litologiche di sito

Considerate le caratteristiche dell'area oggetto di studio e tenuto conto del numero elevato di informazioni elaborate, lo studio realizzato per AdI è un esempio del livello che Eni Rewind può raggiungere nel campo della modellazione geologica di un sito e, disponendo ora anche degli strumenti in house e sofisticate competenze interne, può essere replicato per siti di complessità significativa.

Keywords: Modellazione idrogeologica , Acciaierie d'Italia, *Taranto*

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Il monitoraggio degli ambienti acquatici con Openswap – il primo ASV made in Italy

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OpenSWAP è il primo ASV (Autonomous Surface Vehicle) completamente Made in Italy e realizzato con tecnologie Open Hardware & Software. Può essere impiegato per il monitoraggio geofisico (e non solo) degli ambienti acquatici - compreso quelli di difficile accesso - ed è aperto ad applicazioni custom in base alle applicazioni desiderate. OpenSWAP è un catamarano corredato da 4 motori brushless, dal peso complessivo ridotto e che si distingue per la modularità, l'elevata autonomia, la stabilità, l'ampia capacità di carico ed il basso pescaggio. Il veicolo si presenta come un catamarano in plastica con scafi asimmetrici progettati per minimizzare la turbolenza nello spazio centrale immerso, e ottimizzare cosi l'utilizzo e l'installazione di sensoristica di vario tipo, in primis quella geofisica. La scelta del catamarano garantisce una maggiore stabilità in navigazione, rispetto all'utilizzo di un singolo scafo.

L'utilizzo di 4 motori brushless garantisce una ridondanza sia nella potenza erogata in proporzione al peso, che in caso di avaria di un motore. L'algoritmo di guida infatti consente di gestire al meglio la navigazione anche in caso di guasti. Il software di controllo OpenSWAP-NAV, a tecnologia GIS, consente di gestire il veicolo in tempo reale, di pianificare le rotte, di controllare i sensori di bordo e i dati acquisiti. Il sistema di navigazione è a scelta dell'operatore: completamente autonomo, manuale o con assistenza dell'heading. Il cuore del veicolo è basato su una mainboard che ospita 2 Arduino DUE ed una Raspberry Pi4 in grado di gestire sia la navigazione che la sensoristica di bordo. L'elevata versatilità della mainboard permette di interfacciare sensori esterni grazie a connessioni LAN – WLAN – porte seriali, digitali e analogiche nonché a GPS esterni con standard di trasmissione NMEA. Il sistema base di posizionamento è costituito da una doppia antenna GPS che fornisce true- heading ed una precisione HDOP < di 2m. Per standard idrometrici di maggior

accuratezza è disponibile un sistema GPS ausiliario con precisione centimetrica che si avvale della correzione NTRIP da rete GSM. Il ponte radio WLAN a 2.4 GHz consente di trasferire i dati dei sensori al laptop di controllo mentre la telemetria è garantita da una connessione radio 433 MHz o 868MHz con portata di alcuni km in linea di vista per la gestione della navigazione. Il sistema è alimentato da pacchi batterie Li-PO con singoli moduli da 20 A, che possono essere usati in parallelo da un minimo di 2 fino ad un massimo 8 moduli, in caso dell'utilizzo di sensoristica energivora.
OpenSWAP è un veicolo autonomo di superficie che si caratterizza per: la versatilità della meccanica, dell'elettronica, e del software; l'ampio spazio presente negli scafi e al di sotto del vano centrale che consentono il facile interfacciamento di svariate tipologie di strumenti commerciali come ad esempio side-scan sonar, multibeam, sonde multiparametriche, correntometri ADCP e campionatori d'acqua.
Sono state commercializzate versioni del veicolo equipaggiate con strumentazione sviluppata ad-hoc: i) sistema di acquisizione di dati batimetrici (single-beam 50-200kHz con bottom-tracking e registrazione dell'ecogramma in formato geofisico SEG-Y), ii) moduli di campionatori di acqua superficiale (totale di 500ml a campionatore con doppia siringa, il veicolo ne può ospitare fino a 4), iii) sub-bottom profiler a tecnologia chirp per acque basse.
Sono in fase di rilascio nuovi applicativi WebGIS per la visualizzazione in tempo reale dei dati acquisiti dal veicolo tramite piattaforme opensource (es. QGIS).

Keywords: ASV,ROV, monitoraggio acque, sensoristica

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TETI - TEcnologie innovative per il controllo, il moniToraggio e la sIcurezza in mare

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Il Progetto TETI è un progetto di ricerca sviluppato da una compagine di progetto ampia e che abbraccia le competenze presenti su gran parte del territorio nazionale che vede Ambiente tra i soggetti proponenti e che ha per obiettivo lo studio e lo sviluppo di tecnologie innovative da impiegare nel monitoraggio ambientale e nella sicurezza in mare per la navigazione e per il controllo dei rischi. Si vuole contribuire a ridurre il gap esistente nei processi di controllo remoto e soprattutto migliorare l'interazione e l'integrazione dei dati, soprattutto di tipo ambientale per l'integrazione in aree ad intensa attività antropica come marine e aree portuali, finalizzato alla riduzione dei rischi ed alla salvaguardia dell'ambiente marino costiero e di mare aperto.

Nello specifico si propongono sensori di tipo ottici, optoelettronici o fotonici, elettrochimici, acustici, nonché biosensori con differenti tipi di biomeditori per il riconoscimento di differenti tipi di contaminanti ambientali. La validazione del dato verrà effettuata con un monitoraggio discontinuo, attraverso procedure di campionamento, e attraverso un monitoraggio biologico con l'uso di organismi bioindicatori, opportunamente alloggiati prevalentemente sui sistemi fissi. I bioindicatori (mitili, alghe) permetteranno di accumulare dati di risposte a diversi livelli dell'organizzazione biologica e alle diverse condizioni ambientali, con tempi brevi e alto grado di sensibilità.

Altra finalità è la realizzazione dell'elettronica (a basso consumo energetico), d'interfacciamento, (wireless con protocolli per lunghe distanze) e controllo dei sensori proposti, con lo scopo di progettare il sistema di acquisizione e di verifica dei parametri. Lo sviluppo di una piattaforma IoT integrata per la gestione flessibile e omogenea negli ambienti rilevanti con protocolli di comunicazione (LoRa) che renderanno fruibile l'intero set di dati in tempo reale.

Un'ulteriore finalità del progetto è l'interazione tra boe modulari per il monitoraggio ambientale e la fornitura di servizi, relativa costruzione e installazione in ambiente rilevante, con la progettazione integrata di veicoli marini autonomi sostenibili ed efficienti per il monitoraggio, l'analisi e il controllo di ambienti a rischio come le carene di grandi navi e/o i bacini portuali. Tutto ciò in un quadro di elevata sostenibilità, con sistemi elettrici efficienti per il recupero dell'energia, al fine dell'auto alimentazione di dispositivi di misura e monitoraggio a bordo di boe intelligenti e per la generazione, la gestione e la propulsione elettrica nei veicoli marini autonomi (DRONE e ROV).
"Flessibilità", "Modularità" e "Sostenibilità" sono i principi ispiratori dello sviluppo dei sensori e degli oggetti che li integreranno. La natura di ricerca del progetto non può prescindere infatti da una struttura che possa essere flessibile rispetto ai risultati raggiunti dal singolo gruppo di lavoro in termini di maturità del prodotto prototipale; flessibilità intesa anche come adattamento a campi di applicazione che per ora sono stati identificati nelle marine e nei porti di piccole-medie dimensioni, ma che potrebbero trovare altri mercati con uno sforzo di integrazione e di aggiornamento delle interfacce e della sensoristica limitati e a basso costo.
Il progetto è attualmente nella fase di sviluppo e di validazione della sensoristica di bordo e i sistemi fissi e mobile sono a stadi di progettazione preliminare e dimensionamento di massima, mentre i sistemi di trasmissione dati e la dashboard di controllo dell'utente sono a un buono stato di definizione.
La validazione dei risultati di progetto è prevista per l'estate del 2023 in ambiente reale di applicazione.

Keywords: ROV, monitoraggio

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Monitoraggio dei valori di radon nelle matrici ambientali: un nuovo strumento per la mappatura dei plume di contaminazione da idrocarburi

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Nella presentazione viene illustrato un metodo di indagine innovativo, messo in atto grazie alla collaborazione tra Mares S.r.l., il Centro Nazionale delle Ricerche e l'Università degli Studi di Roma Tre, finalizzato alla mappatura dei plume di contaminazione attraverso la misura dei valori di radon (222Rn) determinati sulle diverse matrici ambientali e confrontati con i valori di fondo naturale del Rn nell'area in esame. Il metodo si basa sulla caratteristica del gas di essere molto più solubile nella contaminazione da idrocarburi in fase separata (NAPL – Non-Aqueous Phase Liquid) che nell'aria o nell'acqua. Pertanto, in caso di uno sversamento da idrocarburi di origine petrolifera, il Rn naturalmente presente nel sottosuolo rimane intrappolato all'interno del NAPL, determinando una riduzione locale della concentrazione di Rn in corrispondenza dell'area contaminata. Vengono in particolare mostrati i risultati ottenuti in casi di applicazione reale della metodica su siti contaminati da idrocarburi.
La determinazione del valore di Rn nelle matrici ambientali viene effettuata prelevando campioni che vengono poi analizzati tramite spettrometria gamma ad alta risoluzione o spettrometria alfa a seconda della matrice. Nei casi di studio sono stati analizzati sia campioni di gas interstiziali del sottosuolo che campioni prelevati dalle acque di falda in più punti e a varie profondità, con lo scopo di mappare la concentrazione di Rn, e di conseguenza anche di contaminazione, sia arealmente che verticalmente.
In aggiunta, attraverso il metodo del deficit di radon è possibile calcolare analiticamente anche il valore di saturazione dell'olio nel terreno (o nelle acque) e stimare di conseguenza i volumi di contaminazione coinvolti nel sottosuolo.

In definitiva i dati ottenuti utilizzando la tecnica innovativa di misurazione del Rn nel nelle matrici ambientali applicata alla caratterizzazione dei siti contaminati da idrocarburi, mostrano come questa sia un valido strumento indiretto e poco invasivo per la stima dell'estensione areale e verticale della contaminazione in tali matrici.

Keywords: Radon, Plume, idrocarburi, monitoraggio

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NORBIT Real-Time Dredging Monitoring

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The traditional dredge & survey scheme is operationally costly as well as time-consuming for the dredging companies as every time when there is a need to QC the are a new survey needs to be done.

Taking advantage of technology proven in the bathymetry survey market NORBIT has introduced a turnkey real-time monitoring system called iSTX360, for dredging, rock dumping, and cable laying applications.

Over the past two years, a dredging monitoring software called NORdredge has been developed and successfully lunched, which constitutes a turn-key solution facilitating the software counterpart to existing proven hardware components. NORdredge allows for fast-paced real-time dredging monitoring that provides instantaneous information to the operators about the bathymetry and mission progress and allows for corrective actions on spot without additional PRE- or POS- surveys. The web-based interface allows the operator to keep only the rugged tablet in the dredger cabin with a simple web browser operating the whole system. Since it is based on web technology it allows other terminals, used by the superintendent or survey manager in the office, to connect to the same underlying data (Postgres/PostGIS database and GeoServer) via WMS and WFS interface. They can prepare templates, centerlines and seamlessly access the data with the GIS software of their choice and prepare reports and perform other manipulation of the data.

This integrated hardware and software solution has been used in many projects around rivers, ports, and harbors, which will be outlined in this presentation. These projects have taken advantage of the real-time monitoring capabilities of NORdredge to efficiently remove or add material in multiple dredging scenarios, thus improving the overall efficiency of the operation.

Keywords: monitoraggio, sonar

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Caratterizzazione del carbonio in suoli di aziende selvicolturali montane in Emilia-Romagna

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A livello globale si stima che nei suoli siano sequestrati quasi 2400 miliardi di tonnellate di carbonio organico, pari circa al quadruplo del carbonio atmosferico (CO2). Nel corso degli ultimi decenni lo sfruttamento intensivo dei suoli ha provocato in molte aree una generalizzata perdita di sostanza organica nei suoli, con conseguente diminuzione di fertilità e produttività delle colture. Inoltre, queste dinamiche degradative comportano l'emissione di gas a effetto serra in atmosfera (es. CO2) che accelerano il fenomeno del surriscaldamento globale. Pertanto, la comunità scientifica sta ponendo sempre maggiore attenzione allo studio della sostanza organica dei suoli (SOM - Soil Organic Matter) al fine della sua conservazione e/o incremento. Alla Convenzione delle Nazioni Unite sui cambiamenti climatici tenutasi a Parigi nel 2015, si è stimato che se si riuscisse ad aumentare ogni anno del 4 per mille (4‰) la quantità di carbonio nei suoli si potrebbero contrastare le emissioni annuali prodotte dai combustibili fossili. Su tale base le Politiche Agricole Comunitarie (PAC) istituite per il periodo 2020-2027 incentivano gli agricoltori a adottare lavorazioni conservative volte all'accumulo di SOM e alla mitigazione dei cambiamenti climatici.
Il confronto dei campioni raccolti in tre differenti contesti aziendali nel 2020 e nel 2021, dopo un anno e dopo un intervento di diradamento, mostrano situazioni diverse nelle tre aziende:

- i campioni di suolo dell'azienda "Branchicciolo" mostrano una diminuzione della concentrazione di tutte le forme di carbonio organico nel tempo dato che i valori medi di OC, TOC400, ROC diminuiscono dal 2020 al 2021 e i valori isotopici di C diventano meno negativi probabilmente per un minore apporto di sostanza organica fresca;

- i campioni di suolo dell'azienda "Beghelli Fabio" mostrano una situazione stabile, dato che i valori i valori medi di OC, TOC400, ROC, 13C/12C non hanno subito variazioni dal 2020 al 2021;
- i campioni di suolo della cooperativa "Montana Valle del Senio" mostrano un aumento di carbonio organico nel tempo dato che i valori medi di OC, TOC400, ROC aumentano dal 2020 al 2021 e i valori isotopici di C diventano più negativi probabilmente per un maggior apporto di sostanza organica fresca.

Il decremento di C organico all'interno dell'azienda Branchicciolo potrebbe essere dovuto al minor contenuto di argilla e più alto contenuto di sabbia che rende il suolo un ambiente più ossidante e meno propenso alla stabilizzazione del C organico, e che promuove il processo di mineralizzazione della SOM. A causa dell'intervento di diradamento, l'elevato tasso di mineralizzazione della SOM potrebbe non essere stato più controbilanciato dall'apporto di sostanza organica fresca proveniente dalla copertura arborea. Nell'azienda Beghelli, invece, nonostante il diradamento, il mantenimento del C organico nei propri suoli potrebbe essere legato al maggior contenuto di argilla che permette la stabilizzazione della SOM. Il suolo della cooperativa Montana Valle del Senio, invece, sebbene abbia una tessitura povera di argilla, preserva il C organico grazie alla pendenza bassa del sito di indagine che non ha innescato significativi fenomeni di erosione. È importante quindi che in un contesto di cambiamento climatico, quale stiamo vivendo, le aziende selvicolturali montane adattino i propri sistemi di gestione del suolo in favore di pratiche agricole sostenibili che prendano in considerazione la componente suolo e la topografia del territorio. In tale contesto, una prerogativa della PAC sta nel definire nuovi metodi per determinare e misurare la quantità di C che effettivamente viene sequestrato nei suoli.. Ripetere analisi geochimiche come quelle eseguite in questo lavoro nel tempo (3-5 anni) per un monitoraggio del C, delle pratiche colturali e delle variazioni climatiche in atto, potrà essere utile per stimare un bilancio del C, finalizzando così le iniziative descritte negli ecoschemi per un'agricoltura e silvicoltura sostenibile.

Keywords: Carbonio, suolo, PAC, Ecoschemi

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La piattaforma EDSS per la creazione dello scenario di evento in sala operativa. Strumenti collaborativi per il supporto alle decisioni ed il monitoraggio di eventi a forzante meteorologica ad elevato impatto

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Sempre più spesso si ha la necessità di acquisire informazioni in breve tempo che possano aiutare a costruire lo scenario di evento in caso di catastrofi naturali o eventi estremi che impattano su aree antropizzate. Prendendo spunto dal Sendai Framework for Disaster Risk Reduction (UNDRR), dove la comunità internazionale ha dato valore totale ai social network, sono stati connessi alla piattaforma EDSS (Emergency Decision Support Systems) sia fonti istituzionali, come le reti di monitoraggio dei Centri Funzionali, sia connettori social, al momento facebook, twitter, youtube.
In questo articolo presentiamo la piattaforma EDSS realizzata con il supporto del progetto E- CITIJENS finanziato dal fondo di cooperazione internazionale Italia-Croazia e più in particolare i risultati raggiunti con le componenti aggiuntive alla piattaforma, finanziate dal del progetto TO BE READY con il fondo di cooperazione internazionale Italia-Albania-Montenegro.
Scopo della piattaforma denominata EDSS quello di omogenizzare dati geolocalizzati e quindi riconducibili ad una posizione x, y, classificarli in funzione di algoritmi semantici che attribuiscono dei pesi in funzione di valori preassegnati, attribuzione di un grado di gravità dell'evento, incrocio e confronto con eventuali dati registrati da fonti istituzionali e, nel più breve tempo possibile, creare uno scenario di evento che possa consentire all'operatore di sala operativa di attivare le risorse idonee a fronteggiare l'emergenza specifica.
Dopo le limitazioni sulla ricerca di dati da parte di alcuni social (limitazione pra, tipo facebook, con il progetto To Be Ready è stata realizzata una app mobile che consente di monitorare eventi registrati

sul territorio attraverso l'azione collaborativa di soggetti laici (sensori mobili) che inviano informazioni e dati.
I risultati attesi da questa piattaforma sono principalmente di duplice natura, il primo è quello di creare uno scenario di evento per l'operatore di una sala operativa che deve prendere una decisione in brevissimo tempo che sia adeguata all'esigenza e congrua in termini di risorse. Spesso si verifica un eccesso di risorse inviate per una sovrastima di gravità o al contrario, una insufficienza di risorse per una carenza di informazioni.

Parallelamente con le componenti aggiuntive della piattaforma si vuole raggiungere un secondo obiettivo fondamentale, quello di andare a monitorare quei fenomeni fin ora poco attenzionanti per carenza di sensori standard sul territorio, come ad esempio le grandinate, o le nevicate a bassa quota. Fra l'altro con una minima formazione di operatori volontari, collaboratori della piattaforma e formati sul tema delle misure meteo, si possono monitorare dati utili in vari settori oltre a quello più classico della meteorologia applicata come ad esempio l'altezza della nella neve alle basse quote e la densità, per cui con un riflesso di interesse di informazione nel campo delle scienze ingegneristiche o di quelle assicurative.

Keywords: crowdsourcing, social media, emergency management, Decision Support Systems, allertamento, eventi ad elevate magnitude

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Una piattaforma digitale per conoscere la dismissione dell'amianto nelle navi

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AMINAVI è una piattaforma digitale in progress, la cui architettura consente l'archiviazione e l'interrogazione di dati e documenti relativi alle navi militari e mercantili italiane a partire dal 1900 ad oggi. Il progetto si inserisce in un percorso avviato da tempo, da un gruppo di ricerca dell'Istituto Ingegneria del Mare del CNR, sul tema della rimozione dell'amianto.

L'uso dell'amianto, trova nell'industria navalmeccanica dagli inizi del 1900 un ambito privilegiato per le sue qualità di prodotto termoisolante ed ignifugo nonché per la sua bassa densità per minimizzare il peso complessivo dell'imbarcazione. Veniva ampiamente usato per le paratie e i ponti, per le guarnizioni, i tubi e i macchinari e per materiali d'attrito. Anche nei sommergibili veniva utilizzato l'amianto nei trattamenti anticondensa per rivestire lo scafo, al fine di garantire la vivibilità degli spazi interni. La Legge 257 del 1992 pose fine alla produzione e commercializzazione di prodotti contenenti amianto.

L'esposizione professionale ad amianto ha interessato i lavoratori addetti alla costruzione, riparazione navale e personale imbarcato. La lunga latenza delle patologie asbesto correlate, oggi stimata dal Re.Na.M. (Registro Nazionale Mesoteliomi) a 46 anni, ne fanno un problema attualissimo, le cui informazioni ancora oggi, nel settore marittimo, sono parziali e frammentarie.

La raccolta e catalogazione delle informazioni di ciascuna unità navale, ad esempio Varo, Radiazione, Cantiere di Costruzione, Rapporti delle Attività bonifica, ecc., oltre a permettere il recupero di dati sommersi, consentono di delineare una visione d'insieme ad oggi mai realizzata. Attualmente nella Banca dati sono raccolti dati di 986 unità navali della Marina Militare, e dati di 356 unità navali Marina Mercantile per un totale complessivo di 1342 unità.

Dall'interrogazione di AMINAVI risultano attualmente in circolazione 161 unità della Marina Militare con presenza di amianto a bordo (realizzate prima della L. 257/92) . Ad esempio cliccando sul nome della nave Artigliere F582, risulta un Pattugliatore di squadra, impostata nel 1982, varata nel 1983, entrata in servizio nel 1994 e radiata nel 2013. L'equipaggio era composto da 16 ufficiali e 169 tra marinai e sottoufficiali. Quanto alla presenza di amianto, risultano effettuati dei lavori di bonifica presso l'Arsenale di La Spezia nell'anno 2001 e 2002, volti ad eliminare sia le guarnizioni contenenti amianto sulle flange delle condotte di scarico delle calderine Stone Plate, sia le calotte spegni carico in amianto su interruttori elettrici. Dai verbali dell'ispezione visiva a bordo dell'unità nel 2008 e dalle analisi di laboratorio dei campioni prelevati, risulta; "la presenza di manufatti in amianto nella stiva in particolare di giunti, ferodo freno, guarnizioni, piastre di cucina, del tipo crisotilo". I campionamenti di fibre aerodisperse effettuati a bordo nel locale mensa dell'equipaggio, per un totale di 480 litri campionati, non hanno rilevato il superamento del limite di soglia di 20 ff/l come previsto dal D.M. 06/04/94.

L'interrogazione della banca dati, una volta completata, non solo potrà delineare un quadro d'insieme mai oggi realizzato, ma permetterà di fornire stime attendibili sulla dismissione dell'amianto nel settore marittimo e sulle bonifiche utili anche al monitoraggio di patologie asbesto-correlate condotte dagli Enti competenti (Ministero della Salute, Re.Na.M. dell'INAIL, Centri Regionali Amianto, ASL ed Osservatori).

Dalla consultazione di AMINAVI si possono conoscere aspetti legati ai processi di rimozione e smaltimento. Infatti attualmente stanno emergendo questioni legate alla globalizzazione, come la rottamazione delle navi "beaching", smantellate sulle spiagge asiatiche come in India e Bangladesh o nella vicina Turchia, dove non sono garantiti gli standard internazionali in tema di lavoro e di protezione dell'ambiente, nonostante il Regolamento UE 1257/2013 "elenco europeo di siti autorizzati al riciclo delle navi".

Keywords: Amianto, navi, piattaforma digitale, catalogazione, banca dati.

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Monitoraggio dei valori di radon nelle matrici ambientali: un nuovo strumento per la mappatura dei plume di contaminazione da idrocarburi

Stella Lucifora[1], Elisa Rainaldi[1], Federico Caldera[1], Federico Failla[1], Alessandra Briganti[2], Mario Voltaggio[2], Paola Tuccimei[3], Martina Mattia[3], Michele Soligo[3]

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È in corso lo sviluppo di un metodo di indagine innovativo, grazie alla collaborazione tra Mares S.r.l., il Centro Nazionale delle Ricerche e l'Università degli Studi di Roma Tre, finalizzato alla mappatura dei plume di contaminazione attraverso la misura dei valori di radon (222Rn) determinati sulle diverse matrici ambientali e confrontati con i valori di fondo naturale del Rn nell'area in esame. Il metodo si basa sulla caratteristica del gas di essere molto più solubile nella contaminazione da idrocarburi in fase separata (NAPL – Non-Aqueous Phase Liquid) che nell'aria o nell'acqua. Pertanto, in caso di uno sversamento da idrocarburi di origine petrolifera, il Rn naturalmente presente nel sottosuolo rimane intrappolato all'interno del NAPL, determinando una riduzione locale della concentrazione di Rn in corrispondenza dell'area contaminata. Vengono in particolare mostrati i risultati ottenuti in casi di applicazione reale della metodica su siti contaminati da idrocarburi.
La determinazione del valore di Rn nelle matrici ambientali viene effettuata prelevando campioni che vengono poi analizzati tramite spettrometria gamma ad alta risoluzione o spettrometria alfa a seconda della matrice. Nei casi di studio sono stati analizzati sia campioni di gas interstiziali del sottosuolo che campioni prelevati dalle acque di falda in più punti e a varie profondità, con lo scopo di mappare la concentrazione di Rn, e di conseguenza anche di contaminazione, sia arealmente che verticalmente.

In aggiunta, attraverso il metodo del deficit di radon è possibile calcolare analiticamente anche il valore di saturazione dell'olio nel

terreno (o nelle acque) e stimare di conseguenza i volumi di contaminazione coinvolti nel sottosuolo.
In definitiva i dati ottenuti, utilizzando la tecnica innovativa di misurazione del Rn nel nelle matrici ambientali applicata alla caratterizzazione dei siti contaminati da idrocarburi, mostrano come questa sia un valido strumento indiretto e poco invasivo per la stima dell'estensione areale e verticale della contaminazione in tali matrici..

Keywords: Radon, idrocarburi, mappatura

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II. Tecnologie di bonifica dei siti contaminati

Nature based solutions e recupero di un suolo multi-contaminato basato sulle interazioni sinergiche tra microorganismi naturali e Brassica Napus

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Il Biorimedio Fito-assistito (PABR, Plant-Assisted BioRemediation) per il recupero di aree contaminate da inquinanti organici e inorganici rappresenta una strategia tecnologica efficace ed ecosostenibile. Negli ultimi decenni, sono state investigate le potenzialità di alcune specie vegetali di promuovere i processi di trasformazione ed estrazione di diversi tipi di contaminanti dal suolo. La famiglia delle Brassicaceae è una delle maggiormente studiate nell'applicazione di tecniche di PABR. La Brassica napus L. è una specie particolarmente adatta a questo scopo, grazie alla sua elevata tolleranza alle alte concentrazioni di contaminanti e alla capacità di fito-estrarre metalli pesanti. In questo studio, sono state investigate le potenzialità di Brassica napus nel biorimedio fito-assistito di un suolo storicamente multi-contaminato da metalli pesanti e da policlorobifenili (PCB) dell'Area di Crisi Ambientale di Taranto. É stato, inoltre, testato l'uso

di due differenti ammendanti organici (compost e biochar) per valutare l'efficacia di trattamenti di biostimulation nell'aumentare l'efficienza di decontaminazione della tecnologia PABR.
Nello specifico, sono stati allestiti microcosmi di suolo mantenuti in serra realizzando sei condizioni sperimentali: suolo contaminato (A), suolo contaminato e compost (B), suolo contaminato e biochar (C) con e senza pianta; gli allestimenti sono stati effettuati in triplicato per ciascun tempo di indagine (0, 80 giorni).
É stata condotta un'analisi multi-disciplinare mediante metodologie chimiche, biocihimiche, microbiologiche e molecolari sui campioni di suolo prelevati ai diversi tempi di sperimentazione dai microcosmi allestiti nelle differenti condizioni sperimentali.

I risultati osservati dopo 80 giorni di sperimentazione hanno evidenziato: un aumento dell'abbondanza microbica e dell'attività deidrogenasica in tutti i microcosmi allestiti con la specie vegetale; una riduzione delle concentrazioni di metalli pesanti maggiore nei microcosmi allestiti con gli ammendanti organici; un ri-arrangiamento dei gruppi di congeneri di PCB evidenziando un decremento dei congeneri diossina-simili e un incremento in quelli markers e non-diossina-simili.
Nel complesso, l'uso congiunto di Brassica Napus ed ammendanti organici (compost e biochar) ha rivelato delle interessanti potenzialità per il recupero della qualità di un suolo storicamente multi-contaminato del sud Italia mediante tecnologia PABR.

Keywords: biorimedio fito-assistito, Brassica napus, metalli pesanti, policlorobifenili, compost, biochar.

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Bio-fito bonifica in un contesto densamente urbanizzato: un esempio di integrazione multifunzionale

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Uno dei vantaggi delle metodologie di bonifica basate sull'impiego delle piante è la possibilità di integrazione con altre tecnologie, normalmente quelle biologiche, ma anche quello di poter creare ambienti multifunzionali integrati nel sistema delle infrastrutture verdi delle aree urbane. In un questo senso, la bonifica diviene un elemento dello sviluppo sostenibile delle città, costituendone parte integrante non solo nel post- ma anche durante e accelerando per quanto possibile la restituzione (progressiva) di aree attualmente sottratte alla comunità.

Il progetto integrativo di bonifica che verrà presentato, è stato sviluppato per un ex- impianto di gassificazione del carbone, situato in una zona residenziale di Pesaro, ad elevata densità abitativa. La contaminazione a hot spots del suolo superiore e profondo è caratterizzata da idrocarburi leggeri (C<12) e pesanti (C>12), IPA. Gli idrocarburi pesanti sono anche presenti in falda insieme a picchi di benzene e altri aromatici, a più basse concentrazioni. Nel sito sono stati già effettuati i primi e più significativi interventi di bonifica con rimozione delle sorgenti primarie, quindi messo in sicurezza grazie ad un impianto di Pump & Treat e alla copertura parziale con geomembrana.

L'approccio integrativo di bonifica si basa sull'impiego combinato e sinergico di due tecnologie biologiche: bioaugmentation e phytoremediation.

Gli obiettivi specifici dei diversi sistemi che sono messi in opera sono riassumibili nelle seguenti tre aree di azione:

- accelerare i processi degradativi dei contaminanti organici presenti nei terreni (superficiali e profondi insaturi),
- ridurre le concentrazioni dei contaminanti presenti in falda, con il ricircolo dell'acqua trattata nell'impianto di P&T e con l'assorbimento e degradazione da parte delle piante,
- evitare la diffusione e migrazione dei contaminanti verso target sensibili, grazie all'azione combinata delle due tecnologie biologiche.

Inoltre, nell'ottica di riduzione degli outputs e di riutilizzo in-situ delle risorse naturali, parte del flusso di scarico dall'impianto di Pump & Treat è reimpiegato per la gestione irrigua dei diversi sistemi bio- fito-tecnologici, attraverso un sistema di fitodepurazione e immagazzinamento (FitoLago).
Gli interventi previsti dal progetto sono stati posti in opera tra l'autunno 2021 e l'estate 2022.

Keywords: fitorimedio, biorimedio, idrocarburi, ambienti urbani

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Attenuazione naturale potenziata per il biorisanamento di falde contaminate da cromo esavalente

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La contaminazione delle acque sotterranee da cromo esavalente, Cr(VI), rappresenta una problematica ambientale su scala mondiale. Sebbene alcune realtà siano caratterizzate da elevati livelli di fondo di Cr(VI) di origine naturale, concentrazioni superiori a 70 µg L-1 sono attribuibili all'impatto delle attività antropiche.
La riduzione del Cr(VI) in Cr(III), forma meno tossica e meno solubile, stabile in ambiente acquatico, è alla base di numerose tecnologie di bonifica, fisiche, chimiche o biologiche. Queste ultime, sfruttano la plasticità metabolica dei microorganismi in grado di accoppiare la detossificazione dell'ambiente circostante la cellula, con il trasferimento di elettroni per accumulare l'energia necessaria alla loro crescita.
Allo scopo di decontaminare dal Cr(VI) una falda caratterizzata da concentrazioni prossime a 100 µg L-1 (CSC 5 µg L-1), è stato testato un approccio di biostimulation a scala di microcosmo. Utilizzando acqua e suolo profondo prelevati nella zona industriale di Barletta (BT), è stata valutata la capacità dei batteri nativi di attenuare la contaminazione senza l'intervento umano; tale fenomeno è noto come attenuazione naturale. Al contempo, è stato valutato l'effetto di due ammendanti donatori di elettroni, l'estratto di lievito ed il

poliidrossibutirrato, nel promuovere e supportare la proliferazione dei microorganismi coinvolti nella rimozione del Cr(VI) dalla fase acquosa, in un processo definito attenuazione naturale potenziata. I risultati ottenuti hanno rivelato un'efficienza di rimozione del contaminante pari al 100%, in soli 7 giorni, utilizzando l'estratto di lievito. Un esito positivo ha avuto anche l'ammendamento con il poliidrossibutirrato, già noto nella letteratura scientifica per il suo impiego nella bonifica di composti organici clorurati ed utilizzato, per la prima volta in questo studio, per il biorisanamento della contaminazione da Cr(VI), ottenendo una rimozione del 70% dopo 21 giorni di trattamento. Nessuna evidenza di attenuazione naturale è stata osservata nei microcosmi non ammendati. Il tasso di rimozione del Cr(VI) è risultato essere dipendente dal tipo di ammendante, che a sua volta influenza la riorganizzazione della comunità batterica. Nel complesso, i risultati della sperimentazione evidenziano come i microorganismi nativi, opportunamente stimolati, possano svolgere un ruolo determinante nella decontaminazione delle acque sotterranee, migliorandone la qualità in un'ottica di gestione sostenibile delle risorse idriche.

Keywords: cromo esavalente, batteri autoctoni, estratto di lievito, poliidrossibutirrato.

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Disarmo ferroviario e gestione del pietrisco contenente amianto. Il caso dello scalo Greco-Breda, Milano

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Stantec

A Milano è in corso un imponente piano di rigenerazione di aree inutilizzate o dismesse, anche attraverso il programma di respiro mondiale "C40 Reinveinting Cities". Alcune di queste aree comprendono anche scali ferroviari dismessi. Dal 2017 il percorso di rigenerazione urbana intrapreso dalla città di Milano ha interessato 7 ex scali. Il disarmo ferroviario costituisce l'attività propedeutica e necessaria per poter procedere alle successive fasi di riqualificazione dell'area. Questa attività comporta la produzione di diverse tipologie di rifiuti, alcuni dei quali classificabili come "pericolosi", che devono essere gestiti con procedure specifiche al fine di non arrecare danno all'ambiente e alla salute umana. Tra questi rifiuti è compreso il pietrisco ferroviario (generalmente denominato "ballast") che, in funzione della cava di provenienza, può contenere minerali amiantiferi. L'amianto, riconosciuto come sostanza pericolosa e cancerogena per inalazione, richiede procedure particolari per la sua corretta gestione, dalla fase di caratterizzazione sino a quella dello smaltimento. Questo caso studio descrive le attività di disarmo ferroviario effettuate presso l'ex scalo ferroviario di Greco-Breda a Milano, con particolare riferimento alle procedure adottate per la corretta classificazione del ballast, le procedure di confezionamento ed invio a smaltimento presso discariche autorizzate off-site.

Keywords: Disarmo ferroviario - Ballast - bonifica - rigenerazione urbana

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Valorizzazione di biomasse vegetali per la sostenibilità agronomica: il ruolo del biochar nella coltivazione e nella riduzione degli inquinanti azotati di origine agricola

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Le acque sotterranee rappresentano una componente importante del sistema di acqua dolce ed il loro ruolo sta diventando sempre più prominente a causa dello sfruttamento delle risorse idriche di superficie. Tuttavia, negli ultimi decenni si è assistito ad un progressivo aumento della perdita della qualità delle acque sotterranee. Una delle principali forme di contaminazione delle acque di falda è rappresentata dai composti azotati di origine agricola, associati all'uso massivo di fertilizzanti. La coltivazione intensiva rende necessaria un'attenta valutazione dei fabbisogni azotati, per evitare sia squilibri nella crescita vegetale che dispersioni di azoto nell'ambiente. Tra le diverse forme minerali, l'azoto nitrico rappresenta la forma azotata maggiormente suscettibile a fenomeni di dilavamento, deteriorando la qualità dei corpi idrici. Recentemente, l'applicazione del biochar è stata suggerita come tecnologia verde capace di migliorare la qualità dei suoli, mediante l'aumento della resa colturale e la riduzione degli inquinanti agricoli. Con il termine biochar si intende un materiale carbonioso derivante dalla pirolisi di biomasse vegetali. Lo scopo del lavoro ha riguardato la valutazione delle potenzialità agro-ambientali del biochar, in un suolo agrario fertilizzato con dosaggio azotato convenzionale (130 kgN/ha-1) e in sovra-dosaggio (260 kgN/ha-1). Inoltre, sono stati esaminati gli effetti sulla produzione di piante di Brassica oleracea L. botrytis, coltivate in mesocosmi fertilizzati e ammendati con e senza biochar. Al termine della ricerca sono state

valutate le proprietà del suolo, le variazioni di azoto nitrico ed ammoniacale nel suolo e nell'acqua di percolazione e le differenze vegetative in piante di cavolfiore. I risultati dimostrano che nei suoli agrari ammendati con biochar, il contenuto dei composti azotati è aumentato rispetto ai trattamenti senza biochar, con una concentrazione pari a 26 mg/L e 48 mg/L, rispettivamente per i suoli fertilizzati con dosaggio convenzionale e sovra-dosaggio. Viceversa, l'impiego del biochar ha ridotto la concentrazione dei nitrati nelle acque di percolazione. Infine, il biochar ha prodotto l'aumento della resa varietale, mediante la raccolta di cavolfiori con un peso medio pari a 989 kg. I risultati della ricerca dimostrano come l'impiego del biochar rappresenta una strategia vincente in agricoltura, in grado di migliorare la produttiva agricola e mitigare gli impatti negativi associati all'uso improprio di fertilizzanti azotati.

Keywords: fertilizzazione azotata; lisciviazioni dei nitrati; inquinamento agricolo; sostenibilità.

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Bonifica e messa in sicurezza di siti contaminati in Liguria: analisi dello stato attuale alla luce del recente aggiornamento del Piano Regionale

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In accordo con il Piano Regionale di gestione dei rifiuti e delle bonifiche emanato nel 2015 e recentemente oggetto di aggiornamento (delibera del Consiglio Regionale n. 11 del 19 luglio 2022), la Regione Liguria si pone l'obiettivo di individuare strumenti amministrativi e finanziari per ottimizzare la progettualità ed il monitoraggio degli interventi di bonifica e messa in sicurezza dei siti contaminati. In tale ottica, l'Anagrafe dei siti da bonificare rappresenta uno degli strumenti fondamentali per la gestione ottimale su scala regionale delle aree contaminate riportante informazioni relative ad aspetti tecnici, ammnistrativi e finanziari. Dall'analisi dell'elenco aggiornato al 31 dicembre 2020 emerge che i siti censiti ammontano complessivamente a 253 e che la procedura di bonifica si è conclusa solo per circa il 48% di essi. Mentre ammontano a 117 i siti iscritti in anagrafe con procedura di bonifica in corso e con progettazione approvata (per i quali gli interventi devono essere ancora avviati, oppure sono in corso di esecuzione, oppure sono stati portati a compimento ma non si è concluso il procedimento di certificazione). Gli interventi possono essere così classificati: bonifica e ripristino ambientale (42%), bonifica con misure di sicurezza (22%), messa in sicurezza permanente (19%), messa in sicurezza operativa (17%). Più della metà degli interventi sono localizzati nel territorio della provincia di Genova (56%), mentre i restanti ricadono prevalentemente nel territorio della provincia di Savona (19%) e della provincia della Spezia (21%), solo in misura minore nel territorio della provincia di Imperia (4%). Secondo il rapporto di ISPRA "Lo stato delle bonifiche dei siti contaminati in Italia: i dati regionali - Edizione 2021", l'estensione superficiale dei siti con procedimento in corso in Liguria è pari a 499

ha di cui 182 ha nel comune di Genova. Inoltre, la città di Genova compare tra i primi venti comuni d'Italia per numero di procedimenti in corso pari a 118. Il numero di procedimenti in corso fornisco indicazione del carico amministrativo di gestione delle procedure di bonifica afferenti a un determinato territorio. Tre le tecniche di bonifica più impiegate vi è la rimozione della sorgente di contaminazione per mezzo di scavo e successivo avvio dei rifiuti prodotti ad impianti ex-situ è la più impiegata. Per la bonifica e messa in sicurezza di acque sotterranee, evince un significativo impiego della tecnologia pump and treat.

Keywords: bonifica, anagrafe siti contaminanti, tecnologie, Regione Liguria

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Bonifica in situ delle acque di falda a seguito di sversamento di gasolio e benzina

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Nel presente abstract sono descritte le attività di MISE e di Bonifica condotte sui terreni insaturi e sulle acque di falda di un sito ubicato in provincia di Verona interessato dallo sversamento accidentale di gasolio e benzina in seguito a sinistro stradale.
Gli interventi di bonifica hanno avuto quali Obiettivo di Bonifica le Concentrazioni Soglia di Rischio definite mediante procedura di Analisi del Rischio e sono consistiti nella realizzazione di un intervento di Capping di un fossato a bordo strada e nell'applicazione sinergica delle tecnologie In Situ Chemical Oxidation (ISCO) ed Enhanced Aerobic Biodegradation (EAB) che hanno portato al conseguimento della conformità dei terreni insaturi e delle acque sotterranee di una vasca di laminazione.
Nelle ore immediatamente successive all'incidente, che ha provocato la fuoriuscita di "gasolio da autotrazione" e "benzina" sono state effettuate le operazioni di rimozione dell'automezzo e sono iniziate le operazioni di messa in sicurezza d'emergenza per il contenimento della contaminazione. Successivamente si è proseguito con l'indagine ambientale e con la bonifica del sito.
Le attività di MISE sono consistite in:
- spargimento di materiali assorbenti sulla sede stradale;
- posa di barriere assorbenti lungo i fossati con acqua corrente;
- lavaggio ad alta pressione delle tubazioni interrate di collegamento delle differenti aree;
- scarifica dei terreni nei fossi a lato della strada ed afferenti alla vasca di laminazione;
- realizzazione di n. 2 pozzi nella vasca di laminazione per la captazione della contaminazione nella falda con interventi di spurgo forzato mediante utilizzo di autobotte.

L'analisi delle migliori tecnologie disponibili (BATNEEC: Best Available Technologies Not Entailing Excessive Cost) ha individuato quali tecniche di bonifica dei terreni insaturi e delle acque di falda per il sito

di studio la copertura dei terreni contaminati (Capping) e l'interazione sinergica di In Situ Chemical Oxidation (ISCO) ed Enhanced Aerobic Biodegradation (EAB).
Il Capping ha la funzione di interrompere il percorso di dilavamento e lisciviazione in falda degli idrocarburi nel suolo insaturo e gli interventi mediante ISCO e EAB permettono di aumentare la biodegradazione dei composti di natura idrocarburica presenti sia nei suoli insaturi che nelle acque sotterranee.
La verifica dell'avanzamento degli interventi di bonifica è stata eseguita mediante un piano di monitoraggio periodico che ha previsto un monitoraggio al "punto zero" prima dell'esecuzione degli interventi di bonifica ed il monitoraggio in corso d'opera.
Le campagne di monitoraggio delle acque di falda sono state condotte con cadenza più frequente a poca distanza dall'esecuzione degli interventi ed a cadenza mensile successivamente ed hanno compreso il rilievo dei parametri chimico-fisici ed il prelievo di campioni che sono stati sottoposti ad analisi chimica per la determinazione di BTEXS, Idrocarburi totali, MTBE e ETBE.
I parametri chimico-fisici registrati (pH, ORP, OD, Conducibilità) hanno permesso di monitorare l'evoluzione del sistema acquifero in seguito all'iniezione dei prodotti ISCO ed EAB per valutare l'efficacia della tecnologia sui contaminanti disciolti.
I risultati delle analisi chimiche condotte sui campioni di acque di falda prelevati sono stati confrontati con gli obbiettivi di bonifica definiti dall'AdR ed il loro andamento è stato riportato su grafici temporali. Nel periodo successivo all'esecuzione delle iniezioni è stata verificata una progressiva diminuzione di tutti i contaminanti fino a valori al di sotto degli obbiettivi di bonifica, che ne ha consentito il collaudo da parte degli Enti. Nel successivo grafico sono riportate, a titolo esemplificativo, le concentrazioni del parametro MtBE nel tempo.

Keywords: Bonifica, acque di falda, gasolio, benzina

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Applicazione ad ampia scala di una tecnologia riduttiva per il biorisanamento di un acquifero storicamente contaminato da alcheni clorurati e metalli pesanti in Lombardia

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L'aggiunta di un substrato organico carbonioso, nella zona satura di un acquifero, risulta una tecnica ben conosciuta per favorire le reazioni enzimatiche riduttive convenzionali. Nutrendosi del substrato in soluzione, infatti, i batteri consumano l'ossigeno disciolto e gli altri elettro-accettori, generando una riduzione del potenziale ossido-riduttivo dell'acquifero.

Il reagente ELS Microemulsion è un prodotto per biorisanamento anaerobico potenziato (ERD) per il trattamento di acquiferi contaminati da composti organici organo-clorurati e metalli pesanti come cromo esavalente. Una volta in falda, infatti, la tecnologia genera rapidamente la formazione di condizioni riducenti potenziate favorendo le reazioni di declorurazione biotiche. Il prodotto risulta essere composto da un substrato fermentabile carbonioso a base di lecitina.

Il prodotto EHC® per riduzione chimica in situ (ISCR) è la formulazione originale brevettata, a base di un substrato carbonioso a lento rilascio e di ferro zero valente (ZVI), utilizzata per il trattamento di terreni ed acquiferi contaminati da composti alogenati persistenti, compresi i solventi clorurati, pesticidi e gli esplosivi organici. La formulazione di EHC deriva da anni di ricerca ed applicazioni di successo in campo; il prodotto EHC è essenzialmente costituito da una sinergica miscela di ZVI alla micro-scala ed una fonte carboniosa solida organica in grado di favorire i meccanismi di declorurazione sia biotici che abiotici.

Si presenterà un recentissimo caso applicativo italiano in cui le tecnologie ELS Microemulsion ed EHC sono state applicate con successo mediante iniezione diretta in pressione nell'acquifero contaminato. In particolare, la falda sottostante un'area industriale manifatturiera in attività del nord Italia presentava una

contaminazione storica diffusa da PCE, TCE ed altri composti organo-clorurati, inclusi alcuni metalli pesanti (Ni, Cu, Zn).
In meno di 12 mesi dall'iniezione in falda nelle zone contaminate, le concentrazioni dei contaminanti risultano essere rapidamente scese oltre un ordine di grandezza rispetto alle concentrazioni pre-trattamento nei principali piezometri di monitoraggio presenti nell'area, raggiungendo gli obiettivi di bonifica (CSC, D.Lgs. 152/2006) ed evidenziando anche l'instaurazione di evidenti e potenziate condizioni riducenti biotiche ed abiotiche.

Keywords: Biorisanamento, acque di falda, metalli pesanti, clorurari

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Dispositivi e-hyrec®/e-lorec® per il recupero selettivo di LNAPL e DNAPL

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La rimozione delle fasi separate rappresenta un elemento fondamentale del processo di bonifica della falda. Le contaminazioni storiche e/o le perdite accidentali di idrocarburi hanno talvolta causato la formazione di sorgenti persistenti di contaminazione dell'acqua di falda, che per diversa densità rispetto all'acqua si depositano in strati di liquido immiscibile.
A seconda della densità di tali inquinanti è possibile individuare due famiglie di miscele:
- LNAPL o surnatante (Light Non Aqueous Phase Liquid ovvero fasi liquide leggere non acquose) rappresentano tutte quelle miscele aventi densità inferiore a quella dell'acqua; esse tendono a depositarsi sopra al livello dell'acqua di falda e i relativi vapori possono diffondere nella zona insatura a seconda della tensione di vapore della miscela;
- DNAPL o sottonatante (Dense Non Aqueous Phase Liquid ovvero fasi liquide dense non acquose) rappresentano quelle miscele aventi densità superiore a quella dell'acqua; esse tendono a posizionarsi tra l'acqua di falda e il primo strato impermeabile.

Per il recupero selettivo delle fasi separate Eni ha sviluppato due dispositivi completamente automatici:

- e-hyrec®: eni HYdrocarbon RECovery, per la rimozione selettiva di LNAPL da acque sotterranee contaminate (Marchio registrato nel 2018)
- e-lorec®: eni LOwered-place hydrocarbon RECovery, per la rimozione selettiva del DNAPL da acque sotterranee contaminate (Marchio registrato nel 2021)

Il dispositivo e-hyrec® funziona secondo il principio della permeazione selettiva, grazie all'utilizzo di un filtro idrofobico/oleofilico in grado di recuperare solo la fase organica. Per le caratteristiche chimico-fisiche del materiale, quando viene immerso all'interfaccia tra lo strato idrocarburico surnatante e l'acqua di falda, la fase LNAPL permea attraverso i pori del filtro e l'acqua resta all'esterno del filtro. I filtri sono assemblati con idonea sensoristica e componentistica che conferiscono totale automazione. e-hyrec® è un sistema altamente selettivo ed efficiente: separando e recuperando la fase oleosa, facilita la risoluzione del problema della presenza di fase separata LNAPL in falda e al contempo consente un sostanziale annullamento delle quantità di acqua estratta da inviare a smaltimento, consentendo così un impatto molto positivo sulla sostenibilità ambientale ed economica delle bonifiche. Dal punto di vista energetico e-hyrec® risulta molto sostenibile, grazie alla possibilità di essere completamente autoalimentato da fonti rinnovabili (fotovoltaico).
Il dispositivo e-lorec® sfrutta il posizionamento del DNPAL tra la falda e lo strato impermeabile, dovuto alla maggior densità rispetto all'acqua, per recuperare il sottonatante quando è presente come fase smiscelata.
e-lorec® è costituito da due parti interconnesse mediante una rete elettrica e pneumatica: un prima parte viene posizionata a fondo foro all'interno di un pozzo piezometrico dove è presente l'inquinante mentre la seconda parte è posizionata in superficie in prossimità della bocca pozzo.
La parte calata è costituita da un sistema pompante in acciaio inox e uno o più sensori in grado di discriminare l'acqua dalla fase organica.
La parte posta in superficie è costituita da un quadro elettrico e uno pneumatico con la funzione di gestire le fasi di recupero mediante azioni controllate da un PLC (Programmabile Logic Controller).
Oltre alle attività di bonifica, il dispositivo e-lorec® può essere utilizzato come monitoraggio di aree critiche dove è possibile una contaminazione da parte di DNAPL.

Keywords: Bonifica falda, monitoraggio, permeazione selettiva

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La remotizzazione, digitalizzazione ed automazione - L'esperienza Eni Rewind

Gianluca D'Aquila

Eni Rewind

Eni Rewind gestisce 42 impianti che trattano oltre 36 milioni di metri cubi di acque all'anno, dei quali 9 milioni vengono riutilizzate per scopi industriali ed ambientali. Le acque trattate sono prevalentemente originate da barriere idrauliche e impianti di bonifica mentre in alcuni siti i processi di trattamento riguardano anche reflui civili ed industriali.
Gli asset, allestiti con elevati livelli di automazione, sono stati digitalizzati e resi disponibili per il presidio e la gestione da remoto. Il modello operativo di Eni Rewind prevede, infatti, il telecontrollo di barriere ed impianti dislocati su tutto il territorio nazionale, attraverso una Control Room centralizzata a San Donato Milanese, operativa 24 ore su 24 e 7 giorni su 7, in aggiunta alle tradizionali attività di esercizio e manutenzioni svolte sugli impianti.
La fase di avvio del progetto ha avuto una durata di due anni, nel corso dei quali i costi sono stati di circa €7,5M.
I vantaggi di questo modello operativo sono:
Standardizzazione del modello di controllo e adozione trasversale di strumenti tecnologici abilitanti a future evoluzioni di business (ad es. sistemi di controllo dinamico);
Aumento dell'efficienza di gestione degli impianti attraverso una maggiore flessibilità operativa e organizzativa, con conseguente riduzione dei costi operativi;
Aumento dell'efficacia dei sistemi nell'ambito dei processi di bonifica della falda e riduzione dei rischi per il personale e per l'ambiente.

Keywords: automazione, gestione bonifiche da remoto, efficienza

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Prove sperimentali per il trattamento in situ di suoli mediante tecnologia di stabilizzazione e solidificazione

Riccardo Crespi

Eni Rewind

Nell'ambito di un sito complesso e di importanza nazionale, tra le diverse tecnologie e modalità di intervento per la bonifica dei suoli, contaminati da metalli ed in presenza di residui di lavorazioni industriali, è stata prevista l'applicazione della tecnologia in situ di Solidificazione/Stabilizzazione (S/S). Nel sito in esame, infatti, vi era storicamente la lavorazione di minerali naturali per la produzione di zinco.

Nello specifico i terreni sono quindi risultati contaminati da: Antimonio, Arsenico, Cadmio, Tallio, Mercurio, Vanadio, Piombo, Zinco, Rame, Stagno, Selenio e Idrocarburi Alifatici C9-C18.

Tale tecnica di bonifica consente di bloccare il contaminante direttamente in posto (stabilizzazione) e di consolidare l'intera matrice trasformandola in un blocco solido (solidificazione).

Tale soluzione è stata individuata nell'ambito del progetto approvato dagli Enti in quanto altre tecnologie in situ e on site non sono risultate performanti per la bonifica. Inoltre, tale tecnologia consente di evitare l'intervento di scavo dei terreni contaminati finalizzato allo smaltimento di rifiuti verso discariche off site.

Nel complesso, la tecnologia è prevista sia applicata full scale su una area di trattamento di 31.000 m^2 e un volume di trattamento pari a 140.000 m^3, tenuto conto di una profondità media di intervento di circa 4.5 m da piano campagna.

Allo scopo, sono state progettate ed avviate indagini in sito finalizzate alla formazione di campioni per l'esecuzione di prove di laboratorio propedeutiche alla successiva prova pilota.

In particolare, da un punto di vista chimico, i test di cessione condotti sui campioni monolitici prelevati a seguito di prova sono stati confrontati con i limiti del DM 5/02/98.

Da tale confronto, si evince che tutti i parametri di interesse risultano conformi dopo trattamento, ad esclusione del solo parametro

Arsenico, in soli pochi punti e in concentrazioni di poco superiori al limite di riferimento.
Tale condizione, non è escludente l'efficacia della tecnologia, considerando l'ottimo risultato ottenuto sull'intero volume di intervento e considerato che tale intervento è previsto sia integrato con la posa di una capping superficiale, atto a bloccare tutti i fenomeni di lisciviazione verticale ad opera di infiltrazione di acque meteoriche. Dunque, il combinato disposto dei due interventi consentirà di bloccare in tutte le forme e direzioni la possibile lisciviazione.
Pertanto, si può concludere che la tecnologia sia efficacie per il trattamento di terreni in situ in condizioni complesse, ove altre tecnologie non sono applicabili e/o non sostenibili e che questa, grazie alla solidificazione delle matrici trattate consenta anche una miglioria meccanica dei terreni. Quest'ultima condizione consente quindi una riutilizzabilità dei suoli, per esempio per nuove costruzioni e impieghi di superficie.

Keywords: tecnologia di stabilizzazione e solidificazione, capping superficiale, metalli pesanti

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Progetto Nuraghe:

un esempio di bonifica sostenibile a km 0

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A Porto Torres, Eni Rewind, la società ambientale di Eni, sta realizzando un importante progetto di bonifica dei suoli per la rimozione e il trattamento di circa 800.000 mc di materiali interrati e contaminati. L'area da bonificare, interessata dal "Progetto Nuraghe", è identificata come Area Minciaredda e ricopre una superficie di circa 30 ettari su un totale di 1.200 di proprietà di Eni Rewind nel Sito di Interesse Nazionale.

Per far fronte alla complessità dell'intervento ambientale, Eni Rewind ha adottato una soluzione unica nel suo genere in Italia in termini di innovazione e sostenibilità, ovvero la realizzazione di una piattaforma polifunzionale on site che copre una superficie di 74 mila metri quadrati ed è dotata di tutte le tipologie impiantistiche per la decontaminazione dei terreni e di una capacità di stoccaggio complessiva di circa 45.000 mc di materiali.

Nella piattaforma polifunzionale, messa in marcia nel 2021, si possono trattare fino a circa 1.000 mc di terreni scavati al giorno mediante l'applicazione di tecnologie sostenibili quali la bioremediation, soil-washing, inertizzazione, desorbimento termico, che lavorano in maniera sinergica, in un unico grande sito per la riqualificazione dell'ambiente. Inoltre, le acque utilizzate nei processi di bonifica vengono sottoposte a trattamento in un apposito impianto ausiliare dedicato ed ubicato sempre all'interno della piattaforma.

Dopo il trattamento, i terreni che risulteranno conformi agli obiettivi di bonifica verranno riutilizzati per il riempimento degli scavi da cui derivano, mentre quelli non idonei saranno conferiti in un apposito deposito permanente realizzato in sito. I terreni contaminati sono quindi integralmente gestiti in sito senza esportazione in discariche esterne, ed in gran parte (circa 75%) recuperati e riallocati in sito. Per questa ragione si può definire il Progetto Nuraghe un grande

intervento di bonifica a km 0 e pienamente in linea con i principi di economia circolare e di sviluppo sostenibile.

Keywords: Bonifica sostenibile, bioremediation, soil-washing, inertizzazione, desorbimento termico

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Nuovi approcci per la bonifica dei punti vendita carburante – Casi di studio

Valentina Rosetti

Eni Rewind

I Punti Vendita sono siti di piccole dimensioni dislocati su tutto il territorio nazionale, in cui possono rendersi necessari interventi di risanamento delle matrici ambientali per contaminazioni storiche o più recenti, connesse allo sversamento nel sottosuolo di prodotti idrocarburici da autotrazione leggeri e/o pesanti.
La complessità della scelta dell'intervento di bonifica più idoneo dipende da alcuni fattori peculiari, quali tipologia del sito (attivo o dismesso), collocazione in aree urbanizzate, in vicinanza di traffico veicolare, luoghi sensibili, estensione della contaminazione e strategia di utilizzo/valorizzazione futura dell'area (che incide sulla determinazione degli obiettivi di bonifica).
Le tecnologie storicamente più applicate per il risanamento delle stazioni di servizio sono quelle cosiddette "tradizionali", quali lo scavo/smaltimento, utilizzata soprattutto in occasione di dismissioni o ristrutturazioni degli impianti di erogazione dei carburanti, o tecnologie in situ quali Soil Vapour Extraction, Bioventing, Air Sparging, Biosparging, Pump & Treat e Multi Phase Extraction. L'esperienza maturata nell'applicazione di queste tecniche alla realtà dei PVC ha permesso di evidenziarne, in molteplici casi, una scarsa sostenibilità dal punto di vista ambientale, oltre che economico per produzione di rifiuti, scarichi idrici, consumo energia elettrica,

impossibilità di valorizzazione dei siti dismessi per anni. Per questo motivo sono stati ricercati ed applicati nuovi approcci tecnologici per il traguardo degli obiettivi di bonifica in ottica di maggiore sostenibilità ambientale, tecnica ed economica.
Vengono a tal proposito presentati n. 4 casi di studio in cui sono stati applicati approcci innovativi e maggiormente sostenibili rispetto alle tecnologie tradizionali, che hanno permesso il raggiungimento degli obiettivi di bonifica.
Come 1° caso di studio viene riportata l'esperienza fatta nell'ambito delle attività di ristrutturazione di una stazione di servizio autostradale, in cui è stata rinvenuta contaminazione da idrocarburi in frangia capillare/terreno saturo, oltre che in falda. Sono stati impiegati reagenti disponibili sul mercato, miscelati con benna direttamente sul fondo e pareti degli scavi realizzati per la dismissione del vecchio impianto di erogazione dei carburanti, che hanno dapprima innescato processi di desorbimento chimico dei contaminanti idrocarburici adesi ai terreni e successivamente hanno favorito la biodegradazione aerobica della contaminazione residuale in soluzione nelle acque, traguardando gli obiettivi di bonifica in circa 28 mesi, per un costo complessivo sostenuto pari a ca. 580.000 €. Si stima pertanto un saving economico di ca. 70.000 € e temporale per ca. 32 mesi rispetto ad una possibile applicazione di tecnologie tradizionali.
Il 2° caso di studio riguarda l'applicazione di composti ossidanti con iniezioni dirette per la bonifica della falda in un Ex PV carburante ubicato in un contesto urbano, densamente abitato e su suolo pubblico. Sfruttando i processi ossidativi dei contaminanti idrocarburici in soluzione dapprima e la biodegradazione aerobica in un secondo momento, questo intervento ha permesso di traguardare gli obiettivi di bonifica senza ricorrere al Pump & Treat e minimizzando gli ingombri di occupazione del suolo pubblico in circa 24 mesi, per un costo complessivo sostenuto pari a ca. 160.000 €. Si stima pertanto un saving economico di ca. 40.000 € e temporale per ca. 12 mesi rispetto ad una possibile applicazione di tecnologie tradizionali.
Il 3° caso di studio illustra un processo di finissaggio della bonifica delle acque sotterranee di un ex PV in cui è stato esercito per circa dieci anni un sistema MPE che non ha permesso il pieno traguardo degli obiettivi di bonifica definiti per Idrocarburi totali (come n-esano) ed Eteri. In questo caso si è optato per l'applicazione di prodotti surfattanti in falda, che agiscono in tempi rapidi sulla contaminazione adsorbita alla matrice terreno saturo rendendola "fisicamente disponibile" ad

essere rimossa con emungimento delle acque. A seguito di n. 3 iniezioni e conseguenti spurghi forzati dopo 48 ore, i monitoraggi hanno confermato il raggiungimento degli obiettivi di bonifica per le acque sotterranee nell'arco di un anno solare.
Nel 4° ed ultimo caso di studio viene presentata l'applicazione di una tecnologia alternativa al pompaggio delle acque sotterranee. Nel caso in esame, con l'obiettivo di rispettare i limiti di legge per i composti idrocarburici nelle acque sotterranee ai punti di conformità, è stata dapprima testata su scala pilota e poi dimensionata e realizzata in scala di sito una barriera adsorbente mediante iniezione di carbone attivo micrometrico che, una volta distribuito nel sottosuolo si fissa ai grani del terreno aumentandone esponenzialmente la capacità di adsorbimento e permette di adsorbire e rimuovere dalla fase disciolta i contaminanti idrocarburici. I carboni attivi sono stati premiscelati con un ammendante utile per la stimolazione dei processi di biodegradazione dei contaminanti a base di solfati e nitrati a lento rilascio. L'intervento nel caso specifico è consistito nella creazione di un fronte adsorbente di ca. 25 m lineari, costituito da n. 26 punti di iniezione con tecnica Direct Push per un quantitativo complessivo di 63 kg di carboni attivi iniettati in uno spessore di 7,5 m ed ha permesso il raggiungimento delle CSC in circa 6 mesi dall'implementazione della barriera in configurazione full scale, per un costo complessivo pari a ca. 180.000 €. Si stima pertanto un saving economico di ca. 70.000 € e temporale per ca. 40 mesi rispetto ad una possibile applicazione di tecnologie tradizionali.
In sintesi, l'esperienza maturata nella bonifica dei Punti Vendita Carburante ha portato ad un'evoluzione degli approcci rispetto all'applicazione di tecnologie tradizionali, con l'intento di promuovere tecniche volte alla sostenibilità. Importante ricordare:

- valorizzare la fase di caratterizzazione per raccogliere tutti gli elementi utili ad una progettazione di dettaglio;
- in caso di dismissioni/ristrutturazioni dei PV, applicare contestualmente al D&D altre tecnologie volte ad accelerare i processi degradativi della contaminazione nel comparto saturo;
- trattamenti come ISCO, Bioremediation, tensioattivi, opportunamente dimensionati e testati in laboratorio e in campo, rappresentano soluzioni sostenibili rispetto alle tecnologie tradizionali quali i sistemi di estrazione (SVE/MPE), delicati, energivori e di complessa gestione, che permettono di ottimizzare tempi, costi ed ingombri. Facendo tesoro delle esperienze applicative nei Punti

Vendita Carburante, queste soluzioni sono opportunamente scalabili a siti di dimensioni più estese;
• il P&T, sempre applicato in fase di Messa In Sicurezza (spesso in modalità P&S per difficoltà amministrative di ottenimento dell'autorizzazione allo scarico) e per anni molto utilizzato anche come bonifica, non è una reale soluzione per il risanamento delle acque sotterranee. Le barriere adsorbenti possono costituire alternative più sostenibili. A differenza delle barriere idrauliche, permettono di agire direttamente sulla sorgente di contaminazione secondaria, favorendone la progressiva rimozione;
• importanza del coinvolgimento delle Università per la ricerca e lo studio di applicabilità di soluzioni innovative e sostenibili;
• importanza del confronto e coinvolgimento degli Enti preposti nelle fasi di progettazione e realizzazione degli interventi per individuare la soluzione più sostenibile e/o condividere percorsi tecnici finalizzati al raggiungimento degli obiettivi di bonifica.

Keywords: punti vendita carburante, Soil Vapour Extraction, Bioventing, Air Sparging, Biosparging, Pump & Treat e Multi Phase Extraction.

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Trattamento Cromo esavalente in acquifero altamente aerobico mediante ISCR ed elettrodonatori

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In un sito manifatturiero dismesso di grandi dimensioni nel Nord Italia, la riconversione ad uso commerciale è vincolata all'esecuzione di interventi di bonifica dell'area. Una porzione del sito risulta contaminata da cromo esavalente, con concentrazioni in falda non estremamente elevate (ordine delle centinaia di ug/L) ma persistenti, a causa delle condizioni di elevata aerobicità dell'acquifero in ghiaie estremamente permeabile e della presenza di numerose probabili sorgenti secondarie difficili da identificare con certezza.

Condizioni di potenziale redox positivo infatti inibiscono la trasformazione del cromo esavalente in cromo trivalente (composto a minore tossicità e minore solubilità), e costituiscono anche uno scenario più complesso per interventi di bonifica in situ, che tradizionalmente si basano sulla riduzione chimica e/o biologica del composto.

Sull'area in esame sono state eseguite nel tempo molteplici applicazioni di un agente riducente a rilascio immediato, che però costringeva all'esecuzione di interventi periodici di iniezione finalizzati ad evitare che nel tempo si osservasse un rebound delle concentrazioni.

Al fine di ottimizzare il processo minimizzando al contempo le attività di campo, è stato pertanto valutato l'utilizzo di substrati a rilascio controllato e prolungato nel tempo. Il mix di reagenti utilizzato include tra gli altri ferro zero-valente colloidale solfurato (S-MicroZVI) e un elettrodonatore a rilascio prolungato (3-D Microemulsion). Questi prodotti hanno caratteristiche tali da consentire un'ottima distribuzione nel sottosuolo (minimizzando i punti di iniezione e favorendo una distribuzione omogenea nell'acquifero) e supportare reazioni di riduzione su un arco temporale di più anni, anche a fronte di condizioni sito-specifiche sfavorevoli come quelle del caso in oggetto.

L’esecuzione di una prova pilota (le cui iniezioni hanno avuto luogo a fine 2021) ha confermato l’efficacia della strategia di intervento, con l’ottenimento di riduzione del cromo ed il mantenimento di concentrazioni basse nei mesi successivi con effetti rilevabili anche a valle della zona pilota, confermando il raggiungimento dei raggi di influenza previsti.
Tali risultati di abbattimento e mantenimento degli effetti si sono dimostrati migliorativi rispetto a quanto ottenuto precedentemente, portando quindi la strategia all’implementazione full scale.
L’intervento full scale risulta in corso di applicazione al momento della redazione del presente abstract, e consiste nell’applicazione del mix di reagenti in postazioni fisse secondo una conformazione a griglia a copertura della porzione principale del plume contaminato. Si ipotizza di avere a disposizione i dati delle prime campagne di monitoraggio full scale al momento del convegno.

Keywords: Cromo esavalente, ISCR, riduzione chimica e/o biologica

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Valutazione della variabilità oraria delle caratteristiche chimico-fisiche del soil gas in un campo prova ubicato all'interno del SIN di Venezia

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In un campo prova ubicato all'interno del Petrolchimico di Porto Marghera – Venezia, così come in altri siti esterni al SIN, è stata studiata la variabilità temporale nel breve termine delle caratteristiche chimico-fisiche del soil gas attraverso misure in continuo, campionamenti seguiti da analisi di laboratorio e misure ripetute con strumenti automatici da campo. Conoscere la variabilità oraria delle caratteristiche del soil gas risulta fondamentale per contestualizzare la misura e definire correttamente modalità e durata del campionamento, i cui risultati sono frequentemente impiegati per la verifica del rischio derivante da esposizioni di lungo termine ai composti volatili presenti nel sottosuolo.

All'interno di sonde per il monitoraggio del soil gas (micropiezometri fenestrati nella zona vadosa) sono stati installati un PID e un misuratore di pressione differenziale predisposti per misure in continuo. Nelle stesse sonde sono stati prelevati campioni di soil gas con canister in vetro (vacuum bottle) da destinare alla successiva analisi di laboratorio e sono state effettuate misure con strumenti automatici da campo. I campionamenti sono stati condotti a intervalli di tempo ravvicinati, scelti sulla base di una analisi statistica preliminare dei dati meteorologici disponibili.

Le misure condotte nell'ambito della sperimentazione hanno evidenziato come sia le concentrazioni dei composti organici volatili (COV) nel soil gas sia la pressione differenziale fra soil gas e aria presentino una variazione ciclica nelle 24h al netto delle variazioni indotte sul sitema dalle evoluzioni meteorologiche (precipitazioni, fronti di bassa pressione…) . Le misure condotte, sia con la strumentazione aspecifica in continuo, sia con campionamenti attivi, sembrano evidenziare una notevole influenza delle dinamiche

all'interfaccia suolo-atmosfera sulla forzante barometrica (barometric pumping) e quindi sulle concentrazioni di COV nel soil gas, indicando l'importanza della misurazione del differenziale di pressione fra queste due matrici per la corretta interpretazione dei risultati dei monitoraggi.

Keywords: caratteristiche chimico-fisiche del soil gas, Porto Marghera

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Marcatori molecolari per la valutazione del potenziale genetico in progetti di biorisanamento

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Il biorisanamento si basa sull'utilizzo di determinati gruppi microbici con capacità degradative specifiche. Nei progetti di bonifica, l'utilizzo di tecnologie biologiche di risanamento presenta innumerevoli vantaggi, sia dal punto di vista dell'impatto sulle matrici ambientali, sia dal punto di vista economico. Le tecniche di biorisanamento quali la biostimolazione o la Monitored Natural Attenuation, si basano sul presupposto che la comunità microbica della matrice contaminata possegga specifiche capacità metaboliche legate alla rimozione degli inquinanti.

Lo studio e la caratterizzazione sito-specifica della struttura e delle funzioni della comunità microbica è di fondamentale importanza i) per definire la strategia di biorisanamento più adatta ed efficace per raggiungere l'obiettivo di bonifica e ii) per assicurarsi, tramite monitoraggio periodico, che le capacità degradative del sito non siano modificate nel tempo.

Tramite tecniche innovative di biologia molecolare è possibile descrivere la struttura della comunità (batterica, fungina o archaea) tramite il sequenziamento NGS ed analizzare le specifiche funzioni metaboliche delle popolazioni microbiche tramite PCR quantitativa (qPCR). L'obiettivo della caratterizzazione della struttura della comunità è individuare e classificare i gruppi microbici presenti nel campione ambientale e valutare l'abbondanza relativa di ognuno di loro all'interno della comunità. Attraverso la tecnica di qPCR, invece, è possibile quantificare il numero di copie di specifici geni coinvolti in specifici processi metabolici, come ad esempio la degradazione di composti organici quali gli idrocarburi alifatici, BTEX, solventi clorurati, MtBE/EtBE o processi legati alla respirazione anaerobica, come la riduzione del nitrato, Fe, Mn e solfato. In particolare l'approccio descritto è stato utilizzato in due differenti siti. Nel il Sito 1 nel quale si riscontra un inquinamento datato dovuto alla presenza di solventi

clorurati ed idrocarburi monoaromatici, si osserva come siano presenti i marcatori della degradazione anaerobica del cloruro di vinile (gene marcatore vcrA) e del TCE (gene marcatore tceA), mentre il gene etnC marcatore della degradazione aerobica del cloruro di vinile non è risultato quantificabile. Anche per quanto riguarda i geni marcatori della degradazione dei BTEX, analogamente al caso dei solventi clorurati, si osserva la presenza del gene bssA marcatore della degradazione anaerobica dei BTEX, ma non il corrispettivo gene todC marcatore della degradazione aerobica.
Il Sito 2, nel quale si riporta una contaminazione da eteri in falda (MtBE ed EtBE), l'analisi di caratterizzazione ha permesso di valutare la fattibilità di un intervento di risanamento biologico tramite ossigenazione della falda per la stimolazione della degradazione aerobica di questi composti. Nello specifico, la presenza di popolazioni in grado di degradare EtBE, MtBE e TBA è stata confermata dalle analisi di qPCR. Inoltre, dalle analisi di sequenziamento del gene 16S rRNA, si osserva la presenza in questo campione del genere Hydrogenophaga, noto degradatore di MtBE. L'analisi della struttura e delle funzioni della comunità batterica delle acque di falda di questo sito ha premesso di ottenere informazioni rilevanti a supporto di una strategia di biorisanamento tramite ossigenazione della falda.

Keywords: Marcatori molecolari, biorisanamento, qPCR

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Declorazione riduttiva dei solventi clorurati: come riconoscere ed evitare lo stallo dei processi

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La Enhanced Reductive Dechlorination ("ERD"), ovvero la declorazione o dealogenazione riduttiva accelerata, è una tecnologia in Situ di bonifica basata sulla stimolazione della biodegradazione in ambiente anaerobico dei solventi clorurati, attraverso l'iniezione di un substrato organico. Nel processo di biodegradazione i solventi clorurati si riducono in quanto accettori degli elettroni messi a disposizione dalla reazione di ossidazione del substrato primario organico, che si comporta come donatore di elettroni, che può essere sia naturalmente presente, come il carbonio organico, sia introdotto opportunamente per stimolare la dealogenazione riduttiva.

Il processo, attraverso una serie di reazioni sequenziale, comporta la riduzione dei solventi più complessi come il Tetracloroetilene (PCE) e il Tricloroetilene (TCE) in cis-Dicloroetilene (DCE), Cloruro di vinile (CV) ed infine Etilene ed Etene; questi ultimi composti sono innocui e non comportano rischi ambientali o sanitari.

L'innesco di tali processi richiede l'instaurarsi nel sottosuolo di condizioni geochimiche favorevoli all'azione dei batteri (presenti naturalmente nel sottosuolo o inoculati) responsabili del processo di declorazione, tra cui condizioni riducenti (potenziale redox inferiore a -200 mV), ambiente anaerobico/anossico (tra 0-1 mg/l) e pH neutro (range 6-8). Le reazioni di declorazione degli alto-clorurati (PCE e TCE) hanno cinetiche più rapide e numerosi sono i batteri in grado di svolgerle, mentre la declorazione dei composti basso-clorurati (DCE e CV) hanno cinetiche significativamente più lente e pochi microrganismi efficaci e capaci di portare a compimento la loro degradazione. Pertanto, nei processi di bonifica con tale tecnologia si può riscontrare un'interruzione o stallo dei processi sequenziali con accumulo di DCE e CV senza ulteriore declorazione.

Nel presente studio è stata approfondita la tematica dello stallo dei processi di declorazione, con l'obiettivo di riconoscerlo

tempestivamente per poter ottimizzare e reindirizzare l'azione di bonifica.
La tecnologia ERD, selezionata come "Best Available Techniques" (BATs), è stata applicata presso un sito nazionale situato, dove è stata riscontrata una contaminazione diffusa da solventi clorurati, principalmente TCE, in un acquifero ad elevata permeabilità. L'applicazione a scala pilota, preceduta da un test a scala di laboratorio, ha previsto una prima fase di iniezione di una miscela di substrati organici, al fine di stabilire le condizioni geochimiche favorevoli all'azione dei batteri, ed una successiva iniezione di specie microbiche selezionate in laboratorio quali i Dehaloccocoides (Dhc), al fine di accelerare i processi di declorazione, garantire un'azione di bonifica più efficace e portare a termine il processo di declorazione.
Il test a scala pilota ha dimostrato l'efficacia nel trasformare i solventi alto-clorurati (PCE e TCE) in 1,2-DCE, CV ed etene, con abbattimento di massa della contaminazione; tuttavia, dopo oltre un anno dall'avvio del test pilota, pur perdurando le condizioni geochimiche favorevoli alla declorazione e una ricca popolazione microbica, è stato rilevato uno stallo dei processi a 1,2-DCE e CV. A questo punto è stata eseguita un'analisi di dettaglio che ha evidenziato il ruolo cruciale di alcuni acidi grassi (Volatile Fatty Acids «VFA») nel processo di degradazione completo dei solventi clorurati. I VFA, comportandosi come donatori di elettroni, stimolano infatti la completa declorazione riduttiva dei solventi clorurati, sia come substrati diretti per le specie microbiche sia tramite il rilascio di H2 libero a seguito della degradazione dei VFA con consumo sequenziale da parte dei batteri, partendo dall'acido proprionico, seguito dall'acido butirrico, formico e lattico ed infine acetico. In particolare, solo i VFA che producono H2 libero sono utili alla popolazione di Dhc per la degradazione del CV. Il rapido consumo del substrato, a causa di un acquifero altamente mobile ed una popolazione microbica particolarmente attiva e reattiva, ha lasciato solo acido acetico, che non genera H2; pertanto, pur con un contenuto adeguato di carbonio organico totale, non sussistevano le condizioni necessarie a portare a termine il processo che restava in stallo sui prodotti intermedi della declorazione ovvero sul CV. La presenza di popolazioni attive di batteri nei pozzi pilota con alte concentrazioni di Dhc e le condizioni geochimiche favorevoli all'innesco dei processi, non sono risultate quindi sufficienti; la programmazione di un'ulteriore iniezione di substrato organico, unita alle già favorevoli condizioni geochimiche e microbiologiche dell'acquifero, hanno

permesso di portare a termine il processo di declorazione già attivato in sito, superando l'ostacolo dello stallo al CV, con formazione di composti finali innocui quali etilene ed etene.
La tecnologia è attualmente applicata a scala di sito e promettenti sono i dati in corso di acquisizione che lasciano presagire il completamento del processo di declorazione e l'abbattimento di massa dei solventi clorurati totali presenti nelle acque sotterranee con una riduzione media delle concentrazioni della sommatoria di solventi clorurati totali maggiore del 75%, calcolata su tutti i piezometri compresi nell'area oggetto di intervento.

Keywords: declorazione o dealogenazione riduttiva, Tetracloroetilene (PCE) e il Tricloroetilene (TCE) in cis-Dicloroetilene (DCE), Cloruro di vinile (CV) ed infine Etilene ed Etene;

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Tecnologie di bonifica: scelte e casi applicativi

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L'esperienza di Ecotherm ha dimostrato come intervenire sul comparto suolo saturo, a beneficio della matrice falda, consenta di ottimizzare tempi e costi nel raggiungimento degli obiettivi di bonifica. A tal fine, sono stati analizzati casi applicativi inerenti interventi di bonifica su Punti Vendita Carburanti attivi, che hanno previsto azioni di risanamento nel comparto suolo saturo, desaturando l'acquifero mediante l'esercizio dell'impianto Pump&Treat (P&T) in contesti con litologie a bassa/media permeabilità e per contaminazioni da composti volatili, abbattuti mediante l'attivazione di un impianto Soil Vapour Extraction (SVE), associato al P&T.

In contesti interessati, invece, da contaminazioni correlate alla presenza di composti più pesanti quali Idrocarburi pesanti e IPA (ma anche da composti leggeri) e da litologie a maggiore permeabilità, sono stati registrati abbattimenti di inquinanti, mediante l'azione di desorbimento della contaminazione adesa al suolo attuata dall'uso di surfattanti, successivamente recuperata con estrazione fisica (mediante cicli di Push&Pull).

Le due metodologie di intervento illustrate nel presente lavoro, seppur applicate a siti differenti in considerazione del contesto preso ad esame e delle contaminazioni riscontrate, hanno permesso il raggiungimento degli obiettivi di bonifica, consentendo altresì di traguardare gli obiettivi di sostenibilità prefissati.

Il primo caso applicativo presenta un sito caratterizzato dalla presenza di un acquifero poco trasmissivo, con contaminazione correlata prevalentemente ad inquinanti volatili e mediamente solubili. L'area, sorgente di contaminazione, risulta libera dalla presenza di strutture interrate e fuori terra che possano comportare una limitazione logistica sull'applicazione di un intervento di tipo impiantistico. La disponibilità di dati analitici rappresentativi del comparto saturo, tali da evidenziare il grado di contaminazione adesa al terreno dell'acquifero, e la distanza dell'area sorgente dai confini del sito, hanno inciso considerevolmente sulla scelta delle tecnologie. La

necessità di intervenire sul comparto suolo saturo e di garantire il confinamento della contaminazione disciolta in falda all'interno del sito hanno condotto all'applicazione di surfattanti con duplici cicli, ripetuti nel tempo, di iniezioni ed estrazioni (Push&Pull, P&P), queste ultime potenziate a fasi alterne con l'esercizio di un impianto di P&T.
A causa della bassa trasmissività dell'acquifero, le fasi di estrazione dei cicli sono state più difficili da completare e hanno necessitato dell'azione del P&T, senza il quale l'intervento non sarebbe stato proponibile. Gli esiti analitici rilevati tra le fasi di iniezione e quelle di estrazione hanno evidenziato l'effetto di solubilizzazione del parametro idrocarburi totali, desorbiti dal suolo, con concentrazioni oltre 10 volte superiori a quelle iniziali, confermando l'efficacia dell'intervento eseguito.
A distanza di circa un anno dalle prime iniezioni, le concentrazioni residuali rilevate in falda hanno consentito di acclarare il raggiungimento delle CSC ai POC del sito. Tuttavia, la persistenza di contaminazione nelle acque sotterranee in area sorgente ha condotto, successivamente, all'esecuzione di ulteriori cicli di P&P, tali da consentire un ulteriore abbattimento della contaminazione in area interna al sito finalizzato al raggiungimento degli obiettivi di bonifica.
Il secondo caso applicativo presenta un sito caratterizzato dalla presenza di un acquifero ad alta trasmissività, con contaminazione correlata a inquinanti sia leggeri che pesanti. Anche in questo caso, l'area sorgente risulta libera dalla presenza di strutture interrate e fuori terra consentendo l'applicazione di una tecnologia impiantistica (P&T). Il fallimento dei tentativi di collaudo hanno evidenziato che il lento rilascio della contaminazione a carico del suolo saturo necessitava di un intervento più invasivo sulla matrice solida. La soluzione del P&T combinato all'applicazione di surfattanti mediante l'esecuzione di n. 3 cicli ha consentito, in questo caso, di traguardare gli obiettivi di bonifica in un periodo inferiore ai 18 mesi, confermati dai monitoraggi eseguiti nell'anno successivo che hanno condotto, infine, alla chiusura del procedimento ambientale.
Nel terzo caso applicativo è stato, inoltre, affrontato un sito con caratteristiche analoghe al primo, dove, in funzione della localizzazione della contaminazione (presente ai confini del sito sia nel comparto suolo che nelle acque sotterranee), si è preferito optare per la combinazione del P&T con l'impianto SVE in modalità Dual Phase Extraction, al fine di desaturare la falda e agire nella matrice solida dell'acquifero strippando i contaminanti leggeri ivi presenti per il

risanamento del terreno saturo appena sotto frangia. La bassa permeabilità dell'acquifero, in questo caso, avrebbe potuto non garantire il completo recupero della contaminazione disciolta in falda durante la fase di estrazione dei cicli P&P. Si è scelto, pertanto, un intervento meno invasivo che ha consentito di osservare il raggiungimento degli obiettivi di bonifica già a distanza di 3 mesi dall'avvio dell'impianto e un azzeramento dei COV estratti dallo SVE in circa 10 mesi di esercizio del sistema.
Pertanto, dai risultati ottenuti, si evince come l'attuazione di soluzioni che prediligono iniezioni e/o installazioni di impianti di bonifica possa determinare l'abbattimento di tempi e costi, la riduzione dei rischi sulla salute e la sicurezza delle persone e la diminuzione dell'impatto ambientale delle bonifiche.
A riprova di ciò, tutti i casi applicativi hanno mostrato il raggiungimento degli obiettivi a circa un anno di distanza dall'avvio delle suddette tecnologie di bonifica, confermando l'efficacia dell'approccio che prevede la sinergia di diverse tecnologie finalizzate a ottimizzare ogni singolo processo in un percorso di maggiore sostenibilità.
Dal confronto tra il primo e il secondo caso, in particolare, emerge chiaramente quanto le caratteristiche idrogeologiche dell'acquifero rappresentino elemento fondamentale nel riscontro dell'efficacia della combinazione delle due tecnologie prescelte – P&P e P&T – al fine di ottenere gli obiettivi di bonifica in tempi brevi.

Keywords: Bonifiche sostenibili, Pump&Treat (P&T), Soil Vapour Extraction (SVE)

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Trattamento di terreni contaminati con PFAS mediante geocompositi attivi

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La rimozione delle sostanze perfluoroalchiliche e polifluoroalchiliche (PFAS) dall'ambiente sta diventando una delle principali sfide ambientali che enti pubblici, agenzie di protezione ambientale, aziende private e progettisti di tutto il mondo devono affrontare. I proprietari, pubblici o privati che siano, di un sito contaminato che vogliono destinare il sito ad un qualsiasi utilizzo si trovano di fronte al problema della gestione del terreno scavato.

Dopo avere effettuato le operazioni di scavo, il terreno non sarà più soggetto alle normative sulla protezione del suolo ma, nella maggior parte dei Paesi dovranno essere applicate le normative relative alla gestione dei rifiuti. Per tale motivo risulterà necessario il conferimento in discarica di quantità molto significative di terreno. Tuttavia, tale conferimento in discarica è oggi piuttosto oneroso, poiché sono necessari particolari trattamenti del percolato e poiché le incertezze e le frequenti modifiche normative rendono impossibile una determinazione precisa a priori dei costi.

Oltre al problema economico del conferimento, c'è anche un problema di tipo ambientale, in quanto enormi quantità di terreno devono essere trasportate su camion, spesso per lunghe distanze.

Di conseguenza, il riutilizzo di siti contaminati da PFAS a seguito dell'escavazione di significative quantità di terreno scavato risulta essere un progetto di bonifica complesso, costoso e quindi difficilmente praticabile.

Per questo motivo, è necessario trovare un nuovo approccio che permetta lo stoccaggio e il trattamento dei terreni di scavo direttamente in sito. Un approccio innovativo, oggetto del presente articolo, è l'uso di geocompositi attivi, posati alla base di stoccaggi di terreno contaminato da PFAS.

Questa soluzione elimina la necessità di realizzare una barriera impermeabile in sommità, e consente all'acqua piovana di entrare

all'interno del volume di terreno stoccato. La solubilità dei contaminanti viene sfruttata per ottenere una decontaminazione passiva del suolo: grazie alle precipitazioni naturali (o, eventualmente, ad una bagnatura artificiale), si attiva un processo di lisciviazione che porta al rilascio delle sostanze chimiche dalle particelle di terreno.
In questo modo il percolato trasporta le sostanze chimiche al geocomposito attivo, all'interno del quale i contaminanti vengono rimossi dall'acqua che poi, depurata, percolerà liberamente nel sottosuolo. A seguito di questa decontaminazione il terreno potrà poi essere utilizzato come materiale da costruzione per opere in terra quali, per esempio, rilevati, argini o barriere antirumore.
Questo tipo di processo di decontaminazione sarà possibile solo se il rischio di infiltrazioni di contaminanti nel sottosuolo potrà essere totalmente eliminato e se il legame tra contaminanti e sostanza adsorbente attiva sarà efficace e garantito a lungo termine.
La soluzione presentata in questo articolo prevede l'utilizzo di uno speciale materiale attivo in grado di scambiare anioni in maniera fortemente selettiva e che presenta quattro grandi vantaggi rispetto ad altre sostanze adsorbenti, come il carbone attivo o l'argilla organofila:
1) la cinetica di reazione molto rapida consente di filtrare il percolato con un'efficacia tale da mantenere la concentrazione di contaminanti al di sotto delle soglie previste della norma;
2) il materiale attivo è in grado di legarsi sia a PFAS a catena lunga che a catena corta;
3) il legame non avviene solo per adsorbimento ma anche per scambio ionico: in questo modo il legame è irreversibile e, conseguentemente, il desorbimento è quasi impossibile;
4) la capacità di legame e accumulo è di diversi ordini di grandezza superiore a quella del carbone attivo.
Sono già state effettuate numerose prove di laboratorio relativamente a tutti i vantaggi sopra elencati. Oltre a tali prove, sono in fase di esecuzione due campi prova in scala reale, uno dei quali all'interno di un sito aeroportuale tedesco: l'acqua che attraversa il terreno e il geocomposito

Keywords: PFAS, geocompositi attivi

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Analisi di rischio ecologica in ambiente costiero

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L'AdR Ecologica (ERA) può configurarsi come un supporto decisionale per gli interventi previsti da Progetti di Fattibilità Tecnico ed Economica in tema di Bonifiche come in casi particolari e complessi ove l'attività industriale durata decenni abbia prodotto drastici cambiamenti ambientali e forme di impatto che continuano a persistere nonostante la dismissione delle attività.
I risultati delle indagini effettuate secondo il piano di caratterizzazione ambientale dell'area marino costiera prospiciente il SIN di Napoli, predisposto dalla Stazione Zoologica Anton Dohrn e approvato in data 26/09/2017 dalla Conferenza di Servizi decisoria, rappresentano la caratterizzazione ambientale di riferimento con i dati di base per l'elaborazione della ERA. Gli studi afferenti alle indagini sono rintracciabili nella relazione "Sperimentazioni Pilota Finalizzata al Restauro Ambientale e Balneabilità del SIN Bagnoli-Coroglio" (acronimo ABBaCo) redatta dalla Stazione Zoologica Anton Dohrn, incaricata dal Ministero dell'Istruzione dell'Università e della Ricerca.
Le conclusioni dello studio di ABBaCo indicano un "inquinamento generalizzato dei fondali, soprattutto nei pressi dell'ex sito industriale nella zona dei pontili e della colmata ed in direzione nord verso l'arenile. (…) La contaminazione pare interessare le componenti biologiche analizzate, con tendenza al bioaccumulo nei mitili nella zona più prossima ai pontili e alla colmata ed attivazione di risposte fisiologiche allo stress. (…) Si evidenzia pertanto un ruolo dei sedimenti nel mediare la biodisponibilità".
Lo stesso studio ha elaborato i dati adottando un approccio pesato (Weight of Evidence) su più linee di evidenza (Lines of Evidence); questo si presenta come un metodo multidisciplinare in grado di sintetizzare ed integrare differenti tipologie di dati con lo scopo di fornire un indice di rischio univoco per il sito.
Il set di dati derivante dai risultati delle linee di evidenza (LOEs), è stato integrato tramite l'approccio Weight Of Evidence (WOE) prendendo a riferimento il modello quantitativo Sediqualsoft. Gli hazard quotient (quozienti di rischio) quantitativi (HQ) ottenuti per ogni LOE sono stati

normalizzati su una scala comune e ad ognuno attribuito un peso secondo la propria rilevanza nell'ambito della caratterizzazione. Gli specifici HQ per le singole LOE, sono poi integrati nella valutazione WOE finale per determinare dei livelli di rischio.
Gli interventi previsti dal PFTE consistono nella rimozione selettiva dei sedimenti risultati contaminati nella fascia prossimale alla costa e la valutazione dell'utilizzo della tecnologia di capping.
L'obbiettivo del presente studio è quello di determinare, con i dati di cui sopra, i Livelli di rischio WOE associati a diversi possibili scenari di bonifica (capping e rimozione dei sedimenti contaminati), individuando quelli che implichino Livelli di rischio WOE accettabili, in corrispondenza delle aree di intervento; con l'obbiettivo ultimo di minimizzare l'impatto ambientale della bonifica.
Il ricalcolo degli specifici HQ per le singole LOE, negli scenari futuri post-intervento, è effettuato, pertanto, partendo dalle concentrazioni residue di inquinanti post bonifica nei sedimenti, stimando il bioaccumulo delle sostanze chimiche in specie bioindicatrici e, se possibile, gli effetti ecotossicologici misurati a livello subcellulare (biomarker).
Per stimare gli effetti del bioaccumulo di sostanze chimiche nei tessuti di mitili e pesci (LOE-2) a seguito degli scenari di intervento, è sviluppato un modello analitico di trasporto degli inquinanti nei sedimenti verso gli endpoint (il mitilo (Mytilus galloprovicialis) e, tra le specie ittiche necto-bentoniche, la triglia (Mullus barbatus), il sarago (Diplodus vulgaris) e il pagello (Pagellus erythrinus)), partendo dai risultati del Progetto ABBaCo, utilizzando software e/o tools prodotti da EPA o altri Enti/Organi internazionalmente riconosciuti.
Tramite la valutazione dell'Integreted Biomarker Response (IBR) si ricavano ulteriori informazioni sui legami intercorrenti fra contaminazione nei sedimenti e risposta dei biomarker (LOE3).
Risultati e conclusioni
Gli studi sono ancora in corso, ma si prevede di classificare le diverse subaree riportando i rispettivi livelli di pericolo (assente, leggero, moderato, alto, grave) per ogni LOE e in base all'integrazione WOE.

Keywords: Analisi di rischio ecologica

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Intervento di bonifica mediante desorbimento termico in situ con riscaldamento conduttivo nel SIN Bussi sul Tirino

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L'area "Tre Monti" occupa una superficie complessiva di ca. 33.000 m^2 e si colloca lungo il fondovalle del Fiume Pescara in prossimità della confluenza con il fiume Tirino, in un'area di estrema complessità geologica ed idrogeologica. Essa è caratterizzata dalla presenza di una coltre superficiale costituita da materiali di riporto/rifiuto antropico di 3-6 m. Le indagini svolte nel corso degli anni hanno evidenziato nei suoli naturali la presenza di contaminazioni costituite primariamente dalla famiglia degli organici clorurati.

Gli interventi di bonifica che dovranno essere attuati per le matrici ambientali avranno come obiettivo il raggiungimento delle CSR sito specifiche. L'avvio degli interventi di bonifica dell'area mediante desorbimento termico in situ è subordinato alla realizzazione di un primo modulo di trattamento che ne confermi l'efficacia. L'area di intervento è stata completamente compartimentata mediante palancolatura laterale e capping superficiale al fine di limitare la circolazione idrica nel sottosuolo, ridurre gli apporti di acque meteoriche, ridurre le perdite di calore e impedire eventuali migrazioni di vapori all'esterno del modulo. All'interno dell'area verranno installati n. 39 elementi riscaldanti da 3"(H1-H39) che avranno l'obiettivo di innalzare la temperatura del sottosuolo nel tratto. compreso fra -9 e – 13 m dal pc sino alla temperatura di ebollizione dell'acqua, determinando la vaporizzazione dei contaminanti ivi presenti. Il sistema prevede di sfruttare le proprietà azeotropiche delle miscele di contaminanti presenti nel sottosuolo per estrarli in forma di vapore a temperatura inferiore a quella di ebollizione delle sostanze pure. In base alle caratteristiche sito specifiche è stato individuato il sistema di riscaldamento conduttivo come il più adatto a raggiungere gli scopi previsti. L'innalzamento della temperatura del suolo è realizzato attraverso resistenze elettriche poste all'interno degli elementi riscaldanti in acciaio dai quali il calore

si diffonde per conduzione all'interno dell'area di trattamento. In superficie gli elementi riscaldanti sono collegati ad una Power Unit che regola l'apporto energetico a ciascun elemento al fine di determinare una diffusione ottimale del calore all'interno dell'area di trattamento, modulandola in base alla distribuzione delle temperature nel suolo, delle concentrazioni estratte e delle depressioni osservate ai punti di ventilazione.
Durante l'esercizio degli impianti vengono effettuati attenti controlli ai punti di emissione affinché sia garantito il costante rispetto di limiti normativi, nonché controlli nelle aree limitrofe alla zona di riscaldamento al fine di escludere eventuali fughe di contaminanti dalla zona di trattamento.
La fase di riscaldamento del suolo, avviata in luglio 2022, avrà una durata complessiva di 100 giorni al termine dei quali verrà effettuato il collaudo degli interventi mediante carotaggio dei suoli trattati e analisi di laboratorio su campioni di terreno prelevati dalle carote estratte. Saranno realizzati n. 3 sondaggi a carotaggio continuo con prelievo di campioni ed analisi chimica di laboratorio di n. 3 campioni per sondaggio con la ricerca dei contaminati caratteristici del sito. Il collaudo degli interventi potrà essere anticipato qualora venissero a manifestarsi una o più condizioni che possano indicare il raggiungimento dei limiti tecnologici o l'esaurimento delle contaminazioni presenti.
Tutti i dati raccolti durante l'esercizio del primo modulo di bonifica mediante desorbimento termico confluiranno in un report di fine intervento che verrà presentato gli Enti competenti per validare l'efficacia del trattamento e costituiranno la base del nuovo progetto operativo di bonifica che verrà presentato per il sito, preludio all'intervento Full Scale su una superficie di 5200 m^2.

Keywords: desorbimento termico, palancolatura laterale, capping superficiale

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Ottimizzazione della risorsa idrica in un progetto di operativo di bonifica nell'ambito della riqualificazione ambientale di una ex discarica di RSU

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Nell'ambito della riqualificazione ambientale di una ex discarica di RSU si è reso necessario procedere alla bonifica delle acque sotterranee, che presentano un'alterazione riconducibile alla presenza di rifiuti in falda, con presenza di contaminanti quali ferro, manganese, boro e azoto ammoniacale in concentrazioni superiori ai limiti di legge.
L'impostazione del progetto di bonifica ha seguito i princìpi di sostenibilità ambientale e di ottimizzazione della risorsa idrica, prevedendo un sistema di ricircolo delle acque sotterranee costituito da un sistema Pump&Treat – finalizzato alla bonifica del boro – e da un sistema di reimmissione in falda, a monte idrogeologico della discarica, delle acque depurate. Prima della reimmissione, le acque verranno opportunamente ossigenate mediante il transito in un canale a cielo aperto con salti di fondo e cascatelle, così da ottenere il giusto grado di saturazione in ossigeno per consentire l'abbattimento per via ossidativa del ferro, manganese e azoto ammoniacale. Il sistema di bonifica è stato progettato mediante modello idrogeologico di flusso e trasporto reattivo dei contaminanti, che sarà tarato con i dati reperiti nel corso dell'intervento per permettere eventuali ottimizzazioni in corso d'opera del sistema.
Un'ulteriore opportunità di ottimizzazione della risorsa idrica nell'ambito del progetto è costituita dal sistema di gestione delle acque meteoriche dell'area. Nell'ambito dell'intervento di riqualificazione, infatti, è previsto un rimodellamento morfologico superficiale dell'area, con lo scopo di creare le idonee pendenze per la regimazione e la raccolta delle acque meteoriche, al fine di impedire la formazione di ristagni ed inibire l'infiltrazione delle stesse nel corpo dei rifiuti. Tale intervento comporta la necessità di dover gestire un grande quantitativo di acque meteoriche, in considerazione dell'ampia estensione dell'area in esame, dovendone prevedere un'idonea laminazione ed individuandone i recapiti finali. Tale aspetto

costituisce una criticità nel caso in esame, non essendovi corsi d'acqua nei pressi del sito dove recapitare le acque, ed essendo l'area sprovvista di fognatura.
Questa criticità è stata trasformata, dal progetto, in un'opportunità per implementare la funzionalità del sistema di bonifica della falda. In tale ottica, le acque provenienti dal sistema di drenaggio verranno rilanciate in una vasca di accumulo ubicata nell'area topograficamente più rialzata della discarica e quindi convogliate in un canale a cielo aperto, analogo e parallelo a quello predisposto per il ricircolo delle acque di falda depurate, costì da consentirne l'ossigenazione, prima della reimmissione in pozzi perdenti ubicati a monte idrogeologico dell'area di discarica. L'apporto delle acque meteoriche nel sottosuolo favorirà l'ossigenazione della falda e la conseguente ossidazione dei contaminanti.

Keywords: Bonifica acque, ex discarica RSU, Pump&Treat

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Mappatura del LNAPL nel sottosuolo e valutazione delle interferenze tra tecnologie per la sua rimozione

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Il primo passo per procedere alla bonifica della falda contaminata da idrocarburi (LNAPL) è quello di individuare e rimuovere l'eventuale prodotto in fase libera presente nella frangia capillare e a contatto con la falda. La corretta e dettagliata conoscenza del modello concettuale del sito assume un ruolo estremamente importante soprattutto nei casi in cui la superficie areale impattata è di grosse dimensioni, sono presenti sistemi attivi di recupero del prodotto in fase libera che alterano la distribuzione della contaminazione e in presenza di un assetto stratigrafico/idrogeologico particolarmente complicato.
Il presente studio descrive le attività che sono state svolte per ridefinire la distribuzione del prodotto in fase libera al fine di rimodulare il Progetto operativo di bonifica della falda (POB) e, in particolare, rivedere in modo critico l'ubicazione dei previsti sistemi di Dual Pump in considerazione della presenza dei sistemi di recupero del prodotto in fase libera e di sistemi multiphase extraction (MPE) ormai attivi da alcuni anni che hanno modificato il quadro ambientale del Sito a cui si riferiva il POB.
Considerato che la presenza di sistemi attivi di recupero rende poco praticabile la ricostruzione della distribuzione del prodotto, basata esclusivamente sull'analisi degli spessori apparenti misurati nei piezometri, lo studio è stato basato anche sull'esame dei volumi estratti, sulla determinazione degli spessori reali, sulla verifica della condizione in cui si trova il prodotto (libera, confinata o sospesa) e sulla composizione del prodotto stesso.
Lo studio è stato svolto secondo le seguenti fasi di lavoro:
- valutazione della ricarica tramite la misura del volume di prodotto recuperato da tutti i punti che sono attrezzati con sistemi mobili o con sistemi fissi per il recupero del prodotto in fase libera;
- esecuzione di baildown test su una selezione di punti, appartenenti alla rete di monitoraggio e controllo del prodotto, e su una selezione

di punti collegati al sistema MPE installato presso il Sito (temporaneamente spento per l'esecuzione del presente studio al fine di evitare interferenze);
- esecuzione di prove idrauliche e prove dual pump (a MPE spento e successivamente ri-acceso) su alcuni punti Dual Pump (DP) previsti dal POB approvato e ad oggi già realizzati.

Gli esiti dei baildown test sono stati elaborati sulla base di quanto indicato nel documento API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis, API publication 4762, Aprile 2016. Per la definizione del volume specifico del prodotto e per la sua distribuzione è stato utilizzato il software Concawe LNAPL Toolbox, Concawe, Brussels, Belgium.

Nel periodo di studio, dall'analisi dei volumi recuperati dai punti attrezzati con sistemi fissi e mobili, sono stati ricavati tassi di recupero generalmente inferiori a 1 l/h, anche se localmente sono stati registrati tassi di recupero più elevati e compresi tra 1,36 l/h e 9,72 l/h. I tassi di recupero sopra esposti sono risultati coerenti con i valori della trasmissività del prodotto acquisiti mediante baildown test eseguiti su alcuni punti selezionati e interpretati con il metodo Bouwer and Rice (B&R). In generale si osservano dei valori di trasmissività poco elevati, a significare un recupero del prodotto difficoltoso. Gli unici punti in cui la trasmissività è superiore all'unità sono MPE-044 (1,54 m2/giorno) e MPE-045 (1,169 m2/giorno). Negli altri punti si riscontra una trasmissività del prodotto inferiore a 0,4 m2/giorno.

Per verificare le condizioni idrostratigrafiche in cui si trova il prodotto in fase libera sono stati elaborati idrogrammi e diagnostic gauge plot. Dall'esame dei risultati emerge che, in generale, il prodotto si trova in condizioni libere: la quota di tutte e tre le interfacce e lo spessore apparente hanno un andamento negativo nei diagnostic gauge plot e lo spessore apparente di LNAPL, infatti, varia in modo inverso rispetto alla quota della falda.

Gli esiti dei test eseguiti in campo integrati con le informazioni di carattere stratigrafico desunte dalle perforazioni eseguite nel passato nell'area di studio e con i dati di soggiacenza acquisiti nel corso delle molteplici campagne di monitoraggio effettuate nel tempo e mediante l'utilizzo del Concawe LNAPL Toolbox permetteranno di calcolare diversi fattori inclusi il volume specifico e il volume recuperabile riferito ai diversi contesti stratigrafici rilevati in sito. I fattori sopra esposti consentiranno a loro volta di stimare il volume di prodotto nel sottosuolo e di mapparne la distribuzione e di

conseguenza ubicare i sistemi di DP alla luce del nuovo quadro ambientale delineato.

Keywords: Mappatura del LNAPL, MPE, interferenze tra tecnologie

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Sviluppi ISCO per il controllo del Rebound

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Le tecnologie di In Situ Chemical Oxidation (ISCO) hanno avuto origine negli anno '90 del XX secolo per la rimozione di contaminanti organici dal terreno e dalle acque di falda. Uno dei maggiori ostacoli per la chiusura dei siti consiste nel rebound che si osserva quando, esaurito l'effetto dei reagenti ISCO, si ha un nuovo rilascio di contaminanti dalla sorgenti secondarie.

Negli ultimi anni sono state sviluppate tecnologie volte alla riduzione del rebound attraverso l'uso di prodotti persistenti, di tensioattivi o di combinazioni di adsorbimento ed ossidazione/riduzione: presenteremo le tecnologie MLO (Carus), RemSURF (Carus), Intrawhite (Intrapore). Di tali tecnologie sarà presentata una breve descrizione e casi applicativi.

Descrizione delle tecnologie

MLO (Mixed Liquid Oxidants) è una miscela sviluppata da Carus composta da diverse proporzioni di permanganato di sodio e di persolfato di sodio che combina l'efficacia del persolfato con la persistenza del permanganato per ridurre il rebound. La presenza dei due reagenti permette di trattare una vasta gamma di contaminanti.

RemSURF è un tensioattivo specifico per applicazioni di risanamento che presenta una buona resistenza agli agenti ISCO consentendo la riduzione della tensione superficiale con la conseguente pseudo-solubilizzazione e trattamento delle sorgenti secondarie riducendo la massa che origina il rebound. RemSURF è applicabile a tutti i contaminanti organici idrofobici (TPH, PAH, clorurati, pesticidi...). RemSURF ha un effetto fisico e non chimico per cui non reagisce con i contaminanti e non genera prodotti/sottoprodotti di reazione.

Intrawhite (brevetto UFZ Lipsia prodotto su licenza da Intrapore Germania) è una tecnologia di Fenton modificato che prevede l'iniezione di Ferro Zeoliti seguita da iniezione di perossido di idrogeno (acqua ossigenata) che genera i radicali Fenton in corrispondenza dei siti attivi delle zeoliti. Non è necessario il controllo del pH. L'effetto di adsorbimento temporaneo sulle zeoliti permette di ridurre le concentrazioni in falda nel corso del trattamento riducendo il

rebound. La tecnologia del tipo di Fenton è efficace su una vasta gamma di contaminanti,

Keywords: ISCO, Rebound, MLO

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Exploitation of natural processes for the remediaton of contaminated sites. Overcome prejudices and identify opportunities of bioremediation

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The balance of the ecosystem has been jeopardized by industrialization and urbanization causing environmental contamination. Therefore, pollution derived by man-made substances and, to some extent, by natural sources is of global concern nowadays. Generally, a variety of remediation techniques are applied based upon physicochemical, chemical or biological methods. Over the past years the understanding of bioremediation processes has developed significantly. It is capable of treating a wide variety of contaminants in a very cost efficient and sustainable manner. In fact, the scope of bioremediation is to biologically catalyze the reduction of the contaminants by establishing the right conditions in the ecosystem so that the environment is finally restored. The key-players in the process are the microorganisms, naturally present into the soil, which are employed to remove the pollutants. Although the application of bioremediation techniques requires a multidisciplinary approach, the understanding of microbiology is crucial. The knowledge of microorganisms responsible for the degradation of certain compounds and their stages of degradation is a key factor for the success of the remediation.

Bioremediation is often underestimated and considered inadequate for several reasons (e.g., remediation time, achieving low objective limits, dealing with high concentrations, unfavorable geochemistry conditions, complex site conditions, etc.).

These aspects are often considered limiting factors most likely due to the lack of knowledge of this environmental field and the ability to manage the parameters involved within the biological remediation processes. Indeed, the power of these techniques lies within the soil and the ability to operate them.

The present study wants to overcome prejudices related to bioremediation and identify application opportunities of different bioremediation approaches by showcasing various case studies.

Case study 1. On-site biopiling of xylene contaminated soil: project completed in short time despite high concentrations.

A former triacetate production facility caused heavy xylene contamination with concentrations up to 27,850 mg/kg, resulting in 83 ton of xylene that required active treatment. A lump sum contract was signed which consisted of 100% on-site and in-situ bioremediation, as it was more sustainable and economical than conventional off-site techniques.

Excavated soil was placed in biopiles, where dosing of nutrients and bioventing stimulates biodegradation of the contaminants. After soil treatment and in areas that could not be excavated due to logistical utility restrictions, an in-situ biosparging system has been installed below ground level.

Individual biopiles were reduced within 60–80 days to concentrations levels < 50 mg/kg. App. 25,000 m3 of heavily contaminated soil were treated to levels far below remedial target within a total period of 18 months.

Case study 2. In-situ aerobic bioremediation to treat in short time high load of BTEX, MTBE and mineral oil (MO).

An old petrol station caused a distinct groundwater contamination plume which migrated over a distance of approx. 300 m and until 20 m depth. In the plume end, high concentrations of MTBE (up to 100,000 µg/l) and benzene (up to 100,000 µg/l) were reported. Given the nature of the contamination, the source zone was treated with SVE and the plume with a biosparging system combined with P&T connected to 5 bioreactors for the groundwater treatment.

Strong decrease in the contamination concentrations in the soil and groundwater plume have been observed (BTEX < 10 µg/l, MTBE < 10 µg/l, MO = 0 µg/l), and remediation has been completed within 1 year.

Case study 3. In-situ anaerobic bioremediation to allow redevelopment of the area and achievement of low target values.

The remediation project of an historical manufacturing site aimed at a full-scale cVOC remediation to enable redevelopment of the site by means of excavation of contaminated mass in the hot spots and in-situ enhanced anaerobic bioremediation.

Concentrations up to 66.000 µg/l PCE and 19,000 µg/l 1,2 DCE decreased to values < 1 µg/l and < 45 µg/l respectively. To note that

meantime, a new building has been built on top of the remediation system to allow the redevelopment of the area.

Case study 4. In-situ aerobic bioremediation despite unfavorable site conditions.

An operational petrochemical site is contaminated with a cocktail of contaminants (e.g., MTBE, MO, monochlorobenzene, BTEX, cVOC). The site conditions are complex due to the high COD and strong reducing conditions. Due to these conditions, bioremediation was not taken into consideration for a pilot test. Therefore, MPE and ISCO were tested but did not lead to successful outcomes. Despite unfavorable site conditions, a groundwater circulation system was implemented to enhance aerobic biodegradation in-situ.

In the first months, the redox conditions remained strongly reduced and the natural oxygen demand of both soil and groundwater was extremely high. However, once the chemical reactions (e.g., Fe oxidation, oxidation of Sulfide complexes) were completed and the environment became aerobic, a strong reduction of the contaminants concentrations was obtained within 4 months.

Keywords: bioremediation, exploitation of natural processes, MTBE, MO, monochlorobenzene, BTEX, cVOC

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PROVECT-EBR® - Generatore in situ di ossidanti reattivi - la nuova frontiera

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I trattamenti di In-Situ Chemical Oxidation (ISCO) sono in grado di ossidare un'ampia famiglia di contaminanti e prevedono generalmente l'iniezione nel terreno di prodotti ossidanti che innescano energiche reazioni di ossido-riduzione in grado di decomporre in contaminanti in composti innocui come anidride carbonica e acqua.
L'esperienza acquisita negli ultimi decenni ha però evidenziato la necessità di una nuova tecnologia ISCO in grado di superare alcune limitazioni correlate alle applicazioni ISCO "tradizionali", quali la ridotta longevità delle specie ossidanti reattive, l'impossibilità di garantire l'applicazione in configurazione PRB e la difficoltà nell'applicazione in acquifero profondi.
Per superare tali limitazioni è stata ideata, progettata e brevettata la tecnologia Provect-EBR® (EBR = Electro - Biogeochemical - Remediation) che consiste sostanzialmente in un generatore ISCO in situ in grado di produrre continuamente specie reattive ossidanti (reagenti Fenton's-like e Ossigeno disciolto), a pH neutro e senza l'aggiunta di agenti chimici esogeni. Questi reattivi colloidali (a scala nanoscopica) e catalitici vengono propagati, grazie a molteplici meccanismi chimico/fisici, al di fuori dei pozzi-reattore (distanziati alcuni metri gli uni dagli altri) all'interno della falda acquifera dove i contaminanti vengono distrutti attraverso reazioni di ossidazione chimica. L'ossigeno e il ferro residuo vengono poi utilizzati come accettori di elettroni per sostenere il biorisanamento aerobico dei contaminanti residui. Provect-EBR® integra quindi meccanismi ISCO, microbiologici e geofisici per il trattamento di diverse tipologie di contaminanti (solventi clorurati, idrocarburi, MtBE in primis).
Il Provect-EBR® può essere applicato efficacemente in area sorgente, ma è la sua applicazione in configurazione tipo PRB che la differenzia

maggiormente dalle altre tecnologie ISCO e che ne supera una delle principali limitazioni.
Ogni pozzo-reattore EBR è composto da tre elettrodi, solitamente installati in piezometri di diametro 3-4", di cui due, ad alta attività catalitica, utili alla generazione di O2 molecolare che viene poi costantemente ridotto a formare H2O2. Un terzo elettrodo serve invece come fonte costante di cationi di Fe (Fe2+ e Fe3+), tramite corrosione indotta del Fe. L'H2O2 interagendo con il Fe2+ forma continuamente specie ossidanti (idroperossidi, superossidi, radicali ossidrili e probabilmente anche ferrati) che vanno ad ossidare i contaminanti presenti nell'acquifero.
Ad oggi la tecnologia Provect-EBR® è stata applicata efficacemente su diversi siti industriali in Israele e negli USA, dove è stata osservata, sia su scala pilota che full-scale, la rapida ossidazione di solventi clorurati, idrocarburi di origine petrolifera e MtBE. Le applicazioni future potrebbero riguardare perclorati, sostanze perfluoroalchiliche (PFAS), 1,4-diossano, prodotti farmaceutici ed altri contaminanti recalcitranti.

Keywords: In-Situ Chemical Oxidation, idrocarburi, MtBE, PFAS.

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III. Intelligence e legislazione ambientale

Lo sviluppo ecologico in attuazione del principio «chi inquina paga» nell'unitario sistema italo-europeo di responsabilità ambientale

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Le incertezze esegetiche della Suprema Corte in tema di bonifica di siti contaminati sono contrastate da orientamenti della giurisprudenza amministrativa volti alla responsabilizzazione dell'inquinatore. Attraverso una rilettura ecologica delle norme civilistiche e di quelle societarie, e in un'ottica di economia circolare, si impedisce che l'utilizzo elusivo dello schermo della personalità giuridica si concretizzi nella violazione dei principi ambientali europei, in particolare del «chi inquina paga». Il sistema della responsabilità ambientale, di matrice italo-europea, appare indebolito da un orientamento della giurisprudenza di legittimità, in continuità con il passato remoto del Codice dell'ambiente, finalmente adeguatosi a quello europeo in termini di responsabilità oggettiva. La natura giuridica dell'azione di rivalsa contro il responsabile dell'inquinamento e la parziarietà dell'obbligazione risarcitoria ambientale inducono il civilista ad un'ulteriore riflessione sull'utilità di un'interpretazione degli strumenti civilistici in funzione di tutela ambientale, in linea con il principio «chi inquina paga». L'unitario sistema italo-europeo di responsabilità ambientale è indirizzato verso una sensibilizzazione intergenerazionale alle tematiche ambientali, attraverso il Green New Deal, a forme di economia circolare che inducano gli operatori del diritto e del mercato a superare il modello antitetico tra sviluppo e tutela ambientale e a giungere al c.d. "sviluppo ecologico". La sensibilità ecologica del proprietario, volta nel contempo a garantire l'interesse alla circolazione immobiliare del bene, non può essere eccessivamente sacrificata nella esplicazione della sua funzione sociale-ambientale, rispetto alle esigenze dell'impresa, soprattutto là dove quest'ultima sia per sua natura nociva alla salute e all'ambiente, perché ciò potrebbe indurre il proprietario alla rinuncia alla proprietà del sito inquinato. E ciò spiega il regime unitario italo-europeo di

responsabilità ambientale di tipo oggettivo, che non riduce i margini di traslazione delle esternalità negative ambientali dalla collettività, e mutatis mutandis dal proprietario non inquinatore, al responsabile dell'inquinamento, in ossequio al principio «chi inquina paga».

Keywords: Bonifica siti inquinati; danno ambientale; principio «chi inquina paga»; responsabilità sociale e ambientale di impresa

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Sicurezza ambientale e competitività: il ruolo della prevenzione e contrasto della criminalità ambientale nell'attuazione delle bonifiche, perno dello sviluppo sostenibile dei territori

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Recenti interventi normativi ed il significativo impegno previsto nel PNRR per le bonifiche, sottolineano la volontà delle Istituzioni di procedere con interventi celeri e fattivi. Non è d'altronde procrastinabile l'impegno per bonificare i territori, anche a fronte del fenomeno della perdita di suolo per lo svolgimento delle attività antropiche. Il recupero dei siti non solo rappresenta una importante attività ambientale, ma può costituire la valorizzazione dei territori con nuovi insediamenti produttivi, affiancando il percorso delle bonifiche a quello dello sviluppo sostenibile e favorendo il raggiungimento degli obiettivi del Green Deal. E' di fondamentale importanza considerare le potenzialità dei terreni oggetto di bonifica prevedendo, fin dalla fase progettuale, un successivo utilizzo per favorire un oculato sviluppo sostenibile, orientato al concreto rispetto per l'ambiente e gli ecosistemi, non più differibile visti gli effetti tangibili della crisi climatica. Le attività di bonifica rappresentano un eccezionale campo di prova della sfida della sicurezza ambientale «di riuscire a coniugare l'interesse primario alla tutela dell'ambiente e della salute con quello, altrettanto imprescindibile, della capacità produttiva e della competitività del Paese» , tenendo ben presente il ruolo centrale che ambiente e salute hanno assunto «anche nell'interesse delle future generazioni» nella rinnovata formulazione dell'art. 9 della Costituzione. Per garantire risultati ottimali e tutelare gli interessi dell'economia sana è necessario non distogliere l'attenzione dai possibili appetiti criminali e potenziare gli strumenti per contrastarli, attuando efficaci attività di intelligence e prevenzione, perché le bonifiche non diventino un'occasione per la criminalità organizzata di attingere ai fondi pubblici, distraendo così

preziose risorse. Sono quindi necessari un approccio interdisciplinare e competenze trasversali per attuare un efficace contrasto alla minaccia che rappresentano i crimini ambientali, con l'elaborazione di strumenti di intelligence finanziaria e specifiche metodologie, come la formulazione di indicatori di rischio e il potenziamento dell'analisi dei dati, per valutare e contestualizzare le connessioni con altre tipologie di reati quali frodi documentali, evasione fiscale, corruzione e riciclaggio di denaro.

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Consiglio Regionale Puglia e Sustainable Development Goals

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Il 25 settembre 2015 le Nazioni Unite hanno approvato l'Agenda 2030 per lo sviluppo sostenibile. L'Agenda globale comprende una serie di 17 obiettivi articolati in 169 target o traguardi. Gli obiettivi generali, sebbene mirino a raggiungere ciascuno dei target specifici, sono strettamente collegati tra loro. Essi puntano a risolvere un'ampia gamma di problematiche riguardanti lo sviluppo economico e sociale, quali la povertà, la fame, la salute, l'istruzione, il cambiamento climatico, l'uguaglianza di genere, l'acqua, i servizi igienico sanitari, l'energia, l'urbanizzazione, l'ambiente e l'uguaglianza sociale. L'attuazione dell'agenda richiede un forte coinvolgimento di tutti i membri della società, in particolare delle imprese e degli enti pubblici. Il presente lavoro si è posto un duplice obiettivo. Da un lato si è realizzato un Geographycal Content Management System (GEO-CMS) basato su codice Open Source. Le attività hanno principalmente riguardato la raccolta di testi normativi e regolamentari, indirizzi tecnici, best practices, pubblicazioni su riviste di settore ed internazionali, relative agli indicatori ISTAT per gli SDGs 6, 12, 13, 15. Tutti i documenti raccolti sono stati digitalizzati e conservati sotto forma di archivio digitale e, ove possibile, georiferiti al fine di poter essere rappresentati in ambiente GIS. I dati sono resi consultabili anche attraverso mappe tematiche di sintesi che ne indicano la distribuzione spaziale e temporale. È stato possibile, quindi, realizzare uno strumento condiviso di conoscenza e supporto all'attività sia di ricerca che istituzionale in tema di implementazione degli obiettivi dell'Agenda 2030.

Dall'altro lato è stato analizzato il contributo della Regione Puglia alle attività di monitoraggio ed alla implementazione concreta degli Obiettivi di Sviluppo sul territorio regionale. Sono stati presi in considerazione documenti e progetti provenienti dal sito dell'Anagrafe delle Ricerche Ambientali in Puglia (A.R.A.P.) riguardante le progettualità di ricerca realizzate, unitamente alle normative approvate dal Consiglio regionale. Ciascuna legge è stata catalogata inserendo i riferimenti agli obiettivi e ai target in modo conciso e diretto. L'Elaborazione dati ha permesso di valutare le eventuali criticità che si sono verificate nel tempo. Tale lavoro ha permesso di porre l'attenzione all'importanza di agire a livello regionale per la diffusione e l'avanzamento di nuove proposte allo sviluppo sancite dalle Nazioni Unite, valutando il grado di coerenza di ogni norma con riferimento ad ogni SDG.

Keywords: Agenda 2030, SDGs, Database, Elaborazione dati

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L'oro blu: strategie di intelligence e di prevenzione per la gestione delle risorse idriche italiane

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L'acqua, oltre ad essere un fattore insostituibile di sopravvivenza, è elemento indispensabile per le attività umane e, minacciare tale importante risorsa significa impattare pesantemente le possibili utilizzazioni di natura potabile, agricola ed industriale. Per tale motivo l'acqua deve essere necessariamente considerata una risorsa strategica da tutelare anche da possibili minacce terroristiche. Nell'anno 2001, Kofi Annan, ex Segretario Generale dell'ONU, aveva dichiarato che l'accesso alle risorse idriche e il loro controllo potranno essere una tra le cause delle guerre che si combatteranno nel ventunesimo secolo. L'acqua come strumento di guerra, porta a considerare tale importantissima risorsa come obiettivo potenziale esposto a rischio di attentati terroristici che possono manifestarsi mediante atti di sabotaggio degli impianti idrici potenzialmente a rischio e facenti parte delle infrastrutture critiche. Appare quindi necessario procedere con una mappatura di tutti gli impianti idrici potenzialmente a rischio ed esposti a possibili attacchi, soprattutto analizzando le relative criticità delle singole infrastrutture. Soltanto al termine di questa analisi, possono essere previste tutta una serie di misure ed interventi volti a scongiurare, o per lo meno a mitigare il più possibile, eventuali conseguenze negative e di impatto sulla popolazione. In tal senso risulta utile anche ricercare ed analizzare le varie tipologie di attacco e sabotaggio che possono essere utilizzate contro le singole strutture per meglio adattare la conseguente risposta di emergenza. Lo studio dei vari elementi, con un'analisi integrata delle informazioni, permetterà di evidenziare le migliori strategie da adottare in tema di prevenzione affiancate da un'attenta e quanto più precisa e puntuale attività di previsione. Proprio per l'importanza che rivestono le risorse idriche, la cui gestione alimenta tensioni geopolitiche e disordini sociali, anche l'Italia dovrebbe sviluppare appositi piani di prevenzione e gestione delle risorse con investimenti

importanti nella questione idropolitica. Il rafforzamento della cooperazione internazionale potrebbe essere un utile strumento di prevenzione alimentando scambi di conoscenze e confronti che possano portare ad una crescita culturale e tecnologica per contrastare efficacemente rischi che derivano anche dalla collocazione geopolitica del nostro Paese.

Keywords: infrastrutture critiche, attacchi terroristici, intelligence

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Le novità introdotte dalla Legge 79 del 29/6/2022 con riferimento alle sanzioni per illeciti amministrativi e penali in materia di tutela ambientale

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Nella Gazzetta Ufficiale n.150 del 29-06-2022 è stato convertito in Legge n.79 del 29 giugno 2022, con modificazioni, il Decreto-Legge 30 aprile 2022, n. 36, Decreto PNRR 2, recante ulteriori misure urgenti per l'attuazione del Piano nazionale di ripresa e resilienza (PNRR).
Questo provvedimento contiene diverse misure nei più disparati campi, uno di questi è quello della tutela dell'ambiente.
Gli articoli relativi alla tutela ambientale sono contenuti nel Capo III "Misure per l'attuazione del Piano nazionale di ripresa e resilienza in materia di ambiente, fonti rinnovabili, efficientamento energetico e salute" e sono quelli che vanno dall'art. 23 al 27.
L'art. 23 prevede l'utilizzo di fonti rinnovabili per la produzione di energie elettrica senza l'applicazione agli oneri generali del sistema elettrico e, pertanto, non sottoponendo ad accisa la produzione di idrogeno.
L'art. 24 adotta le misure per il potenziamento del sistema di monitoraggio dell'efficientamento energetico attraverso le misure di Ecobonus e Sismabonus e governance dell'ENEA.
L'art. 25 fissa gli obiettivi del programma nazionale per la gestione dei rifiuti di gestione delle macerie e dei materiali derivanti dal crollo e dalla demolizione di edifici ed infrastrutture a seguito di un evento sismico.
L'art. 26 bis reca novelle alla disciplina sanzionatoria degli illeciti amministrativi e penali in materia di tutela ambientale, con riferimento alle prescrizioni da impartire al contravventore, alla verifica dell'adempimento e all'irrogazione della sanzione.

In particolare, l'art. 26-bis modifica l'art. 318 ter del Codice dell'ambiente che reca novelle alla disciplina sanzionatoria degli illeciti amministrativi e penali in materia di tutela ambientale, con riferimento alle prescrizioni da impartire al contravventore, alla verifica dell'adempimento e all'irrogazione della sanzione.
Inoltre, la Legge di conversione prevede l'emanazione, entro 30 giorni, di un Decreto Interministeriale nel quale verranno stabiliti gli importi a carico del contravventore in caso di:

- attività di asseverazione tecnica fornita dall'ente specializzato competente nella materia cui si riferisce la prescrizione, quando questi è diverso dall'organo di vigilanza che l'ha rilasciata;
- redazione della prescrizione rilasciata, previo sopralluogo ed in assenza di asseverazione, dallo stesso organo accertatore, nell'esercizio delle funzioni di polizia giudiziaria quando si tratti di ente diverso da un corpo od organo riconducibile a un'amministrazione statale.

L'art. 27 istituisce il Sistema nazionale prevenzione salute dai rischi ambientali e climatici.
L'obiettivo è quello di migliorare ed armonizzare le politiche e le strategie messe in atto dal Servizio sanitario nazionale per la prevenzione, il controllo e la cura delle malattie acute e croniche, trasmissibili e non trasmissibili, associate a rischi ambientali e climatici.

Keywords: illeciti amministrativi, illeciti penali, ecobonus

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La transizione ecologica della filiera olivicolo-olearia, tra economia circolare e finanza sostenibile

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La trasformazione e l'innovazione in senso sostenibile della filiera olivicolo-olearia rappresentano momenti strategici del processo di transizione ecologica del comparto agroalimentare. Tali processi rivestono grande importanza sia per la nostra regione Puglia, principale realtà olivicola in Italia, sia per il nostro Paese, data la rilevanza economica, sociale (in particolare per la salute e le condizioni di lavoro) e ambientale del comparto, riconosciuta anche a livello europeo.

Il processo di produzione dell'olio extravergine di oliva può essere innovato secondo una duplice prospettiva: da un lato si può agire sugli scarti di produzione, per ridurli, smaltirli o riutilizzarli al meglio; dall'altro si può innovare il processo produttivo rendendolo più sostenibile.

In merito alla prima prospettiva, la produzione di olio comporta una rilevante generazione di reflui (solidi e liquidi), in grado di causare inquinamento ambientale, se smaltiti senza adeguati trattamenti. Tali scarti di produzione, identificabili come "rifiuti", possono essere considerati "materie prime seconde" in ottica di sostenibilità ambientale, di bioeconomia e di economia circolare, intesa come nuovo paradigma economico che supera il tradizionale modello lineare (estrarre, produrre, utilizzare, gettare) e che considera i rifiuti non come elementi di scarto, ma come risorse da trasformare e reintrodurre sul mercato (cfr. Parlamento Europeo, Economia circolare: definizione, importanza e vantaggi, 2018; D.M. n. 264 del 13 ottobre 2016 "Regolamento recante criteri indicativi per agevolare la dimostrazione della sussistenza dei requisiti per la qualifica dei residui di produzione come sottoprodotti e non come rifiuti"). Allo stato attuale, i reflui oleari vengono destinati alla produzione di bioenergia,

utile a ridurre i costi energetici di produzione della stessa filiera dell'olio EVO, ma appare possibile individuare ulteriori utilizzi economicamente vantaggiosi degli scarti, anche al fine di prevenire fenomeni di smaltimento illecito, che hanno rilevanti impatti ambientali negativi.
In merito alla seconda prospettiva, la maggiore sostenibilità del processo produttivo si può ottenere introducendo nuovi macchinari che possano permettere risparmi idrici ed energetici, oppure adottando nuovi metodi di controllo e gestione del processo per migliorare l'efficienza dell'estrazione e la qualità del prodotto.
Il ripensamento del sistema produttivo e di smaltimento dei reflui della filiera, volto a contribuire alla diffusione del paradigma dell'economia circolare, richiede al comparto importanti investimenti di risorse finanziarie che possono essere reperite attraverso gli intermediari finanziari, in particolare le banche in grado di erogare finanziamenti green, ma anche attraverso il ricorso ad emissioni di titoli, come minibond e green bond, oppure partecipando ad appositi bandi pubblici di finanziamento.
In questa cornice, il Progetto ECOSNODO, "ECOnomia circolare, Sostenibilità e profili di evoluzione Normativa nella produzione dell'Olio extravergine Di Oliva" (Horizon Seeds, Università di Bari, 2022) ha l'obiettivo di: 1. Identificare le possibili forme di innovazione in senso sostenibile dell'intera filiera dell'olio d'oliva; 2. Trasformare gli scarti/rifiuti dell'industria olearia in una risorsa preziosa nell'ottica della transizione ecologica e dell'economia circolare; 3. Individuare nuove forme di finanziamento green idonee a supportare i processi menzionati e sperimentare nuove metodologie di valutazione degli investimenti aziendali che tengano conto dei parametri ESG (ambientali, sociali e di governance), in linea con l'Agenda ONU 2030, con il Green Deal EU, con il Piano per la transizione ecologica (PTE, 8.3.2022-14.6.2022) e con il PNRR (M2C1-Inv.2.3).

Keywords: Filieria olearia, rifiuti, Horizon Ecosnodo, economia circolare

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Innovare la filiera olivicolo-olearia in senso sostenibile e circolare nella prospettiva costituzionale

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La Puglia è la principale regione olivicola italiana, una filiera olivicolo-olearia del valore di oltre 1,2 miliardi di euro nella fase agricola e 3 miliardi di euro in quella industriale.

È noto che la produzione dell'olio extra vergine di oliva è associata alla produzione di reflui (solidi e liquidi), in grado di causare un non trascurabile inquinamento se rilasciate nell'ambiente senza adeguati trattamenti. Per tali scarti di produzione, inizialmente identificati come 'rifiuti', si è assistito ad un'evoluzione anche normativa, sollecitata dall'affermazione del principio della sostenibilità ambientale, in esito alla quale, da "sostanza od oggetto di cui il produttore o detentore si disfa, abbia l'intenzione o abbia l'obbligo di disfarsene" (art. 183, D. Lgs. n. 152/2006), sono divenuti 'sottoprodotto', ossia "sostanza od oggetto originato da un processo produttivo, di cui costituisce parte integrante, e il cui scopo primario non è la produzione di tale sostanza od oggetto" (art. 184-bis, D. lgs. n. 152/2006), suscettibile di ulteriori utilizzi (cfr. d.m. n. 264 del 13 ottobre 2016 "Regolamento recante criteri indicativi per agevolare la dimostrazione della sussistenza dei requisiti per la qualifica dei residui di produzione come sottoprodotti e non come rifiuti").

Per la valorizzazione dei reflui oleari si tende oggi, sempre più, al loro utilizzo per la produzione di bioenergia, che rappresenta non solo una possibilità di abbattimento dei costi di produzione dell'olio di oliva, ma anche una possibile fonte di reddito. Peraltro, l'individuazione di utilizzi alternativi ed economicamente vantaggiosi degli scarti oleari appare idonea alla configurazione di misure di prevenzione dello smaltimento illecito degli stessi, fenomeno dalle significative dimensioni in Puglia e nel Sud Italia in generale, con impatti negativi sulla salute e sull'ecosistema. Si tratta di ripensare il sistema

produttivo e di consumo, incentrandolo sulla c.d. 'bioeconomia', un'economia basata sull'utilizzo sostenibile di risorse naturali rinnovabili e sulla loro trasformazione secondo criteri di 'circolarità'. In questa direzione, la costruzione di soluzioni concrete e rapidamente implementabili, volte ad attuare una reale economia circolare in ambito oleario e modificare in senso sostenibile i paradigmi produttivi e commerciali della filiera, postula adeguate azioni sinergiche tra pubblica amministrazione, enti di ricerca ed imprese.

Proprio in tale ottica muove il Progetto ECOSNODO, "ECOnomia circolare, Sostenibilità e profili di evoluzione Normativa nella produzione dell'Olio extravergine Di Oliva" (Horizon Seeds, Università di Bari, 2022). In particolare, sul piano dell'uso efficiente dei sottoprodotti del frantoio, il progetto - in linea con il focus dell'Agenda ONU 2030, con il Green Deal EU, con il Piano per la transizione ecologica (PTE, 8.3.2022-14.6.2022) e ovviamente con il PNRR (M2C1-Inv.2.3) - mira a: 1. Identificare le possibili forme di innovazione in senso sostenibile dell'intera filiera dell'olio d'oliva, come motore chiave di produttività, competitività e resilienza del settore oleario europeo; 2. Trasformare gli scarti/rifiuti dell'industria olearia in una risorsa preziosa e contribuire a un migliore utilizzo delle fonti di energia rinnovabile, nell'ottica della transizione ecologica; 3. Puntare all'efficienza delle risorse in un'ottica di economia circolare. Nella prospettiva costituzionale, infine, interventi come quello in oggetto consentono un ragionevole bilanciamento tra l'implementazione di strategie tese a rafforzare l'iniziativa economica privata (art. 41 Cost.) e a tutelare la proprietà privata (art. 42 Cost.) con la loro necessaria preordinazione alla garanzia della utilità e della funzione sociale cui queste ultime devono essere improntate in modo da non recare danno alla sicurezza, alla libertà, alla dignità umana e (dopo la recentissima revisione costituzionale dell'art.41 Cost.) anche alla salute e all'ambiente.

Keywords: *Filieria olearia, rifiuti, Horizon Ecosnodo, economia circolare*

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L’innovazione negli impianti oleari quale strumento per una più razionale e sostenibile gestione delle risorse naturali

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Nella cornice di una rivoluzione agroalimentare sostenibile europea, diversi indizi suggeriscono di guardare all’olio d’oliva come settore strategico per questa transizione. Allo stato attuale la filiera olivicolo-olearia si allinea verso una economia lineare in cui si parte dalla materia prima e dall’energia per avere un prodotto ma anche una considerevole produzione di rifiuti. In quest’ottica nell’industria olearia si stima che circa il 20% della materia prima impiegata viene convertita in prodotto, mentre l’80% in rifiuto. Gli scarti di frantoio, la sansa di oliva e l’acqua di vegetazione, sono sottoprodotti significativi dell’industria alimentare ad alto impatto ambientale, quando non adeguatamente trattati. Nell’ultimo ventennio abbiamo assistito ad una progressiva necessità di introdurre aggiornamenti tecnologici nella trasformazione olearia volti sia al miglioramento della qualità che alla necessità di chiudere il ciclo produttivo nella salvaguardia dell’ambiente, attraverso il riutilizzo dei sottoprodotti e lo smaltimento dei reflui in modo sostenibile, ma il potenziale di espansione e di crescita sostenibile del settore della trasformazione delle olive rimane ancora ampio. L’ambizione dell’Europa è quella di rendere i prodotti delle proprie filiere alimentari uno standard globale di sostenibilità, facendo leva sulle recenti scoperte scientifiche e tecnologiche e soprattutto sull’innovazione. In tale direzione il Progetto Horizon Seeds ECOSNODO dell’Università di Bari “Aldo Moro” vuole inquadrarsi. Obiettivo principale del progetto ECOSNODO è identificare le possibili forme di innovazione dell'intera filiera di estrazione dell'olio d'oliva, al fine di renderla più efficiente in termini di qualità e quantità dell'olio estratto ma, soprattutto, ecologicamente più sostenibile. In tale prospettiva si propone una reale rimodulazione del modello produttivo orientata alla transizione ecologica da economia lineare a economia

circolare. L'obiettivo del progetto è, dunque, l'implementazione di nuove ed innovative macchine per un risparmio idrico ed energetico, nuovi metodi di controllo e gestione del processo di estrazione volti a migliorare l'efficienza di estrazione dell'olio d'oliva e la qualità del prodotto finale, riducendo al contempo il consumo di acqua e prevedendo l'efficientamento dei consumi elettrici dell'impianto. Nell'ottica di un approccio integrato, sarà contemplata l'introduzione di innovazioni che consentiranno il recupero e il riutilizzo degli scarti/rifiuti con la finalità di produrre biocombustibili ed avviare processi di produzione di energie rinnovabili. Ciò consentirà di riutilizzare tutti i prodotti di scarto/rifiuti dell'impianto oleario per il recupero energetico, evitandone così lo smaltimento con i relativi problemi ambientali.

Keywords: Filiera olearia, innovazione impiantistica; Horizon Ecosnodo, Efficienza; Sostenibilità

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Filiera olearia e approccio One Health in un'ottica costituzionalmente orientata

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La filiera olivicolo-olearia riveste grande importanza per l'Italia non solo per il correlato impatto economico e sociale, ma anche per la rilevanza del comparto sul piano ambientale e salutistico. Sempre più numerosi sono gli studi e i progetti di ricerca sul miglioramento del processo di produzione e valorizzazione dei residui della lavorazione, in una prospettiva di agricoltura circolare e di uso efficiente delle risorse. Sul piano normativo, deve rilevarsi che particolare attenzione è stata posta dal MIPAAF [cfr. D. Dir. Mipaaf del 31.03.2022-c.d. Bando quadro frantoi, in attuazione del PNRR, (M2C1, Inv. 2.3)] all'innovazione tecnologica quale elemento, da un lato, di potenziamento delle performance ambientali dell'attività di estrazione dell'olio EVO; dall'altro, di aumento della sua qualità sul piano bio-nutrizionale e salutistico. La stessa strategia "Farm to Fork", al centro del Green Deal europeo, affronta in modo esaustivo le sfide poste dalla realizzazione di sistemi alimentari sostenibili, riconoscendo i legami inscindibili tra persone sane, società sane e un pianeta sano. La salute diviene, dunque, elemento cardine di ottimizzazione della filiera olearia in un'ottica One Health che, sin dal 2008 (OMS), ha guadagnato slancio internazionale come standard per l'elaborazione di politiche che riconoscano e perseguano l'interdipendenza della salute umana, animale e ambientale. È, questa, una delle nuove dimensioni di economia circolare e sostenibilità degli ecosistemi presa in considerazione dal Progetto Horizon Seeds ECOSNODO dell'Università di Bari "Aldo Moro" (2022) con riferimento al comparto oleario. In particolare, la nuova definizione completa di One Health (OHHLEP, dicembre 2021) mira a sottolineare che il cibo, l'acqua, la salute umana, il benessere animale, l'energia e l'ambiente, pur costituendo ambiti ampi e con problematiche settoriali e specialistiche, sono prevalentemente interconnessi e che soltanto la collaborazione tra settori e discipline

può contribuire a risolverle. Tutto ciò è ben rappresentato dal comparto oleario e dalle criticità del processo di produzione: si pensi alla gestione del suolo e alla fertilizzazione del terreno realizzata con prodotti chimici che sono tossici per l'uomo e gli animali, ma che impattano negativamente anche sulla biodiversità e sulla contaminazione delle acque; oppure alla potatura e raccolta delle olive con i relativi problemi di gestione dei residui. A ciascuna di queste fasi corrispondono, in un'ottica One Health, azioni di economia circolare che risultano risolutive delle accennate problematiche e ottimizzanti l'intero processo produttivo. In ogni caso, il successo delle iniziative di "sostenibilità" e di "circolarità" dipenderà anche dalla implementazione di misure strutturali e tecnologicamente avanzate per prevenire lo smaltimento illegale degli scarti oleari - che ancora interessa alcuni contesti territoriali, specie del Meridione - ed "evitare conseguenze tali da mettere in pericolo l'approvvigionamento idrico, nuocere alle risorse viventi ed al sistema ecologico" (cfr. l. n. 574/1996, art. 4).

Si auspica che, nonostante l'implicita pluridimensionalità dell'approccio One Health, anche le fonti prodotte dal legislatore (statale e regionale) e dai Ministeri competenti, in conformità ai principi costituzionali in materia (cfr., in primis, gli artt. 9 e 41 Cost. novellati, ma anche gli artt. 2, 3, 5, 32 e 117 Cost.), lo considerino esplicitamente, non quale mera petizione di principio, ma quale obiettivo imprescindibile di attuazione della tutela interrelata tra salute umana, benessere animale e sostenibilità ambientale.

Keywords: Filiera olearia, One Health, Horizon Ecosnodo, Sostenibilità

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La disciplina della bonifica dei siti inquinati nell'era della transizione ecologica: aspetti critici e soluzioni eco-sostenibili

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I nuovi paradigmi della sostenibilità ambientale, della transizione ecologica e dell'economia circolare sembrano inaugurare una nuova fase di "conversione ecologica" nell'ambito della disciplina sulla bonifica dei siti inquinati.

La recente sensibilizzazione intergenerazionale alle tematiche ambientali conferma la necessità di un modello di economia circolare che coniughi le ragioni dello sviluppo con la tutela dell'ambiente.

In questa prospettiva "unitaria" si indirizza il nuovo Green Deal europeo che affronta il problema a partire proprio dall'opportunità di un modello sistematico-globale nel quale l'alleanza tra persona e ambiente si ponga quale presupposto irrinunciabile per lo sviluppo sostenibile.

Del resto, le recenti modifiche agli artt. 9 e 41 della Costituzione, nel segno di una rinnovata consapevolezza ecologica, hanno consentito di "rileggere" il sistema ordinamentale vigente adeguandolo ai principi personalistici e solidaristici del sistema giuridico italo-europeo.

L'approccio "olistico" con il quale l'ambiente è inserito nella nuova Costituzione "verde", tra i princìpi fondamentali dell'ordinamento nazionale, conferma il carattere trasversale della tutela ambientale, la cui natura interseca fattori naturali, economici e al contempo umani.

Il profondo aggiornamento in chiave ecologica dei principali istituti trova conforto anche nella necessaria dimensione ecologica che l'esperienza giuridica sta assumendo negli ultimi tempi, sol che si pensi che le grandi crisi che irrompono nei sistemi giuridici, come dimostra la recente pandemia, sono prima di tutto "emergenze ecologiche".

Il ragionamento trova la sua legittimazione soprattutto alla luce delle recenti vicende. La salute, l'ambiente, la qualità della vita costituiscono, oggi, a seguito della riorganizzazione dell'apparato ordinamentale che la recente pandemia ha determinato, valori costituzionali apicali in quanto funzionali all'esistenza stessa della persona umana.

Si profila, dunque, un mutamento di paradigma radicale inteso come «eco-antropocentrismo» , che induce, persino, a ritenere che il concetto di sviluppo sostenibile sia ormai desueto alla luce delle attuali tendenze umanistiche dell'ambiente fondate sui diritti inderogabili della persona e sulla priorità del valore ambientale.

E' agevole constatare quanto le politiche europee abbiano condizionato l'accesso alle risorse finanziarie, previste dal RRF e inserite nel PNRR, all'utilizzo di misure ed investimenti che concorrano agli obiettivi di sviluppo sostenibile e all'uso efficiente delle risorse naturali.

L'incentivazione all'utilizzo di fonti rinnovabili e la lotta al cambiamento climatico costituiscono tematiche oggetto delle recenti iniziative della politica ambientale europea, sviluppata intorno alla riconversione del sistema ordinamentale ad una gestione sostenibile delle risorse naturali.

La protezione dell'ambiente non può essere scissa dai problemi dello sviluppo economico e dalla connessione con i diritti fondamentali della persona umana: il fine ultimo resta sempre il soddisfacimento dei bisogni delle generazioni presenti senza compromettere la qualità di vita di quelle future.

La disciplina della bonifica dei siti contaminati è oggi più che mai al centro dell'attenzione ciò in quanto lo scorso 4 giugno 2020 il Ministro della transizione ecologica ha sottoscritto la prima Carta sulle bonifiche sostenibili nella quale è cristallizzato il principio della sostenibilità nella sua pluridimensionalità: ambientale, economica, temporale, sanitaria ed etica.

In tale prospettiva le finalità di recupero delle aree contaminate vengono attuate secondo un disegno complessivo ed unitario fondato sul contemperamento di una serie di esigenze ed interessi: la tutela dell'ambiente, il rilancio economico e il diffondersi di uno stile di vita ecosostenibile.

Si afferma dunque una vera e propria conversione ecologica fondata sulla sostenibilità e dunque sull'equilibrio "ecologico" tra uomo e natura.

Keywords: Sostenibilità, transizione ecologica, bonifica dei siti inquinati

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Le innovazioni introdotte dalla strategia nazionale per l'economia circolare ed i risvolti normativi

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La recente "Strategia Nazionale per l'economia circolare", approvata lo scorso 24 giugno 2022 con DM 259, ha introdotto importantissime innovazioni che potranno conferire un impulso decisivo per consolidare percorsi di "autogenerazione" delle materie prime, favorendo una imponente riduzione della produzione di rifiuti, accompagnata da una significativa riduzione di consumi energetici. L'economia circolare, infatti, rappresenta la risposta vincente alle attuali crisi internazionali che hanno determinato un crescente incremento dei costi energetici e delle materie prime, la cui importazione in Italia supera il 70% del fabbisogno complessivo. L'approccio utilizzato per favorire l'economia circolare punta a massimizzare i vantaggi, anche di natura fiscale, oltre che ambientale, commerciale ed energetica, con un sistema di leve incentivanti che puntino sulla convenienza economica, ora più che mai, particolarmente evidente.

Per far agevolare il percorso del riutilizzo è stata immaginata l'introduzione del nuovo Registro Elettronico Nazionale per la Tracciabilità dei Rifiuti (RENTRI) che, oltre a tracciare "digitalmente" i rifiuti, contrastando eventuali smaltimenti illeciti, consentirà di agevolare il matching tra domanda ed offerta di materiali di scarto-materie prime seconde (MPS).

Straordinariamente importante è la leva fiscale introdotta dalla Strategia nazionale che incide contemporaneamente su due fulcri: il sostegno alle aziende che riciclano ed utilizzano materie prime seconde da un lato, la revisione completa del sistema di tassazione ambientale dei rifiuti dall'altro; questo renderà estremamente più conveniente il riciclaggio rispetto alle tradizionali pratiche di smaltimento come il conferimento in discarica e la termovalorizzazione. Di fatti, il nuovo quadro strategico-normativo concorrerà a rendere molto più conveniente l'intera catena di produzione circolare, generando nuova occupazione nel settore del

re-manufacturing effettuato in fabbriche di “rigenerazione dei materiali”. Ad oleare tale sistema anche la redazione e l’aggiornamento dei regolamenti End of Waste (EoW), che consentono di definire un quadro regolamentare chiaro entro cui gestire i materiali di scarto nella piena legalità, trasformandoli in nuove materie utili in cicli produttivi di altre aziende, sostenuti da un “sistema di convenienze”. Anche i Criteri Ambientali Minimi (CAM), che rappresentano gli standard minimi ambientali necessari da rispettare nell’acquisto di prodotti e servizi della Pubblica Amministrazione (PA) con gare d’appalto, saranno opportunamente aggiornati, con la finalità di precostituire canali commerciali di sbocco, opportunamente incentivati. Naturalmente, in tale contesto, appare assolutamente strategica la creazione di un sistema di controlli che possa limitare e contrastare i rischi derivanti dallo smaltimento illecito di rifiuti e da truffe di natura fiscale generate dalle stesse incentivazioni. Alla luce delle suesposte considerazioni appaiono straordinariamente importanti la collaborazione con le Forze dell’Ordine ed anche la prevista riforma del sistema EPR (responsabilità estesa del produttore) e dei Consorzi, accompagnata dall’istituzione di uno specifico organo di vigilanza sotto la Presidenza del MiTE.

Keywords: Economia circolare, riutilizzo, materie prime seconde

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Etica e bene comune: Riscoprire il senso di responsabilità

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Etica e bene comune: un tema di interesse generale, di grande attualità e dai risvolti importanti per il benessere della città, dei singoli, delle istituzioni pubbliche e private, su cui Milano sta riflettendo, adoperandosi per implementare delle buone pratiche da parte di tutti. La città del volontariato, dell'impresa, della buona politica, del coinvolgimento dei cittadini è chiamata a porsi quale capo fila e a dare il buon esempio su come promuovere il bene comune avvalendosi di un atteggiamento etico. E questo atteggiamento lo individuo nel "servizio" in ogni campo: sociale, politico, economico.

Non si tratta di operare necessariamente presso la Caritas ma di promuovere uno stile ben preciso. Servizio, a mio avviso, vuol dire operare nei campi professionali, pubblici, associativi con senso di responsabilità personale. Significa mettere al primo posto le esigenze di coloro ai quali si devono delle risposte. Sottintende il creare un clima di fiducia e di serenità. Implica l'avere presente il senso delle istituzioni e tessere relazioni e legami che non siano autoreferenziali o racchiuse in circoli elitari ma utili per la crescita di tutti.

Il valore aggiunto, poi, è dato da un comportamento personale che non sia di protagonismo (che rovina tutto). Piuttosto è importante che si operi nella continuità che talvolta richiede sacrificio poiché non si sposa con il "mi piace" o con "lo faccio quando ho voglia" ma con un impegno costante, rigoroso e serio.

Del resto, un autore a me caro ha scritto che "chi non vive per servire non serve per vivere". Spesso ci accorgiamo di quanto sia vera questa affermazione, quando chi non serve diventa un intralcio e un elemento divisivo per la comunità.

Solo un atteggiamento di servizio, che poi vuol dire anche umiltà, benevolenza e mitezza, può produrre qualcosa di buono per tutti e contribuire a costruire e rafforzare la comunità sociale. La nostra comunità. La nostra Milano, non da bere ma da amare.

Keywords: Etica, bene comune, responsabilità, servizio, città
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Prevenzione e riparazione dei danni all'ambiente

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Il Pool Ambiente, consorzio di Coriassicurazione attivo dal 1979 nella valutazione e assicurazione dei rischi ambientali delle imprese è fortemente impegnato nel sensibilizzare le imprese a una migliore gestione dei rischi ambientali e a una più efficace prevenzione dei danni all'ambiente. Un altro aspetto importante sono le coperture assicurative dedicate per i rischi ambientali, uno strumento concreto per l'attuazione del principio "Chi inquina paga" nel nostro paese e per far sì che i responsabili siano in grado di ottemperare agli obblighi di messa in sicurezza e ripristino delle risorse naturali danneggiate. Per colmare l'attuale vuoto normativo sulla prevenzione dei danni all'ambiente e per fornire alle imprese uno strumento concreto per una prevenzione più efficace, il Pool Ambiente si è fatto promotore presso UNI di un tavolo tecnico che ha prodotto la nuova PdR UNI 107:2021 "Ambiente Protetto". Dall'analisi di 1031 casi di danno all'ambiente (Dati Pool Ambiente) è emerso che il 73% non si sarebbe mai verificato se le aziende avessero avuto la certificazione Ambiente Protetto. Questa certificazione può essere applicata da imprese di qualunque settore ed è studiata per integrarsi perfettamente con altri schemi di certificazione esistenti potenziandone l'effetto di protezione delle risorse naturali.

Come si costruisce una politica di sostenibilità ambientale efficace

Le attuali politiche di sostenibilità attuate dalle imprese, anche quelle più impegnate sul fronte green, sono solitamente carenti e poco trasparenti dal punto di vista dell'impegno alla prevenzione e riparazione dei danni all'ambiente.

Riteniamo che tale impegno nei confronti dell'ambiente possa essere visto come un albero. Oggi la comunicazione ambientale si concentra su due parti dell'albero, le fronde e i frutti che rappresentano rispettivamente l'impegno al miglioramento delle performance ambientali dell'azienda e dei suoi prodotti. Si tratta di alberi che sono però alquanto fragili in quanto le radici e il tronco non vengono presi in esame da tali attività.

La nuova certificazione Ambiente Protetto si colloca invece alle radici di questo albero ideale, garantendone la sopravvivenza e lo sviluppo. Concretamente tale prassi prevede un kit di requisiti che si adattano agli scenari di danno a cui è esposta l'azienda e che devono essere rispettati per ottenere la certificazione.
Oltre ai requisiti specifici per ogni scenario è inoltre previsto un set di requisiti generali che riguardano ad esempio la formazione del personale e la sottoscrizione di una polizza assicurativa per danni all'ambiente.
Nel 2022 il Pool Ambiente ha condotto uno studio sui sinistri occorsi nel periodo 2000-2019. Si tratta di 1031 casi di danno all'ambiente gestiti dalla Segreteria del consorzio e di cui si conoscono cause e conseguenze. Dall'analisi di questi casi, incrociati con i requisiti previsti dalla prassi è emerso come almeno il 73% non si sarebbe mai verificato se l'azienda fosse stata certificata Ambiente Protetto. Sono sinistri che hanno comportato per anni l'impossibilità di fruire delle risorse naturali impattate, creando un grave danno all'azienda, ai suoi lavoratori ed alla comunità locale. Dal solo punto di vista economico questo avrebbe comportato per il Pool il risparmio di 104 milioni di Euro su 140 milioni di spese per bonifiche e ripristino delle risorse naturali danneggiate, per non parlare del danno economico comunque a carico dell'azienda e di quello non quantificabile. In assenza di politiche di prevenzione i danni diventano permanenti o comportano il drenaggio di risorse economiche della collettività.
La prevenzione e la riparazione devono diventare parte integrante delle politiche di sostenibilità, nell'interesse collettivo e privato di cittadini, lavoratori e aziende.

Keywords: Prevenzione, riparazione, politiche sostenibiltà

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Environmental and social project financing: opportunities and requirements

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Nowadays, a number of energy, industrial, infrastructure, and other large-scale projects that may potentially impose negative impacts to the communities and the environment are located in developing countries with underdeveloped environmental and social regulations. While many developing countries have made considerable efforts and progresses to establish a robust environmental and social regulation system to address these adverse impacts, it is not as effective in developing countries. Therefore, the risk that a new Project can potentially negatively affect the environment and local communities has to be taken into account and a series of monitoring and management measures need to be implemented with the aim of leading to an acceptable degree of environmental and social risks associated to the Project.

This emphasizes the importance of the overarching standards established by the International Financial Institutions (IFIs), Commercial Banks and Export Cretit Agengies (ECAs) - the Lenders - can sponsor the Projects in developing countries, with the aim of ensuring that also Projects in such countries are developed in an environmentally and socially responsible manner and reflect good environmental international management practices.

All the tools and procedures required by the International Standards are designed to provide direct and indirect benefits to the Project proponent and the Lenders.

Methodology

A Project located in a developing country, for example in case of unreliable infrastructure, an untested legal regime, an unstable political situation, or a combination of all these, will likely pose greater environmental and social risks than a Project located in in the so called high incoming countries.

The main challenge of financing projects in developing countries is the possibility of significant environmental and social risks to occur and

the assessment of these risks is uncontrolled and not based on consolidated procedures. It is very common that environmental and social risks are underestimated, with the consequence that impacts may create discontent or even opposition from local communities, which can affect both the Project proponent and Lenders, creating delays to the Project implementation or even increasing its costs, questioning the Project's viability (World Bank, 2016).

In case a Project is applying for financial support from international Lenders, it is required a Project proponent to prove its eligibility by ensuring that the Project is developed guaranteening high environmental and social requirements and where all the possible risks and impacts associated to the Project are identified and properly addressed through the implementation of a series of mitigations and management measures. The Project proponent shall comply with specific environmental and social standards, established by the Banks that will secure the finance.

These standards are comprised of a set of rules, requirements and procedures that the Project proponent has to follow in order to bring the Project in compliance with the standards and prove its eligibility for the financing.

The most commonly applied international standards are as follows:

• International Finance Corporation Performance Standards (IFC PSs) and Guidelines;

• Equator Principles (EPs);

• European Bank for Reconstruction and Development Principle Requirements (EBRD PRs); and

• Organization for Economic Co-operation and Development Environmental and Social Standards (OECD standards).

The Project Financing induces some direct benefits related to the enhance of Project viability, the avoidance of delays to the Project implementation with increase of costs, and ultimately achieving environmental and social sustainability of the Project.

As indirect benefit, the implementation of the environmental and social standards in developing countries may result in positive outcomes to the country itself by the promotion of effective Project management. Benefits identified and evaluated in regard to the increased focus on public participation and engagement; the enhancement of local environmental and social regulations and its re-development of an inclusive, sector specific system; improved enforcement of these regulations due to regular monitoring activities

required by the standards; and capacity building which is linked to all of the identified benefits.
The main aspects may come as positive impacts from application of bankable EHSS standards in developing countries, at a Project level, but also for local stakeholders and authorities, and ultimately for the developing country in which the Project is developed are mainly related to:
• Social Aspects and Public Participation;
• Improvement of Local Environmental and Social Standards;
• Control and Implementation of Environmental and Social Regulations;
• Capacity Building.

Keywords: Environmental and Social Regulations, Public Participation, Capacity Building

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H2020 PROMISCES – PFAS e persistent mobile chemicals nel trattamento e gestione circolare di acque e sedimenti. Framework europeo e risultati preliminari del cluster italiano

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PROMISCES (Preventing Recalcitrant Organic Mobile Industrial chemicalS for Circular Economy in the Soil-sediment-water system - www.promisces.eu) è un progetto Horizon2020 finanziato nell'ambito della prestigiosa call EU Green Deal che vede collaborare 27 partner provenienti da 9 paesi differenti. Scopo del progetto è l'identificazione di strategie per uno sviluppo tecnologico industriale compatibile con le ambizioni dell'European Green Deal e del Circular Economy Action Plan, progettando e validando soluzioni analitiche, tecnologiche e gestionali che quantifichino e minimizzino presenza e rischio derivato da PFAS e persistent mobile chemicals in: (i) cicli idrici semi-chiusi per l'approvvigionamento di acqua potabile; (ii) riutilizzo delle acque reflue per l'irrigazione in agricoltura; (iii) recupero dei nutrienti dai fanghi di depurazione; (iv) recupero dei materiali dai sedimenti portuali dragati.

Le sostanze perfluoroalchiliche, i cosiddetti PFAS, sono un gruppo di sostanze, persistenti e potenzialmente pericolose per la salute umana, considerate tra i principali ostacoli allo sviluppo dell'economia circolare, in quanto il riutilizzo di materiali provenienti da rifiuti ne potrebbe favorire la diffusione nell'ambiente. Tra le attività prioritarie ed iniziali PROMISCES punta allo sviluppo e validazione di metodologie analitiche che quantifichino PFAS su matrici complesse, anche per sviluppare ed ottimizzare le tecnologie di risanamento adeguate alla loro rimozione da diverse matrici ambientali (es., sedimenti, suoli, acque, percolati di discarica). In tal direzione è focalizzata parte dell'attività di ricerca del team italiano partner del progetto

PROMISCES (Acea Elabori, Simam gruppo Acea SpA e Università Politecnica delle Marche), che ha avviato la messa a punto di metodologie analitiche e lo studio di tecnologie innovative per una completa rimozione di PFAS dell'ambiente in accordo con l'obbiettivo generale del progetto "development of innovative approaches to prevent and manage the occurrence of iPM(T) in circular economy routes".

In Italia, oltre al disegno di impianti pilota per il trattamento di percolati, fanghi e sedimenti di dragaggio, focus dei primi mesi di lavoro è stata la progettazione e messa a punto di una metodologia robusta, semplice e "cost-effective" per l'analisi di un numero significativo di composti perfluoroalchilati. La metodologia doveva comprendere l'identificazione e quantificazione anche dei possibili precursori (polifluoralchilati) dei PFAS. Ulteriori requisiti erano la sua implementazione nell'ambito degli ordinari piani di monitoraggio ambientale e applicabilità per la determinazione degli analiti nei flussi di massa del ciclo idrico e su altre matrici ambientali (percolati, fanghi, sedimenti, emissioni al camino). In tale contesto sono state effettuate le prime campagne di campionamento di impianti di trattamento di percolato in piena scala, in Italia ed altri Paesi europei, con lo scopo di determinare il destino dei PFAS e dei suoi precursori lungo la filiera di trattamento. Sono stati monitorati due impianti di trattamento del percolato, un primo impianto composto di tipo convenzionale con trattamento biologico e membrane di ultrafiltrazione, mentre un secondo impianto prevede una sequenza di ultrafiltrazione e un doppio step a osmosi inversa.

Infine, sono stati eseguiti test funzionali dei trattamenti di lavaggio acido/basico di sedimenti di dragaggio in scala di laboratorio, al fine di indagare i meccanismi di migrazione dei PFAS nei processi di recupero dei sedimenti, i quali una volta trattati adeguatamente potrebbero essere riutilizzati nel settore delle costruzioni, piuttosto che accumulati in vasche di colmata o smaltiti in discarica.

Il metodo analitico utilizzato nello studio è basato sulla tecnica in UHPLC/MS-MS ed è applicabile per la determinazione, con accuratezza e precisione, di 30 analiti rientranti nella classe PFAS, inclusi i 20 presenti nella Direttiva Acque 2184/2020 CE.

Dalla campagna di campionamento dell'impianto di trattamento dei percolati con comparto biologico e ultrafiltrazione è stato riscontrato un adsorbimento nel fango biologico dei PFAS a catena lunga, mentre i composti a catena corta sono stati tutti ritrovati nel effluente in

uscita all'impianto. Inoltre, la concentrazione di qualche composto in uscita dal trattamento biologico è risultata maggiore di quella in entrata causa degradazione di precursori durante il trattamento biologico.
Nel caso dell'impianto di trattamento che utilizza processi ad osmosi inversa, si è riscontrata una completa rimozione dei PFAS sia a catena lunga che quelli a catena corta dal percolato, ottenendo così un permeato privo di sostanze perfluoroalchiliche, le quali vengono ritenute all'interno del flusso concentrato. Sviluppi futuri riguarderanno lo studio di tecnologie innovative termochimiche, per la distruzione delle sostanze perfluoroalchiliche nei fanghi di depurazione e nel concentrato da osmosi inversa.
Infine, si sono rilevate concentrazioni minime di PFAS nei sedimenti di dragaggio trattati, che risultano al di sotto del livello di rilevabilità nel sedimento recuperato dopo il trattamento di lavaggio acido/basico.
La presentazione illustrerà oltre ai risultati parziali attualmente ottenuti, anche il framework complessivo del progetto che prevede casi studio in diversi Paesi europei, oltre ad attività trasversali di support alla futura policy euro-unitaria.

Keywords: PFAS, perfluoroalchilati, Direttiva Acque 2184/2020 CE

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PMI un patrimonio sostenibile non valorizzato

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Negli ultimi anni la "sostenibilità" è stata sempre più spesso associata al mondo delle imprese, ponendo l'attenzione sull'impatto delle loro attività sull'ambiente naturale e sul benessere delle persone e dei territori dove operano. In particolare il crescente interesse verso i temi dell'impatto ambientale e della responsabilità sociale delle imprese ha generato una continua spinta interna alla ricerca di comportamenti sempre più virtuosi.

I dati dell'Istat (Comportamenti d'impresa e sviluppo sostenibile, 2019) confermano un'attività in continua crescita, con risultati molto interessanti.

Ma cosa si intende per sostenibilità ambientale? Sono quei comportamenti volti a ridurre gli impatti negativi sull'ambiente naturale derivante dalle loro attività, quali ad esempio il controllo e la riduzione dell'uso di energia, l'aumento dell'uso di energia da rinnovabili, il controllo per la riduzione dell'uso dell'acqua, il riciclo e il trattamento dei rifiuti, la riduzione dell'emissioni in atmosfera, il riciclo e il riuso di materiali di scarto, la condivisione temporanea di beni e servizi.

Mentre per sostenibilità sociale? In questo caso si intende l'insieme dei comportamenti delle imprese che si legano a effetti positivi sul benessere dei propri lavoratori e sulla comunità.

Alcuni dati (Istat 2019)

In Italia lo 0,1 % delle aziende ha + di 250 dipendenti, il sistema produttivo che compone il mercato italiano è costituito per 99,9 % di PMI (fonte ISTAT).

91% delle imprese con 50 ed oltre addetti svolge attività di raccolta dei rifiuti differenziata, il 71% controlla attivamente l'uso dell'energia, il 56% controlla l'uso dell'acqua e oltre la metà controlla le emissioni in atmosfera.

80% delle imprese con 50 ed oltre addetti svolge attività di formazione continua, il 73% delle imprese promuove l'occupazione nel territorio e il 71% delle imprese fa valutazione con i dipendenti del benessere lavorativo. Solo il 18% delle imprese adotta programmi di marketing

per valorizzare il patrimonio sostenibile e il 24% inserisce un incaricato in organico per la responsabilità sociale.

Keywords: PMI

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Standard di riferimento per l'economia circolare: stato dell'arte e prospettive

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Il paradigma dell'economia circolare è diventato un asset imprescindibile per tutte le Organizzazioni che promuovono la sostenibilità e che comunque vogliono mantenere la propria competitività nel mercato attuale: un numero sempre più ampio di iniziative e progetti viene declinato come "circolare" senza che ci sia, tuttavia, un approccio sistematico, univoco e condiviso tra i diversi portatori di interesse.
In questo studio si intendono analizzare gli unici standard di riferimento per l'economia circolare oggi attualmente disponibili (BS 8001:2017 e AFNOR XP X30-901:2018), definendo gli ambiti di applicazione degli stessi e le prospettive operative di sviluppo.
Gli attuali standard di riferimento per l'economia circolare (BS 8001:2017 e AFNOR XP X30-901:2018) sono stati analizzati a partire dai testi originali, evidenziando per ciascuno standard le peculiarità operative secondo l'esperienza applicativa di ambiente s.p.a., con riferimento sia agli aspetti tecnici che comunicativi.
Lo standard BS 8001, norma inglese pubblicata nel 2017 dall'ente di standardizzazione britannico BSI, è il primo standard nato esplicitamente per guidare le imprese nella transizione a modelli di produzione più circolari. Presentato come guida, lo standard fornisce indicazioni e raccomandazioni, ma non può essere definito come un insieme di requisiti o una buona prassi; per questi motivi non possono essere accettabili dichiarazioni di conformità. La norma BS 8001 identifica sei fattori in grado di declinare il concetto di economia

circolare e calarlo nella realtà aziendale (approccio sistemico, simbiosi, innovazione, gestione responsabile, ottimizzazione del valore, trasparenza). Secondo la norma, le organizzazioni posseggono livelli di confidenza e conoscenza diversificati nei confronti dell'economia circolare: da quelle che iniziano ad approcciarsi alla tematica a quelle che già sono ad un livello di conoscenza avanzato, ma che vogliono comunque rivedere o controllare il proprio approccio. Lo standard propone uno strumento tabellare (ed un set di domande di supporto) per aiutare le organizzazioni a valutare il proprio livello di maturità nel processo di implementazione dei principi dell'economia circolare nell'ambito delle proprie decisioni ed attività. Tale strumento, se opportunamente declinato, permette di aumentare la consapevolezza delle organizzazioni. Inoltre, può essere utilizzato nella comunicazione verso gli stakeholder interni ed esterni per dimostrare l'impegno dell'organizzazione verso un'economia circolare. In un'ottica di analisi di trend, i successivi miglioramenti dell'organizzazione in merito alle performance relative ai sei principi individuati dalla norma, possono divenire oggetto di comunicazione di anno in anno, a prova della volontà e della capacità attuativa dell'organizzazione stessa.

Lo standard AFNOR XP X30-901:2018, d'altro canto, specifica i requisiti di un sistema di gestione per l'avvio, la pianificazione, l'implementazione e la misurazione dei progetti avviati da un'organizzazione per migliorare le proprie prestazioni ambientali, economiche e sociali al fine di contribuire allo sviluppo di un'economia circolare. Lo standard AFNOR è ad oggi l'unica norma internazionale che rende possibile implementare l'Economia Circolare nel Sistema di Gestione Aziendale, permettendone una certificazione da parte di Enti Terzi. In particolare, lo standard AFNOR XP X30-901:

- è applicabile a organizzazioni di ogni dimensione, tipo e natura;
- presenta una struttura di alto livello (HLS) analoga agli standard di sistema più conosciuti (9001, 14001, 45001, ecc.);
- richiede all'organizzazione di ricondurre il proprio processo di transizione all'economia circolare a progetti concreti e misurabili;
- richiede all'organizzazione di identificare quale strumento centrale del proprio sistema di gestione una matrice che considera le 3 DIMENSIONI (ambientale, economica e sociale) e le 7 ARRE DI AZIONE (approvvigionamenti sostenibili, progettazione ecocompatibile, simbiosi industriale, economia dei servizi, consumi responsabili,

estensione della vita utile di prodotto, gestione efficiente del fine vita) dell'Economia Circolare

• richiede all'organizzazione di definire una Situazione di Riferimento: la Situazione di Riferimento consiste in una diagnosi condotta dall'azienda per mappare la propria esperienza maturata sull'economia circolare.

Da quanto evidenziato, si comprende come l'implementazione dello standard AFNOR per l'Economia Circolare sia ancora più immediata se l'Organizzazione dispone già di un Sistema di Gestione Ambientale conforme alla norma UNI EN ISO 14001:2015: se si riflette sull'economia circolare, sul ruolo che essa riveste nei confronti del contesto aziendale, se si considera la sua importanza in termini di comunicazione e lo stretto legame con il ciclo di vita di prodotti e servizi, si può concludere che i sistemi di gestione dell'economia circolare costituiscono la naturale integrazione dei sistemi di gestione ambientale. Lo standard AFNOR in ogni caso, una volta certificato da Ente di Parte Terza, è spendibile nella comunicazione con gli stakeholder come elemento distintivo che aumenta la credibilità dell'organizzazione nel suo percorso verso la sostenibilità. Più in generale, la certificazione AFNOR provvede a consolidare la reputation complessiva dell'organizzazione.

Keywords: economia circolare, standard di riferimento

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Le Comunità Circolari: nuovi modelli di produzione e consumo sostenibili

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Le sfide ambientali globali e l'instabilità geopolitica hanno chiaramente dimostrato come la sostenibilità, l'autosufficienza e la resilienza dei territori siano i fattori chiave per uno sviluppo duraturo nel rispetto dell'ambiente e della salute umana. Le attività economiche dalla produzione energetica a quella alimentare devono essere sempre più interconnesse e volte ad una chiusura dei cicli biogeochimici che limiti al massimo le esternalità ambientali. La produzione energetica diffusa costituisce il punto di partenza per la realizzazione di una Comunità Circolare come organismo coordinato, autosufficiente, sostenibile che integri il riciclo di materia all'interno dei territori di riferimento al fine di ottimizzare ancora di più le sinergie tra i diversi settori. La circolarità permea i comparti acqua e suolo applicando soluzioni per il risparmio ed il riciclo delle acque e per la trasformazione dei rifiuti organici in ammendanti per il terreno agricolo. In questo modo vengono alleggerite ulteriormente le pressioni sul comparto aria che già beneficia della produzione di energia diffusa e rinnovabile. Il modello di comunità circolare oltre ad essere replicabile è anche dinamico e adattabile alle peculiarità del territorio mirando ad individuare soluzioni circolari per quei residui prodotti nel territorio della comunità che nella stessa potrebbero trovare adeguata valorizzazione.

Keywords: Comunità circolare, sostenibilità, autosufficienza, resilienza

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Bonifiche sostenibili: profili sociali, ambientali ed economici

Elisabetta Maria Frisari

La questione delle bonifiche dei siti contaminati ha assunto, nel corso del tempo, grande rilevanza sul piano socio – economico.
Le attività di bonifica, ad oggi, non sono più volte al solo perseguimento dei tradizionali obiettivi di sicurezza idraulica del territorio e dell'irrigazione ma, sul piano operativo, si collegano ad altre attività finalizzate ad uno sviluppo socio - economico e territoriale sostenibile.
Il business delle bonifiche è, e sarà quindi nei prossimi anni, uno dei settori più allettanti per gli investimenti delle imprese in termini di risorse umane ed economiche.
Investire per effettuare le bonifiche costituisce un'opportunità di lavoro, di recupero del territorio, di risanamento dell'ambiente e della salute e si inserisce, dunque, in un processo virtuoso di sostenibilità.
Sostenibilità intesa come strategia operativa che, nella rappresentazione "pluridimensionale" percepita dalla prima Carta sulle bonifiche sostenibili del 4 giugno 2020, si fonda su tre pilastri fondamentali: sociale, ambientale ed economico.
Sotto il profilo sociale, sostenibilità vuol dire garantire condizioni di benessere per le persone, ovvero assicurare salute e sicurezza.
Sotto il profilo ambientale, sostenibilità vuol dire non intaccare il capitale naturale a disposizione delle generazioni future attraverso un modello che consente di soddisfare i bisogni del presente senza compromettere la capacità delle future generazioni di far fronte ai bisogni che potranno insorgere.
Sotto il profilo economico, si tratta di generare il c.d. green business, ovvero investire i fondi pubblici anche per valorizzare le imprese più virtuose di spiccata connotazione green.
In questo modo, l'impresa che sceglie di investire in percorsi di sostenibilità genera anche benefici per le persone e per l'ambiente contribuendo alla transizione dal modello di sviluppo lineare, basato sul consumo di energia e risorse naturali, ad una economia incentrata sull'innovazione, sul recupero, la rigenerazione e il riutilizzo delle risorse naturali e dei beni prodotti.

La centralità dell'argomento in tale ottica pluridimensionale, funzionale e soprattutto pro-attiva, è tale da richiedere nella valutazione di un programma di bonifica nuovi criteri di stima e di bilanciamento degli impatti.
Diversi studi ed evidenze progettuali hanno dimostrato che potenziali impatti negativi derivanti da attività di bonifica potrebbero essere bilanciati, cercando di far coesistere istanze anche molto distanti tra loro riguardanti gli ambiti ambientale, economico e sociale.
A titolo esemplificativo, a supporto del processo decisionale dedicato alla valutazione della sostenibilità delle bonifiche in siti contaminati da solventi mono-aromatici (BTEX), il Politecnico di Milano sta sperimentando lo sviluppo di un software con l'obiettivo di selezionare l'alternativa preferibile tra quelle comparate da un punto ambientale, economico e sociale.

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VI. RemTech Europe

Integrated Nutrients Management is Key for Sustaining Crop Productivity and Soil Health

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Soil fertility, health and sustainability is continuously declining due to removal of essential plant nutrients from the soils in the current changing climate scenario. Low and high water and temperature stresses results in the deficiencies of essential plant nutrients, organic soil carbon and beneficial soil microbes that had negative impact on soil health, crop productivity and growers income. Integrated nutrients management not only increase crop productivity and growers income but also increase soil fertility, health and sustainability in changing climates. Integrated nutrients management refers to the maintenance of soil fertility and improvement in crop productivity with application of plant nutrients through combined application of organic carbons sources (animal manures and plant residues), chemical and bio-fertilizers. Stable and productive soils having sufficient amount of soil organic carbon affect the resilience of farms to cope with the effects of climate change. Our long term field experiments on field crops e.g. cereals, pulses and oilseed crops, etc.), confirmed a significant increase in yield per unit area with integrated nutrients management under arid and semiarid climates. The combined application of plant nutrients especially major nutrients (nitrogen, phosphorus and potash) along with different organic carbon sources (farmyard manure; animal manures: poultry manure, cattle manure, sheep manure, goat manure etc.; plant residues: onion residues, garlic residues, wheat residues, rice residues, chickpea residues, fababean residues, canola residues etc.) into the soil had significantly improved soil fertility and crop productivity. Application of beneficial microbes (Biofertilizers) was found beneficial in terms of higher nutrients use efficiencies, yield, growers income, soil health and sustainability.

Keywords: Integrated Nutrients Management, Biofertilizers, soil health and sustainability.

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Constructed wetlands for drained wastewater treatment and sludge stabilization: Role of plants, microbial fuel cell and earthworm assistance

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This study reports drained wastewater treatment and sludge stabilization performance of an unplanted system and four Phragmites plant-based sludge treatment wetlands (without or with earthworm assistance and microbial fuel cells integration). Biochemical oxygen demand (BOD5), chemical oxygen demand (COD), nitrogen(N), phosphorus (P), solids, and coliform removal percentage from the drained wastewater (produced because of sludge stabilization) was 96, 99, 89, 99, 98 and 97%, respectively in the five systems. Electrochemically active or inactive organic decomposition, nitrification, denitrification, filter media-based adsorption, and other chemical- based mechanisms primarily contributed to wastewater organic, nitrogen, phosphorus removal. N and P accu- mulation percentage in plant tissues was not substantial: accumulation percentage (with respect to total removal) ranged from 3 to 9% and 0.2 to 1%, respectively. However, plants improved suspended solids and coliform removal (from the drained wastewater) because of root-

based filtration. Total solids (TS %) content in the re- sidual sludge ranged between 83 and 89% within the five systems; the planted-microbial fuel cell integrated sludge treatment wetland with earthworm assistance produced the highest TS (%) content in the residual sludge. Organic matter, N, P concentration in the residual sludge ranged between 23 and 42 mg/kg, 8 and 13 mg/kg, 1 and 1.1 mg/kg, respectively. Earthworm assistance and microbial fuel cell integration improved drained wastewater purification and sludge stabilization within the planted systems. Activation, ohmic, and concentra- tion losses influenced current3production in microbial fuel cell integrated wetlands. A maximum power density production rate of 60 mW/m was recorded. This study shows the potential application of planted, earthworm assisted microbial fuel cell-based constructed wetland for drained wastewater and sludge treatment.

Keywords: Coliform, Nutrient, Organic, Sludge, Solids, Treatment wetlands

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Distribution of pathogens and antibiotic resistance genes in the vadose zone of soil-aquifer treatment (SAT) system

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The main objective of this study was to quantify the distribution of pathogens and antibiotic resistance genes in the vadose zone of the soil aquifer treatment (SAT) system. Soil samples were collected from a treated wastewater infiltration basin to a depth of 25 m in two sampling events: (i) at the end of flooding and infiltration and (ii) following three days of drying before the subsequent flooding event. Viable count parallelly of bacteria determines compared with microscopic live/dead count and enzymatic activity FDA hydrolysis. The abundance of the total bacteria, coliform, antibiotic resistance bacteria (ARB), were examined. In addition, total genomic DNA was extracted from soil samples (n-28 for both flooding and drying cycle), and quantitative PCR (qPCR) was used to determine the relative abundance of antimicrobial resistance genes (ARGs), including 1 integron integrase intI1, blaTEM, blaCTX-M-32, sul1, qnrS. In both sampling events, the results demonstrate that the distribution of antibiotic resistance genes in the vadose zone exhibits a similar pattern to the one obtained for the examined pathogen. We observed a high concentration of pathogens in topsoil layers and a gradual decline with depth. In this presentation, the profile obtained will be described and discussed with pathogens and ARGs transport and retention in the SAT system.

Keywords: pathogens, antibiotic resistance genes, quantitative PCR

Removal of methyl green from aqueous solutions by adsorption on the shrimp carapace and photodegradation using UV-C

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Effluents that are discarded by industries are important sources of water pollution because they can contain large concentrations of organic matter and have intense colour. We determine priority the influence of pH on dyes which is investigated by different methods. Study has shown that methyl green is influenced by basic pH, upper 8 and demonstrated that pH affects the ADMI colour number of methyl green from aqueous solutions. We propose in this study to remove this dye by adsorption. Characterization of the powder shrimp carapace by chemical analysis, FTIR and SEM, was studied. Photodegradation experiments were carried out in a stirred batch photoreactor equipped with a low-pressure mercury lamp as UV source at 254 nm. The adsorption, photolysis and photocatalytic experiments were conducted in a batch system at different operating parameters such as, contact time, pH, adsorbent dose, initial dye concentration and temperature. According to the experiments results, the equilibrium time, was found 112 min of contact time. Langmuir, Freundlich and Dubinin-Raduchkevich isotherm models were applied to describe the experimental data. Three simplified kinetic models were tested to investigate the adsorption mechanism. Results of the present study suggested that shrimp carapace could be suitable as a sorbent material for removal of dyes from aqueous solutions. Kinetic studies reveal that the degradation process UV-Shrimp carapace follow the The Langmuir-Hinshelwood model.

Some of the chemicals, including dyes and pigments, are toxic or can lower the dissolved oxygen content of receiving waters, threaten aquatic life and damage general water quality downstream. Effects on organisms in the environment can be either short term (acute) or long term (chronic). however, the use of dyestuffs and pigments may cause

a number of adverse effects to health. Health effects may be exerted directly at the site of application (effecting the workers) and later in the life cycle (effecting the consumers). Many chemicals used in textile processing have adverse effect on occupational and community health (Hua, Ma, & Zhang, 2013) Researchers are particularly interested in the toxicity of azo dyes, which are characterized by the presence of azo group (-N = N-). The azo bond breakage recent results in the formation of primary amines causing methemoglobinemia, characterized by an inability to transport oxygen in the blood. Respiratory allergy to reactive dyes has been reported for the first time in 1978 by (Liao, Hung, & Chao, 2013). In subjects engaged in weighing and mixing of powder dyes for two years with asthma and / or rhinitis of occupational origin (Rizzo, 2011). Cationic dyes (or bases) are usually highly toxic and resistant to oxidation. Indeed, other studies have shown that the cationic dye is very toxic to microorganisms (Meyer et al., 1982). Thus, treatment of effluents containing dyes is essential to safeguard the environment. Adsorption is one of the most efficient methods to remove pollutants from wastewater. Many studies have been made on the possibility of using adsorbents based on natural support. However, adsorption capacity is not very large, so new absorbents are still under development to improve adsorption performance. Algeria provides for developing its shrimp production during the 2014-2020 period; and it is hoped a shrimp production to more than 30 tons per year in 2020, that is why, in this study, we have valued Shrimp carapace by transforming it to fine powder by milling, to remove cationic dye (green methyl dye) which was used as a surrogate indicator to simulate industrial wastewater in order to evaluate the adsorption capacity of powder Shrimp carapace in the study.

The shrimp carapace is washed in the tap water then in distilled water, dried in 105°C during 3 hours then crushed and sieved. We use powder of shrimp carapace which has particle size between 50 et 800 µm.

Methyl green is a triphenylmethane group of rosanilines; it derives from the hexamethylpararosaniline. It consists of three benzene rings with seven methyl groups linked by a carbon, it colors the silk.

Technical grade of 100% purity (IUPAC name: 4-[[4-(dimethylamino) phenyl][4 (dimethylimino)-2,5-cyclohexadien-1-ylidine]methyl]-N-ethyl-N,N dimethylbenzenaminiumdichloride; molecular formula: C26H33Cl2N3; Molecular Weight (458,47) n,136.6 g mol-1 Absorption Maxima (λmax) 633 nm.

Addressing high concentration solvent sites (DNAPL) with a combined-remedy: emulsified oil and ZVI

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The use of in situ chemical reduction (ISCR) and enhanced in situ bioremediation (EISB) for treating recalcitrant compounds in groundwater has become a cornerstone in the environmental industry over the last decade. They are also sought-after during Brownfield redevelopment projects because they require no on-site infrastructure, have a relatively low cost of implementation and provide long remediation life typically on the order of years for a single application.

It is common that practitioners will use one or the other at any given site when addressing chlorinated solvents like Tetrachloroethene (PCE). In fact, these technologies are often married together because they share a similar redox state and do not directly compete in the subsurface. However due to this popularity sometimes one technology or the other is not appropriately applied. This especially true when dealing with very high concentrations typically encountered with DNAPL. EISB for example can have inefficiencies when groundwater conditions are acidic, or the plume is co-mingled with both ethene and ethane compounds. Whereas ISCR reagents (zero valent iron) must come into direct contact with the contaminant in order to degrade it into less chlorinated daughter products.

In this presentation we will explore both the strengths and weakness of both technologies. It will cover example site conditions and limitations that must be over come for either technology to result in a successful outcome. Finally, we will share a case study from a California, USA dry cleaner where both EISB and ISCR were deploy in tandem resulting in several orders of magnitude decrease in PCE, from greater than 100 mg/L to ND within one year of implementation.

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Environmental impact assessment of remediation strategy in an oil spill in the Ecuadorian Amazon region

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Petroleum is among the main Ecuadorian product of exportation and it contribute almost 9% of the Gross Domestic Product in 2019. The Ecuadorian petroleum industry is located mainly in the Amazon region (east of the country). However, despite the economic importance of the petroleum industry to the country, environmental damages attributable to these activities are evident. For example, wastes resulting from the oil exploration and production activities (sludge, oil, water and drill cuttings, and others) were disposed of in the vicinity of the extraction facilities without any treatments. As a consequence, these areas have environmental liabilities that require attention. In general, environmental liability is associated with a source of pollution and tends to increase over time . Indeed, the affectation of soil, water, flora, and fauna, attributable to inappropriate practices of the petroleum industry was largely reported.

However, remediation activities also demand the use of a considerable number of natural resources, fossil fuels, energy, and human labor. Therefore, they also generate hazardous and non-hazardous wastes, as well as gaseous emissions. Consequently, a negative environmental impact can be also attributed to remediation activities and must be considered. In this regard, a cost-benefit analysis of these activities is necessary. Quantification of those impacts is also required to propose improvements in the process to reduce their global environmental impact.

In this sense, this study assesses the environmental impact of the remediation activities of a representative environmental liability

attributed to the petroleum industry in the Amazon region of Ecuador, using the Life Cycle Assessment (LCA) methodology, which considers the ”cradle to grave” approach. This study was carried out according to the ISO 14040:2006 standard. The goals were: to carry out the life cycle inventory of remediation activities, develop the environmental assessment of the life cycle inventory, compare the LCA of the environmental-remediation scenario with a scenario of no-action, and propose strategies to improve environmental remediation.

From the 16 environmental impact categories considered in this evaluation, 12 categories showed higher impact values in the no-action scenario than in the environmental remediation scenario. These categories are climate change, ozone depletion, human toxicity with non-carcinogenic effects, particulate matter, ionizing radiation for human health, ionizing radiation for ecosystems, photochemical ozone formation, acidification, terrestrial eutrophication, marine eutrophication, freshwater ecotoxicity and depletion of mineral, fossil, and renewable resources. In contrast, the remaining 4 categories (human toxicity with carcinogenic effects, eutrophication of freshwater, land use, and depletion of water resources) showed higher impact values in the environmental remediation scenario.

Weighted results show a greater environmental impact in the no-action scenario with 5.45 points respecting no action scenario that shows 2.14 points. Therefore, the environmental load for the remediation scenario is lower by 39.4%.

The following activities were associated with the environmental impacts in the remediation scenario:

- Consumption of fossil fuels by heavy machinery, vehicles, and pressure pumps, because this equipment is crucial in all stages of remediation activities. The gaseous emissions generated are related to the following environmental categories: climate change, stratospheric ozone depletion, particulate matter, acidification, and human toxicity.
- Gaseous emissions and discharges generated by the incineration of hazardous waste produced during the activities, for example, waste collected from the liability, PPE, and tools at the end of their lifetime. This activity has an impact on all the environmental categories evaluated especially that related to human toxicity.
- Gaseous emissions and discharges related to the manufacture of tools and materials for remediation activities and PPE.

- Transfer of crude oil and other chemical compounds present in contaminated soil and sediment in the soil washing phase, causing an affectation in the category of freshwater toxicity and depletion of water resources.
- Impact on the landscape and soil by the environmental remediation activities.
- Direct exposure to contaminants to workers, since remediation activities are carried out in many cases manually, despite the rigorous use of PPE, the exposure to carcinogenic and non-carcinogenic substances cannot be ruled out.

Otherwise, in the no-action scenario, the environmental impacts may be related to the contamination of natural resources. Besides the specific climatic conditions, the pollutants have probably migrated, following the natural course of the nearby bodies of water, affecting at this way to a broad range of related organisms and causing toxic effects at all levels of the trophic chain. Regarding soil use, oil contamination could cause damage to infiltration, stability, and use of habitats. In turn, these generate midpoint impacts in the filtration and purification of water, regulation of the water flow, resistance and stability of the soil, functional diversity, diversity of species, and aesthetic and cultural values.

Moreover, the air emissions and discharges generated in the production of crude oil present in the oil spill have a significant impact on all the environmental categories evaluated, especially climate change, photochemical ozone formation, human toxicity, freshwater ecotoxicity, acidification, eutrophication of freshwater and resource depletion .

LCA of the studied process shows that the execution of remediation activities reduces the global environmental impact indeed approximately 39.4%, contributing at this way to mitigating the environmental effects generated by the presence of sources of pollution associated with wastes from hydrocarbon activity in the Ecuadorian Amazon. Moreover, according to the results, better strategies to reduce the global environmental impact can be implemented aligned to sustainability criteria.

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The process of production of Fe Mn and Si mn in r.ž "Topilnica" jsc Skopje

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The main source of manganese in raw materials for SiMn production is Mn-ore and Mn-rich slag from the high carbon FeMn production. The amount of slag per tonne of SiMn and FeMn metal is mainly determined by the ore/slag ratio. Increasing share of FeMn slag at expense of Mn-ore will lead to larger slag/metal ratio in the SiMn process. High volume of slag leads to an increased consumption of energy and probably to higher losses of metal inclusions in the final slag. Excavation of a SiMn furnace has shown that only modest pre-reduction of Mn-ore with CO gas seems to be obtained. All reduction of MnO was finished at the top of the cokebed. The Dissolution and reduction of quartz obviously takes place in the cokebed zone after the main reduction of manganese oxide is finished. The 'pick up' of Si in the metal is quite fast and takes place as the metal trickles down through the cokebed towards the metal bath. The distribution of Si between SiMn alloys and multicomponent MnO-SiO 2 -CaO-Al 2 O 3 - MgO slags is mainly determined by the process temperature, the silica content of the slag and its R-ratio = (CaO+MgO)/Al 2 O 3. As an example, the equilibrium content of Si in the alloy will increase by about 6 % if the R-ratio is reduced from 2 to 1, provided constant temperature and silica content. The effect of temperature is also considerable. The equilibrium content of silicon will increase by approximately 6 % per 50°C in the temperature range 1550°C to 1700°C. The equilibrium content of MnO in SiMn slags depends first of all on the temperature and secondly on the silica content of the slag. At 1600°C the MnO content decreases from about 9 % at silica saturation to a minimum of about 3-4% when the silica content is reduced to about 40-45%.

Keywords: SiMn, FeMn, ores, slague, furnance

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Immobilization of soil metal(loid)s with engineered biochar: Modeling the long-term performances under accelerated aging

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Soil amendments suffer from natural forces after application, resulting in evolving performances in contaminant immobilization. Long-term field monitoring provides direct evidence of the aging process of amendments following their application to soil. However, acquiring field aging data is challenging in most cases. In this context, we have developed a quantitative aging method that can be easily applied to simulate the effects of proton attack, a major reason for faded immobilization performance of soil amendments in the long run (namely, post-application aging). Engineered biochar co-doped with metal oxides were fabricated, pre-aged via chemical oxidation, and demonstrated excellent long-term resistance to post-application aging. Two models on the basis of conditional probability were also developed to describe the differences between various soil amendments and reveal their aging features.

Engineered biochars were fabricated according to a green synthesis method. In brief, iron and magnesium oxides were doped to either fresh biochar (BC-MgFe) or H2O2 treated wood biochar (OBC-MgFe). After that the resulting biochar was added to a soil contaminated with arsenic (As) and antimony (Sb) at a dosage of 5% and incubated with 30% water content for 21 days. After that, the soils were subjected to quantitative aging on the basis of quantitative proton attack. Furthermore, two conditional probability-based aging models (constant aging rate vs changing aging rate) was developed to depict long-term immobilization performances under this accelerated aging protocol.

Both FTIR spectra and XRD patterns suggest successful fabrication of engineered biochar. Excellent short-term immobilization performances towards As and Sb were achieved shortly after the application for BC-MgFe and OBC-MgFe. For instance, even on the first day of soil amendment, As and Sb concentrations can be reduced

substantially by 82.8-84.4% and 50.3-50.4% by both materials. Compared with BC-MgFe, OBC-MgFe presented better resistance to aging. For instance, the immobilization rate for As and Sb on the 100th year were 67.2% and 12.0% for OBC-MgFe, while those for BC-MgFe were 50.3% and 0, respectively. A constant aging rate contributed to long-term immobilization of OBC-MgFe, whereas a changing aging rate led to faded immobilization performance for BC-MgFe. Direct evidence was observed with both STEM and TOF-SIMS, suggesting thorough mixing of amendment with contaminated soil media contributed to long-term immobilization. As a long-term effective soil amendment that can be fabricated and modified in a facile way, OBC-MgFe may serve as a promising candidate in future practical immobilization applications.

In this study, a novel biochar composite for soil As and Sb immobilization, namely, OBC-MgFe was successfully fabricated via a facile method. To test the long-term effectiveness of this green soil amendment, a novel quantitative artificial aging method was developed, simulating the effects of proton attack on soil amendments. Two models were further used on the basis of conditional probability-induced aging to depict the long-term aging features of different biochar-based amendments. It was observed that a constant aging rate is the key to long-term immobilization. We argue that evidences from the field are required to further calibrate this aging method.

Keywords: biochar composite for soil As and Sb immobilization

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Effects of Endophytic fungi on phytoremediation ability of Jatropha sp. of heavy metal contaminated landfill soil

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Phytoremediation is a branch of bioremediation that involves the utilization of plants to remove, detoxify or transform contaminants including heavy metals from polluted sites. Thus, plants are used as cleaning agents. It is an inexpensive, and aesthetically, and environmentally friendly option. Over the past years, the method has been accepted to detoxify polluted soil and water. Yet, it is also regarded as a natural process that was identified more than 300 years ago. Several plant species are involved in rhizosphere, as well as microorganisms that are associated with roots to thrive in nutrient-deficient and toxic environments. This kind of association is beneficial to both organisms, in which the plants provide nutrients to the micro-organisms. The microbes protect the plants against toxic contaminants, enhance their development and ability to degrade contaminants through their metabolic activities. Phytoremediation achieved through bioaugmentation with fungi is promising in the decontamination of metal-polluted soil (Bilal et al., 2020). The study is therefore aimed to demonstrate the effect of endophytic fungi on the phytoremediation capability of Jatropha sp. of heavy contaminated landfill soil.

The concentrations of the metals in the shoots and roots of inoculated Jatropha sp. assumed the highest plateau of 953.20 mg/kg and 153.80 mg/kg, respectively and the accumulated metals were Fe and Ni, respectively. The accumulation of Cr, Fe, Ni, Pb, and Zn in the shoots

of inoculated Jatropha sp. surpassed that of the non-inoculated shoots of the same plant ($P < 0.05$). In contrast, with exception of Fe and Pb, most of the metals accumulated in the roots of treated Jatropha sp. did not vary with those in the roots of the untreated Jatropha sp. ($P > 0.05$). The results indicated that the interaction of the fungal consortium with the plant might have alleviated metal induced stress and enhanced their accumulation in the plant. For instance, the accumulation of Cr, Fe, Ni, Pb, and Zn in the roots of inoculated Jatropha sp. and their subsequent translocation to the shoots were noticed to be substantially higher as compared to the uninoculated plant. Current results are consistent with those of Ma et al. (2016) and Yamaji et al. (2016). On the other hand, the improved uptake and translocation of the metals in the plant could possibly be associated with the continuous decrease in pH from the beginning to the final day (Day 120) of the experiment. The decreased acidic pH might have possibly resulted in the dissolution of the metals in the soil leading to the increase in their mobility and bioavailability, thereby enabling more absorption through the roots of the plant (Yu et al., 2016). This can further be justified by the release of low molecular weight organic acids witnessed in the research. The influence of fungal inoculation on the metal uptake and translocation by the plant was further examined following calculation of the bioabsorption coefficient (BAC), bioconcentration factor (BCF), and translocation factor (TF) values). Meanwhile, the residual metal concentrations in the treated soil were significantly lower than those in the control soil ($P < 0.05$). Various metabolites which are known to improve the heavy metal tolerance and accumulation capacity of plants are detected in the plant. Such compounds include 5,7,2',3'-Tetahydroflavone, Tryptophan, S-(4-Nitrobenzyl) glutathione, Indole-acrylic acid, 5,2-Dihydroxy flavone, Asp-Pro-Ser, Val-Lys-Met, His-His-Arg, Lys-Gln-Ile, Ser-Pro-Arg, Arg-Thr-Glu, Thr-Ser-Asn, and Arg-Arg-Gln.

Significant ($P < 0.05$) accumulation of heavy metals has been reported in the fungi inoculated Jatropha sp. The residual concentrations of the metals in the treated soil were significantly ($P < 0.05$) lower than those in the control soil. It is concluded that inoculation of endophytic fungi improves the phytoremediation capacity of Jatropha sp. for heavy metal contaminated landfill soil.

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Phyto-assessment of copper, lead and zinc in water spinach and Okra

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Water spinach and okra are readily available tropical vegetables found in many countries located across the equator region. Even though vegetables are an important component of our daily diet, there is little information available as to its contamination by heavy metals. Heavy metals contamination in food specifically in vegetables, have been reported in many countries including Malaysia and other Asia-Pacific countries. Plants have the ability to accumulate metals from the environment and can be categorized as unsafe for consumption if the plants are cultivated on or near to contaminated land.

The aims of this study were to determine the responses of heavy metals toxic effect; and to evaluate the environmental and health aspects of heavy metals accumulation for both water spinach and okra grown under contaminated soil conditions. The growth performance, metal tolerance and metal accumulation properties of both water spinach and okra were assessed while the obtained metals accumulation were evaluated in light of the permissible levels of metal concentrations stipulated by the Malaysian Food Act 1983 & Food Regulations 1985 together with the Codex Alimentarius Commission - Joint FAO/WHO Expert Committee on Food Additives (JECFA) standards.

Heavy metal accumulation of Pb, Zn and Cu was significantly higher ($p < 0.01$) in all spiked metal treatments as compared to the control of both water spinach and okra. Between shoot and root; Pb, Zn and Cu accumulation was relatively higher in the roots of both water spinach and okra. Among treatments, Pb treated okra (80.20 ± 4.7 mg/kg) and water spinach (27.69 ± 3.5 mg/kg) recorded a significant increase ($p < 0.01$) of Pb accumulation in the roots as compared to control. Similarly, the Pb accumulation of shoots in Pb treated water spinach (30.31 ± 4.1 mg/kg) and okra (18.51 ± 5.2 mg/kg) also showed significantly higher ($p < 0.01$) with the non-metal spiked control treatment.

On the other hand, the highest Zn metal accumulation in water spinach and okra were recorded in the Zn treated plants for both roots and shoots with a significant increase ($p < 0.01$) of Zn metal accumulation to control treatment. All spiked metal treated okra showed significantly higher ($p < 0.01$) when compared to the control treatment for Zn accumulation in the roots. However, only Zn treated water spinach (35.10 ± 2.7 mg/kg) and okra (5.18 ± 1.2 mg/kg) recorded significant increased ($p < 0.01$) with the control treatment for Zn accumulation in the shoots. A significant increase ($p < 0.01$) of Cu metal accumulation was observed among the roots of Cu treated water spinach (34.80 ± 3.4 mg/kg) and okra (10.08 ± 2.4 mg/kg) with the control treatment. The shoots of Cu treated water spinach (18.87 ± 2.6 mg/kg) and okra (2.62 ± 2.4 mg/kg) also showed significantly higher ($p < 0.01$) of Cu metal accumulation with the control treatment. And between shoot and root, a greater accumulation of Cu was observed in the roots of all treatments for both water spinach and okra but the opposite was found in some of the treatments with Pb and Zn metal accumulation. Amongst all three different types of heavy metal, water spinach recorded the highest metal accumulation for Pb (30.31 ± 4.1 mg/kg), Zn (35.10 ± 2.7 mg/kg) and Cu (18.87 ± 2.6 mg/kg) in the shoots of different spiked metal treatments, respectively.

For okra, heavy metal accumulations were in the order of Pb > Zn > Cu whilst Zn accumulated the highest followed by Pb and Cu in water spinach. It highlights that there were significant differences ($p < 0.01$) found in both water spinach and okra cultivated under the three spiked metal treatments of Pb, Zn and Cu. Among all the three different spiked metal treatments, both water spinach and okra showed great tolerance for Pb accumulation as the accumulation of Pb was high in the roots and shoots of both plants. The concentrations of Pb in the shoots of water spinach and okra exceeded maximum permissible levels of the national Malaysian Food Act 1983 & Food Regulations 1985 as well as the international Codex Alimentarius Commission limits.

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Evaluation of river sediment trend and status from the aspect of pah content

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Polluted industrial sites, runoff from agriculture and lack of facilities for municipal wastewater treatment continues to contribute to a significant amount of organic and inorganic pollutants which were accumulated and thus detected in river sediments. Polycyclic aromatic hydrocarbons (PAHs) are generated due to incomplete burning of organic substances. Use of fossil fuels is the primary anthropogenic cause of PAHs emission in natural settings. Although several PAH compounds exist in the natural environmental setting, only 16 (namely: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g, h, i)perylene and indeno (l, 2,3-cd)pyrene) of these compounds are considered priority pollutants. PAHs imposes several health impacts on humans and other living organisms due to their carcinogenic, mutagenic, or teratogenic properties. The level of PAHs in sediments depends on the distance from the emission source, with higher quantities in industrial and urban areas than in suburban and rural areas. The aim of this study was to evaluate the quality of the sediment from The Great Bačka Canal by the content of PAH. This canal is an integrated part of the large Hydro- system Danube-Tisa-Danube, designed for melioration of the developed agricultural region. The Canal has accumulated around 400,000 m^3 of contaminated sediment and practically is non-navigable and without runoff. This implies highly disturbed water quality, and the impossibility of river transport, which is very important for the food industry in the region. The quality of the investigated sediment

and sources of contamination will define a specific approach to sediment management for this region.

he obtained values were compared with the limit values of PAHs for the assessment of the status and trend of sediment quality prescribed by Serbian Regulation limit values of pollutants in surface and groundwater and sediment and deadlines for their achievement.

Serbian regulation prescribed limit values for sum of PAHs for assessing the quality of sediment and permitted ways of dealing with dredged sediment. If obtained value is greater than Limit value (1 mg/kg) but smaller or equal of Verification limit (10 mg/kg), than examined sediment is class two. For that matter sediment quality of Great Backa Canal for both samples (GBC-S is 2.46 mg/kg, and GBC-D is 3.19 mg/kg) is within the second class. Class 2 sediments are slightly polluted and during their dislocation they can be disposed without special protection measures in a belt up to 20 m wide in the vicinity of watercourses.

The results obtained by PAH analysis are part of the initial phase of sediment characterization /sediment monitoring for further manipulation. Due to the large amounts of sediment in GBC, mechanical dewatering is a very sustainable solution as an alternative treatment approach for dredged sediments. Management options for the dredged sediment depending on its physical and chemical characteristics, are sediment relocation and the use of dredged sediment as substrate for soil amendments to enhance agriculture or retaining sediment within the natural sediment system to support sediment-based habitats. The beneficial reuse of sediments as a construction material can optimize the management of the natural resources. Clay and silt as the most common materials acquired from the maintenance dredging in rivers, reservoirs and ports, can find more engineering uses. Further studies of the bioavailable fraction of PAHs and potential ecotoxicity are certainly needed, as well as constant monitoring of sediment in canal and as dredged material over the time.

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Leaching pollutants from municipal waste in a lysimeter experiment

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Municipal landfills are actual and potential sources of groundwater pollution characterized by toxicity and long-range transport (Vaverkova et al., 2020). Many pollutants, especially xenobiotics, are difficult to biodegrade and accumulate in the environment, which is a threat. Waste management forces the use of a method of waste disposal other than landfilling (Esmaeilian et al., 2018). In this context, recycling of materials such as metals, plastics, glass is obligatory. Unfortunately, landfilling is still the most popular method of disposing of waste (Sourkova et al., 2020). Contaminants washed out from waste migrate to groundwater, as a result of which the quality of groundwater in terms of physicochemical and bacteriological parameters may deteriorate (Rykala and Dabrowska, 2020). The proper functioning of the liner system requires the determination of the amount and composition of leachate. The aim of the research is to assess the efficiency of the lysimeter test stand performance and present the results of the interdisciplinary experiment.

The lysimeter was filled with municipal waste with 19 05 99 European Waste Code. The lysimeter experiment operated from the end of November 2018 until the end of December 2019. In each month of the experiment (except for February), the total volume of the effluents obtained was measured and the values of electrolytic conductivity, temperature, pH and Eh were determined. In addition, the characteristic indicators of groundwater pollution in municipal landfills were observed. The leachate samples were subjected to microbiological analyses, which included among others: the determination of the total number of mesophilic and psychrophilic

microorganisms, the determination of the total number of Escherichia coli and coliforms, enterococci, Pseudomonas aeruginosa and Clostridium perfringens. To determine seasonal metabolic changes of microorganisms in the leachate of waste dumps, Biolog® 96-well EcoPlatesTM contained 31 different carbon sources (in three replicates) were inoculated with 120 µl of 100-fold leakage water diluted with 0.85% NaCl.

The chemical composition of the effluent was determined primarily by the high concentrations of bicarbonates, chlorides and sulphates. The value of electrical conductivity reached over 30 mS/cm. The dominant cations are Ca, Mg, Na, K. The content of nitrogen compounds is much higher in the initial phase of the experiment. All metals: Ba, Cr, Cu, Ni, Al, Mn show a decrease in the content during the experiment. The highest leachability of heavy metals was found in the case of copper. The conducted microbiological analyses showed that the number of heterotrophic bacteria varied significantly in leachate samples collected in the spring. From spring to autumn, the number of mesophils was at the same level (107 CFU cm-3) and was higher than in winter (105 CFU cm-3). Similar observations were recorded for psychrophilic microorganisms isolated from the leachate collected in spring and autumn (107 CFU cm-3) with the lowest number in winter (105 CFU cm-3). Higher temperatures in summer and the lowest ones in winter reduced the ability of the microbiome to oxidize polymers and amines by 80 and 86%, respectively, compared to spring and autumn. Simultaneously, the highest capacity for oxidizing carbohydrates (44.19%) in the summer, and amino acids (35.72%) and surfactants (27.19%) in winter were observed.

According to the results of the lysimeter experiment performed, the influence of the leachate can be deduced from several aspects, such as chemical, microbiological and biochemical hazards. The research showed that for the studied area, the lysimeter experiment allows to reflect the conditions in the landfill. However, it is not possible to obtain the same type of waste as in the closed old landfill.

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Management of contaminated sites in the Slovak Republic

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The State Remediation Programme of Contaminated sites (2022 – 2027) is the principal and planning document for contaminated sites issues of the Slovak Republic. The 3rd State Remediation Programme of Contaminated sites for 2022 – 2027 was approwed by the Slovak government via Resolution No. 320 from May 11, 2022 and consists of binding part and guideline part. The binding part describes the priorities, objectives and measures to achieve these priorities in legislative, financial, technical and educational aspects. The guideline part focuses on the possibilities for state aid in remediation the most risky contaminated sites. The Programme is in full compliance with the Water Plan of the Slovak Republic.

Priorities of the State Remediation Programme of Contaminated sites in terms of the riskiness of contaminated sites are:

1. To ensure a comprehensive, systematic and sustainable solution of contaminated sites issues.
2. To ensure synergies with measures of national strategic documents and transnational strategic documents.
3. To ensure systematic monitoring, survey and remediation of contaminated sites and thereby to reduce health and environmental risks.
4. In the context of the development of the information society, improve public access to information in the field of contaminated sites, thereby to promote the integration of the public, in particular local communities, in their management.
5. To promote the exchange of experiences within international communities on contaminated sites and related topics, thereby to contribute to the development of human potential expertise in the field of contaminated sites management.
6. To promote an educational platform for the public.

The main objectives of the State Remediation Programme are:
1. Improving the management of contaminated sites;
2. Identification and geological survey of potentially contaminated sites;
3. Detailed geological survey of contaminated sites;
4. Remediation of contaminated sites;
5. Monitoring of contaminated sites.

The list of contaminated sites proposed for survey, monitoring and remediation was created on the basis of projects funded by Operational programme Quality of Environment and the government budget and on the basis of the requirements and needs of selected ministries and addressed specialized agencies.
Information System of Contaminated sites (ISCS) represents a basic and an official platform for record keeping of contaminated sites in Slovakia. A register of contaminated sites supports the content of the information system. It records the life cycle of contaminated site and all information resulting as a consequence of processes defined by Act no. 409/2011 on certain measures in relation to environmental burdens and on the amendment of certain acts. ISCS is a part of the public administration information system according to § 20a, section 1 of the Act no. 569/2007 on geological work as amended (onwards referred to as 'Act no. 569/2007'). A register of contaminated sites consists of section A – comprising records of potentially contaminated sites, section B – comprising records of contaminated sites and section C – comprising records of remediated and reclaimed localities. Currently (March 2022) register contains information on 2,020 registration sheets of which 879 sites are classified into the section A, 323 sites in the section B and 818 localities into the section C..

Keywords: Management of contaminated sites, Information System of Contaminated sites

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Education and awereness in the field of contaminated sites in Slovakia

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Slovak Environment Agency (SEA) has implemented a lot of information and education environment projects since 2007, which have been co-funded especially by the EU funds and by the Environmental Fund.

The current National project No. 3 INFORMATION AND PROVIDING ADVICE ON IMPROVING THE QUALITY OF ENVIRONMENT IN SLOVAKIA (acronym INFOAKTIVITY – INFOACTIVITIES) has been implemented by SEA since 2016 and its duration is expected till the end of the year 2023.

Project INFOACTIVITIES covers a number of information activities on selected environment topics which are addressed to various target groups. This activities are thematically divided into 6 main project activities (MPAs). The Main Project Activity No. 5 (MPA 5) is called Information Activities in the field of Contaminated Sites. The target group of the significant part of the MPA No. 5 are university students, postgraduate students and their lecturers in relevant branches of university study related to contaminated sites (geologists, environmentalists, ecologists, natural scientists, geophysicists, urbanists, land planners, ...) as well as representatives of state bodies and private companies in the field of contaminated sites and the general public, too. The basic types of information activities are field trips, educational excursions, workshops, courses, conferences, school programmes, environmental consulting and various types of publications (incuding flyers, conference proceedings, methodical guides) – in a printed or electronic form.

Excursions are 5-day field courses in various regions of Slovakia, where students get acquainted with many enviromental problems of contaminated sites. They visit selected sites – contaminated or potentially contaminated as well as remediated sites, there they also practice selected geological or environmental fieldwork and are taking lectures on related topics.

Keywords: Education, contaminated sites

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Assessment of shear-thinning fluids and strategies for enhanced in situ removal of heavy chlorinated compounds-DNAPLs in an anisotropic aquifer

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Chlorinated organic hydrocarbons (COHs) are hazardous and widespread contaminants in soils and groundwater. COHs have been released for decades into the environment because of their use in anthropogenic activities and the presence of dense non-aqueous phase liquids (DNAPLs) of COHs in these media results of spillages. These DNAPLs percolate to the aquitard because of their high density and low solubility in water. Improving the sweeping efficiency and the mobilization ability of flushing fluids for DNAPL-recovery in anisotropic media requires to increase their capillary number. This well-known issue led to the use of viscous, but shear-thinning fluids in oil recovery. These behaviors, observed for associative polymers like xanthan and for foams, are useful for the in situ remediation (ISR) of contaminated underground .

Within the PAPIRUS project (French acronym for Upwelling Technology and Injection of Stabilizing Agents for Assisted Pumping using Tilted Recovery Wells), the removal of chlorinated organic hydrocarbons (COHs) -DNAPLs was studied in permeability-contrasted 2D-sandboxes and 3D-tanks with an egg-box shaped substratum. In 2D-sandboxes, first, the non-spatially targeted DNAPL recovery (NSTR)

was assessed for various water-based fluids whose propagation was only controlled by injection forces. Unique aspects of this work include the comparison of the sweep efficiency of non-dense Newtonian and non- Newtonian fluids to recover the contamination in anisotropic 2D-sandboxes, essentially in the form of a pure phase. Second, spatially targeted DNAPL recovery (STR) was performed after the high permeability layer (HPL) was blocked. Fluids propagation in the low permeability layer (LPL) was assisted by pumping which allowed to induce their converging flow. In the 3D-tank study, the STR strategy was applied for DNAPL recovery after the blocking of the most permeable layer with a highly viscous xanthan solution. In addition, a geophysical monitoring based on electrical resistivity tomography was setup in the tank to image the DNAPL movement and behavior during the remediation process.

NSTR results showed that DNAPL recovery with non-viscous liquids did not exceed 40% in 2D- sandboxes. DNAPL-recovery increased by 2.1 and 3.3-times as compared to pure water from tension-active and viscosity effects, respectively. When combined in a flushing fluid made of xanthan 2 g.l-1 and SDBS 1.3 CMC, the pure phase recovery was improved by a 4.2 factor and reached approximately 90% in 2D-experiments. It was observed that polymer solutions are more controllable and robust than foams as flushing fluids. STR and NSTR were compared and provided similar recovery rates for the best chemical formulations of the displacing fluids, yet the former allowed to reduce the xanthan concentration by a factor of 10 to 20. Applying the STR strategy for DNAPL recovery in the 3D-tank allowed to reach DNAPL recoveries of 70-75%.

Whenever possible and regardless of DNAPL-recovery, the high permeability layer should be blocked first before flushing to improve the sweeping efficiency at high to low permeability interfaces and in the LPL where DNAPL accumulates. This shear-thinning polymer technology is therefore promising for the in situ remediation of anisotropic aquifers contaminated with DNAPLs. Moreover, the geophysical monitoring during DNAPL recovery is an attractive tool to track DNAPL propagation and behavior at lab-scale and will be tested at field-scale soon. Results suggests that the developed technology is quite robust.

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Performance of raw zeolitic tuff for pharmaceutical wastewater treatment using constructed wetland

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Constructed wetlands (CWs) are nature-based solution that used to treat various wastewater in high removal efficiency and low cost depending on the substrates, aquatic plants and microorganisms through physical, chemical and biological processes. Substrates have different properties such as specific surface area, pore quantity and volume, and element composition, this makes different substrates perform differently in terms of pollutants removal. Therefore, there are many important criteria should be considered for the selection of the substrate such as the substrate cost, pollutant removal capacity, accessibility, permeability and sustainability. Recently, Zeoltie which is micropores aluminosilicate with crystaline structre is used in CWs as a substrate. The selection of specific substrates can also improve nitrogen removal in wetlands. For example, zeolite can improve the ammonia removal performance by 6% to 100% depending on its porosity and cation exchange properties . Moreover, it has been reported that a high natural reoxygenation capacity ban be achieved at tidal flow constructed wetlands (TFCWs) during alternating wet and dry operations, consequently will enhance nitrification. Also, the reoxygenation capacity of TFCWs (350 g/ (m2 ·d)) is higher than those of VFCWs and HSSF CWs at 50–90 and 1–8 g / (m2 ·d), respectively .
The objective of this study is to compare the perforamance Tidal flow constructed wetlands (TFCWs) filled with Sand and RZT for the removal of COD, PO4 and TN.
The removal efficiencies for COD, PO4 and TN in the CWs system filled with Sand and RZT, it's very efficient . The CWs system on the removal efficiency of PO4 and TN shows that the system filled with RZT (35.5, 32.5) have higher removal efficiency than the system filled with sand (18.1, 21.5) respectively. However, for the removal efficiency of COD

both CWs systems shows approximately the same removal efficiency. A recent study conducted by Cao et al. 2022 reported that the removal efficiency of TN using half zeolite pyrite for F/D = 4 h:2h reached 78.36%. In addition, 49% removal of TN was achieved using TFCWs. Moreover, a study reported that the removal of COD was 60-84% with usually operating longer HRT and higher influent COD concentrations. Therefore, the removal efficiency results obtained in this study are approximately low comparing with those reported in the literature where all the samples were collected at winter season and the temperature was low. Consequently, the CWs performance is highly affected on the cold weather.

It is important to mention here that the results reported in this paper are very promising since these results representing the collected samples during the winter (temperature = 0 – 10^{o}C). So, it is expected that the efficiency removal by CWs will be highly increased during the warm weather. Varma, M. et al. 2020 has mentioned that the performance of CW's is highly affected in cold climate due to several limiting factors such as drying up of plants, decline in microbial action, freezing and clogging of pipes resulting in inadequate removal efficiency .

The results of starting up stage show a good performance for the removal of COD, PO4 and TN using sand and RZT. However, RZT showed higher removal efficiencies of PO4 and TN than sand. The results demonstrated the feasibility of using innovate nature-based solutions for organic and nutrients removal and provided the data for the further pilot-scale study and implementations. The reported results in this paper are representing the startup operation of CWs groups and during the winter season (from December 2021 until February 2022). So, it is expected that the efficiency removal by CWs will be highly increased during the summer season.

Keywords: Performance of raw zeolitic tuff, for pharmaceutical wastewater treatment, constructed wetland

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Demonstration and evaluation of an on-site treatment train for PFAS polluted groundwater: the LIFE SOuRCE project.

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The LIFE SOuRCE is a European project funded by the LIFE Programme of the European Union, and aims to provide alternative cost-effective technologies for on-site remediation of PFAS (per- and polyfluoroalkyl substances) polluted groundwater.

Per- and polyfluoroalkyl substances (PFAS) are chemicals that contain one or more perfluoroalkyl moieties and are extremely stable due to their resistance to heat and chemical agents, low surface energy and low friction properties . Because of their stability, this group of more than 5,000 anthropogenic chemicals are used in innumerable industrial applications. Their broad use over the last 5 decades have caused a global spread of these compounds. Now they can be found in the blood of most of the population living in industrialized countries, and even in wild animals living in isolated areas such as polar bears. Toxicology studies have connected the increasing exposure to PFAS with pathologies like kidney cancer. In fact, the estimated costs of treatment of this pathology for all countries in the European Economic Area is around 26 million EUR.

The project arises from the concern at European level about the presence of PFAS in drinking water and groundwater. This concern has led over the past years to the development of new regulations and

legal requirements aiming to control production, use and disposal of these compounds. At the European level, the European Comision has included PFAS in the REACH regulation (Registration, Evaluation, Authorization, and Restriction of Chemicals), in European Chemicals Strategy with the objective of ban them in the medium term, and as part of the new Framework Directive for Drinking Water, setting the limits to 0.1 µg/l for individual PFAS and 0.5 µg/l for PFAS in total. This last regulation is of special importance as it will be transposed to the national laws of each country in the European Union in the coming years.

The imminent regulation of PFAS concentrations in groundwater questions the available technologies for on-site remediation, as the necessity for cost-effective solutions becomes more pressing. Granular Activated Carbon (GAC) is the most used technology for on-site remediation. However, its costs increase for large volumes of water, and the efficiency of GAC is lower for short chain PFAS. Therefore, alternative technologies to GAC are needed. In response to this necessity the LIFE SOuRCE project aims to demonstrate and optimize a cost-effective treatment train for remediation of PFAS contaminated groundwater. The resulting treatment train should be able to remove long-chain PFAS (> 99 %) and short-chain PFAS (> 95 %), meeting the new EU Drinking Water Directive targets, and within affordable costs of around 0.1 €/m^3 groundwater treated.

The LIFE SOuRCE project started in September 2021 and will run for four years. Bench scale testing was started in beginning of 2022 and we expect to have our first results ready to present at REMTECH September 2022. Results from the bench scale tests will provide further evidence about the efficiency of each individual technology. The conclusions of the tests will be used to combine the technologies in the treatment trains. Both pilots will be monitored, so that removal efficiencies, costs and impacts like emissions can be compared to GAC. This information is also necessary for the application of the technology at a larger scale

Results and conclusions from LIFE SOuRCE will be disseminated continuously throughout the project time at the project website: https://life-source.se/ . Here you can find more information about PFAS and the different treatment techniques used in LIFE SOuRCE together with news from the LIFE SOuRCE team.

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Improving Deodorizing Efficiency by Nutrients Medium Optimization of Odorous Hydrogen Sulfide Biological Trickling Tower

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Odorous emission from wastewater treatment process are generated by a number of wastewater components, and hydrogen sulfide (H_2S) is considered to be the main contributor to odorous emissions from wastewater treatment plant. Biological trickling filter is cost effective deodorant technology which is free from secondary pollution. microbial community structures and nutrients affect the efficiency of biological trickling fiber deodorizing. Nutrients had important effect on the growth and metabolism of microorganisms on the bio-filler. In this study, Bio-tricking filter was used for removal of hydrogen sulfide from a waste water plant pump station in Shanghai. To improve biological trickling fiber deodorizing efficiency, nutrients medium for the biological trickling tower were optimized according to the microbial community composition.

Among the top 20 species, no Fungi was found. bacterial accounted for 95% of the biological trickling microbial communitie. The bacterial Acidithiobacillus which can oxidize hydrogen sulfide (H_2S) accounted for more than 93% of the the biological trickling microbial communities. They were Acidithiobacillus thiooxidans(61%） ,Acidithibacillus albertensis(22%),Acidithiobacillus sp. SH(10%), Acidithibacillus ferrooxidans, Acidithibacillus candus, Acidithibacillus ferrivorans.

Archaea accounted for 4% of the biological trickling microbial communiti, they are Ferroplasma acidarmaus(2%), Ferroplasma acidiphilim(1%), Thermoplasma volcanium(1%). The archea Ferroplasma spp. are acidophilus and thermophilic,. The optimal growth temperature of Ferroplasma spp. is above 37 °C and the optimal growth pH value is between 0.5 with 2.0, Ferroplasma spp. can derive energy from the oxidation of ferrous ion. Ferroplasma spp. are capable of chemomixotrophic growth on ferrous sulphate and 0.02% (w/v) of yeast extract, with rapid absolute oxidation of iron.

The nutrient medium were arranged to satisfy nutrient requirement of primary microorganism group that could utilize hydrogen sulfide . The nutrient medium can satisfy the 6 kinds of Acidithiobacillus, which account for 93% of the microorganism community. The nutrient requirement of three kinds of archaea were also satisfied. To improve efficiency of odorous gas removal of biological trickling tower, we tried to improve community composition by supplying nutrients for acidophilic microbial, capable of autotrophic growth using elemental sulfur and reduced sulfur compounds. The optimized media broth were:0.2% yeast extract, $(NH_4)_2SO_4$ (3.0g/l), K_2HPO_4(3.5 g/l), KCl(0.1 g/l), $MgSO_4.7H_2O$(0.5g/l), $Ca(NO_3)_2$(0.01 g/l), $Na_2SO_4.10H_2O$ (3.2 g/l),$FeSO_4.7H_2O$(0.5g/l); trace element:$FeCl_3.6H_2O$ 11(mg/L), $CuSO_4.7H_2O$ 0.5(mg/L),Na_2SO_4 50(mg/L),H_3BO_3 2(mg/L),$MnSO_4$ 2(mg/L),$Na_2MoO_4.2H_2O$ 0.8(mg/L),$CoCl_2 \cdot 6H_2O$ 0.6(mg/L),$ZnSO_4 \cdot 7H_2O$ 0.9(mg/L),$CaCl_2$ 5.54(mg/L),$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ 1.1(mg/L), $MnCl_2 \cdot 4H_2O$ 5.06(mg/L). It was found that using optimized nutrient medium the whole system operated well . Efficiency of odorous gas removal of biological trickling tower was improve from 81.7% to 93%

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Removal of chlorinated phenols from water using biochar

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Chlorinated phenols (CPs) are aromatic organic compounds widely used in industry and agriculture, thus their main sources in the environment include direct discharge of waste streams and the combustion of organic matter . Highly toxic, and poorly biodegradable, CPs are considered a priority and hazardous substances. In the Water Framework Directive (2000/60/EC), pentachlorophenol (PCP) has been included on the list of priority substances, and Directive 2013/39/EU (2013) defined surface water quality standards for this compound. In the Danube river, CPs were detected in a wide range of concentrations ranging from 1.64 ng/L to 155 ng/L. The fate CPs in the natural environment depends on a number of factors, including their acidity and polarity expressed through the dissociation constant, pKa and octanol-water partition coefficient, logKOW. Further, one of the most important factors influencing the fate of CPs is the pH value of water since with increasing pH value, the share of the more soluble ionic form of the compounds in the solution also increases.

Biochar is a material that is successfully applied in contaminated mediums to reduce the bioavailability of contaminants in the environment. The efficiency of biochar application in the remediation of contaminated water depends on the physicochemical properties of biochar, such as elemental composition, specific surface area (SSA) and pore volume, surface charge, as well as environmental conditions, primarily pH value. The aim of this study was to estimate the potential of biochar application for the removal of four CPs, 4-chlorophenol (4-CP), 2,4-dichlorophenol (2,4-DCP), 2,4,6-TCP and PCP, from contaminated water, under different pH conditions.

In the course of biochar characterisation, pHPZC was determined at 10.8. This property is especially important in the sorption process of

compounds containing ionizable functional groups, such as CPs. Namely, this result suggests that at pH 4 and 7 (pH < pHPZC) the surface of the biochar is positively charged, and it is expected that, in these conditions, interactions will occur primarily with negatively charged chemical species, while at pH 12 (pH > pHPZC) the surface of the biochar is negatively charged.

For all four investigated compounds, the removal rate ranged between 35% and 75%, and the CP concentration on biochar, calculated from the initial and the residual concentration in water was from 582 μg/g (removal of 2,4-DCP at pH 4) to 1216 μg/g (removal of 4-CP at pH 7). These results show that the investigated biochar have a significant capacity to bind CPs.

For all four investigated CPs, the highest removal rate was obtained at pH 7. For 2,4-DCP removal at pH 4 was only marginally lower than that at pH 7, whereas, for the other three compounds, there was a significant increase in removal rate with the increase of pH from 4 to 7. With further increase of the pH to 12, removal rates of all CPs decreased. These results indicate that CPs are removed from water by different mechanisms at different pH conditions. At pH 12, all four CPs are in ionised state given that their dissociation constants vary between 4.74 for PCP and 8.85 for 4-CP. At the same time, biochar surface is negatively charged (pH > pHPZC), thus the drop in removal rate might be the result of electrostatic repulsion. On the other hand, at pH 7 the biochar surface is predominantly positively charged (pH < pHPZC) and can bond with the partially ionised CPs via electrostatic attraction. At pH 4, CPs are predominantly in molecular form and cannot engage in electrostatic interactions, thus the main mechanism at these conditions are likely hydrophobic and π-π interactions.

The investigated biochar obtained from Basna d.o.o. Čačak, Serbia has proven to be an excellent sorbent for CPs removal from water. Removal efficiency was significantly influenced by the pH conditions with pH 7 being the optimal condition for the process. The changes in pH conditions causes change in both the surface charge of the biochar, as well as the dissociation rate of the CPs. As a consequence, different bonding mechanisms occur, resulting in an increase or decrease in CP removal.

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Enhanced Affinity for Per- and Polyfluoroalkyl Substances on a Modified Clay

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Water contamination by per- and polyfluoroalkyl substances (PFAS) impacts many countries and leads to regulatory actions to reduce human exposure to these toxic chemicals. PFAS are used to make water and oil repellent coatings, specialty polymers, pesticides, and aqueous film-forming foams (AFFF) for controlling class B fires. However, the stable and strongly electron-withdrawing perfluoroalkyl moieties [F(CF2)n–] that make PFAS versatile in applications also lead to persistent pollutants. Drinking water guidelines as low as 10 ng/L for perfluorooctane sulfonate (PFOS) or perfluorooctane carboxylate (PFOA) are developed in the US. The long-chain PFAS remain widely detected despite phase-out, while replacements with short perfluoroalkyl chains (e.g., perfluorobutane sulfonate, PFBS) or alternative chemistry (e.g., polyfluoroalkylether) pose emerging concerns and are highlighed in the newly released "PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024". Stringent guidelines result in costly water treatment processes because existing adsorbents used for removing PFAS from water are often not effective.

Most commonly used activated carbon relies on large specific surface areas and the hydrophobic effect to remove organics of low solubility from water. However, activated carbon shows limited efficacy for removing short-chain PFAS (n < 6) because of the high solubility imparted by charged functional groups (e.g., carboxylate, sulfonate). Alternatively, adsorbents that enable ion exchange processes (or ionic interactions) are utilized to remove anionic PFAS. Such adsorbents are either functionalized with amine groups (e.g., diethylaminoethyl, quaternary amine) or are inherently aminated (e.g., polyacrylonitrile). Low-cost smectite clays can be modified by intercalating quaternary ammonium surfactants into the interlayer space via ion exchanging with cations (e.g., K+, Na+, and Ca2+). Such materials have long been

shown to improve adsorption capacity towards metals and organic compounds (e.g., Cr2O72-, methylene blue, and phenolic) due to hydrophobic interactions, ionic interactions as well as increased interlayer distance . The first generation of modified smectite clays (Fluoro-Sorb) has proven highly effective for removing long-chain PFAS and is increasingly used for PFAS water treatment and soil remediation . Demand for treating short-chain PFAS requires further improvement of sorbent performance. In the study, we conducted a comprehensive assessment of the second generation of such clay products (FLEX) with the following objectives.

Adsorption of PFAS on FLEX was first carried out in deionized water (DI) to obtain the adsorption isotherm and determine the adsorption capacity. The adsorption isotherms of perfluorobutane sulfonate (PFBS) and PFOS on FLEX, which were fitted by Langmuir-Freundlich equation. The qmL-F of PFBS and PFOS were determined to be 22.2 mg/g and 71.1 mg/g, respectively.

The adsorption of PFOA, GenX, PFBA in DI water, the adsorption of PFAS mixture in AFFF-impacted groundwater, the effect of water chemistry and co-contaminants, and the comparison with other adsorbents will be included in the final presentation. The elucidation of the adsorption mechanism via multiple characterization and molecular simulations will also be presented.

Laboratory sorption experiments confirmed that modified bentonite clays (e.g., FLEX®) are highly effective in removing diverse types of anionic and neutral PFAS from AFFF-impacted groundwater. Organic co-contaminants such as diesel, as well as varying levels of common cations and anions at the levels typically observed at groundwater, do not affect the sorptive removal.

Keywords: PFAS, Modified Clay, FLEX®

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Adsorption performance of hydrochars for chlorfenvinphos removal from water

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Chlorfenvinphos (CVP), 2-chloro-1 vinyl diethyl phosphate is an organic compound of artificial origin used as an organophosphorus pesticide and is harmful for human health due to its neurotoxicity. Also, CVP have been found in wastewater and natural water bodies (Barco-Bonilla et al., 2013). For these reasons, it was included in Decision 2455/2001/EC of the European Parlament and of the Council of 20 November 2001 amending the Water Framework Directive (2000/60/EC) and establishing the list of 33 priority substances in the field of water policy (Mora-Gómez et al., 2022). Hydrochars are carbon-based materials produced by hydrothermal carbonization (HTC) process which includes thermochemical conversion using heat to convert wet biomass feedstocks to hydrochar. The application of hydrochars has been shown as very important for carbon sequestration, energy production, contaminated soil remediation and as potential adsorbents for the removal of organic pollutants from water. These carbon materials have a highly porous structure as well as oxygen-containing functional groups (e.g., –OH, –C═O, and –COOH groups) which play an important role in the adsorption process (Phan et al., 2022). HTC conditions and the type of raw biomass, can influence which functional groups are present on the surface of hydrochar, the size and structural shape changes, and instigate adsorption of organic pollutants (Santana et al., 2022).

Kinetics experiments aimed to investigate the time required to establish the adsorption-desorption equilibrium. Based on the obtained dependence of the equilibrium concentration to initial concentration ratio (Ce/C0) on time (t), adsorption-desorption equilibrium of the tested compound for both hydrochars was established after 24 h.

Adsorption isotherms: the Freundlich isotherm defines the surface heterogeneity and the exponential distribution of active sites and energies and is applicable to adsorption on heterogenous surfaces (Ayawei et al., 2017). Adsorption of CVP on selected chars is well presented with the Freundlich model with satisfactory determination coefficients (R2=0.963–0.994) for both adsorption isotherms.
Adsorption of CVP was nonlinear for HTC_MIS 180 (n=0.822) which indicates that the affinity of sorbent decreases with increasing CVP concentration which indicates a favorable adsorption process, whereas for HTC_SBS 180 adsorption process indicates unfavorable adsorption (n=2.65) (Worch, 2012). Adsorption coeffcients (KF) were 0.144 and 745 (μg/g)/(μg/L)n for CVP sorption on HTC_MIS 180 and HTC_SBS 180, respectively, indicating significantly higher adsorption the hydrochar originating from sugar beet shreds. Positive correlation was found between the obtained partition coefficients (Kd, calculated at three equilibrium concentrations of 1, 10 and 50% of CVP water solubility) and pore radius (Å) of the chars (HTC_MIS 180=39.5; HTC_SBS 180=119), indicating that CVP is adsorbed into the pores of the hydrochars.
This study investigated the potential of the application of two hydrochars as adsorbents for the removal of CVP during water treatment. CVP is adsorbed into the pores of the hydrochars as indicated by the positive correlation between the obtained partition coefficients (Kd) and pore radius (Å) of the two hydrochars. Thus, the significant difference in pore radius of these carbon materials, as a result of a different chemical composition of the used feedstock, may be the cause of the disparity between the adsorption capacities of the two hydrochars. Adsorption of CVP for HTC_MIS 180 (n=0.822) indicates a favorable adsorption process, whereas for HTC_SBS 180, the results indicate unfavorable adsorption (n=2.65).

Keywords: hydrochars, adsorption performance, chlorfenvinphos

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Phytoremediation of PFAS in leachate and effects of biochar

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The main aim with this study was to investigate if phytoremediation can be used as a remediation technique to reduce concentrations of per- and polyfluoroalkyl substances (PFAS) in landfill leachate. Specific objective were to investigate uptake of PFAS to different plant species and to calculate the bioconcentration factor, (BCF), defined as the uptake of PFAS to the plants from the leachate; BCF=Cbiota/Cwater. It is well documented that plants can take up PFAS. Uptake and accumulation depend on many factors, such as soil properties, type of plant, and the physico-chemical properties of the substance, (chain length, functional group, solubility, volatility). The state of knowledge about the types of plants that are suitable for phytoremediation of various PFAS is, however, limited. Information on uptake of PFAS in different plants has so far had an emphasis on edible plants. Studies focusing directly on phytoremediation of PFAS are very scarce and most of them have been conducted on a laboratory scale. Only a very few large-scale studies (performed in greenhouse or as field studies) have been published.

Filborna landfill is a municipal landfill in the southern part of Sweden. It was founded in 1951, and has at present approximately 11 million m3 household and industrial waste deposited. The outgoing water contains approx. 3 800 ng ΣPFAS11/l. The annual discharge to Öresund, is between 300 000 and 400 000 m3. Hence, there is an urgent need to find cost efficient techniques to reduce the concentrations of PFAS.

The focus of this project has been on short chained PFCA (PFBA, PFPeA, PFHxA) and 6:2 FTS because: 1) they are found in high concentration at Filborna; 2) there is an lack of reliable, and affordable techniques for treatment of short chained PFAS in complex waters, and 3) phytoremediation of this group of PFAS may be a complement to other treatment techniques.

Qualitative measurement of PFAS in Salix: Both Linnea and Klara showed uptake of PFAS in all parts of the plant. The greatest accumulation of PFAS was, by far, in leaves (Table 1). A major part consisted of PFPeA even though 6:2 FTS was the dominating PFAS in leachate and foam. The measured concentrations in Salix indicates a higher uptake of PFPeA and PFBA compared to 6:2 FTS.
Pot trial study: Typha latifolia replicates, including the reference, were not viable enough to be analysed, but all other plants were viable and tolerated the irrigation with leachate. Carex elata grew even larger when irrigated with leachate compared to the reference.
Carex elata and Miscanthus gigantus (substrate without biochar) had the highest concentrations of PFAS in biota, with ΣPFAS11 of 10.5 and 11.5 µg/kgbiota w.w., respectively. These concentrations are much lower in relation to the concentrations found in Salix after one growth season in the pilot study, where the ΣPFAS11 was found to be 1 700 and 2 000 µg/kg w.w. The Salix was, however, exposed to a higher concentration of PFAS and during a longer timespan. The only PFAS for which biochar had a clear trend of increasing the soils sorption capacity was for 6:2 FTS (results not shown).
Calculated BCFs indicate that PFBA have the greatest potential for phytoremediation and the most promising plant species was Miscanthus giganteus. Phragmites australis and Glyceria maxima showed the least potential of phytoremediation of short chained PFAS (no data for uptake in roots though). For Phragmites australis, the results indicate that biochar provides some improvement in the uptake of PFBA and PFPeA. Further studies are needed before any conclusions can be drawn about the effect of biochar.
Salix, (and to some extent Miscanthus giganteus and Carex elata) shows an interesting potential in phytoremediation of short chained PFAS. Salix and Miscanthus might be most interesting since they are plants known to have a high yield. The effect of biochar for the uptake of PFAS in plants has been exemplified in this study, and the results indicate that the effect is plant-specific.

Keywords: Phytoremediation, PFAS, biochar

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Examining the applicability of the soil gas radon deficit technique for quantifying residual LNAPL contamination

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Hydrocarbon spills into the subsurface can lead to the formation of light non-aqueous phase liquids (LNAPL), i.e., a separate phase that is immiscible with water, presenting long-term environmental concerns as they can act as a primary source of contamination.

Traditionally, the presence of mobile LNAPL is evaluated by installing monitoring wells in the area of potential concern. This approach, however, provides only qualitative evidence of the thickness of LNAPL observed in the wells, thus not providing information on the distribution of the residual LNAPL in the subsurface. To overcome this limitation, it is possible to focus on alternative techniques.

In the last decades, radon (Rn) has been widely proposed as a naturally occurring tracer for non-aqueous phase liquids in the soil since it has been shown to tend to partition into LNAPL. This work examines the feasibility of using soil gas data collected at some distance from the source zone to apply the Rn deficit technique to identify and quantify LNAPL contamination.

The developed 3-layer analytical model was validated using a more detailed numerical model available in the literature. The differences between the analytical and numerical solutions resulted, on average, for all the simulated cases of about 5% and in almost all cases within 10%.

Then, a one-way sensitivity analysis was carried out by varying within the ranges expected in the field the various parameters that may affect the migration and distribution of Rn in the subsurface to evaluate the vertical concentration profiles of Rn in soil gas above the source zone and in background location not impacted by LNAPL. In particular, the investigated parameters were LNAPL saturation, LNAPL

composition, soil type, source zone thickness, and groundwater depth.

The sensitivity analysis results showed that the critical parameter that affects the effectiveness of the Rn deficit technique is the distance of the soil gas probe from the source zone. Other parameters that affect the Rn transport and distribution in the subsurface are the LNAPL saturation and the Rn partition coefficient between LNAPL and water (kN/w). To a lower extent, the soil type also affects the calculated Rn deficit. In nearly all cases, less significant are the contributions given by the contaminated zone's thickness and the water table's depth.

The results obtained in this work showed that the parameter that most affects the effectiveness of the Rn deficit technique using soil gas data for quantifying the LNAPL content in the subsurface is the distance of the soil gas probe from the source zone. At distances higher than 2m, the method is indeed not more sensitive to the presence of LNAPL, and for distances higher than 1m, the method can provide only qualitative evidence on the presence of NAPL as even minor uncertainties associated with the deficit can result in significant variation of the estimated NAPL content. These results are ascribed to the characteristic diffusion length of Rn, which is typically less than 1 m. To a lower extent, the type of soil and contamination (e.g., diesel or gasoline) can affect the expected Rn profiles above the source of contamination. Thus, for an accurate estimation of the LNAPL content, these two aspects should be carefully examined and identified. Other parameters such as the thickness of the source zone or the water table depth do not significantly affect the estimated LNAPL content. Thus, the nomographs provided in this work, which allow the estimation of LNAPL saturation as a function of the distance of soil gas probes from the source zone and the type of soil and contamination, are generally applicable to all sites involving relatively homogenous soils.

Conversely, in the case of heterogeneous soils involving geological barriers or stratified contaminations, a more sophisticated numerical model should be preferred . Other aspects not addressed in this work are the diurnal and seasonal variations expected in shallow soil gas samples because of barometric pumping. In this view, the results obtained in this work should be used for soil gas data collected at depths greater than 1 m, where these effects become less relevant.

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Biochar - from organic waste to resource for treatment of contaminated soil

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The objective of the project was to test if biochar can be used as a soil remediation technique in order to stabilize pollutants and improve soil quality. The goal was to find a more sustainable and resource-efficient management of soils in conjunction to remediation of contaminated sites. If the treated soil could be reused instead of disposed, juvenile soil resources for backfilling could be saved and less waste would be landfilled.

Biochar is a solid material, with a high carbon content that can be produced from most organic wastes by pyrolysis (oxygen-free combustion). Biochar is used as a soil amendment, due to its good capacity of retaining water, air and nutrients. It can also sorb pollutants in the soil, hence lowering the risks for negative environmental and health effects.

Our lab- and field study (WP1) showed that biochar can sorb PAH and cationic metals, but the effect is site and biochar specific. Biochar was less efficient for anionic substances and can even in-crease spreading of arsenic, chromium, molybdenum, antimony and vanadium if pH is increased. The field trial showed that 3% (w/w) of biochar addition was sufficient to radically reduce the solubility of PAH; leaching was reduced to 1% of the leaching in untreated soil. The effect on copper, mercury and zinc was also good; the concentration in soil porewater was reduced to 13, <30 and 43%, respectively, of the pore water concentration in untreated soil.

The greatest positive treatment effects, in relative terms, was achieved in soils with low soil quality (low content of organic material,

low clay content, pH <7). Additions of biochar (and peat) provided more favourable conditions for vegetation, earthworms and microorganisms, but the availability of nitrogen was reduced (only one growing season has been studied).

Results from WP2 (Legal issues) highlighted that Swedish and international law, regarding waste and remediation of contaminated sites, are complex . Case law and clear guidance are lacking. Regarding biochar as a treatment technology, the legal conditions for its use are not clarified, which creates uncertainty among users. The project has identified a set of critical issues that a user of biochar can take a stand on, in order to correctly navigate through current Swedish environmental regulations. With the help of these questions, more confident judgements and well-considered decisions can be made. The questions can also facilitate for regulatory authorities, which will get a clearer picture of what documentation they need to request.

Results from WP3 (Prerequisites for locally produced biochar) showed that Swedish municipal waste companies generally have very good conditions for producing biochar. A major advantage is that they often already have established infrastructure for materials and waste streams, as well as good knowledge of the characteristics of the waste. By producing biochar at a waste facility, there are several collaborative gains to be made, not least in the energy sector.

The environmental system analysis, showed that biochar treatment has a significantly lower environmental impact compared with landfilling. Treatment on-site as well as off-site, results in negative CO2 emissions under prevailing Swedish conditions. The substance flow analysis showed that significantly smaller amounts of PAH and copper are leached out when the soil is treated with biochar instead of being disposed (seen over a 100-year period). For other metals, the same simple conclusion cannot be drawn. Which alternative is best (disposal or treatment) is governed by site-specific conditions and the choice of biochar.

An important next step is to verify the sustainability of the technology over time. More research is needed to investigate the stability of biochar, its resistance to degradation, and how durable the treatment is regarding various pollutants and different soils. An on-going follow-up of the field trial, will provide valuable knowledge about such long-term effects.

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Simulateous degradation of PAH and immobilisation of arsenic in contaminated soil by electrokinetics

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Excavation of soil is still the predominant soil remediation method in EU member states. One of the reasons behind this is that legislations are primarily based on the total levels of contaminants in soil instead of on the risks posed by those contaminants in the soil. These risks would ultimately depend on the chemical speciation of the contaminant, which would lead to different mobility, bioavailability or toxicity of the contaminant. In EU alone, the number of contaminated sites is estimated to be about 2.8 million. To transport and landfill all that soil would be unsustainable, both from an economical and an environmental point of view. If contaminant speciation and the risks associated to the contaminant are taken into account, rather than their total concentration, the development of soil remediating techniques in situ would lead to a more sustainable remediation practice.

Creosote and CCA (Copper, Chromium and Arsenate) are a commonly used wood preservatives in the past. Whereas creosote is a PBT/vPvB substance showing high concentrations of polycyclic aromatic hydrocarbons (PAH), CCA contains metal(oid) contaminants. Both, PAH and metal(oid)s are persistent in the environment showing high toxicity levels. Although the use of these chemicals has been restricted for wood impregnation purposes in the EU, inappropriate industrial practices in the past have left many metal(oid)s/PAH contaminated sites that have to be dealt with in the present time. Arsenic is toxic to living organisms, as it bioaccumulates and bioconcentrates in the food chain. Migration of arsenic from contaminated soil to groundwater poses an environmental and health risk since groundwater is a common source of drinking water. Human exposure to arsenic from drinking water is associated with several types of cancer and increased mortality. The World Health Organization (WHO) recommends that arsenic levels in drinking water should not exceed 0.01 mg L-1.

However, due to economical and technical limitations, millions of people worldwide are chronically exposed to exceeding levels of arsenic via drinking water.
Arsenic can be found in nature at two different oxidation states, three valent arsenic, As(III), and five valent arsenic, As(V). The oxidation state in which arsenic is found affects the bioavailability and thereby the toxicity of the contaminant. As(III) is 5-10 times more toxic than As(V). As(V) can bind onto iron oxide minerals surface to a higher extend than As(III) becoming thus less toxic and less bioavailable than As(III).
Electric conductivity and pH remained fairly constant throughout the experiment indicating that pulsating application of voltage and switching the polarity in our EK resulted in a better control of these parameters. Although an initial increase in the concentration of PAH during the first weeks of the treatment was observed, the application of EK resulted in a significant decrease in the PAH concentration in the groundwater by the end of the treatment time. A higher decrease on the heavier PAH molecules as compared to the lighter PAH molecules indicated that a PAH degradation process might have taken place. In the sand layer results from both boxes showed that arsenic levels in porewater decreased over time during the EK treatment and as anticipated, the levels of iron in porewater simultaneously increased, suggesting that the iron played a role in the immobilisation of arsenic. By the end of the experiment a depletion of oxygen in the groundwater was induced observing an increase in arsenic mobilisation. This mobilisation can be easily explained by the reductive dissolution of iron oxyhydxide minerals which again confirms the role of these minerals in arsenic immobilisation.
This study showed that EK can be a suitable remediation technique for a mix of organic and inorganic contaminants. Levels of PAH was lower after the EK treatment compared to before. In sand porewater, arsenic levels decreased over time. The levels of arsenic, however, seems to be dependent on the redox potential and hence, further research should be focused on how to control redox potential in order to opimise EK as a suitable remediation technology.

Keywords: polycyclic aromatic hydrocarbons (PAH), Arsenic,

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Soil microarthropods for monitoring the soil pollution hazard in an industrial region in Kerala, India

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Soil microarthropods are have ecological relevance in determining the soil health, thereby giving information regarding the level of stress in soil ecosystems. The survival of soil microarthropods depends on various environmental factors like soil moisture content, soil pH, soil organic carbon and seasonal variations (Lakshmi & Joseph, 2016), and hence their enumeration can give information regarding the health of soil ecosystems. The use of soil microarthropods has been found helpful for determining the soil quality of different ecosystems like forests, agricultural landscapes, deserts and home gardens. The use of soil microarthropods as indicators to determine home garden soil quality is much easier compared to other ecosystems due to ease of sampling, ease of access and comparatively less land area. This study was conducted in home gardens of Eloor, an important industrial area in Kerala, India.

We hypothesized that the home gardens of an industrial area will show difference in soil quality which can be quantified by the study on soil microarthropod community of each home garden. The objectives of the study include:

- Assessment of soil properties and nutrients in the soils of the industrial area
- Estimation of biological Soil Quality (QBS-ar) using soil microarthropods
- Study the interrelationships between soil properties, microarthropod abundance and bring out the most important parameters affecting microarthropod abundance

The results indicate that the Biological Soil Quality increases with the distance from industrial centre Z1<Z2<Z3. Similarly Zone 1 had the highest share of home gardens under poor quality than the other two

zones. This indicates that industrial pollution can be estimated using soil microarthropods.

The PCA analysis of the microarthropod abundance and soil variables in Zone 1 showed that the microarthropod abundance is positively related to Nitrogen, Phosphorus, Potassium, and Magnesium. Abundance is negatively related to Sulphur, Zinc and Copper. In Zone 2 the abundance was significantly linked with Nitrogen, Phosphorus, Potassium, Magnesium, Sulphur, Zinc, Copper and Manganese. Among these Nitrogen, Potassium, and Copper has significant positive loadings with abundance and the variables Phosphorus, Magnesium Sulphur, Zinc and Manganese show significant negative loadings. In Zone 3 the abundance was significantly linked with Nitrogen, Calcium, Magnesium, Zinc, pH, and Iron. Among these Nitrogen, Iron has significant positive loadings with abundance and the variables Calcium, Magnesium, Zinc, pH show significant negative loadings. Therefore it can be seen that in Zone 1, Zone 2 and Zone 3, the presence Zinc in higher amounts can be negatively influencing microarthropod numbers.

Biomonitoring using soil microarthroods is a good method to identify the soil quality of a large area where intensive sampling and analysis of nutrients can be a tedious, time consuming and economically non-viable. The use of QBS-ar scores along with soil chemical analysis can be a good option of soil quality enumeration using microarthropods as biomonitors.

Keywords: Soil microarthropods, monitoring,

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A non routinary inspection campaign in non hazardous waste landfills in Sardinia

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The Sardinian Regional Environmental Protection Agency (ARPAS) General Direction, within the framework of the "Three-year plan for the prevention of corruption and transparency 2020-2022", has set up an interdepartmental Working Group for the execution of non-routinary inspections at the IED landfill installations for non hazardous special waste.

As part of the non-routinary inspection campaign, the specialist group on groundwater sampling carried out sampling in the upstream and downstream piezometers as included in the Landfill Operator self-monitoring Plans.

During the inspection campaign waste samples has been taken from each of the inspected landfill to verify compliance with the waste acceptance criteria as specified in the EU and national legislation: both samples of hazardous and non-hazardous special waste were acquired.

The inspection campaign has been also supported by the drones team, which supported the inspection groups with high resolution aerial photogrammetric surveys. It has been possible to reconstruct the three-dimensional geometry of the photographed areas.

During the inspection visits, non-compliance with the IED permit requirements and / or environmental legislation was found. The detection of non-compliance involves a communication to the Competent Authority, with the related proposals for measures to be

taken which are attributable to progressive levels of severity according to the seriousness of the non-compliance detected.
During the inspection visit, some criticalities were also detected, by which we mean evidence of situations, which, while not constituting a violation of the requirements of the integrated environmental permit or of the environmental regulations of the sector, generate an effect or an environmental risk such as to require the identification of conditions for the Operator capable of limiting or preventing its impact.
The experience gained during the inspection campaign and the results of the inspection visits have highlighted some transversally critical aspects, as well as a certain lack of homogeneity in the landfills IED permits. In this regard, it is believed that the review process of the IED permits can be an opportunity to guarantee the homogeneity of the prescriptive requests within the permits. This is also in order to simplify the control activity, where the interpretation of regulatory provisions requires greater clarity.
As a starting point for the discussion with the Competent Authorities, some of the issues that deserve further study have been defined and discussed in a plenary metting with the permitting authorities.
Furthermore, an initial analysis was made of the monitoring obligations incumbent on the operators in order to highlight inconsistencies and differences due to site-specific situations. Subsequently, a minimum content of Operator Self-monitoring plan was defined for a landfill installation.The performance of the activity has concretely constituted, for the Agency as a whole, a valuable opportunity for professional exchange which has allowed to:
- stimulate technical discussion and the transfer of skills;
- stimulate the self-training of technical staff;
- experimenting with new inspection techniques through the use of drones;
- create a personal support network;
- verify the quality of the control procedures on waste management plants subject to IED.
It was also observed a massive use of non-hazardous landfill to dispose hazardous waste (stable non reactive) and a massive entry of extra regional waste.

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Dynamic skimming – a new and highly effective approach to skimming LNAPL

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"Remediation begins with the elimination of the pollution source." This may seem obvious, but it is not always the case, and can result in permanent contamination of the aquifer, sometimes for decades and even centuries.

The DYNASKIM® solution allows for the dynamic 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.

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.

Using dynamic skimming technology, DYNASKIM® maximizes the performance of groundwater skimming and retrieves the pollutants as fast as the nature of the soil permits it. DYNASKIM® guarantees the complete disposal of the thinnest free phase, but also viscous layers (liquid honey type) in combination with heating. Such performance is unmatched using traditional techniques.

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…).

Skimming is carried out using pump cycles. During each cycle, the supernatant 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 SKIM 2 or 4 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.

Keywords: Dynamic skimming, groundwater skimming, DYNASKIM®

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Thermoreact® - An innovative remediation product for in-situ neutralization of halogens, sulphur, phosphorus and mercury during thermal desorption

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During In Situ Thermal Desorption, polluted soil (generally with TPH, PAH, Mercury, chlorinated solvents, etc.) is heated until vaporization of target contaminants is reached out of the soil. This results in the vaporisation of those pollutants, which are then drawn through perforated steel tubes, called vapor tubes, surrounded by gravel acting as a draining medium preventing the clogging of the tube perforations (by fine particles, sludge, etc). These recovered vapours are then either treated in a vapour treatment unit or re-injected into the flame (in case of hydrocarbon pollution and heating with smart burners).

In many cases, the pollutants to be treated in the soil are accompanied by other process-disturbing elements (such as phosphorus, sulphur or halogenated compounds like chlorine). The heat causes the vaporization of many chemical compounds, including those disruptive compounds that are conducted through the porous medium to the extraction wells. The problem with these disruptive compounds is that in some cases they become very corrosive and therefore tend to destroy equipment and render the remediation technology less effectively. Additionally, if not treated, they can cause non-compliant air emissions as well.

Thermoreact® is an innovative product that replaces the conventional gravel around vapour tubes. The product allows for in-situ neutralization of the vapors before exiting the soil pack, reducing the treatment requirements and saving substantial treatment costs overall.

Its composition varies in function of the pollutants present in the soil in order to always obtain the best neutralization reaction while keeping permeability at the required level for proper vapor extraction.

The products of said neutralization are inert minerals that can be left in the soil, making In Situ Thermal Desorption a truly zero-waste treatment for many more contaminants than is currently the case.

The paper presents the results of various tests and cases where In Situ Thermal Desorption has been adapted to use Thermoreact® instead of conventional gravel. Before and after results are compared (example below of In Situ sulphur captation)

Keywords: Thermal Desorption, neutralization of the vapors, Thermoreact®

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Treatment by thermal desorption of dioxin-contaminated soils and vapour management through thermal oxidizer at Bien Hoa airbase, Vietnam

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During the US-Vietnam War, millions of liters of herbicides were dropped over Vietnam: The Rainbow agents. Bien Hoa Airbase was a joint operating base for the South Vietnam Air Force and the United States Air Force where thousands of barrels of Agent Orange were stored. Agent Orange was proven to cause severe health issues, including birth defects, neurological problems, and cancers. Agent Orange is a mixture of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic. Traces of dioxins were also found in some Agents. Dioxins are generally very insoluble in water, are lipophilic and are very persistent.

More than four decades after the Vietnam War ended (in 1975), the stability and bioaccumulation of dioxins still affect the inhabitants. Measures had to be taken to improve living conditions for residents, starting with the remediation of dioxin contaminated soil.

The Center for Technology Environmental Treatment/Chemical Force (CTET/CF), the GAET Corporation and HAEMERS Technologies SA agreed to establish a joint operation to proceed testing activities proving the effectiveness of thermal desorption treatment on dioxin-contaminated soils at Biên Hòa Airbase.

The key objective of the trial treatment is to demonstrate the effectiveness of the Smart BurnersTM treatment technology and design in order to meet the site-specific dioxins and furans target levels.

Therefore, Haemers Technologies has designed a thermal treatment pilot plant composed of two main units:

• The soil pile to be heated;

• The vapour treatment unit where dioxins are destroyed composed of a Thermal Oxidizer, avoiding the production of any liquid and solid waste.

Haemers Technologies has been operating a pilot-demonstration project at the Bien Hoa Airforce Base to apply its proprietary technologies to treat agent-orange contaminated soil. Although the project was mobilized and started early 2020, it was interrupted due to the COVID pandemic.

At the end of December 2021, Haemers returned on site and resumed its activities to fulfill its commitment on the demonstration project. On February 2nd 2022, the pile was restarted. The materials treated are considered as the most contaminated materials in the whole area. Treatment stopped on March 14th, 2022, after 40 days of treatment. The target temperature of 335°C has been reached in the thermal pile and maintained for at least 5 days.

After this pilot project, it can be concluded that:

• The heating went as planned and target temperatures have been reached by mid-March, 2022.
• Air emissions are fully compliant with VN, EU and US standards.
• All equipment has been operating effectively.
• No fugitive emissions occurred during the treatment.
• Ambient air measurements are all compliant.
• The treatment confirms it is a zero-waste solution (no solid nor water waste produced).
• Concrete used to seal the soil was proven clean and fully recyclable.
• The soil is remediated: the target remediation concentrations are reached.

This project demonstrates an improved thermal treatment technology for the remediation of dioxin contaminated soils compared to what has been performed in the past.

Keywords: thermal desorption, thermal oxidizer, dioxin-contaminated soils

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Urban soil remediation: in situ thermal desorption under a building, in the center of Brussels

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Nowadays, urban soil is a natural resource to preserve. Indeed, the fast urbanization of the recent years led to considerable consequences in terms of space and energy consumption as well as water and soil pollution. At the present time, urban areas contain many contaminated sites.

Two main issues can be identified which would need to be addressed through further reflection: first, the space consumption. Polluted areas in the centre of the cities are a waste of space. The clean-up of these sites is a necessary requirement to accommodate housing, parks, schools, etc. Second, some polluted areas are located under existing buildings. Their remediation is often complicated, even sometimes impossible due to stability reasons, environmental impact or access.

HAEMERS Technologies © has conducted an In situ Soil Remediation by Thermal Desorption in the centre of Brussels. The polluted area was located under a building. The origin of the contamination was a fuel tank leaking. The contaminated zone represented 48 m² and 3 meters deep and the contaminants of concern identified at the site were hydrocarbons. The highest concentration detected was 8 000 mg/kg (C10-C40). The aim of this project was to reach the target concentration of 300 mg/kg.

In Situ Thermal conductive heating is perfectly suited for urban soil remediation for the following reasons:

Heating is done directly on the ground

It requires no excavation

The size of the installation can be adapted according to the size of the polluted area

No noise is produced

Moreover, In Situ Thermal Desorption has a fast application: the target temperature, fixed at 220°C, was reached in 45 days.

The results of this project showed that the remediation was successful: the target concentration (300 mg/kg) has been reached. Even more, the presence of hydrocarbons in the soil after the treatment was almost non-existent. This project also demonstrated that the technology has a high efficiency and is perfectly suited for urban soil remediation.

The paper addresses the remediation goals that can be imposed today in urban areas thanks to technological improvements which made multifunctional use no longer unaffordable.

The case illustrates the many instances where problem owners have chosen to remediate down to background levels, despite leaving no legal obligation to do so, but mainly because the extra cost was very minor, and the benefits were much larger.

Keywords: thermal desorption, Urban soil remediation

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The use of Aeroponics as a tool in mitigating eutrophication in the Notwane freshwater river system: A partial aquatic restoration project

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Ecological restoration and bioremediation in Botswana are the hottest issues as far as conventional farming is concerned. The degradation of enormous earth resources e.g., the freshwater systems, as well as range resources for unsustainable agricultural development along the Notwane Freshwater River system. The use of traditional farming systems has been fading the conservation and environmental sustainability aims in the area along the Notwane Freshwater River systems. Eutrophication on freshwater systems as a result of runoff from agricultural fields along the Notwane Freshwater River system which now distance human from nature. Agrochemicals leads to eutrophication through the oversupply of nutrients, most commonly nitrogen or phosphorus containing detergents, fertilizers into an aquatic system, which leads to overgrowth of plants and algae in such. Heavy use of fertilizers causes pollution of both surface and underground water supplies.

Nitrogenous and phosphatic fertilizers have been used for the longest period of time in the farm fields of Oodi, along the Notwane River, with the aim to increase agricultural yields and maximize on the returns. Agrochemicals lead to the oversupply of nutrients in aquatic systems following agricultural runoff, resulting in algal bloom with promotion of cyanobacteria. The research was motivated by recognition of the algal bloom, tarnishes the ecological well-being of the aquatic ecosystem through bad smell and high turbidity. It was a way of bringing up sustainable development and innovative agricultural technologies to uphold the SDGs number 6, 14 and 15, and defend ecological stability, paving way for sustainable green revolution and innovative urban agriculture, and green revolution approach towards conservation, environmental sustainability and food security.

Aeroponics is the process of growing plants in an air or mist environment without the use of soil, the roots are left to dangle in the air, and they are periodically puffed by specially designed misting devices (Peterson et al. 2018). (Hoehn, 1998) aeroponics was initiated to use up to 95% less water compared to soil-based farming. This technology reduces the risk of pests and pathogen infestation in the early establishment, and it uses about 1⁄3 to 50% of the nutrients relative to conventional farming, which in this case appear to be a solution to eutrophication in the freshwater systems. Besides the reduction of water and fertilizer usage by aeroponics, it has advantages of incredible use of limited space, reduces the most ground used for production, plant roots are exposed to sufficient oxygen and can easily absorb it which promotes quick and disease-free plant growth, and for natural growth to occur, the plant must have unrestricted access to air (Peterson et al. 2018).

Nitrogen fertilizers have been applied to farm fields along the Notwane Freshwater River system in order to maximize yields of agricultural lands. However, an unintended consequence is that excessive quantities of these nutrients are washed into aquatic ecosystems and become harmful through excessive nutrient loading, as observed in the Notwane Freshwater River system. According to (Markus, 1999) conventional farming systems have the potential of directly increasing the deposition of nitrogen i.e., nitrates and phosphorus i.e., phosphates concentrations levels in the aquatic ecosystem initiating the foundation of blooms of algae which deplete oxygen, affecting plants, fish and other life forms. The algal bloom gives the aquatic system a light colour, with combination of nitrogen, phosphorus and carbon whereas the algal bloom with only nitrogen and carbon gives the aquatic system a dark colour (Schindler, 1974).

Aeroponics promoted urban agriculture through tremendous potential fresh produce while reducing agriculture's mounting carbon, nitrates, phosphorus and water footprint. Benefits through aeroponics also helps empower urban farmers to manage resources for their long-term social, economic and ecological. Therefore, aeroponics helps in contribution of mitigating eutrophication in Notwane freshwater river system through restoration process that cuts off nutrient loading into aquatic systems and resonate life in rivers and streams.

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The influence of phytoremediation on heavy metals bioavailability in sediment

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With the growth of industry and agriculture, heavy metal environmental pollution has become a serious problem. These elements are not biodegradable, which posese a treath to environment. Heavy metals are found in aquatic ecosystem, mostly due to the discharge of wastewater that has not been treated or is insufficiently treated. Sediment, as an integral part of the aquatic ecosystem, is equally at risk of heavy metal pollution. In addition to environmental, sediment pollution has economic and social negative effects because sediment serves many purposes (hydro-engineering system for flood control and hydrotechnical management, amelioration, forestry, water supply, waste water recipient, navigation, tourism, fishing, recreation). When the sediment is significantly polluted, it is necessary to remediate it. In order to remediate soils and sediments contaminated with heavy metals, phytoremediation has been used more and more recently. It is a technology that uses plants to clean up contaminated soils. As an efficient, environmentally friendly and cost-effective remediation method that is easily applied, phytoremediation has gained great interest from researchers. Energy plants are the best solution for phytoremediation, because after harvesting, they can be used to obtain energy, for example biogas, which represents an economic benefit.

The aim of this experiment was to assess whether sowing plants in contaminated sediment could change the biavailability and distribution of heavy metals in sediment. Pseudo-total metal content is often insufficient to assess the mobility and bioavailability of heavy metals. This information is very important because metals that are not in a bioavailable form cannot be uptaken by plants, but, plants can

increase the bioavailability of heavy metals by releasing a variety of root exudates, which can change rhizosphere pH and increase heavy metal solubility. An experimental approach frequently employed studying the mobility, transport and bioavailability of metals in different types of environmental samples (soils, sediments), is the use of sequential extraction methods. Sequential extraction that has been widely accepted and applied to metal fractionation in different environmental sample has been developed by the Community Bureau of Reference (BCR). Sequential extraction allows the determination of different forms of heavy metals in sediment using individual extraction agents, because the metals are distributed among the following fractions: exchangeable, carbonates-bound (BCR1), reducible, Fe-Mn oxides-bound (BCR2), oxidizable, organic matter-bound (BCR3) and the residual (BCR4). The more mobilizable metals correspond to the two first fractions, which can be released simply by increasing the ionic strength and by slight pH changes. The fractionation methods provide relevant information about the possible metal content that could be released in the environment.

Based on the obtained results main conclusion is that the content of the metal in the contaminated sediment has not changed significantly during the experiment. Bioavailable fraction of the metals is very low, and most of the metal content is distributed in the residual fractions (non-bioavailable fraction). Based on the above, we can conclude that plants (phytoremediation) did not significantly increase the bioavailability of metals, that can be attributed to the short growing season in pot experiments (10 weeks). Further research will focus on the application of agents that could increase the bioavailability of metals, such as acid fertilizers and chelators, but also the testing of plant species that could potentially have a higher degree of accumulation and increase the bioavailability of metals.

Keywords: phytoremediation, heavy metals bioavailability, sediment

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Produced water treatment: phytodepuration assessment of the halophytes *halocnemun strobilaceum* and *suaeda fruticosa*

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Oil produced water (PW) is the most significant wastewater stream in the oil exploration and production processes. The treatment of PW usually includes physical, chemical and biological steps and it is one of the most expensive processes in the oil industry. An alternative method could be using a phytoremediation approach (artificial wetlands) that is cost-saving compared to conventional methods. Since PW is also characterized by high salinity, to develop a phytodepuration system capable of effectively treating this kind of wastewater stream, the first step was the selection of salt-tolerant plants. The plants tested for salt tolerance were selected among those growing in humid and estuarine habitats. The first salt tolerance tests were performed with Juncus maritimus Lam., Phargmites australis (Cav.) Trin. ex Steud., Halocnemum strobilaceum (Pallas) M. Bieb. and Suaeda fruticosa (L.) Forsk. These species were adapted to the hydroponic floating condition and then tested for their resistance to saline stress for each designated salt rate (0-15-30-50-100 g L-1). Investigation of plant performance showed that Halocnenum and Suaeda were able to maintain the photochemical efficiency of photosystem II (PSII) during the treatment period until 50 g L-1 of NaCl, while the highest dose (100 g L-1) induced a progressive decrease of PSII photochemistry. Conversely, Juncus and Phragmites showed a detrimental effect on the PSII functionality starting from 50 and 30 g L-1 of NaCl, respectively. Thus, Halocnenum and Suaeda demonstrate to be the most adapted species to hypersaline environments and suitable for the trial. The research aimed to

evaluate the selected plants' growth in hypersaline condition and their potential petroleum degradation. Experiments were then set up in mesocosms with growing saline concentrations and hydrocarbons to test the plant tolerance and the hydrocarbon degradation capacity.

Preliminary results showed that the plant tolerance to hypersaline conditions, and petroleum hydrocarbons degradation were species-specific. Halocnemum showed better tolerance for the salt content and hydrocarbons, but Suaeda plants showed better performance in degradation hydrocarbons. At the end of the experimentation in mesocosms (18 months), metagenomic analysis of the endophytic microbial communities was performed on the root samples from three treatments (50 g L-1 of NaCl + 600 ppm of crude oil with and without oxygenation, 65 g L-1 of NaCl + 600 ppm of crude oil) showed significant family speciation both in the different conditions and between the two plant species. The selected plant for the mesocosm experiment showed different behaviour under different hypersaline growth conditions, oil tolerance and petroleum hydrocarbons degradation. Halocnemum showed the highest resistant to hypersalinity, while Suaeda showed the highest aerial and radical biomass production even when grown at 50 g L-1 but survived with difficulty at 65 g L-1.
The Pseudomonadaceae family was predominant in the mesocosms with Suaeda and the Halomonadaceae family in those with Halocnemum. This investigation has allowed us to define a range within which the technology could be used as an alternative to established technologies

Keywords: phytodepuration, halocnemun strobilaceum, suaeda fruticosa

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Phytoremediation potential of cereals on petroleum hydrocarbons mixed soil

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Phytoremediation has been applied as a treatment technology that is cost-effective, ecologically friendly and efficient for the decontamination of hydrocarbons pollution (Salt et al., 1995, 1998; Alkorta & Garbisu, 2001; Pilon-Smits, 2005; Sandhu et al., 2007; Reichenauer & Germida, 2008; Wenzel, 2009; Prasad et al., 2010, Manasievska Simikj et al. 2018). Plants especially legumes and grasses have been identified to play important role in remediating oil polluted soil. The initial physiological response of plants to petroleum hydrocarbons (PHCs) in soil includes PHC uptake, translocation, and accumulation in organs such as roots and shoots and the rates of these processes are generally related to PHC concentration (Wild et al., 2005; Lu et al., 2010). OKTA refinery located near urban areas of Skopje, during the period 30 years of crude oil processing, generated oily sludges as a waste product. This study was conducted to evaluate the growth and phytoremediation potential of wheat, barley and rye in soil mixed with petroleum hydrocarbons derived from OKTA basins.

Rye (Secale cereale L.) was selected, as crop with high potential to phytoremediate PHCs, wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) was selected as tolerant to PHCs. Field trials were established at oil refinery near Skopje, during period of three years (2017/2018; 2018/2019 and 2019/2020) in randomized block system with three replications, in eighteen trial microplots (9 microplots were in the basin with soil mixed with petroleum hydrocarbons and 9 microplots on soil without PHCs as a control trial). Morphological characteristics (plant height and spike length) and

productive characteristics (spike mass, number of grains, grain mass and mass of 1000 grains) were analyzed.

Analyzed morphological and productive characteristics are higher in control trial compared with the results from the trial in the basin with soil mixed with petroleum hydrocarbons. Plants from each crop were able to grow on contaminated soil. The presented results evidently demonstrated that rye provided better results on phytoremediation process of a soil mixed with petroleum hydrocarbons, as compared to the other two cereals, especially barley.

Keywords: Phytoremediation, legumes, grasses, petroleum hydrocarbons

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Different approach to assessment of heavy metals contaminated sediments in the Great Backa Canal (Serbia)

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The problem of sediment quality is closely related to water quality and represents a complex synthesis of processes and factors in sediment and water. The problem of water and sediment quality cannot be simply linked to only one of the phases and therefore must be monitored within the sediment/water system. Physico-chemical and biochemical processes are responsible for the distribution of substances in the sediment/water system, the forms in which they are present, the behavior and fate of pollutants. Due to their accumulation, non-biodegradability and persistence, heavy metals have major consequences on the environment. Sediment quality assessment is a complex process, involving an integrated approach to defining the sources, distribution and potential impacts of organic and inorganic contaminants. The total metal content provides useful information on the overall status of pollution, but it is not enough to assess the behavior of the metal and its potential bioavailability. Remobilization of elements depends on the chemical forms in which they are bound to the sediment and therefore react differently when environmental conditions change. Sequential extraction analysis is a technique developed for the overall assessment of speciation and mobility of elements in sediments. Accordingly, in addition to measuring their total concentration, determining the geochemical fractionation of metals in sediments is equally important in assessing their potential toxicity and hazard to ecosystems.

The aim of this study was to perform a risk assessment in the sediment/water system of Great Bačka Canal, one of the three major environmental “black spots” in Serbia, based on the application of pseudo total metal content and sequential extraction methods.

Surface (VBK-S, 0-50 cm) and deep (VBK-D, 0-100 cm) sediment samples from the Great Bačka Canal were analyzed. Granulometric composition and content of organic matter were performed. Determination of clay content (particles <2 μm) and organic matter in sediment was performed due to correction of limit values on metal content in order to determine sediment class according to the Regulation on limit values of pollutants in surface and groundwater and sediment and deadlines for their achievement. According to this Regulation, limit values are given for standard sediment with 25% clay and 10% organic matter. In the sample VBK-S the clay content was 21.77%, and in the sample VBK-D it was 25.24%. The percentage of organic matter was 21.90% (VBK-S) and 15.25% (VBK-D).

Based on the Regulation in both samples, copper concentrations are classified in class 3. In this class, the sediment is considered contaminated and its disposal is not allowed without special protection measures. Although other metals are in the lower classes, the sediment is classified in class 3 due to copper concentrations.

The use of pseudo-total concentrations of metals in sediment to determine the toxicity and bioaccumulation capacity does not provide information on their possible origin, nor on the method of binding metals in sediment. In order to test the toxicity of metals, sequential extraction is used to determine the binding of metals in sediment, as well as the level of mobility and bioavailability of metals in sediment.

Based on the obtained results presented in the paper, it is necessary to apply some other methods such as the method of extraction with polymers (colloquially called "passive sampling methods"), which is considered the best developed and has the strongest scientific basis. A more detailed picture of the distribution of pollutants and their impact on the surrounding organism can be made with the help of risk assessment models that predict the movements, transformations and impacts of pollutants on the surrounding organisms.

Keywords: heavy metals contaminated sediments, the toxicity and bioaccumulation capacity, passive sampling methods

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Assessment of Drinking Water Treatment Processes in Nanoplastics Removal: Pilot- scale and Modelling Studies

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Plastic pollution of water bodies is a global environmental concern. Microplastics (diameter between 1 µm and 5 mm) have been already detected in both potable water sources and tap water. Moreover, the environmental degradation of microplastics to produce smaller particles (nanoplastics, particle size < 1 µm) has been demonstrated in laboratory experiments, leading to concerns about the efficacy of current drinking water treatment processes to remove these contaminants.

The aim of this study was to investigate the nanoplastics (NPs) removal efficiency through different filtration media typical of drinking water treatment plants (DWTP), i.e. sand and activated carbon. Two pilot-scale filtration experiments of surface water collected from the Lake Zurich were conducted at the Zurich Water Works (WVZ-Lengg, Zurich, Switzerland). The lake water was spiked with NPs and injected in two filters (diameter 1.1 m, length 2.65 m) respectively filled with granular activated carbon and sand. Metal doped NPs (160 nm) were used to track the mobility and retention of these particles within the filter media. Results from the pilot-scale DWTP showed higher retention of NPs in the sand filtration compared to activated carbon.

The MNMs software (Micro- and Nano-particles transport, filtration and clogging Model Suite – www.polito.it/groundwater/software) developed at Politecnico di Torino was used to model the

breakthrough curves obtained from the pilot-scale DWTP to derive the hydrodynamic parameters of the filtration systems and characterize the filter retention capacity. The calibrated model was then used to simulate the behaviour of NPs in a full-scale DWTP composed of multiple filtration steps, i.e. rapid sand filtration, activated carbon filtration and slow sand filtration. Modeling results indicate a high capability of the filtration units in DWTPs to remove NPs from water across the entire treatment chain (>99%). According to the results from the model, the removal of NPs during slow sand filtration dominated the overall NPs removal (3.6 log removal). The results of this study can serve as a baseline for assessing the performance of DWTPs to remove NPs from polluted water sources and the capability of current water treatment infrastructure to provide plastic-free, potable water.

Keywords: Nanoplastics Removal, Drinking Water Treatment Processes

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Development and update of ASTM international standard method for toxicity tests with freshwater mussels

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Freshwater mussels are one of the most imperiled groups of animals and environmental contamination has been linked as a contributing factor to the decline of mussel populations . However, mussels were generally under-represented in toxicity databases used for the development of environmental guidance values before the standarization of toxicity test methods in the early 2000s. In 2006, ASTM International published a standard for conducting laboratory toxicity tests with freshwater mussels. More mussel studies have been conducted recently on the propagation and culture of test organisms, starting ages of organisms for toxicity testing, test duration, feeding, and toxicity endpoints. In addition, a new short-term test method for estimating the chronic toxicity of effluent to freshwater mussels was developed. These recent findings and the new method have been included in the 2022 revision of the ASTM standard E2455-22 for toxicity tests with freshwater mussels. This presentation will illustrate the standard method and application, as well as highlight the use of mussel data generated from toxicity tests.

ASTM standard method E2455-22 describes methods for conducting laboratory toxicity tests with different life stages of freshwater mussels in acute and chronic water-only exposures and in short-term effluent exposures to estimate chronic toxicity. A toxicity test intended to allow calculation of an effect concentration (e.g., 50% effect concentration, EC50) usually consists of one control treatment and a 50% dilution series of five concentrations of test material.

Acute toxicity tests with glochidia (larval mussels) should be conducted for 24 hours at 20°C. Glochidia should be collected from at least three adult mussels brooding mature glochidia. The viability of glochidia isolated from each adult mussel is determined by assessing the valve closure response of a subsample of glochidia exposed to a saturated solution of NaCl. If the viability of each mussel's glochidia is >80% (preferably >90%), the remaining glochidia can be composited and mixed with glochidia from the other females for the toxicity test. The test endpoint is viability and test acceptability criterion is ≥90% viability in controls after the adjustment of initial viability.

The ASTM standard method for toxicity tests with mussels has been routinely used around the world, and the mussel data generated from the toxicity tests have been used to develop regional, national, and international water quality criteria, standard, or other environmental guideline values for the protection of freshwater organisms. Studies conducted using the standard have demonstrated that mussels are among the most sensitive freshwater species to a variety of contaminants, including ammonia, metals (e.g., aluminum, copper, nickel, and zinc), and major ions (e.g., chloride, nitrate, potassium, and sulfate). Importantly, these studies indicate that current environmental guideline values for many of these chemicals established for protecting freshwater organisms may not be adequately protective of mussels. For example, when mussel data were included in an update to the USEPA 2013 ambient water quality criteria for ammonia, the acute criterion decreased by 1.4 fold and the chronic criterion decreased by 2.4 fold.

The ASTM standard method for toxicity tests with mussels provides validated and reliable guidelines and procedures to evaluate the effects of chemical contaminants on freshwater mussels around the world. The results of mussel tests have been widely used for environmental regulation, management, and policy decisions to protect freshwater organisms.

Keywords: ASTM standard method for toxicity tests, mussels, effects of chemical contaminants

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Coal power plant ashes: a prospective look at a source of rare earth elements

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Environmental liability, including that associated with coal and coal by-products, is a challenge – on the one hand, to remediate or restore the damaged ecosystem, and on the other hand to look for processes to pave the way for the reintroduction of specific elements into the value chain, changing the paradigm from "waste" to resource.

Rare earth elements (REE) have recognized economic, social, and environmental importance. REE are used as components in digital technologies, electric traction motors, or permanent magnets. The increasing attention on alternative sources of REE is mainly due to the European Union's high dependence on REE imports, coupled with low substitution and recycling ratios. From an individual perspective, dysprosium (Dy) has a high supply risk due to the increasing demand rate and the lower proportion in rare earth ores. Dy and neodymium (Nd) are used in traction motors, making their recovery from alternative sources valuable. Residues from industrial processes such as coal power plant ashes can be one of these secondary sources, which is a scenario with particular significance in the context of the energy transition given the millions of tons of coal fly ash deposited in landfills.

REE recovery from secondary sources has been studied using different processes and approaches, but some limitations in selectivity and purification have been reported. The electrodialytic (ED) process is based on the application of a low-intensity electric field generated between electrodes along with the use of ion- exchange membranes that promote separation between the contaminated matrix and the electrolytes. This technique promotes the separation of a wide range of contaminants from different types of matrices also promoting the selective recovery of positively and/or negatively charged ions. The

work described here evaluated the application of the ED process tackling the recovery of REE from anthracite coal ash using a two-compartment ED cell and introducing the matrix in the anode compartment. The experiments lasted between 3 and 7 days applying lower and higher current intensities (10 and 50 mA) and a pH adjustment in the cathode compartment (pH≈2).

The selection of anthracite coal ash had to do with the triple REE concentration compared to bituminous coal ash (~450 vs ~140 ppm, respectively), along with the historical and geostrategic location of Lehigh (anthracite coal sampled at Mammoth Vein, Eastern Middle field, Pennsylvania, USA). In terms of individual REE, anthracite ash presented 8.5 ppm of Dy and 65.3 ppm of Nd.

The choice of testing the ash in the anode compartment allowed us to take benefit of the acidic pH (2-3) generated due to water electrolysis. The acidic character naturally increased the solubility of the REE avoiding the addition of enhancement agents, such as mineral acids, to promote the desorption of REE from the coal ash. When converted into mobile ionic species, REE can migrate towards the cathode compartment, from where they can be recovered.

The application of the lowest current intensity (10 mA) for 3 days promoted the desorption of up to 20% of the REE from the ash to the anolyte where they remain mainly ionically charged (+3). From the anolyte, a part migrates to the cathode compartment as happened with Dy and Nd with recoveries between 5 and 12%, respectively. Still, 80% of REE remained bounded to coal ash particles. The recovery in the cathode compartment increased when the treatment was extended to 7 days, as REE extraction nearly quadrupled (between 20 and 78%) promoting migration towards the cathode end. REE recoveries were between 15 and 41%, including 20% for Dy and 32% for Nd.

Application of higher current intensity (50 mA) for 3 days had positive effects on desorption, electromigration, and recovery. REE extraction was between 27 and 86% and recovery between 22 and 50%. For the critical elements Dy and Nd, the recovery ranged between 24 and 36%. This work proved that the application of higher current intensity (50 mA) can counterbalance longer treatment periods (between 3 and 7 days) while maintaining recovery efficiencies.

Optimization of the process in this work finished with catholyte pH adjustment in the best set-up (50 mA, 3 days). The presence of a nearly homogeneous pH across the cell (pH ≈2 in anolyte and catholyte),

suggests that avoiding sharp pH changes between one side of the ion exchange membrane and the other (pH ≈12 in the catholyte and ≈2 in the anolyte) improves both extraction (between 70 and 100%) and REE recovery (between ~50 and 78%) efficiencies. From an individual perspective, Nd presented 80% of extraction and 74% of recovery while Dy was 74% and 62%, respectively.

Conclusion

The proof of application of the ED process for the recovery of REE from anthracite coal ash is presented. Placing the ash in the anode compartment promotes the desorption of REE from the coal ash into the liquid phase of the ED cell due to the pH decrease. This is an optimized REE recovery process that relies on speciation changes derived from the application of the ED process, without the need for enhancement agents.

Under the best conditions tested, more than 70% REE was extracted from the coal ash. Among the individual REE, recovery was between 62% for Dy and 74% for Nd. Given the similar physicochemical properties of REE, more research is needed to target the selective recovery of REE with higher socio- economic value, rather than their recovery in a mixed solution. This is one of the future endeavors: to evaluate the potential of introducing a complementary step that promotes selective recovery of REE present in a mixed catholyte solution.

Keywords: rare earth elements, coal power plant ashes

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Dehalogenation of trichloroethylene vapors through horizontal permeable reactive barriers based on zero-valent bimetals in the unsaturated zone

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Chlorinated solvents, such as trichloroethylene (TCE), have been extensively used in various civil and industrial applications in the past decades due to their chemical and physical properties such as stability, volatility, polarity, and density. In the case of an accidental release into the subsurface of such compounds, these characteristics determine a high mobility and, at the same time, low biodegradability with consequent persistence in the environment. As a result, the massive and uncontrolled use of chlorinated solvents has caused groundwater pollution for years. Consequently, in most industrialized countries, the groundwater bodies are currently characterized by diffuse contamination by chlorinated compounds, which can cause potential long-term risks to human health due to the toxicity and carcinogenicity of these substances. In particular, the most critical migration pathway for chlorinated solvents is the volatilization from the subsoil into overlaying buildings. In sites characterized by a diffuse source of contamination of chlorinated solvents, traditional remediation techniques are not sustainable as they typically involve the use of significant amounts of reagents or energy. In this scenario, it is more suitable to act through risk management strategies aimed at interrupting the migration pathway of chlorinated solvents vapors to air ambient or into buildings. Specifically, passive barriers to physically block the vapor flux can be used, eventually combined with passive or active ventilation systems to avoid vapor accumulation below the barrier. Recently, it was proposed to use horizontal permeable reactive barriers (HPRB) placed in the unsaturated zone aimed at treating upward volatile organic compounds (VOCs), in imitation of the application of vertical PRBs for the treatment of groundwater

contaminated by chlorinated solvents, already widely applied for more than 20 years. Zero-valent iron (ZVI) was proposed as reactive material for HPRBs and tested for TCE degradation in the gas phase through reductive dehalogenation. To improve ZVI reactivity, transition metals with a redox potential higher than that of iron such as nickel (Ni) or copper (Cu), have been used as catalysts for dechlorination in the aqueous phase. In particular, the use of a secondary transition metal increases the rate of reduction of chlorinated contaminants as these metals are catalysts of the corrosion reaction of iron and dissociation of molecular hydrogen on the surface of the material. Furthermore, the addition of a noble metal lowers the activation energy of the reaction, increasing the dechlorination reaction rate.
The disc milled bimetals produced were characterized by a homogenous distribution of Ni or Cu in the Fe phase and micrometric size. In the batch degradation tests of TCE in the gas phase Fe-Ni bimetals have shown better performances in terms of TCE removal than Fe-Cu bimetals leading to a complete degradation of TCE in the gas phase after 32 hours. The experimental results were then integrated into an analytical model to simulate the reactive transport through a horizontal permeable reactive barrier consisting of the tested materials, to estimate the thickness of the barrier to ensure a sufficient attenuation of TCE vapor concentrations. It was found that an HPRB of 0.6 m thickness for Fe-Cu bimetals and 0.4 m for Fe-Ni bimetals ensure a reduction of TCE vapors by 99.9%. Finally, the costs esteemed for installing HPRBs containing bimetals in the unsaturated zone were estimated. For a sample site it was found that the capital costs of HPRBS are comparable or likely somewhat lower than traditional remediation techniques such SVE. The obtained results thus suggest that ZVI-based bimetals are effective in the dehalogenation of TCE vapors in partially saturated conditions and potentially suitable for the application as filling materials for HPRBs.

Keywords: Dehalogenation of trichloroethylene vapors, partially saturated conditions, ZVI-based bimetals

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Heavy metals in overbank sediments of the Serbian part of the Ibar river

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The Ibar River is an international river. Its river source is located on the Hajla Mountain in Montenegro at an altitude of 2,400 m. It flows through Montenegro and Serbia. In central Serbia, near Kraljevo, it flows into the West Morava River as its largest tributary. The upper, middle and lower courses can be differentiated. The upper course is mainly located in Montenegro and partly in Serbia (Kosovo and Metohija). The paper presents the research results on overbank sediments of the middle and lower reaches of the Ibar. The Ibar River flows through areas with specific geomorphological structures. The inflow of wastewater, which originates from mining-industrial complexes, tailings, intensive agriculture, illegal landfill sites, et cetera, into the river basin is high. Due to orography, the river often overflows. Numerous studies indicate that more than 12% of watercourses that belong to the Ibar River basin are susceptible to flooding. When the water that flooded the area retreats, it leaves pollutants behind. The water quality in the river is systematically and continuously controlled by measuring the parameters that influence it the most, which are the concentrations of Pb, Cu, Ni, Co, Cd, Mn, Zn, Cr, and Hg.

Suspended material transported by the river during a flood, which is frequent, is deposited as overbank sediment in the soil on the banks of the Ibar. This sediment, most of all, affects the chemical properties of the soil. However, the geological stratum on which the soil is developed has the greatest influence on the structure and mineral and chemical composition of the soil. The overbank sediment is flood sediment formed under the conditions of the higher energy of relief from the material transported in the suspension. The overbank

sediment is a complex, dynamic system susceptible to changes. Heavy metals can pose a risk to human health when they become available to living organisms. Their mobility and bioavailability depend on geochemical factors (pH, redox potential, et cetera). This aspect has not been addressed in the paper.

The tributaries of Ibar often form smaller basins. The basins of the following rivers were included in this paper: Raška River, Brvenica River, Jošanica River, Gokčanica River, Studenica, River Rudnjačka River, and Ribnica River. Sediments from smaller watercourses were also analyzed .

Factor analysis identified two synthetic factors around which the analyzed heavy metals were grouped and further formed geochemical associations. Factor 1 explained 68.96% of the variance. Cd-Zn-As-Pb-Cu were concentrated around factor 1. Factor 2 was substantive, and it defined 95.16% of the variance. Ni-Cr-Co were grouped around factor 2.

The origin of the heavy metals in sediments from watercourses that form the Ibar river basin and Ibar River were analyzed in this paper. Increased concentrations of Cd-Zn-As-Pb-Cu concentrated around factor 1 in the northern and northeastern tributaries of the Ibar. These extreme concentrations are in basins where the occurrence and deposits of these metals have already been confirmed. About factor 2 about when Ni-Cr-Co is concentrated, these heavy metals are practically in increased concentrations in all analyzed sediments. It has been determined that this geochemical association is characteristic of the ophiolites that make up the researched geological environment. However, due to the specificity of anthropogenic sediments (numerous tailing sites and mining-chemical compounds) in the Ibar river basin, especially in its upper and middle course, periodic control of the chemical composition of overbank sediments from its tributaries has been necessary. The Ibar river basin is covered in forest and has many geothermal water sources whose enormous potential is not fully exploited.

Keywords: Heavy metals, mining-chemical compounds, sediments

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Microbial electrochemical Cr(VI) reduction in continuous flow system

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Bioelectrochemical systems (BESs) are emerging technologies combining electrochemistry and biological methods. Consisting of biological reactors and two electrodes connected by an external circuit, they exploit the ability of certain bacteria to exchange electrons with solid substrates. These bacteria are called electroactive bacteria (EB). BESs applied to the remediation of contaminated soil have shown great efficacy to treat various pollutants: heterotrophic bacteria break down organic pollutants, including phenols, PAHs, and PCBs, into simple substrates which are oxidized by EB at the anode. The released electrons circulate to the cathode where other EB transfer them to a terminal electron acceptor (TEA), for example, oxygen or contaminants such as trichloroethylene and hexavalent chromium, that thus get reduced at the cathode. Bioelectrochemical technology is a versatile system that offers an adaptable platform for the removal of both organic pollutants and heavy metals from contaminated soils. The soil is a particularly complex and challenging environmental medium, as many factors, such as soil permeability, electrical conductivity, heterogeneous compositions, limited substrate mass transfer, and soil-contaminant interaction influence the pollutants' bioelectrochemical removal. To overcome these obstacles, different configurations of BESs have been proposed such as the single chamber, dual chamber, U-shape, and column type systems. In this study, a bioelectrochemical continuous flow (BECF) system with saturated Cr(VI)-contaminated soil has been set up to evaluate Cr(VI) reduction performance in comparison to an abiotic electrochemical system (AC) and an open circuit control (OC) to simulate natural attenuation mechanisms in aquifers.

During the first 20 days of operation, the systems were subjected to an initial concentration of 20 mg/l Cr(VI). A reduction in Cr(VI) concentration of more than 80% of the initial value was observed in all the systems. At the end of the test, the concentrations of dissolved chromium in the systems were 2.66 ± 0.13, 0.10 ± 0.01, 1.37 ± 0.07 mg/L in the AC system, the BECF system, and OCC, corresponding to Cr(VI) reductions of 86.7%, 99.5% 93.2% respectively. The trend in dissolved Cr(VI) concentration is similar in the various systems, but, differently than in both OCC and AC, in the BECF a reduction as high as 99.4% was observed on the ninth day of testing, demonstrating a faster removal rate than the controls. The average chromium removal rates in the 20 days of the test were found to be equal to 0.87, 1.00, and 0.93 mg l-1 d-1 respectively in the AC, the BECF, and the OCC.
Another test has been performed by increasing Cr (VI) dissolved concentration up to 50 mg/L, following a no-operation period for the columns of about 28 days. At the end of the test, the concentrations of dissolved chromium in the systems were 24.92 ± 1.25, 0.02 ± 0.01, 1.09 ± 0.05 mg/L, equal to removals of 26.3%, 99.9% 96.7% in the AC system, the BECF system, and the OCC. In BECF and OCC, despite in the first 70 days, the trends in chromium concentrations were similar with over 90% removal in both systems (93% in BECF and 91% in OCC), at longer times a divergence in the concentration trends was observed. Conversely, in the AC, Cr(VI) concentrations following a fast reduction to 20-25 mg/l remained pretty stable until the end of the experiment.
Bioelectrochemical chromium removal from saturated soil was performed in a continuous flow system. The tests have been benchmarked with controls tests and it was shown that the microbial electrochemical removal of Cr (VI) can occur, even without the addition of organic carbon and nutrients in a continuous system; the electroactive bacterial community development on the electrodes and closest to them allowed the treatment of hexavalent chromium highly contaminated soil and water. Furthermore, the tested lab-scale configuration could be considered for a future scale-up of the technology for in-situ soil remediation.

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Accelerating the exploration of the contaminated sites registry of the state of São Paulo, Brazil

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Brazil is a water-rich country with nearly 90% of its freshwater lying on its subsurface. Brazilian groundwater plays a crucial role in the water supply as 16% of the population depends solely on it. However, rising anthropogenic contamination threatens this resource, especially in urban areas, industrial districts, and storage areas.

The state of São Paulo is the most densely populated in Brazil and is heavily industrialized. It is also one of the most dependent states on groundwater. Its environmental agency, CETESB – The Environmental Company of the State of São Paulo – was the first of its kind to be created in Brazil in 1968 and has contributed to the leap of advances in contaminated sites (CSs) management that São Paulo has on the other Brazilian states. Indeed, it is one of three Brazilian states with a database and a publicly published registry of its CSs. This registry promotes identifying CSs and yearly monitoring of remediation and controlling measures applied to each site.

This study looks into 16 years of this registry and presents an overview of CSs management in São Paulo. The objective is to accelerate the understanding and the analysis of the data gathered to provide insights on the state of remediation and the efficiency of used techniques and thus lay the ground for future studies planning the use of innovative technologies within the Brazilian context. Furthermore, in preparation for a future big-data stage, automating data entry of publicly available forms and subsequent data analysis will become an indispensable step toward a more efficient and fact-based communication with stakeholders.

Throughout the 16 years of surveying, more than 60 000 forms were generated. Therefore, an automated digitization process was needed. To this aim, a form recognizer platform based on a computer vision program was developed. An optical character recognition (OCR) engine and edge detection techniques were deployed in a python

script to transform the data from a portable document format (PDF) into a tabular format for data analysis in Microsoft Excel. The accuracy of the text extraction depends on the OCR engine used and the image quality as well. The OCR engine used in this study is Tesseract version 5 that supports the Portuguese language.
Data analysis concentrated on industrial contaminated sites with a focus on chlorinated solvents and it comprised a spatial analysis showcasing the pollution hotspots in the São Paulo metropolitan region districts.

This study shows that groundwater is the most impacted media by the contaminated sites in the state of São Paulo (59%, in 2020). Although the registry is biased towards the gas station cases, more than 1200 industrial contaminated site were reported by the end of 2020.
An important number of sites is concentrated in the municipality of São Paulo. Within this area, three contamination hotspots stand out. These areas highlight the highest density of contaminated sites among the districts of the municipality of São Paulo. Some districts (e.g., Santa Amaro, Campo Grande) host more than 25 contaminated sites by chlorinated solvents including an important number of complex sites (i.e., sites where different contaminant types were detected).
The remediation of industry sites took off starting from 2012. A decade later, the rates of rehabilitation the in-remediation in the most contaminated region of the state reached 71% and 12% by 2020, respectively.
Concerning the remediation measures used, the conventional ex-situ techniques (removal of soils and the pump and treat) are the most common for the remediation of the industrial cases. However, the chemical oxidation comes second in the frequency of use and the efficiency as it has achieved a high rehabilitation rate in the last decade.

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In-situ treatment of PFAS in groundwater and other tall tales

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Poly-and perfluoroalkyl substances (PFAS) are contained in fire-fighting agents such as AFFF (aqueous film foaming foams) and as such have they have been used extensively at facilities such as military bases and airports over the past fifty years. They have also been used in the manufacture of plastics (i.e. PTFE) as well as many consumer goods for grease repellency and waterproofing. Long-chained PFAS in particular have been shown to bioaccumulate and demonstrate a high degree of persistence in the environment.

Due primarily to the strength of the C-F bond, traditional in-situ remediation technologies such as chemical reduction, chemical oxidation, and bioremediation have shown limited success in treating PFAS. Thermal treatment can be effective, however very high temperatures are needed for complete mineralization thereby making treatment expensive and less practical for in-situ application. Groundwater pump and treat systems can remove PFAS however they are not effective at removing large amounts of contaminant mass and are typically required to operate over long periods of time i.e., decades. Some success in reducing PFAS loading to groundwater has been reported using immobilization however long-term performance under in-situ conditions has not been demonstrated.

D-FAS is an in-situ remediation technology that efficiently removes PFAS from soil and groundwater without groundwater extraction. D-FAS utilizes the physiochemical properties of PFAS to accumulate at air-water interfaces such as gas bubbles. Gas is injected into a groundwater well which causes a foam to accumulate on the groundwater surface. This foam is then removed by vacuum and condensed into a highly concentrated liquid ex-situ. This ESTCP

DEM/VAL project demonstrated that D-FAS is capable of removing high levels of PFAS in source areas or high strength plumes. The technology can also be implemented for lower groundwater concentrations in down-gradient areas.
Laboratory and field data will be presented that demonstrate the effectiveness of PFAS removal from groundwater at a Naval Air Station (NAS) on the East Coast. Final results show 1,800 gal of PFAS concentrate and 93 g of PFOS have been removed from the pilot test area over three months of operation. The impacts of a shallow clay-rich layer, extreme rainfall events, and tidal fluctuations on overall performance will be presented along with engineered solutions to each impact.

Keywords: PFAS, groundwater

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RIBAS, reactive infiltration basin for in-situ soil treatment

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RIBAS (Reactive Infiltration BAsin for in-situ Soil treatment), developed by Eurecat and Amphos 21 under the POSIDON project initiative, has been conceived as an innovative soil remediation technology for in-situ application. The main functionality of the solution is that it allows remediating a contaminated soil, with metals and/or petroleum hydrocarbons, avoiding its excavation, thus, it is an approach for in-situ implementation. In fact, the novelty of RIBAS solution is the smart combination of different technological assets: 1) an infiltration basin, 2) a permeable reactive barrier (PRB), 3) soil confinement with sheet-pile walls, and 4) a hydraulic barrier with well-points for water extraction. Based on the market and State-of-Art evidence monitoring, it is the first time that our innovative technological approach is implemented for an in-situ soil remediation of various pollutants. Moreover, the first estimations of its economic and environmental sustainability indicate that the whole life-cycle footprint of RIBAS is considerably lower compared to the landfilling option, achieving an 81% reduction of greenhouse emissions, estimated for a real scale implementation, and economic costs are also strongly decreased: 35% reduction of expense.

To date, this solution has been proved at prototype scale. The aim of this prototype was to mimic the RIBAS solution at small-scale. The design of the prototype operated at bench-scale, in order to fulfil all features of the RIBAS solution. The prototype consisted of a rectangular prism shaped glass box recipient separated into three different compartments (A, B, C) by permeable walls. All the components were specifically designed to respond the demands and mimic the RIBAS solution at large scale. Compartment A mimicked the main feature of the RIBAS solution, the infiltration basin. Sheet pile walls to be installed on the field were emulated by the same lateral walls of the glass box, and the soil layer with low permeability in the field, by the bottom of the prototype. In this sense, the compartment A of the prototype was filled with the experimental polluted soil, the compartment B with the materials forming part of the permeable

reactive barrier (PRB), and the compartment C with sand. The overall prototype had also the following components: a tank for the feeding solution (chemical-amended groundwater), well-points in compartment C for water extraction, pumping equipment, and a drip irrigation system. In addition, piezometers and soil samplers in compartments A and B, where installed for the groundwater and soil/PRB process controls.

The conclusions obtained during the prototyping process, regarding the treatment efficiency achieved for a contaminated soil, were that the removal of TPH of the polluted soil was homogeneous and it showed to be effective to attain the target thresholds (<50 mg/kg). Regarding the removal of metal(oid)s, was achieved at the following removal rates of 0.9, 3.2, 6.5, and 9.5 in mg/kg/day, for As, Pb, Cu and Zn, respectively. These indicate a timeframe needed to reach the target thresholds limits of 21, 28, 4.5 and 2.5 months for As, Pb, Cu and Zn, respectively. Thus, the RIBAS solution has showed a great potential for the restoration of polluted industrial sites and valorize polluted soil. Furthermore, RIBAS is a versatile system since is a flexible solution which can be adapted to many different environmental conditions, soil characteristics and pollution. According to these factors, different remediation strategies can be conducted using the same RIBAS engineering solution. For instance, by the choice of different reagents, their sequence, and the operating conditions (e.g., nutrients, oxygen-releasing compounds, oxidants, surfactants, acids, amendments, etc.). In order to choose the most appropriate strategy depending on site-specific conditions, the consortium Eurecat- Amphos21 has developed a decision-support tree to route the remediation strategy of a given site. This decision-support tool has the following objectives:

- To evaluate the technical feasibility of the RIBAS implementation based on the hydrogeology of the specific site
- To evaluate the potential of the RIBAS solution to achieve soil remediation targets
- To determine the remediation strategy (i.e., biological or chemical degradation of organic pollutants, metal mobilization, etc. and the corresponding appropriate reagents) based on the specific contamination profile and soil physicochemical characterization.

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Dark fermentation and methane production, the microbiology of a two stage process for the optimisation of methanogenesis

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Dark fermentation (DF) is an efficient technology for hydrogen production by the valorization of various organic wastes, exploited as reactor feedstock. In particular, the organic fraction of the municipal solid waste is an easily gathered fermentation substrate, providing high yields in biogas and value-added organic compounds, such as Volatile Fatty Acids. Dark fermentation, however, produces hydrogen at relatively low yield: its potential can be improved by coupling DF reactor stages with different bioractor assets. In this study a two stage DF-metanogenic reactor was conducted and monitored by optimizing the Hydraulic Retention Time to maximize methane production, obtaining a corresponding increment of 51.7% . A focus on functional inference based on NGS metabarcoding analysis and comparison of microbial communities that populate each reactor stage will be discussed.

Keywords: dark fermentetion, hydrogen, metanogenesis, predictive functional metagenomics

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Hydrocarburoclastic fungi and bacteria to improve bioavailability and degradability of petroleum hydrocarbons in a historically contaminated soil

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A Ciboria sp. strain (Phylum Ascomycota) was isolated from Total petroleum hydrocarbon polluted soil (8538 mg/kg) of an abandoned oil refinery in Italy. The strain was able to utilize diesel oil as a sole carbon source for growth and was used in laboratory-scale experiments to evaluate the use of this fungal strain for remediation. Mesocosms soil experiments were inoculated with the fungal strain at 1% or 7%, on a fresh weight base ratio. After 90 days of incubation, the depletion of TPH contamination was of 78% with the 1% inoculant, and 99% with the 7% inoculant. 16S rDNA and ITS metabarcoding of the bacterial and fungal communities was performed in order to evaluate the potential synergism between fungi and bacteria in the bioremediation process. The functional metagenomic prediction indicated Arthrobacter, Dietzia, Brachybacterium, Brevibacterium, Gordonia, Leucobacter, Lysobacter and Agrobacterium sps. as generalist actinobacterial saprophytes, active in the first 30 or 60 days. These species were correlated also to the presence of a-specific extracellular enzymes as Dye -decolourizing peroxidase which primed the later depletion of hydrocarbons by increasing their bioavailability. This first action allows the onset of hydrocarbonoclastic specialist bacterial species, identified as Streptomyces, Nocardoides, Pseudonocardia, Solirubrobacter, Parvibaculum, Rhodanobacter, Luteiomonas, Planomicrobium and Bacillus sps., involved in the Total Petroleum Hydrocarbon depletion.

Keywords: mycoremediation, generalist bacterial species, specialist bacterial species, predictive functional metagenomics

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Degradation of PFAS by electrochemical oxidation

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Known as "forever chemicals," Per- and polyfluoroalkyl substances (PFAS), anthropogenic hydrocarbons, are found in everyday products from food packaging to firefighting foam. These substances, chemically stable, can accumulate in ecosystems. PFAS are increasingly detected in European surface waters (Xiao 2017) and they have been found in drinking water and human blood in countries across Europe (Chohan et al. 2021). The detection of PFAS in natural waters is a major environmental problem and exposure to these substances can lead to adverse human health effects.

Electrochemical anodic oxidation (EO) is considered a promising remediation technique for water contaminated with PFAS (Zhuo et al. 2012; Wang et al. 2020). Previous studies using Boron-doped diamond (BDD) electrodes showed a higher EO efficiency with high concentrations of PFAS (order of mg/L).

Since higher concentrations of PFAS provide higher EO efficiency than low concentrations (order of µg/L) (Liao et Farrell 2009; Pierpaoli et al. 2021), this implies the importance of a treatment combining a concentration phase followed by anodic electro-oxidation mineralization. Ion Exchange Resins (IXR) is an attractive technology for pre-concentration of PFAS from water, especially for the possibility of reusing resins after an in-situ regeneration step. Non- and fairly-hydrophobic resins can be regenerated with a mixed non-toxic brine solvent (NaCl+ NaOH, NH4Cl + NH4OH, etc.). This allows for PFAS treatment in low volume brine wastestreams. Knowledge of the behavior of PFAS during electrochemical oxidation in brine mixtures is much needed.

Results showed that the degradation of some PFAS tested individually was higher than those tested in a mixture since long-chain's PFAS were found to produce short-chain's PFAS as by-products, similar to some findings of previous studies (Hori et al. 2004; Yang et al. 2015). The

molar balances of carbon and fluorine were investigated to ascertain the electrooxidation pathway of each molecule of PFAS. Long chain's PFAS were found to be better degraded individually than the short ones, being more hydrophobic compared to the other PFAS with low carbon chain. The PFAS with a sulfonic headgroup has the same tendency of degradation as the PFAS with a carboxylic headgroup.

Different types of electrodes were tested on the degradation of PFHxA. EO using BDD electrodes clearly showed better efficiency than the one using Ti4O7 electrodes under similar experimental conditions. The presence of the dissolved organic matter (DOM, 5 mg/L to 20 mg/L of humic substances isolated from surface water) in solution with PFHxA (50µg/L) showed a slight effect on the degradation of PFHxA. Different types of DOM (SUVA = 1 to 5) were tested and appear to have a similar effect on the degradation of PFHxA regardless of the aromaticity of organic matter.

Factors such as current density, electrolyte, and PFAS initial concentrations were varied and studied to obtain the optimized operation conditions for the elimination of PFAS. The results reveal that the degradation of PFOA in hydroxide salts (NH4OH, KOH, and NaOH) as electrolytes has the same effect as in sulfate salts ((NH4)2SO4, K2SO4 and Na2SO4) and carbonate salts((NH4)2CO3, K2CO3 and Na2CO3). Besides, the type of cation in the electrolyte has no impact on the degradation and defluorination of PFOA.

Conclusion

Electrochemical anodic oxidation of PFAS was examined using two different sets of batch experiments. Perfluoroalkyls carboxylic and sulfonic acids were tested. Factors such as current density, type of electrolyte, type of electrodes, the presence of natural organic matter in solution, and PFAS initial concentration were studied.. The type of the electrolyte salts, either individually or in a mixture does not affect the degradation and the defluorination of PFOA. This implies an advantage in industrial applications, where any type of brine solution that enables the highest percentage of PFAS regeneration from the IX process can be used to treat the concentrate PFAS laden IX brine solution by EO.

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Assisted phytoextraction as a nature- based solution for sustainable soil remediation

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Mining and metallurgical activities have had historical importance for the economical, technological and social progress of countries throughout the world. However, the extraction of metals from sulphide minerals often resulted in the production of waste materials, tailings, atmospheric particulate matter and acid mine drainage that, to this date, still cause major environmental hazards and public health emergencies due to the high content of potentially toxic elements (PTE, i.e., As, Cd, Cu, Pb, Zn). The risks arise from the release of PTE from inadequately disposed solid wastes, which are physically unstable and chemically reactive, and their dispersion and mobilization to the surrounding soils, sediments and water resources. Soils are often the main receptors of wind-blown dust from mine tailings and acid mine drainage. This poses serious concerns related to the capacity of soils to provide essential ecosystem services. Due to tailings dispersion, soils in the vicinity of solid waste deposits may become a secondary source of PTE contamination as a result of agricultural practices. Soil tillage may cause the resuspension of airborne PTE-containing particles, while cultivation of contaminated soil may lead to the uptake of PTE by crops, therefore leading to human exposure to hazardous elements through dust inhalation, ingestion, and skin absorption. It is therefore essential to study the potential bioavailability and mobility of PTE in contaminated soils, and remediation strategies in order to tackle possible effects on human health and biota.

Crop yields in PTE-contaminated arable lands may be significantly lower than those in non-contaminated areas. Apart from the aforementioned effects on food safety, this may also result in lower income for farmers and landowners, often leading to the abandonment of agricultural soils surrounding the contamination hotspots. Since soil is a fragile, non-renewable resource, that is fundamental to life on earth, it is important to identify

decontamination methods that would lead to achieving the goal of sustainable development.

Phytoremediation is based on the strategies employed by metallophytes, i.e. metal-tolerant plant species, to cope with the toxicity of PTE, which include the prevention of PTE accumulation in the cytoplasm, their detoxification or PTE excretion from the tissues. The ability PTE excluder species to restrict toxic metal uptake and translocation to the shoots is harnessed for the phytostabilization of PTE in soil, while the ability of includer species to assimilate, translocate and stock high concentrations of PTE without signs of toxicity is used in phytoextraction. Phytovolatilization, on the other hand, is a plant strategy for the detoxification of highly volatile PTE (As, Hg).

These strategies alone usually do not provide the necessary benefits to achieve land restoration, risk mitigation and economic gain simultaneously, therefore a synergistic approach to phytoremediation is generally encouraged. Assisted phytoextraction, for example, consists in enhancing PTE availability in soil and uptake by plants, by modifying soil physicochemical properties and improving plant fitness.

The remediation of PTE contaminated soils is a key direction for achieving the European Green Deal. Traditional approaches no longer respond to the current urge for strategies to ensure environmental, social and economic sustainability. Phytoremediation, in particular phytoextraction has nonetheless proven a promising technique for the remediation of PTE contaminated soil. However, phytoextraction has a major limitation: it is time consuming due to the slow growth rate, low biomass and low availability of the toxic metals. Therefore, improving plant performance and promoting PTE solubility are two critical steps for increasing the efficiency of phytoextraction. The silver lining of the reviewed literature is that in-depth understanding of the mechanisms of PTE uptake, translocation, and detoxification is essential for the design of a sustainable phytomanagement plan, which can be effective for the remediation of PTE contaminated soil only if it combines different clean-up approaches.

Keywords: phytomanagement plan, assisted phytoextraction, detoxification of highly volatile PTE

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FLUX measurements to design a nature based barrier in an urban canal

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The Interreg's RESANAT project promotes nature-based remediation techniques for residual soil contamination. The project concerns a full scale field test of a reactive mat in an urban canal threatened by groundwater contamination. The contamination originates from former industrial activities on the bank. The contamination migrates with the groundwater into the surface water, posing spreading and ecological risks. Measurement of groundwater and mass flux allows to identify flow patterns and determine mass discharge to the surface water. Based on the results the most appropriate remediation technique and materials are selected. The results helped our partner to dimension the barrier, both the needed hydraulic conductivity and its capacity to filter contaminant influx.

In 2019, restoration of the drainage capacity of the canal was needed, and the sediment was dredged. By dredging the canal the drainage capacity increased and adsorption of contamination decreased. It leads to an increase of contamination in the surface water. The horizontal flux of groundwater and contamination is measured before and after dredging. Additional vertical flux, upwards and downwards is measured after dredging in the sediment of the canal. Horizontal flux samplers are installed on 2 depths, in existing wells in the bank of the canal. To know the vertical flux of groundwater and contamination, in a first stage digital flux measurements of groundwater are performed in 30 locations. The results were available in real time. Based on these measurements 10 locations are selected to install samplers to measure vertical flux over a longer period. The flux measurements provided useful information about the distribution of the inflow over the length of the canal and the effect of dilution and degradation downstream and allowed to refine the conceptual site model.

The groundwater and mass flux before dredging was rather low. Flux measurements showed an significant increase of the groundwater flux

after dredging. The BTEXN flux measured in the wells in the banks increased till 15 times in comparison with the flux before dredging. The PAH flux increased till 3times. After dredging an additional flux of mineral oil is measured. The mineral oil compounds were mobilised after the dredging.
In the sediment of the canal the flux was dominantly upward, from groundwater to surface water. The flux varied strongly because of the heterogeneity of the sediment and characteristics of the canal. The use of passive mass flux sampling in combination with real time continuous flow velocity and direction measurement with digital sensors allowed to characterize exchanges at the interface between groundwater and surface water and to create illuminating insights in the dynamics influencing the water quality. The data led to an effective remediation concept.
Based on the groundwater and mass flux data it became clear where targeted action was needed. With the data it was possible to divide the trajectory into three segments, with each its own dimensions for developing a remediation concept based on the natural characteristics, i.e. drainage capacity, a green adsorbent and biological activity to cope with the inflow of contamination and improve water quality.
In addition, a monitoring plan has been developed including assessments of the effectiveness and progress with flux measurements.

Keywords: nature based barrier, sediment of the canal, measurement with digital sensors

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Overview of the CONCAWE LNAPL toolbox, a new Web-Based Decision Support System for managing LNAPL sites

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LNAPL stands for 'Light Non-Aqueous Phase Liquids' or hydrocarbons that exist as a separate undissolved phase in the subsurface at some sites with legacy releases of fuels. They are referred to as 'Light' because most petroleum hydrocarbons are less dense than water. Because LNAPLs can sustain dissolved groundwater plumes for long time periods, it is important to understand how much LNAPL may be present at site, if the LNAPL can migrate, if it can be recovered, how the LNAPL composition changes over time, how long it may persist, and finally quickly the LNAPL body is attenuating.

Understanding LNAPL behaviour is complex, and therefore Concawe has with the support of GSI Environmental compiled a unique collection of useful tools, calculators, data, and resources to help LNAPL scientists and engineers better understand how to manage LNAPL at their sites. It led to the developed of the Concawe LNAPL Toolbox, a wide-ranging but easy-to-use web-based toolbox to deliver key LNAPL knowledge to the LNAPL remediation community.

In creation of the web-based toolbox application a combination of the programming languages R, Python, JavaScript and HTML were utilised. The toolbox uses a three-tiered approach that provides access to over 20 different LNAPL tools (key infographics, nomographs, calculators, mobility models, videos, checklists, and other formats) with different levels of complexity and time requirements. The three tiers of complexity are:

- Tier 1: Simple and quick graphics, tables, background Information
- Tier 2: Middle level quantitative methods and tools
- Tier 3: Gateway to Complex Models.

Firstly, Tier 1 provides a simple summary regarding a specific question that the toolbox is set to address (described below as questions 1-6).

The material in Tier 1. Secondly, Tier 2 is where the bulk of the novel programming of the toolbox was performed to develop user-friendly calculation tools. Finally, Tier 3 offers a gateway to more complex calculation tools that are available, either by videos or text explaining how these tools can be used.
Tool 1 includes an "LNAPL volume model" where users enter the LNAPL apparent thickness in monitoring wells, soil conditions, LNAPL characteristics, and the model estimates specific volume at each location and provides a general estimate of the LNAPL volume in place. Tool 2 includes a new "LNAPL Body Additional Migration Tool" where users enter LNAPL hydraulic gradient, LNAPL Transmissivity, and NSZD rate and the tool estimates if the LNAPL is likely to expand will, and if so, by how much. A simple mass balance box model used in the US Environmental Protection Agency's LNAPL model has been adapted in Tool 3, where users enter an estimated LNAPL mass, area of the LNAPL body footprint, NSZD rate and the model estimates a range of LNAPL lifetimes. Tool 4 includes an "LNAPL dissolution calculator" and Tool 5 includes an "LNAPL transmissivity calculator" to estimate of LNAPL can be recovered by LNAPL pumping. Finally, Tool 6 includes a number of tables, references, resources, videos, calculators regarding how to measure and how to process Natural Source Zone Depletion (NSZD) data.

The Concawe LNAPL Toolbox can be accessed and used freely via a webpage on an internet browser (https://lnapltoolbox.concawe.eu/lnapl_toolbox/), or by downloading the toolbox via GitHub (https://github.com/concawe/LNAPL-Toolbox-) for the use on a personal computer. The Toolbox User Manual is also published on the Concawe website as Concawe Report 5/22.

Keywords: LNAPL, toolbox, Web-Based Decision Support System

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Acque ad uso umano e contaminanti ubiquitari: PFAS e Bisfenolo A, dal testo della nuova direttiva ai test di laboratorio

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La nuova Direttiva europea sulle acque ad uso umano 2020/2184 propone un approccio alla sicurezza dell'acqua potabile basato sul rischio, attraverso la valutazione dei vari bacini idrografici, sia nei punti di estrazione che nel sistema distributivo.
Affronta inoltre la questione dei contaminanti emergenti, sostanze scarsamente o per nulla normate in maniera armonizzata in Europa, ma che pongono serie preoccupazioni in termini di sicurezza a causa della loro presenza ubiquitaria e degli studi che ne confermano la pericolosità per la salute.
Tra questi i PFAS e il Bisfenolo A, accomunati, tra i vari aspetti, proprio dal fatto che precedentemente la loro concentrazione nelle acque non era normata, e dalla sfida che pongono in termini di rilevazione analitica.
Non si tratta degli unici contaminanti emergenti posti sotto la lente di ingrandimento: la Decisione di esecuzione (UE) 2022/679 integra il controllo di altri composti che destano preoccupazione (già citate nella suddetta Direttiva Europea): 17-betaestradiolo e nonilfenolo, determinando ulteriore chiara evoluzione normativa a riguardo delle acque destinate al consumo umano.
Il laboratorio è un osservatorio privilegiato, soprattutto quando può valutare la presenza di questi contaminanti nei campioni di acqua provenienti da diverse parti d'Italia e da molti diversificati clienti. Lo è ancora di più se, vista l'estrema ubiquitarietà e mobilità chimica di questi contaminanti, è in grado di testare la loro presenza anche negli alimenti e nei materiali a contatto con gli alimenti.
Sarà possibile per esempio concentrarsi sui PFAS indicati tra i più problematici secondo la bozza di emendamento della Direttiva EU 1881/2006, valutando dati analitici sia in acqua che negli alimenti.

Similmente il paragone potrà essere fatto su acque e alimenti per il bisfenolo A.
Attualmente non esiste una legislazione armonizzata che regolamenti la presenza nei PFAS nel packaging alimentare. Esistono due differenti regolamenti per gli alimenti e per le acque ad uso umano. Nell'attuale draft sugli alimenti i limiti arrivano anche a 0,1microgrammi/chilogrammo. Come non pensare che in tutti i comparti (alimentare, acque, packaging) sarà indispensabile ragionare su limiti e molecole, visto che l'origine stessa dei PFAS non intenzionalmente aggiunti in un comparto potrebbe derivare da un altro? – negli alimenti e nel packaging dall'acqua, o, al contrario, negli alimenti dal packaging e dall'acqua, ecc.
Per i PFAS, l'approccio con metodo LC-MS/MS, può essere un vantaggio in termini di sensibilità e selettività: questa tecnica può aiutare a rilevare e quantificare con precisione i livelli di PFAS a bassa concentrazione. Ma quali molecole scegliere in un panorama di contaminazione così ampio?
Altre tecniche danno un'indicazione della quantità totale di specie perfluorurate in un campione, ma non del tipo, e possono non tenere conto di alcuni precursori.
In alcuni casi le indicazioni locali hanno indicato la strada al laboratorio: in Veneto viene indicato il metodo ISO 25101:2009, con tecnica HPLC MS/MS che consente di arrivare a rilevare concentrazioni anche di 0,001microgrammi/chilogrammo.
Il laboratorio è un osservatorio privilegiato di fronte a contaminazioni dell'acqua che possono influenzare anche altri comparti, come quello alimentare. E' anche luogo di sperimentazione di metodi e può investire sulla migliore delle tecnologie esistenti per arrivare a limiti di concentrazioni molto basse.
Di fronte a contaminanti che pongono una sfida in termini di metodo di analisi, in cui l'Europa stessa nel legiferare si pone l'obiettivo futuro di condividere un metodo unitario idoneo (es. per il monitoraggio dei contaminanti ubiquitari in acqua), il laboratorio non può che cercare la strada che ritiene più affidabile e, appena individuato il metodo condiviso, orientarsi su quello, al fine di ottenere risultati rappresentativi e comparabili.

Keywords: contaminanti ubiquitari, PFAS, Bisfenolo A

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Kuwait environmental remediation program: bioremediation treatment optimization study

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DND Biotech has been working on a bioremediation treatment optimization study with the objective to demonstrate that this remediation method will meet the required targets and to optimize the remediation efficiency and the full-scale design. The project is taking place in portions of North and South Kuwait, where the soil is contaminated by petroleum compounds (TPH). The project consists of 3 phases of testing, from lab scale to field scale.

The first phase takes place in Pisa. Italy, and it includes laboratory analyses and small-scale bioremediation tests (mesocosm). The focus is on the physical-chemical characterization of the soil and of the contaminants as well as the microbiological features of the soil. By means of metagenomics, microorganisms colonizing the contaminated matrices are identified and their capacity to transform the contaminants are predicted. The lab phase also includes selection and isolation of degrading microorganisms and definition of models of the degradation kinetics based on the mesocosms results. In particular, these tests (1 kg of soil each) are carried out in duplicates with a combination of 4 factors: 2 TPH levels (1-3%, 3-5%), 2 salinity levels (high and low), 4 microbiota inoculums (autochthonous, 2 types of allochthonous and none), 2 types of surfactants, nutrients and zeolites amendments. A total of 64 mesocosms are incubated in controlled environmental conditions and analysed in parallel for residual TPH content and metagenomic analysis, collecting monthly time points of analysis.

The second and third phases will take place in Kuwait and are respectively medium scale and field scale trials. The medium scale tests will consist of 192 piles (96 in south area and 96 in north area) of a 3 m3 cubic meters, for a total of about 573 m3. These piles will be placed in a mobile shed set up in a light-roofed hangar and will be used to test different scenarios: different types of soils, pollutants present in different states (wet oil lakes / dry oil lakes / oil contaminated piles),

irrigation patterns and remediation amendments. The duration of the medium scale tests will be four months for lower TPH concentrations (1-3% and 3-5%) and eight months for higher concentrations (5-7% and 7-10%).
The third phase, the field scale tests, will consist of trial tests on 80 piles (40 in south area and 40 in north area) of 100 m3/pile for a total of 8000 m3 of soil. The same configurations of the medium scale tests will be replicated on this scale. Both medium and filed scale trails will have a monitoring plan which includes weekly measurements of soil moisture, pH, temperature and TPH %, interstitial gases and surface emissions (CO2, O2, CH4, VOC), and monthly C/N/P ratio and metagenomics analyses. At the beginning and at the end of the trials, toxicity of the matrix will be tested on Vibrio fischeri (UNI EN ISO 11348-3:2019) and Vicia faba (UNI EN ISO 29200:2020). A mobile laboratory will be set up in a light-roofed hangar on-site to perform the weekly analyses.
In addition to testing the effectiveness of the technology in terms of the ability to reduce contaminants in the soil being treated, it is of great importance to acquire data on the potential impacts that the technology has on the environment and on people's health, also with a view to define the risks for workers and their respective mitigation measures. This is why we will also install on the construction site the ROBONOVA® station, a mobile laboratory that fits into a container, equipped with instrumentation and systems that model soil composting on a pilot scale and measure air quality, emissions and the chemical quality of the percolation water. The key assets provided by the ROBONOVA® station will be: (i) continuous, detailed, and reliable monitoring of gas and micro-dusts emissions (CO2, O2, CH4, VOC) from bioremediation activities, compared to the weekly/monthly probing activities in the medium scale and field scale trials areas, (ii) continuous monitoring of both metabolic activity of microorganisms and ongoing process during remediation, validating the findings of protocols and processes developed in the first laboratory phase and implemented in the medium scale and field scale trials areas, (iii) continuous monitoring of energy and water consumption, leachate and liquid waste.

Keywords: bioremediation, ROBONOVA®

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Firefighting Validation Testing of the Leading Commercially Available PFAS-Free Foams ESTCP Project WP21-346

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The program has conducted in phases, Phase I was conducted using a 125 gpm PFF hose line to combat the fires and Phase II was conducted using a 250 gpm turret installed on a P-25A shipboard fire truck (i.e., mini ARFF vehicle). During both phases, the candidate PFFs (and the baseline AFFF) were tested against an uncontained 2-D fuel spill fire and a running fuel fire that included a 3-D component as well as a 2-D growing spill fire. During the Phase I tests (hose line), the running fuel fire was the legacy debris pile fire scenario developed during the Nimitz test series back in the 80's. During Phase II tests (Turrets), the running fuel fire consisted of a fuel manifold that spilled onto a small/short steel table about 6 inches above the ground. All fires were produced using F-24 as the fuel. F-24 is the military variant of Jet A (i.e., it is Jet A with additional corrosion inhibitors). The spill fire sizes were scaled to assess a foam application rate of 0.05 gpm/ft2, which is less than half of a typical ARFF response. The candidate foams/agents were assessed on their ability to knockdown (control) and to completely extinguish the fires. The burnback protection provided by each foam was also investigated.

The differences in the PFF's capabilities as compared to the AFFF's capabilities are best described through the visual observations made during the tests. As the firefighters approached and attacked the fire with AFFF, one sweep with either a handline or a turret tended to extinguish all the fire in the sweep area including behind small obstructions. However, one sweep with the PFFs tended to leave holes in the foam blanket and typically would not extinguish the obstructed fires. Any December 2019, Congress passed the FY20 National Defense Authorization Act (NDAA), which prohibits uncontrolled release of AFFF at military installations except in emergency response or in training or testing if complete containment, capture and proper disposal is in place.

As a result of these differences, the PFFs typically took two passes with the stream to completely extinguish all the fires in the seep area as opposed to only one with AFFF. The need for the two passes caused the extinguishment times for the PFFs to be about double that observed for AFFF. However, the PFFs were capable of controlling and extinguishing all of the spill fires and most of the 3-D fires conducted during both phases of this program.

After the burnback tests were complete during Phase II, the fires were manually extinguished by two firefighters with minimal "hands-on" training. As the firefighters began their attack on the fire, it was obvious that they were thinking about their past training and trying to follow a systematic approach to combat the fire. Specifically, they would set the nozzle on a wide fog pattern, advance a few steps toward the fire, and then apply foam to the fire using a straight stream or narrow spray pattern. This process was repeated numerous times and they slowly progressed toward the fire. The process looked awkward, and the fire tended to grow faster than the advancement on the fire. During the application of the foam with the narrow angle spray pattern, the firefighters tended to punch holes in the foam blanket at the stream impingement location. As a result of the slow/awkward advancement and the punching of holes in the foam blanket, the fires always got worse (i.e., larger) before they got better. The control application densities measured for the PFFs during both phases of this program ranged from 0.035-0.075 gal/ft2 which are about half that of the control application density requirements stated in NFPA 403/460. Since the firefighters were able to advance through the fuel spill during the hose line tests (i.e., Phase I), the control application densities were typically much lower than those observed for the ARFF vehicle turret in Phase II.

In conclusion, these tests have demonstrated the efficacy of these products in combating a range of worst case ARFF type scenarios. Although the capabilities of these products cannot match those of the legacy AFFFs, they can be made to provide adequate protection with the proper equipment, tactics and training. As stated previously, this is still a work in progress and will be addressed during the Phase III assessment.

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The occurrence, distribution, and risks of PFAS at AFFF-impacted sites in Finland

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Per- and polyfluoroalkyl substances (PFAS) comprise a wide group of persistent chemicals, whose ubiquitous occurrence in the environment, particularly due to their extensive use for fire suppression in aqueous film forming foams (AFFFs), has raised global attention. We evaluated the impacts of PFAS at three firefighting training sites and one industrial site in Finland, to highlight key elements to be considered in the retrospective risk assessment of these chemicals regarding both its methodological and regulative aspects. The site assessments covered the occurrence and distribution of PFAS in multiple environmental matrices, i.e., soil, sediment, surface water, groundwater, and biota, and the subsequent risks to human health and the environment owing to the migration of and exposure to the selected compounds. The main objective of our study was to fill some of the existing data gaps regarding PFAS and to advance risk-based decision making at AFFF-impacted sites.

The highest ∑23PFAS soil concentrations at the firefighting training sites (around 3,000 µg kg-1) covered only a small surface area (i.e., the actual training field), where PFOS was the dominant compound alongside FOSA and other long-chain PFAS (e.g., 8:2 FTSA and PFTrDA), while concentrations declined significantly as a function of distance outside the center of the area. Estimated human exposure for the target PFAS (i.e., PFOS, PFOA, PFNA and PFHxS) at those sites was only around one fifth (0.11 - 0-13 ng kg-1bw d-1) of the European Food Safety Authority's new reference value (TDI = 0.63 ng kg-1bw d-1; EFSA 2020). Soil sampling was not carried out at the industrial site due to technical structures and pavements, but we estimated that the amount of PFOS released into the soil during the isohexane fire in 1989 may have been up to 1,400 – 2,000 kg. Considering the conservativeness of the exposure assessment in the training grounds and the pavements and other site information at the industrial terrain,

human health risks due to direct exposure at all the sites was considered negligible in the current land use.
Bioaccumulation of PFAS in earthworms (studied at one site) was higher for PFSAs than for PFCAs, and the calculated biota-soil accumulation factors (BSAF) were 20, 60 and 260 for PFOS, PFHxS, and PFBS, respectively.
In groundwater, the highest ∑23PFAS concentrations were measured in the monitoring wells adjacent to the training site, while concentrations decreased in the downgradient wells by several orders of magnitude. Considering the conservativeness in our modeling and the findings from several international studies done at AFFF-impacted sites, where PFAS mass discharges have been significantly shown to decrease along the groundwater flow path due to non-destructive attenuation processes, we estimated that PFAS concentrations at the water intake will not reach the reference value, however. Yet, we recommended to verify our conclusions by additional site investigations designed to measure the actual mass discharges, preferably at least across two transects intercepting the plume.
Our study showed that the extensive use of nowadays restricted or substituted PFAS, particularly PFOS, are still often the predominant compounds detected at AFFF-impacted sites and will continue to cause long-term risks to the environment. The most significant environmental or health risks at these sites are likely to concern aquatic ecosystems, fish consumption or groundwater usage due to the off-site migration of PFAS. Here, even a single fire extinguishing event can be a considerable contributor. We also illustrated that conventional procedures based on simple mass-balance, and exposure models, with a focus on PFOS and other site-specifically relevant PFAS may provide sufficient means to assess the risks. Moreover, we addressed that despite the exceedance of the very stringent regulatory threshold values issued recently for PFAS, the actual site-specific risks to human health and the environment may remain reasonably low. However, additional research is still needed on the toxicity and the environmental behavior of many PFAS common to AFFFs, including short-chain PFAAs and their derivatives. Moreover, open dialogue and expedient policy decisions are required on the procedures and the environmental objectives for PFAS within the regulatory context of their retrospective risk assessment and management.
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Combined Oxidative Remedies in a Single Application to treat Petroleum Hydrocarbon Contamination

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In situ chemical oxidation (ISCO), aerobic bioremediation, and anaerobic oxidation can be combined into a single product that is injected as a solid slurry into the subsurface in a single application. Klozur® CR is a combined remedy treatment technology consisting of Klozur® SP (sodium persulfate) and PermeOx® Ultra (extended oxygen release compound). By combining these two products, Klozur® CR provides self-activating Klozur persulfate oxidation technology, utilizing both hydrogen peroxide and alkalinity generated by the calcium peroxide to create activated persulfate which is capable of destroying a wide range of contaminants, including petroleum hydrocarbons and chlorinated solvents. Following the initial chemical oxidation phase, the slow hydration of the engineered calcium peroxide (PermeOx Ultra) in Klozur® CR will continue to release oxygen to be used as an electron receptor for aerobic bioremediation treating BTEX, PAH's and petroleum hydrocarbons. The residuals after ISCO with persulfate include the sulfate anion, which can be utilized by sulfate reducing bacteria as an electron acceptor under anaerobic conditions to degrade BTEX, PAH's and petroleum hydrocarbons in a process called anaerobic oxidation. With three active mechanisms from a single application, the details regarding the science, design strategies and details from an Italian site will be discussed.

This technology was successfully applied at a site in the northern Italy city located in a densely populated urban area and which was characterized by historical contamination of various toxic contaminants. The site, a dismantled former petrol station, was impacted by the storage of fuels which has resulted in the groundwater contamination including hydrocarbons (C<12 ~ 2000 µg/L), benzene (~ 500 µg/L), ethylbenzene (~ 380 µg/L) and MtBE (~ 13000 µg/L). Two injection campaigns were carried out 15 months apart and a total of 4800 kg of Klozur CR (25% aqueous solution) was injected at the site.

Following 18 months after the first application, the concentrations of contaminants had reached and maintain concentrations below the remediation goals in all monitoring piezometers in the treatment area. Total petroleum hydrocarbons were reduced by greater than 80 percent while MtBE was reduced by greater than 90 percent. Monitoring data confirmed sustained elevated oxidation- reduction potential (ORP) and dissolved oxygen (DO) that are the result of in situ chemical oxidation and used to support enhanced aerobic bioremediation.

Keywords: in situ chemical oxidation (ISCO), aerobic bioremediation, anaerobic oxidation

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Organic soil mitigation

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Ocean health is declining due to increasing rate of algal blooms due to higher temperature and artificial fertilizer nutrients from land runoff from farmlands agriculture, cities and states. Anthropogenic activities are destroying land and ocean biodiversity, ecology. It will lead to trophic cascade in marine ecosystems and lead to the destruction of terrestrial ecosystems by killing microbial in soil, hypoxia in coastal seas. These all will be reason for ecological problems and economical loss globally to food supplies. This will lead to competition for resources. Probably such situations will lead to migration or massive deaths of organisms, people and animals. This will lead to conflicts between human and animals for resources and territory as soils become unproductive by artificial fertilizer salting soil killing microbial effectiveness in soils. We are witness to the destruction of our planet today because of growth models that do not consider future needs which satisfy ecologic needs and must now change to a development model and holistic cultural management or symbiotic relationship learning on mass scales. The question now is when do we begin to repair our past and current mistakes to include viable realized pathway narratives which now exist?

This is where Planetary Health Project LLC with symbiotic relationship technology (SRT) will incorporate its keen sense of individual empowerment for the farmer, agriculturalist, even gardeners. We believe that on a local basis as people believe in a better pathway for them and can see this future clearly in a package will remove any doubts and present a product that corrects for artificial fertilizer use. The farmers have no trouble performing the next steps of understanding and learning which present the solution because the product has been tested and meets future need requirements as a no guess package . Our methodology will bring hope, and clear direction making the farming, agriculture, gardens symbiotic relationship technology for generations to come. The individual will recognize his or her part easily knowing the future has a dividend, the future has a

healthy direction, and the future has a pride knowing they tried for the next generations benefit to change and succeed doing so.
Simply the Planetary Health Project LLC is our advantage (social economic ROI) and our planets health is maintained as well as migration of people checked if we start now in 2022. How?

The Planetary Health Project is unique, it's nonpolluting its life giving its easy to deploy produce and when done right will reverse ecological degradation quickly. We have worked out the soil conditioning and mineralization. We have worked out the planning and funding to start the first plots in our proposal full build out for university and farmer.
Studies on Microbial and Coal ash a waste product of burning coal for energy as an organic fertilizer blend have found to be astonishing results. Studies already done since 2005-2016 with 70% coal ash and the rest trade secret materials is hands down the most important invention of our time. We believe when we use this Organic fertilizer our deserts will become green, our oceans, seas, gulfs reverse hypoxia. Our Farmlands more nutrient rich much longer no leeching, no pesticides, herbicides less detrimental to nature. Then our seas oceans and waterways will become a viable ecology again without algal blooms from nitrate phosphate run off, our soils recover biology, we are no longer desert makers.
To further this vision, we are creating GroUS®, the us is we on this planet. This will serve as the for-profit to raise the necessary ROI funds to carry out the larger projects. Cost of building tree nurseries, coal conversion plants for soil mineralization, agroforestry plots, and forest plots, farming and farming interests. These are all huge markets and huge venues to get established quickly worldwide. We will serve as the Paradigm change, we need for future educational building and infrastructure, teachers, professionals who direct social specific activities that enhance the regions with ever changing methods and educational needs that benefit mankind and our planets health to compliment nature pathways. Our planet is out of balance, since 1920-2022 Our current growth-oriented economics are hurting the health of our world. Resource management must correct to a proper use waste management or the world we see today will fall into disrepair to a point unrecoverable.

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Air Sparging Technology Status Review – Advanced Design and Implementation Tools

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[1] Haley & Aldrich

Air sparging involves injecting a pressurized, hydrocarbon-free gaseous medium into contaminated saturated soils and groundwater to change the physical state of strippable contaminants from free, dissolved, and/or sorbed phases to the vapor phase through volatilization. Air sparging was first applied in Europe in the mid-1980s and in the United States (U.S.) in the early 1990s. Since its initial implementation in the U.S., the technology has been used at numerous remediation sites including over 80 Superfund sites across the country and is considered a well-documented and proven remedial technology. It has been applied as a source treatment technology, as well as a treatment barrier or trench for source containment and plume mitigation. Several advancements in the technology have been made over the years that can enhance treatment effectiveness, such as cometabolic air sparging, biosparging, oxygen injection, ozone-air mixture injection, steam injection, in-well stripping, and enhanced air-to-water ratios and operational pulsing techniques. These advancements in the technology not only have improved the treatment effectiveness for contaminants previously accepted as “strippable”, but also have enhanced the treatability of emerging contaminates with poor air stripping capabilities, such as MTBE and 1, 4-dioxane.

Advancements in design and implementation techniques continue to be made, further enhancing the remedy effectiveness, the ability to better project remedial timeframes, and the systems performance optimization. These advancements include improved pilot-testing techniques, more sophisticated mass-transfer and 2-D/3-D pneumatic modeling tools, and modifiable implementation methodologies—adjustable sparge screens, remote telemetry, and control interlocks—which allow for more flexible system performance and real- time

remote monitoring and manipulation of the system operating parameters.

Through the use of mass-transfer models, the effectiveness of air sparging remedial systems can be more accurately projected on a site-specific basis. One such mass-transfer model, using temperature-dependent Henry's Law constants, air-to-water ratios, and initial and required final contaminant groundwater concentrations, was developed and calibrated with data from various sites across the country. This mass-transfer model, in conjunction with innovative pilot testing and pneumatic modeling techniques was used to develop effective air sparging remedial strategies for three sites in northern New Jersey with complex lithology that constrains conventional air sparging methods. Pilot testing data, modeling results, and innovative design techniques—including operational pulsing, thermally enhanced air sparging, advanced aquifer pressure relief mechanisms—will be discussed. The full-scale air sparge systems operational data for these three sites will also be presented.

Keywords: Air Sparging Technology

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Landfill Remediation and Redevelopment - A Status Review of the Current Practice and Technology Advancements

Omer Uppal, Peter Bennett, James W. Little, Darrin Costantini, Christopher Tsiatsios, and Scott P. Zachary.

Haley & Aldrich

As the world's population continues to grow and unused land for development is resultantly dwindling at a rapid pace, the importance of brownfield redevelopment continues to become more and more paramount. In addition to the environmentally contaminated sites those result from industrialization, remediation and redevelopment of the former landfills sites is also becoming much more prevalent. Over the past two decades, the United States has seen a substantial increase in development on closed municipal-waste landfills. The construction value of these projects could be substantial in addition to the numerous end-use benefits such as tax revenues and new jobs.

Redeveloping landfills is particularly challenging not only because of the issues associated with remediation, but also because of the environmental and geotechnical issues of building on refuse. Landfill gas containing elevated levels of methane poses a significant risk of fire and explosion. Other landfill gases such as sulfur-based corrosives like hydrogen sulfide and volatile organic compound vapors pose significant exposure risks to human health, safety, and the environment. The geotechnical challenges include installing building foundations over refuse that is highly susceptible to differential settlement over time because of the natural degradation processes. With the progression of more sophisticated remediation, landfill gas mitigation, and geotechnical technologies, redevelopment of the former landfills into commercial, retail, and even residential space is becoming much more achievable.

Although all brownfield sites possess inherent challenges to redevelopment, landfills, in particular, must be carefully investigated and considered when planning for redevelopment. As landfills age

over time, the chemical, physical and biological characteristics of the land (i.e., refuse) change accordingly, making it much more challenging to ensure that the remediation and redevelopment activities are protective of human health and the environment over the life of the project. As a result, the environmental, geotechnical, and regulatory requirements are much more stringent for landfill redevelopment. Close collaboration amongst all disciplines is required in order to achieve successful landfill redevelopment. Case studies to demonstrate the aforementioned challenges, the applied remediation, landfill gas mitigation, and geotechnical strategies to overcome such challenges, as well as the environmental, social and economic benefits resulting from landfill redevelopment will be presented. A status review of the current practice and remediation technology advancements facilitating successful landfill redevelopment will also be presented.

Keywords: Landfill Remediation and Redevelopment

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Thermal desorption of heavy polluted oily sludge from a deposit in a refinery

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Thermal desorption is a remediation technique aiming to remove the pollutant from the matrix. Formerly applied in specialized centers, VALGO partipated in the development of an on-site technique, also implemented in situ, to prevent excessive transport of hazardous material and to keep the waste onto the production area.

From lab assays to full scale applicaiton, we will present here the different steps allowing VALGO to manage this powerful technique, with the highest level of security, for people, equipment and environment. The case study is performed in the SIR refinery of Abidjan.

Energy consumption is one of the key factors to success in a thermal remediation realization. To secure the costs of the full scale remediation, VALGO developped a whole integrated procedure, involving several steps.

The first step consist in a perfect knowledge of the site, the terrain and the waste to remediate. During this initial visit, sample are collected, and/or some in situ assays could be run, to refine the data about the physical behavior of the matrix.

Collected samples are sent to the internal lab for the second step, including tailor made assays, to determine the target temperature that will by applied for the remediation.

Physical and chemical values are then implemented in a proprietary software, to determine the kinetics of the removal and adapt the whole process to the local thresholds of the remediated site.

Demonstration of the efficacy of the technical settings could be implemented in an optional pilot step, that bring the 2nd advantage to validate the choices regarding the materials.

In the presented case study, gas burners were used to heat 5000 m3 of sludges up to a target of 250-350°C, as demonstrated during the lab assays.

The lecture will present part of the works allowing VALGO to totally remove the pollutants, looking like heavy tars, meeting the requests of the site owner, SIR. Terrain and local adaptation was the main motto, to ensure the results 5000 kms away from VALGO's headquarters.

When the physical and chemical behavior of the pollutant and the matrix are taken in account, when energy is properly handled, thermal desorption appears as a strong answer to impossible cases of remediation.

Keywords: Thermal desorption, oily sludge from, refinery

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The First Implementation of a Combined Electric Resistive Heating (ERH) and Multi Phase Extraction (MPE) Remedy at a Fractured Bedrock Site in Scotland, UK

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High resolution site characterization at a site in Scotland (UK) delineated a hot-spot area of residual soil TCE contamination (>200 mg/kg) within a clay dominated subsoil, which represented a historical remnant of the original disposal area at the site. A high concentration, predominantly TCE, plume had developed within the underlying sandstone aquifer and the uppermost mudstone aquitard.

Due to the complexities of this fractured bedrock setting, a detailed remedial alternatives evaluation was undertaken to achieve mass flux reduction. The remedial goals were to reduce soil concentrations from 200-300mg/kg (observed in the environmental characterization phase of works) to <1mg/kg and to recover at least 90% of the estimated TCE mass within the aquifers, which should resultantly reduce TCE source concentrations from ~200mg/l to less than 5mg/l.

Electrical Resistance Heating (ERH) was identified as the preferred remedial technology for this specific environmental setting. The remedial design was optimized to achieve the mass flux reduction remediation goals by targeting the treatment zone where the highest proportion of residual mass resided, which occupied an area of ~900m2 and approximately ~8,000m3 of fractured bed-rock. Additional hydraulic and vapor control, using a complementary peripheral MPE system, was included in the overall remediation design to protect nearby sensitive receptors including adjacent residences. Based on an overall mass flux remedial objective and an optimized target treatment zone, a multiple lines of evidence verification strategy was agreed to with the regulatory authorities.

During the first two weeks of ERH subsurface installation, peripheral MPE wells were advanced and connected to the vapor and water treatment systems. This allowed for localized mass which was released into the fractured bedrock aquifer to be recovered. Active

mass recovery during ERH-related drilling activities avoided an increase in the mass flux leaving the site as part of the installation works, which was vitally important given the nearby sensitive resceptors and the mass flux derived remediation criteria established for the project.

Following ERH system startup, subsurface temperatures rapidly increased. Within two months of operation, subsurface temperatures were above the azeotropic boiling point of TCE (73°C). By the end of the project, on average subsurface temperatures were greater than 95°C. This led to a secondary phase in overall TCE mass recovery where it is inferred that mass residing in not easily accessible fractures and the bedrock matrix was effectively recovered. The remediation process removed ~1,200kg of TCE from the targeted remediation treatment zone. As designed, the remediation was successfully completed within the 20-week estimated timeframe. Notably, effective and efficient remediation optimization driven by Geosyntec and TRS Group resulted in only 80% of total power demand being required, providing significant cost savings to our client. The MPE and ERH systems recorded high levels of operational uptime (>95%) with the MPE system boundary vapor/temperature required to mitigate risk to the surrounding sensitive receptors.

Throughout operations, multiple lines of evidence were evaluated to confirm that hydraulic and pneumatic control were maintained throughout operation of the ERH system. Most notably, the boundary wells were generally found to be under applied vacuum induced by the MPE system and the temperatures in the boundary wells only increased by ~5°C despite the dramatic temperature increases within the ERH treatment volume.

To achieve the agreed mass flux remediation goal, site models indicated that groundwater concentrations within the treatment target zone would need to be reduced by approximately one order of magnitude. The validation results showed that, compared to the maximum TCE concentrations in the source zone, post remediation concentrations had been reduced by approximately two orders of magnitude, demonstrating via multiple lines of evidence that the bespoke remedial approach had successfully removed the source of TCE contaminant from these two fractured bedrock aquifers to the satisfaction of our client and the regulatory authorities.

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Environmental Sequence Stratigraphy (ESS) as a framework of a process-based conceptual site model to optimize groundwater remediation

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Background/Objectives. Groundwater remediation at many Air Force installations is inherently complex due to long histories of multiple releases, multiple source areas and numerous chemicals of concern including emerging contaminants. This paper will introduce the decision logic and approach for applying Environmental Sequence Stratigraphy (ESS) as an example of Remediation Geology to provide the framework to developing Process-Based Conceptual Site Model (CSM) that support optimization of groundwater remediation strategies to reduce life-cycle costs and accelerate remedial systems towards cleanup goals.

Approach/Activities. The ESS approach presented in the 2017 U.S. Environmental Protection Agency [USEPA] Groundwater Forum Technical Issue Paper [EPA/600/R-17/293] examines existing subsurface data available in the context of appropriate depositional environments (e.g., facies analogues) and uses vertical trends in grain size to identify packages of sediment deposited at roughly the same point in geological time. For groundwater restoration projects, a sequence stratigrapher identifies and correlates genetically-related chronostratigraphic units, rather than lithostratigraphic units, resulting in a more representative definition of hydrostratigraphic units (HSUs) and understanding of their connectivity. To date, the ESS approach has been applied at over fifty Air Force facilities ranging from site-specific to regional-scale geologic models. These facilities encompass a wide range of sedimentary depositional environments, providing an opportunity to understand benefits of using an ESS approach to implement and optimize site remediation across a diverse set of hydrogeological settings.

Results/Lessons Learned. Case studies in different geologic settings will be presented to show how application of ESS principles to better understand complex subsurface geology can accelerate projects towards cleanup goals by reducing uncertainty with respect to the nature, extent, and fate and transport of groundwater impacts. Accurate geologic cross-sections are critical to creating realistic hydrostratigraphic models to support simulation of flow and contaminant transport by defining contaminant transport and storage zones and the geologic conditions that promote diffusive contaminant mass transfer. Specifically, the study shows the benefits of using ESS methods to resolve contaminant migration uncertainty and target active remediation to treat contaminant mass associated with preferential pathways as well as low permeability contaminant storage zones and developing appropriate cost-effective remediation strategies. Relatively small upfront capital investment in analysis and data interpretation of existing site data, regardless of the current phase of site cleanup, can substantially enhance remedy effectiveness, provide significant cost avoidances, and reduce project life-cycle costs.

Keywords: Environmental Sequence Stratigraphy (ESS), groundwater remediation

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Evaluation and remediation of a large commingled chlorinated solvent plume in the united states eastern coastal plain

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The White Swan Laundry and Cleaners Inc. Superfund site is in a mixed residential suburban area in Wall Township, New Jersey. The site consists of two source areas, represented by two former dry-cleaning operations - White Swan Cleaners and Sun Cleaners. The former source area is being remedied by a potentially responsible party (PRP); the latter source area has no viable PRP, so it was remedied by the USEPA. Groundwater in this region occurs in a sandy and unconfined aquifer with a low permeability unit approximately 65 feet below ground surface (bgs). A remedial investigation reported a groundwater plume of primarily tetrachloroethene (PCE) within the shallow and intermediate zones (0-65 feet bgs). This roughly 2- mile-long plume migrates eastward until discharging into north and south bounding surface water bodies (north by Hannabrand Brook and Wreck Pond and south by Judas Creek, Mac Pond and Stockton Lake) and the Atlantic Ocean. Site challenges are two source areas where the White Swan is PRP led and the Sun is EPA led, superfund site 2 miles long and 1 mile wide, plume tidally influenced by Wreck Pond and Stockton Lake, irrigation/production wells create irregular flow patterns, aerobic aquifer limits biological degradation of PCE, and residential area-vapor intrusion into homes. Subsurface soil sampling detected PCE in soil as high as 57,000 ppb at White Swan and as high as 1,200,000 ppb at Sun. Soil gas PCE levels from the area- wide investigation showed levels as high as 10,381 ug/m3 in sub-slab air and indoor air. PCE soil content were up to 28,000 ppm and PCE mass approximately 4,360 pounds. PCE contamination was as high as 51 ppm with a total PCE mass of approximately 140 pounds. Surface water samples in 2003 and 2008 were 996 ppb PCE and 31 ppb PCE, respectively. Through the years, the soil, subsurface soil, surface water and sediments contamination varied. Project objectives include remediation of groundwater exceeding the NJ Groundwater Quality

Standards for PCE (currently 1 ppb PCE). The NJ surface water quality standard is 0.34 ppb in fresh water. The NJ ecological screening criteria is 0.45 ppm for sediments.

For White Swan, the building, equipment, and larger septic system were removed as well as a total of 820 tons of surrounding soil. During removal, an additional 820 tons of PCE were removed. The source and soil removal at White Swan included 2 septic tanks, 1 seepage pit and 7,312 tons of soil. In 2016, a SVE system was installed at the Sun Cleaners property with 4 SVE wells, 15 air sparging (AS) wells, and 6 vapor monitoring points. As of March 1, 2022, from the SVE system, a total of 2,940 lbs of VOCs was removed from unsaturated zone soils. 800 homes in the area were contacted for indoor air sampling. To date, we completed 600 homes, installed 40 vapor mitigation systems venting vapors from beneath the foundation and 40 long term monitoring locations. A network of 60 monitoring wells were installed with locations and screen intervals derived from the groundwater field screening evaluation. Based on these results, 60 permanent monitoring wells at 21 locations as well as 6 piezometers and 6 stream gauges were installed to define the groundwater flow direction. The Far Field is generally between 1 ppb to 1,000 ppb with hot spots above 1,000 ppb. The installation of a P&T remedy will be implemented to isolate the residual continuing source area from the downgradient areas of the plume. As specified in the Remedial Design, groundwater extraction wells with a maximum influent flow rate of 200 gpm, in addition to existing commercial and municipal wells, will be installed at strategic locations within the PCE plume. MNA will be employed after hotspot PCE concentrations are reduced. MT3DMS groundwater modeling was utilized with the most conservative parameters from the sensitivity analysis suggests that slightly over 15 years of operation may be the worst-case scenario to achieve a maximum sitewide PCE concentration followed by MNA until sitewide concentrations reach NJ Groundwater Quality Standards.

It is anticipated that the groundwater treatment plant and MNA will remediate the site as SVE continues to operate and long term monitoring is conducted to ensure cleanup goals.

Keywords: Evaluation and remediation, chlorinated solvent plume, Groundwater Quality Standards

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Proven low-cost PFAS treatment: converting polluted aquifers into purifying filters

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The application of colloidal activated carbon (PlumeStop®) directly to polluted aquifers has proven to be a highly effective and low-cost method to eliminate the risk associated with PFAS contamination. Suspensions of activated carbon particles, milled to <2.0µm, are applied directly into the aquifer under low pressure, permanently coating the aquifer matrix. Once in place the carbon serves as a purifying filter adsorbing PFAS compounds from solution and retarding their movement. This successfully eliminates any down-gradient risk to human health and the environment. Modeling of resulting PFAS retardation within the treated subsurface zone indicates that a single injection of PlumeStop will eliminate the risk of PFAS movement and down-gradient exposure for decades.

At a US Department of Defense airfield site in the state of Michigan, USA, groundwater was polluted with perchloroethene (>6.0 µg/L) and PFAS constituents (>120 ng/L). A very controlled pilot study was undertaken by the US Dept of Defense to understand the effectiveness of PlumeStop to eliminate the movement and associated risk of the pollutants. Passive flux tracing tools were used to confirm groundwater velocity and contaminant flux throughout the vertical contaminated zone. PlumeStop was then injected under low pressure directly into the contamianted aquifer through the use of direct push technology. Required colloidal carbon distribution was confirmed. Modeling indicated that the single injection of PlumeStop should eliminate PFAS movment for >20 years time.

Within three months time after the injection of the PlumeStop colloidal activated carbon, the average concentration of PFAS contaminant species in all monitoirng wells declined to below detection levels. The average PCE concentration within all monitoring wells declined to below detection levels witnin 12 months' time.

Subsequent data collection over the course of 42 months has shown no increase in contaminant concentrations.

PlumeStop colloidal activated carbon can be injected directly into PFAS contaminated aquifers converting the aquifer itself into a purifying filter. By removing PFAS species from the groundwater to below detection levels, the remediation eliminates any risk to down-gradient receptors. This technique has now been successfully demonstrated on >25 project sites including a US EPA Superfund project, airport sites, industrial facilities and US Department of Defense sites.

Keywords: low-cost treatment, PFAS

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Improving permeable reactive zone performance outcomes through combining plume dimension analysis with passive flux meter studies

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Successful designs and application of In Situ Permeable Reactive Zone (IRZ's) requires an accurate set of inputs. Two of the most critical inputs to successful implementation and performance are accurate groundwater velocity and contaminant flux. Accurate measurements of groundwater velocity and contaminant mass flux zones are particularly important because they largely control the size and shape of the contaminant plume. It has become more apparent that contaminant plumes migrate through transport zone(s) comprising a small percentage of the overall aquifer thickness. Therefore, two critical elements are necessary to implement successful design and performance of an In Situ Permeable Reactive Zone (IRZ) 1) identify in detail each mass flux zone present in the Target Treatment Zone (TTZ) and 2) quantify each zone's contaminant mass flux and groundwater velocity. The flux rate of contaminants through an IRZ is largely driven by groundwater velocity; therefore, poor estimations of groundwater velocities can lead to significant variability in remedial designs and result in poor remedial outcomes. This presentation will address the notion of how groundwater velocity estimates are derived and introduce a novel way of obtaining more accurate velocity estimates using a method that correlates plume shape ratios to groundwater velocities obtained from passive flux meters (PFMs).

We will present data that demonstrates a strong correlation between a low-resolution analysis method referred to as a plume aspect or dispersion ratio (plume length ÷ plume width) and a high-resolution numerical method using passive flux meters. This analysis combines the two different methods to arrive at a site-specific groundwater velocity for 21 individual sites. Results to date demonstrate good correlation between the two methods. This discussion will also include analysis demonstrating significant differences between the

traditionally derived groundwater seepage velocities using field measured hydraulic conductivity and gradient versus the combined methods of plume aspect ratio and passive flux meters. One of the objectives of this work is to provide the industry with an easy-to-use predictive tool that can help calibrate and reality check traditional groundwater seepage velocity estimates for remedial designs.

Mounting evidence supports the notion that a significant difference exists between traditional estimates of seepage velocity and those derived from passive flux meters. PFMs provide a high-resolution method to accurately measure groundwater velocity and contaminant flux for IRZ designs. Analysis of the PFM velocities and contaminant plume shape indicate a strong relationship that can be directly correlated using a linear regression analysis. It appears that two different lines of evidence support the underlying groundwater velocity estimates. This linear relationship creates a reasonably accurate way to validate groundwater velocity estimates as well as function as a predictive tool at sites where PFMs have not been used. The resulting groundwater velocities using the plume aspect ratio method will optimize and improve designs as well as remedial outcomes.

Keywords: In Situ Permeable Reactive Zone, groundwater velocities

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Uncovering electrochemical removal mechanisms in the remediation of emerging organic contaminants from a clay soil

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Concerns about soil pollution are growing worldwide, can, severely degrading major ecosystem services provided by soils. A new class of compounds, the contaminants of emergent concern (CECs) that comprise a wide variety of chemical such as pharmaceuticals and personal care products (PPCPs), has emerged as the focus of many scientific publications. These compounds are prone to accumulate in soil, to hinder the food chain and to leach to ground and surface waters, carrying unexpected risks to the environment and human health. The development of novel electrokinetic (EC) technologies for the remediation of soils contaminated with CECs is a goal and is underway, but its mechanisms of action remain largely ignored.

The soil used (0–15 cm depth, 1 m2) was collected in an organic tomato plantation located in São Nicolau, Santarém, Portugal (39°12'42.6"N, 8°42'41.5"W). Prior to use, the soil was sieved (2.0 mm) to remove the coarse fractions, and its physiochemical characterization was undertaken, presenting a clay texture and a high contend of minerals and organic colloids. The microcosms set-up was designed in order to: (i) assess EC potential to enhance CECs removal without the use of a processing fluid, and (ii) disclose EC contribution to CECs decay. The soils were spiked with four CECs – sulfamethoxazole, ibuprofen, triclosan and caffeine – and their status (i.e. residual amounts and spatial distribution) evaluated at the seventh day of EC treatment at a defined current intensity, directionality and duration of void period.

The microcosm assays (graphite electrodes inserted in the soil; no electrolyte; spiking only at the central soil section; 7 days treatment)

allowed to hypothesize about some of the main mechanism involved in CECs removal. It was proposed that caffeine (virtually immobile) presents mostly electrochemical induced degradation when 12h OFF periods were followed by 12h of DC current application. This is probably related with the time needed for caffeine to suffer desorption from the soil particles (desorption coefficient logarithm is 2.87 and 3.89 for silt and sandy loam soils, respectively).
Sulphamethoxazole and triclosan degradation increases with water mobility (and possibly also soil microbes' mobility), with sulphamethoxazole biodegradation being favoured away from the electrodes . Thus, in both cases, if ON/OFF periods or polarity reversal is used, their degradation decreases. Under unidirectional constant current application, the high mobility of the CECs towards the electrodes contribute to their degradation (electro and bio).
However, near the electrodes soil pH suffers more pronounced changes which may negatively affect biodegradation around the electrodes , where CECs mostly undergo electrochemical degradation. Besides the direct and indirect electrochemical reactions, electro-degradation mechanisms may also be promoted further away from the electrodes, as the soil particles may act as micro-electrodes. Thus, CECs further away from the electrodes can also undergo redox reactions as a result of a wider electro-chemical degradation range. This effect is especially important if CECs with lower mobilization velocities, or even immobile compounds, are being treated. Still, very few studies focus in this degradation mechanism, and further studies are needed. The results obtained so far support that EC treatment is highly promising for the remediation of clay soils contaminated with CECs.

Keywords: electrochemical removal mechanisms, remediation of emerging organic contaminants, clay soil

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Forever chemicals captured and destroyed: PFAS selective ion exchange resin treatment

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PFAS Selective Single Pass Ion Exchange Resins for treatment of per- and polyfluoroalkyl substances are an affordable and established technology. Extensive piloting, modeling, dozens of treatment sites and hundreds of point-of-entry / point-of-use systems are using IX. PFAS selective resins have been developed specifically for drinking water applications over the past several years with great success.
In this very practical presentation, the audience will learn how PFAS Selective Single Pass Ion Exchange Resin has successfully brought contaminated water to non-detect for PFAS in drinking water at mulitple sites across the US. A review of lessons learned will also be conducted. Comparitive costs will also be provided.

We will show the process of going through the steps of design and modeling, piloting, and finally full-scale implementation for multiple drinking water sites with PFAS Selective Single Pass Ion Exchange Resin. The accuracy of the throughput models will be discussed.
We will discuss why ion exchange was chosen over alternative technologies for each site and review advantages and disadvantages of competitive technologies. Finally, we will discuss how buffered resins can be provided where there are corrosivity and chloride to sulfate mass ratio (CSMR) concerns.

As many sites have started using ion exchange resin for PFAS, there is much learning that can be shared. We will review design considerations and how they have translated to real-world full scale savings. We will share the (unwelcome) startup surprises and how they can be prevented. We will highlight six projects (some award-winning) and the best practices that have contributed to their success. PFAS Selective Single Pass Ion Exchange Resins demonstrate many cost saving advantages over competitive technologies including; smaller footprint which means lower capital costs, better removal of

more PFAS species, lower operational cost depending on water quality, and long throughput of the media. The systems are easy to run, and treatment to the low levels of PFAS required for drinking water is affordable.

Keywords: PFAS, selective ion exchange resin treatment

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Forever chemicals and climate change: physical risks assessment for pfas impacted sites

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PFAS are known as forever chemicals due to their extreme persistence in the environment. Their capacity to bioaccumulate and their high mobility has brought the international environmental agencies to set acceptable criteria in soil and water in the range of the Parts per trillion (PPT), whose descent to lower numbers seems not stabilized yet. For these reasons, the liabilities associated to PFAS impacted sites continue to increase in value and their legacy is in many case to stay there for a long time.

On the other side, climate is changing much faster than PFAS do. Global warming and climate change are becoming central for determining and managing environmental and social risks in projects. The Equator Principles (EP) is a risk management framework for financial institutions intended to provide a standard to support responsible risk decision-making, bringing together the largest international banks and in particular those lending to infrastructure projects.

For certain projects, the EP standards require to prepare a "climate change risk assessment" aimed at answering the following questions:

• What are the current and anticipated climate risks (transition and/or physical as defined by the Task Force on Climate-related Financial Disclosures) of the Project's operations?

• Does the client have plans, processes, policies and systems in place to manage these risks? i.e., to adapt, transfer, accept or control.

Within the context of the EP framework, considering that a large amount of PFAS legacy sites (fire-fighting training areas, landfills, industrial sites, contaminated land, often uncontained are in areas that may be affected by climate change impacts (such as groundwater table falling levels, soil erosion, extreme weather events, or sea level changes), the aim of our project was to implement a methodology to perform a physical risk assessment for different PFAS legacy sites,

according to different scenarios (Shared Socioeconomic Pathways and Representative Concentrations Pathways) and time periods.
The implementation was conducted taking into consideration well recognized institutions such as: Intergovernmental Panel for Climate Change (IPCC), the World Meteorological Organization (WMO), the European Commission (EC), the US Environmental Protection Agency (EPA) and the AU National Climate Change Adaptation Research Facility (NCCARF) amongst others.
The methodology is composed of two phases:
- phase 1: site characterization;
- phase 2: vulnerability and climatic risk assessment.
Phase 1 is a comprehensive characterization of the site, from historical climatic events and future projections to the complete recognition of geomorphological and hydrological features, passing from the characteristics of the remediation systems in place.
Phase 2 is based on the characterization (throughout a set of indicators) of all risk factors that contribute to assess both the vulnerability and the climatic risks. Such risk factors are then combined with specifically designed matrix operators in order to qualitatively evaluate the risk.
Applied to two case studies, the methodology showed how climate change would modify the risk of PFAS sites and affect the remediation practices, when already in place. It also provided useful indications on potential adaptation strategies and actions to undertake to reduce the risks.
Global warming is asking to introduce a key climatic perspective in the decision-making processes. Based on the outcomes of a climate change risk assessment, Golder aims at identifying elements of weakness and strength in Client's planning, addressing climate change impacts in short-, medium- and long-term scenarios. A first, important step toward adaptation strategies to anticipate climate impacts and to cope with uncertainties linked to the climate change, integrating resilience into remediation projects.
An effective PFAS sources management strategy, due to the persistence of these sources and impacts, requires to take a long lasting view, and requires considering the effects of climate change.

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On-site stabilization of PFAS contamination in volcanic ash soil using Rembind® – A case study in New Plymouth New Zealand

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PFAS contamination caused by historic electroplating activities has been treated by on-site stabilisation using the proprietary soil additive Rembind® .

The contamination with Poly- and Perfluoroalkyl Substances (PFAS) was present to a depth of approximately 3 meters at the locations of former chromium bath and trade waste interceptor. The source of the PFAS was the demisting additive used in the chromium bath which contained the heat resistent detergent Perfluorooctanesulfonic acid (PFOS).

Bench testing of the effectiveness of stabilisation with Rembind® was undertaken by ChemWaste, part of Enviro (NZ) Limited group. Tests were carried out with 1, 2, 4 and 8% Rembind®. Even at the 1 and 2% concentration Rembind® reduced the concentration of PFAS in the leachate to non-detect (<0.01 µg/L). Longterm stability has been demonstrated in a number of studies.

Based on the bench test result 300 Ton of soil contaminated with PFAS was treated with Rembind®. Due to operational constraints the blending was carried out in two stages. The first stage involved blending 1% Rembind® into the soil and during the second stage a further 0.7% Rembind® was blended into the soil. The purpose was to assess if full leaching control was reached with 1% or if not whether the additional 0.7% would achieve this goal.

The Rembind® is produced by Rembind Pty Ltd in Australia and distributed in New Zealand by EnviroWaste Services Limited.

The soil was blended and homogenised by rotary hoe prior to application of rembind. Blending of the Rembind® into the soil was also carried out using a rotary hoe. Samples of the soil were collected prior to the addition of Rembind® and after each stage of adding Rembind®.

The soil samples were analysed for total PFAS and Australian Standard Leaching Procedure (ASLP) tests (Australian Standard AS4439). This is the Australian/NZ leaching procedure which is conducted at both pH5 and un-buffered reagent water- approximating the “worst case” for leaching conditions. Which basically gives the best representation of a landfill condition for PFAS-contaminated materials to landfill.
All PFAS analyses were carried out by Eurofins Environmental Testing Australia Pty Ltd in Brisbane, QLD, Australia, using method: LTM-ORG-2100 Per- and Polyfluoroalkyl Substances (PFAS).

The 300 Ton of vulcanic ash soil contaminated with 58 mg/kg PFOS was succesfully treated on-site with Rembind®. The concentration in the leachate of the untreated soil was on average 0.55 µg/L.
After stabilisation with 1 % Rembind® the concentration in the leachate dropped to below 0.01 µg/L. The addition of 0.7 % Rembind® did not further reduce the PFAS concentration in the leachate; however, it increased the certainty of long term stability of the soil which is important to the regulatory authority.
On-site stabilisation of PFAS compounds in soil was succesfully achieved with Rembind®. The concentration of total PFAS compounds in the leachate was < 0.01 µg/L. On-site treatment is more sustainable than transporting the soil to a landfill.

Keywords: PFAS, volcanic ash soil, Rembind®

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Urban regeneration: managing complex social and regulatory challenges in Chile

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The regeneration of contaminated sites in urban centers is a relatively new topic in Chile – with limited regulatory guidance, no soil and groundwater quality regulations and a law that requires large remediation projects to be approved within the environmental impact assessment (EIA) system – using the same criteria as a thermoelectric plant or a mine site. These projects are approved by a commission that includes more than 20 agencies – the authorities reviewing the project generally have limited experience in human health risk assessment and remediation. Additionally, the EIA system includes a mandatory public consultation, which integrates community participation in the approval process.

Further complicating the process, there is not a direct link between environmental and urbanistic regulations – limiting the feasibility of considering engineering and/or administrative controls as part of a remediation strategy. As a result, issues related to residual contamination can restrict property transfer, force the property owner to resort to contractual obligations or use highly conservative remediation endpoints.

Consequently, the drivers for these projects are predominantly company reputational gains and sustainability goals, including the potential financial benefits from the urban redevelopment. Furthermore, the current sociopolitical climate in Chile is shaped by new expectations for public participation in decision-making regarding public and private projects.

In this challenging context, Antofagasta Railway Company (aka Ferrocarril de Antofagasta a Bolivia or FCAB) has gained approval for the risk-based remediation of their railyards located in the coastal city of Antofagasta that were impacted with heavy metals during more than 130 years operations. The remediation will be the first step towards the redevelopment of 48 hectares located in the heart of the

city – with plans to relocate their railyard operations outside of the city, complete the necessary remediation and facilitate the redevelopment of the property.
Following a detailed soil and groundwater investigation, impacts were identified primarily in shallow soils due to surface stockpiling of lead concentrates. Consequently, the remediation strategy considers excavation and offsite disposal – based on maximizing viability of the future redevelopment project and providing certainties for the local community. Stabilization and confinement were also considered but discarded based on the current regulatory framework, public perception and potential future use restrictions.
Antofagasta is in the heart of the Chilean mining country and has known issues related to the presence of heavy metals – mostly related to arsenic from high natural background levels and historical industrial activity in the region. Additionally, the railyards are completely surrounded by residential and commercial properties, resulting in a highly visible project with numerous stakeholders.
The project´s stakeholder engagement plan ensured that the strategy and overall goals were clearly communicated and feedback from the engagement process was incorporated into the project design. The plan included meetings, presentations, and workshops with authorities, community leaders, workers and neighbors and more than 1,000 people participated in the process. The stakeholder engagement plan will continue until project completion, ensuring transparency and building trust during all phases of the project.
The EIA was approved in June 2021. The project´s positive reception by the community and the authorities has shown that the strategy undertaken by FCAB, which focused on sustainable decision-making processes, a robust stakeholder engagement strategy and ensuring the long-term reputation of the company has been successful in overcoming the regulatory and social challenges that exist in Chile regarding remediation of contaminated land. The presentation will focus on how the unique regulatory and social challenges were overcome.

Keywords: Urban regeneration, Chile, arsenic

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Sustainable remediation projects that prioritise the reuse of resources as well as the circular economy

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Within the development of subsoil and aquifer remediation projects, Litoclean is focusing on sustainable remediation projects, trying to prioritise the reuse of resources from some facilities or valorising part or all of the waste recovered from the subsoil.

This abstract aims to highlight four successful cases of sustainable subsoil remediation systems that have enabled the reuse of resources or the recovery of wastes for subsequent reclamation, thus boosting the circular economy.

Of the various sustainable projects developed, four have been chosen that stand out for their high efficiency and success, combining both soil recuperation and reuse/recovery capacity. The results presented are summarised below:

1.- In the case of the improvement for multiphase extraction of light non-aqueous free phase of high viscosity by thermo-remediation, it has allowed to successfully carry out a predictably complex extraction due to the impossibility of implementing other more invasive measures because of the activity. Previously, laboratory and pilot tests were carried out successfully. The implementation and commissioning of the remediation system has made it possible to vary the aquifer conditions by an increase of 60ºC in actuation wells, and up to 30-40º Celsius in controlling wells and, to recover around 155 litres of fuel oil in 4 months of operation.

2.- Taking into account the problem generated by the contamination of 5,000m3 of production water, a project was proposed to reduce the contamination to a quality level suitable for a the fire defence system. Given that the contamination corresponded to light hydrocarbon chains, essentially aromatic, a water treatment system was proposed for the water vector by means of water stripping. From the pumping and treatment flow rates, concentrations, etc., a water air-stripping

system was assembled and commissioned. It was estimated that the system would have to perform at least three cycles of treatment. At least, there were performed five cycles and the results were clearly successful given that it was achieved reductions up to 95% of the contaminants

3.- In order to protect a vulnerable area from a possible arrival of Light non-aqueous free phase (LNAPL) aviation kerosene plume on the surface of the groundwater table, a hydraulic barrier was installed and operated using a combined pump & treat system and multi-phase extractions by means of high vacuum. The operation of this hydraulic barrier has allowed the recovery of 1,900,000l of pure jet, of which 57% (more than 1,000,000l) has been valorised again as diesel.

4.- For the remediation of a vulnerable and exploitable deep aquifer (groundwater at 80m depth) contaminated with light aromatic hydrocarbons in a petrochemical plant, it was necessary to design a system that would reuse the water within the production process due to limitations in the discharge flow. In this sense, the necessary treatment tests were designed to achieve the standard water quality values to be able to be reused. Thus, once the requested quality values have been achieved, the remediation project is elaborated, taking into account the characteristics of the site. The project is approved by the administration and is currently being implemented for its forthcoming commissioning.

Promoting sustainable remediation systems that aim to valorise waste or enhance the circular economy allows progress to be made towards environmental recovery in line with sustainable development horizons. There are ways to rethink subsoil remediation processes and, in this respect, there is a wide field to be explored. Clearly, soil decontamination must be at the forefront of rethinking in a more sustainable and circular way. Recent data and active projects show that this is possible.

Keywords: Sustainable remediation, circular economy, groundwater

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The state of the art toolbox for chlorinated solvent investigations: Smart combination of Enhanced MIP, targeted soil and groundwater sampling and the 3D conceptual site model

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Chlorinated solvents are known to be a major challenge in both the investigation and remediation of soil and groundwater contamination. Most problems and difficulties are related to inadequate investigation. This limitation arises from an underestimation of the complexity of the subsurface and the typical low resolution of soil and groundwater data. The distribution of DNAPL's (dense non aqueous phase liquids) is largely determined by the heterogeneous geology of the subsoil with subtle variations in properties influencing the migration pathways. Consequently, source and plume zones of DNAPL pollution often follow a very erratic course. When based on insufficient data points, uncertainties quickly creep into the Conceptual Sound Model (CSM) and the risk of incomplete, incorrect characterization and missing the contaminant plume is substantial.

Detailed and reliable information on the contamination is a key aspect to design an effective remediation. The daily output of a skilled drilling and sampling team that is providing geologic descriptions and collecting proper soil samples is not very high. And when it comes to sampling groundwater, a high vertical data density is absolutely impossible to

Today's site characterization toolbox also features High Resolution Site Characterization (HRSC) methods. In situ screening methods like MiHPT (Membrane Interface Probe + Hydraulic Profiling Too) are designed to provide higher data densities with a scale of measurement that is adopted to the scale of the geologic variations and resulting contaminant distribution. HRSC tools are capable of enhancing the data density in soil and groundwater investigations and can deliver usefull information to guide subsequent drilling and sampling efforts. With a combination of new and traditional methods a clearer

representation of the subsurface can be achieved and CSM's will move closer to the ground truth.
To increase sensitivity and selectivity of the conventional MIP system, the EnISSA method uses a modified GCMS system which is connected to the MIP. The advantages of using a GCMS detector, are the low intrinsic detection limits of the detector and the capabilities to measure individual compounds. Field evaluations demonstrated that the EnISSA MIP is capable of measuring soil and groundwater profiles for individual compounds with detection limits near 10-20 µg/l. Since individual components are measured below or near soil remediation standards, the applicability of the membrane interface probe has substantially increased. Both source and plume delineation are possible. The component specific soil profiles allow reliable "on site" decisions and a dynamic sampling strategy. 18 EnISSA MiHPT soundings to depths varying between 10 and 20 m-bgl have been performed. The high-resolution data on the site provided unique insights in the presence and distribution of the contaminants. With the EnISSA MiHPT field campaign a total of 585 GC-MS measurements of PCE, TCE, DCE and VC together with 233 logged meters with a 1.5 cm interval of EC and HPT data are collected
Modern visualization tools such as EVS allow for a clear representation of the data. By toggling through different data sets correlation can be oberserved or demonstrated in discussion with the project team or stakeholders. 3D visualisation tools can also support the calculations of contaminated volumes at different tresholds.
PCE was observed in the EnISSA-MIP profiles at variable depths in concentrations ranging from 10 to 6000 µg/L. The higher concentrations are observed in spikes of 30 cm. The core sampling shows the same high variability as concentrations ranges from 1 to 14 mg/kg in less than 0,5 meters. Biological degradation is not occurring. DCE and VC are not observed at the site. TCE is detected in only 1 MIP sounding at concentration levels <100 µg/L.
As a result of new data, a new remediation strategy has been developed (pinpointed ISCO injections). To accurately design the injection program an additional field campaign is scheduled which will triple the amount of data points on site. The outcome of this new campaign will also be presented at the conference.

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An accurate injection strategy by combining EnISSA-MIP data and the SPIN® injection technology

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A site located in East Flanders (Belgium) has been seriously contaminated with tetrachloroethylene. The contamination has spread both vertically and horizontally from the source. A remediation is planned as part of the redevelopment of the site into a residential area. To tackle the contamination, an excavation of the unsaturated source zone and an in-situ remediation by means of in-situ chemical oxidation (ISCO) in the saturated zone between 4 and 12 m-mv by direct injection are planned.

Fast and direct contact between the reagent and the contamination is essential for a successful ISCO remediation. Due to the heterogeneous geology of the subsoil with subtle variations in properties that control the distribution of the contamination, source and plume zones of DNAPL contamination often follow a very erratic course. To design an effective remediation, detailed information on the presence and distribution of the contamination is therefore a first key aspect. Subsequently the challenge is to get the reagent into the impacted (often less permeable) zone.

In situ chemical oxidation with permanganate as reagens was selected as most appropriate remediation method. During the investigation phase preceding the current remediation design, more than 1,000 soil analyses and more than 1,000 groundwater analyses had been performed.

In light of an ISCO remediation, that rudimentary description of the contamination led to overestimation of injection trajectories and uncertainty on horizontal distribution of injection positions. To optimize the remediation a High Resolution Site Characterization was performed using compound specific EnISSA-MIP soundings. By a direct coupling of amodified fast GC-MS method to the Membrane Interface Probe (MIP), detailed vertical depth profiles of the presence of individual compounds can be provided. At the project site 23 MiHPT soundings to 12 m-bgl were spread over a target area of

approximately 63 acres. The results confirmed that quasi no degradation occurred and the distribution of contamination in the groundwater is mainly PCE. Under the influence of the alternation of more and less permeable layers, the contamination spreads at different depths in a kind of waterfall pattern.

When performing traditional direct-push injections, problems often occur with daylighting of the injection product around the injection rods, through nearby monitoring wells or through the open borehole after the injection lances have been removed. Frequently, nor the exact depth nor the injection parameters are followed during conventional direct push injections As a final result, the injected product does not arrive at the desired location and the remediation efforts do not efficiently achieve the desired effect. Given that the aforementioned phenomena mainly occur in less permeable soil (layers) and in a heterogeneous soil structure, and given that for ISCO it is crucial to have the reagents come into direct contact with the contamination, it was decided for this project to carry out the direct injections using the SPIN® injection technology. The injection head specially developed by Injectis in combination with an infinitely variable pressure controller and the precise depth measurement on the machines, ensures accurate and precise injection of the reagents into the soil layers that exhibit a concentration above the predefined target decontamination value.

The HRSC field investigation delivered 3100 data points for PCE/TCE/DCE and VC and more than 18500 measurement for EC and permeability (HPT) each. Based on this data, an accurate estimate of the contamination contour could be made in an interactive 3D environment.

As a result of the addtional insight from HRSC investigation an accurate injection desig was made. Besides a 17% increase in the number of injection points to cover an increased contour in northern direction, a 53% reduction in the amount of injection meters was obtained. In addition to significant time savings, this also meant a sharp reduction in the amount of product required. Including the investment of additional HRSC investigation the overal remediation budget could be reduced by 30%. The data driven approach and targeted injection strategy resulted in not only a significant total remediation cost reduction butalso a reduced failure risk of the remediation effort.

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Photochemical degradation of contaminants of emerging concern in aqueous matrix

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Protection of fresh and salt water ecosystems through the reduction of toxic organic pollutants is certainly one of the cornerstones of EU environmental policy. In particular, the environmental pollution due to emerging contaminants, which include pharmaceuticals and personal care products is a global concern since these substances have been linked with numerous endocrine, reproductive, neurologic, and carcinogenic effects in biological systems. Therefore, it is mandatory to remove these substances from water.

The use of advanced oxidation processes (AOPs) has been demonstrated to be a possible approach for the remediation of contaminated waters. AOPs are based on the in situ production of free radical species, such as (OH●), which being a strong oxidant characterized by a very high standard reduction potential (E0 = +2.80 V vs. SHE) rapidly oxidizes electron-rich organic compounds up to their mineralization. Among the large variety of oxidation processes, photochemical methods offer the advantage of energy efficiency, rapidness and limited use of chemicals (oxidants), which together concur to the sustainability of the process. Different photocatalysts can be employed and among them, tungsten oxide (WO3, Egap ~ 2.7 eV) is suitable for photoxidation reactions. Efforts to increase the efficiency of WO3, by controlling its nanostructure through an optimized synthetic strategy, have been conducted to obtain extended electrochemically active surface, effective light harvesting and reasonably good charge transport and collection efficiencies. It has been reported that the hydrothermal/solvothermal synthetic approach is suitable for the scalable functionalization of different substrates with a photocatalytic coating having good mechanical stability. In this contribution, we report on the photoelectrochemical

degradation under visible light of pharmaceuticals of emerging environmental concern, frequently detected in natural waters. In particular, the removal of Drospirenone and Ethinylestradiol, which are extensively used in medical treatments and contraception, and Oxazepam, a short-to-intermediate-acting benzodiazepine, was investigated
Photooxidation tests were performed with a LED at 400 nm, by using solutions of Drospirenone and Ethinylestradiol and Oxazepam in MilliQ water. In the system used, water solutions recirculate through the tube filled with photocatalyst supported on glass beads. The irradiation was carried out for 6 h and solutions were sampled at different time and analyzed by HPLC-MS.

Spherical glass beads, where the yellowish color comes from the presence of a light scattering overcoat of photocatalytic WO3, were used to fill a lab scale flow reactor, where beads filling the glass tubes were illuminated by the 400 nm light generated by a LED strip coiled around the tube, resulting in the production of OH radicals by WO3. Water recirculates through the tube. We have preliminarily investigated the effect of the photocatalytic treatment on organic matter present in polluted water. The degree of organic contamination is generally expressed by the Chemical Oxygen Demand (COD). The water sample to treat was a real sample collected at the inlet of a waste water treatment plant, with a COD value of 220 mg L-1. It can be observed that the relative COD decreases of about 70% in 1 hour, thus indicating that the photocatalyst is fast and efficient in the decomposition of organic matter.
Contaminant solutions test show a substantial decrease (ca. 80%) of contaminant concentration consistent with photodegradation. By comparison, without illumination the contaminants do not undergo a substantial concentration reduction.

Keywords: Photochemical degradation, photoxidation,

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Inventory of leakages underground industrial pipelines

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On different industrial sites through Europe we received challenges on possible leakages in underground pipelines / sewage systems. The construction of these systems differs (different materials / depths / magnitude) and it transports different kind of liquids (water, solvents, waste, etc.). But in all these challenges the possible leakage had a threat to environmental impact or even safety issues. Environmental impact due to emitting solvents to the subsurface; safety issues due to leaching sand under construction and possible collapsing of industrial parts. Every location needs a tailor-made solution in detecting the locations of the leakage points, how to repair these systems and how to reduce the environmental impact done.

Due to the fact we encounter more of these challenges in time – we conducted an inventory on what possible threat it is to the total chemical industry.

Within public areas in the Netherlands the underground pipe network is due to an extensive change. Lots of the systems are built in the 50s /60s of last century and are at end-life time and needs to be replaced, in addition to this the energy transition needs a large requirement of new underground infrastructure. TAUW is receiving a lot of knowledge on these different kind of systems in the public area and see a shift happening to the industrial (private) sites.

On an industrial level, many chemical plants within our market segment (Europe) are also outdated and the underground pipes need to be replaced, more and more these pipes (especially in the Netherlands) have been placed above ground, but this is not yet the case with the necessary companies. The challenge in the public domain is great, but the potential (and the consequences for soil contamination, damage, unsafe situations) can be even greater for industrial sites.

To encounter the impact of these challenges we have made an inventory in which we used different kind of data on industrial sites in

Europe. The inventory focusses on highlighting outdated industrial pipes in various sectors. Where are the biggest opportunities? Where we use the classification of location-related risk and group risk and quantify & qualify the risks along the same line. The inventory follows the risk assessment (risk = probability x effect); An exact determination of the probability and consequence is often not possible due to the lack of statistical data for a specific situation. That is why, for example, to estimate the chances of failure (leakage), a so-called 'expert judgement' is used with a classification as small, medium or large probability. By then making an estimate of the consequences (the damage), the risk (= probability x consequence) can be determined. Specific attention needs to be paid to the situation in which one incident causes another: the domino effect. Based on this, we will set priorities for follow-up research. What kind of cable or pipeline, what kind of companies, perspective estimate, potential estimate?

This inventory helps us detect those industries with possible issue upcoming. Waiting until the leakages cause situations that needed to be highly priories', cause a lot of more (financial) impact on the continuation of the business. Earlier insights in future risk create room in planning, downgrading impact and staying compliant to authorities.

As mentioned, each construction has its own challenges – and therefore it needs a broad overview of possible technologies in detecting these kinds of leakages. Traditional technologies with camera-inspections or excavating surrounding soil are mostly used, but new technologies are developed in getting insight in these kinds of issue. The application of certain technologies is depending on the local situation. TAUW has a broad knowledge on (the development) of these kinds of technologies and are able to prioritize them into an action plan in which costs and speed are compared to changes of success and local impact. Our goal is to create that strategy that is most efficient in the situation of the industrial client.

In the presentation we will use concrete examples within projects where we have applied these types of technologies and where we have facilitated internal and external communication.

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Considerations within different digital communication techniques

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The idea of using digital technologies in communication has become more interesting and necessary due to the COVID-19 pandemic. Digital meetings are very common due to the obligation of working from home. In a short period of time it became normal to do our work as consultants remotely and this has inspired us to extent this remote working experience to connecting to our outside specialists in the field – like connecting to supervision work on industrial sites. Supervision of work traditionally requires presence at the remediation location, to check if the contractor works as planned, to adjust strategy in case of unexpected circumstances, to take samples in the excavation pit and to control the safety on the worksite.

Today, more and more technologies are becoming available on the market with which a certain part of the internal and external communication can be filled in, in recent years we as TAUW have tested the necessary techniques; such as standard video solutions with (for example with Whatsapp), more extensive possibilities with sharing images via TEAMS, but also specific technologies such as fixed ultra resolution camera systems, vGIS and Hololens 2. Recently, a new technology has been added with which information can be exchanged with specific voice-controlled glasses.
Based on the experiences we gain in our projects, we try to get a good grip on what the techniques are suitable for and how to implement them. Because that's what it's all about in the end – to be able to connect our employees and customers to the field staff. For them, the techniques are all similar – one perhaps more futuristic than the other – but in a general sense there is already a resistance to the use of the techniques in advance. This resistance is mainly caused by the fear that field staff have in the future development of these kinds of possibilities – the fear that these types of systems will completely take over the work. How you implement such a technique – whether it is a

simple or complex technology – is very decisive for the ultimate impact you can achieve. Our experience shows that it is extremely important to make everyone involved aware of the advantages and limitations of the different systems and that in every form the systems support the work of the field staff instead of replacing them.
With the presentation we want to make two aspects clear:
1. The differences within the available technologies with which we carry out internal and external communication and when we choose which technique:
•There is a variety of technologies available where a categorization can be made in which market segment it is suitable (so for what purpose is it intended), but there are also different providers of the same segment = > we select the provider that is most suitable for us (and the question of what is most suitable depending on the final use: fastest, robust, highest quality, cheapest, etc.).
• What added value does this technique offer in the execution?
• What future developments do we foresee?
2.Our experience on how to implement such techniques
• The technology is an important aspect of this development, but the added value of the technology is only used if it is used in the right way. Properly adopting the technology to the users is the most decisive in the entire implementation process
In the presentation we will use concrete examples within projects where we have applied these types of technologies and where we have facilitated internal and external communication. For the audience it is easy to understand which technologies for which reasons can be applied.

Digital Transformation provides us with a lot of new opportunities. The use of video's is not new in itself, but clever analysis of the data and integration of this information in the work flow of the supervisor provide new opportunities. Digital Transformation is not about making these kind of professions unnecessary, but to apply available technology to improve the quality and efficiency of our way of working.

Keywords: digital communication techniques

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High PFAS Values In Water – A Treatment Challenge?

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On military bases, airports and/or industrial sites contamination can occur which are caused by fire- extinguishing liquids that contain per- and polyfluoroalkyl substances (PFAS), such as aqueous film-forming foams (AFFF). Origin of these liquids can be spills or fire-fighting training events such as tests in hangars or in fire-training pits.

For understanding better composition and behaviour of such a liquid from a fire-fighting event, a fire was simulated in a vessel. Afterwards, a sample was taken from that liquid and more parameters were measured in the laboratory than usual. Not only PFAS but additional fluorine compounds (organically bound fluorine, capstones) and surfactants had been part of that analytical process. The results made obvious that more parameters play a role in such a liquid. Moreover, their concentrations can be far higher than the concentrations of PFAS in such a liquid.

Based on these early results, it seemed appropriate to further consider the treatability of such liquids. A column system was used to evaluate the treatment performance that granular activated carbon (GAC) and ion exchange resins (IX) can achieve. For this purpose, small-caliber columns (5 cm in diameter and 1 m tall) were filled with the corresponding materials. For filling hard coal (900 m2/g) and polystyrene crosslinked with divinylbenzene was used.

The objective of the test was first to determine the treatability in such a column unit at different concentrations of the premix (0.25, 0.5 & 1%). In a second step, the 1% premix solution was pre-treated before the liquid was pumped through the columns. A flocculent called PerfluorAd has pre-treated the solution. In this step, PerfluorAd connects to the PFAS in the water which generates a floc because the new molecule is larger and visible in the water. Since the water passes a bag filter, these flocs get removed before the liquid enters the column unit.

Investigations of the solution which was utilized for that test showed that a concentration of about 3.6 ppm PFAS (including CDPOS or Capstone B) were present in that liquid. The main components of PFAS

were 6:2 FTS with about 67% and Capstone B with about 31%. However, the concentrations of organically bonded fluorine in this solution were in the range of about 100 ppm. After feeding the cleaning stages, both the activated carbon and the ion exchanger showed a rapid increase in the effluent values for organically bound fluorine (about 60 to 70 mg/l) and also for PFAS (about 3 mg/l).
A repetition of the experiment involved pre-treating the water to remove part of the pollutant as particles by filtration and/or sedimentation. This revised approach produced the following results. The contents of organically bonded fluorine and PFAS were reduced by about 90.7% and 94.6% respectively after pre- treatment. However, the charging of carbon filters and ion exchangers with this pre-treated water did not result in a further reduction of the concentrations of organically bonded fluorine. Only the contents of PFAS were reduced from about 192 ppb in the pre-treated water to about 30 ppb in the effluent of the activated carbon and to about 83 ppb in the ion exchanger. The activated carbon filter showed a slight increase in effluent values after about 260 BV, but without reaching the inlet concentrations.
Results of these tests implicate that it can be difficult to treat water from fire-fighting training due to the additional compounds which can be present in the fire-fighting solution. These compounds consume space on the carbon bed and there is none left for the PFAS. This has generated a rapid and unpredictable breakthrough during this test.
On the other hand, a pre-treatment of such a water can generate a behaviour on the carbon bed (or resin) that allows a smooth operation of such a treatment system. Since the majority of both PFAS and additional fluorine compounds are removed in a filtration step before the water enters GAC and/or IX, there is space left for the PFAS.
Moreover, these data encouraged us to move into further applications in the field. The technology enabled both the cleaning of fire extinguishing systems (like fire-fighting trucks) and of the resulting rinse water as illustrated below. Furthermore, it was possible to treat 3500 m3 of fire-fighting water in the BeNeLux-region with a mobile treatment unit which was able to match the discharge criteria reliably.

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PFAS In Soil – Limitation and Solution in Germany

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Soil contamination with PFAS is an increasing problem in Germany. Excavation during the construction of Terminal 3 in Frankfurt illustrated this in the last years. This is made more difficult by the fact that no uniform regulation on the recycling and disposal of contaminated soil is yet in force.

In some cases, an EU regulation (EU 1342/2014) is adopted and this regulation, which applies to a concentration of PFOS in soil, is transferred to the sum of the determined PFAS in order to choose a conservative approach. The consequence of this classification is that at concentrations above 50 mg/kg PFAS it is no longer possible to landfill contaminated soil above ground. However, the possibility of disposal on a landfill requires, among other things, that a base seal is in place and that the leachate treatment plant is designed for the removal of PFAS. But however, the capacity for PFAS contaminated soil at landfills is limited. Alternative solutions are required.

Although capacity is limited, disposal on a landfill is still the preferred solution for PFAS soil. But soil washing gains in importance, but although results of that treatment technique can achieve the requirements in sand and gravel, fines limit the application. Therefore, considerations in which the contamination with PFAS is immobilised are gaining in importance. To achieve immobilisation of the PFAS, a powdered mixture of activated carbon, kaolin and amorphous aluminium hydroxide is intensely mixed with the contaminated soil with moisture added to 20%. After a reaction time of 24 hours, the immobilisation is complete, and the soil can be sampled. In order to determine the optimal approach for the addition, different amounts of powder are mixed to samples of the contaminated soil.

The extension of a gravel pit in Baden-Baden (D) reaches into horticultural areas where large-area contamination with PFAS was detected because of the application of compost with PFAS-containing sludge from the paper industry in the past. Soil from this area was treated with the powder in the laboratory and the concentration of the PFAS in the eluate was reduced from a maximum of 1.36 ppb PFOS

and 1.1 ppb PFOA to <0.01 for PFOS and 0.02 ppb for PFOA with the addition of about one percent by weight of the powder. But even at a dosing rate of 0.5 percent by weight (% w/w) the concentrations of PFAS in the eluate had been below target levels.
On an industrial site in Germany about 2,3 µg/l of PFAS (mainly PFOS and PFHxS) were detectable in the eluate of an excavated soil. The client showed interest in the immobilisation and therefore this method was tested in the laboratory first. The test showed that the application of 0,5 % of that powder brought the PFAS values in the eluate below the single detection limits.
Encouraged by these results, 200 tons of soil were treated in such a way in the field. The powder material arrived in big-bags and was applied on the surface of the soil pile. With an excavator soil and powder were slightly mixed before all the material was put into a screen trommel plant. After the reaction was completed, soil samples were taken and the concentration of PFAS in the treated soil was measured again in the laboratory. No PFAS had been detectable in the eluate of that sample.
Now, further tests will follow with that treated soil. The subject of the study is the long-term stability of the bond, although investigation results from other countries are already available in this regard.
Under normal circumstances, between 1 and 2 weight percent of RemBind are suitable to achieve an immobilisation of the PFAS in soil. Tests in advance with a representative soil sample from site allow the identification of the ideal dosage rate for the application in the field and it is possible to develop an idea on cost.
Immobilisation can be used to reduce the hazard category to allow safe landfill disposal. However, because landfill disposal is considered environmentally unsustainable and the capacity is limited anyway, the final target of such an immobilisation approach needs to be that the treated soil can remain on site for appropriate uses (e.g. noise barrier, beneath runway pavement).

Keywords: PFAS in soil, PFOS

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Soil gas emergency safety measures and environmental monitoring activities through multiple lines of evidence

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This study illustrates the emergency safety measures (Messa In Sicurezza d'Emergenza - MISE) on soil gas and the environmental monitoring activities through multiple lines of evidence, realized following pipeline break even caused by a intentional effraction. The area affected by the event, notified pursuant to Articles 249 (later converted to Art. 242) and 245 of Legislative Decree 152/06, is characterized by the presence of residential and commercial buildings, as well as underground structures such as sewers and underground services. Potential vapor migration pathways related to the sources of hydrocarbon contamination (spilled product: gasoline/diesel) are identified in surface soil, deep soil and groundwater, and there is presence of separated phase (LNAPLs).

MISE's interventions on soil gas consist of a vapor recovery system from purpose-built wells with action on residential underground structures such as building crawl spaces.

Environmental monitoring through multiple lines of evidence was initiated in order to monitor the effectiveness of MISE interventions and to verify and discriminate potential contributions of the notified contamination to observed concentrations, with specific reference to indoor ambient air quality at residential and commercial buildings near the spill area.

Soil gas and groundwater interventions with the Pump&Treat system implemented as MISE measures from the early stages made it possible, for residential and commercial buildings to continue to be used without interruption by activating daily monitoring of the environments and modulating it according to the evidence.

MISE's groundwater interventions have resulted in a gradual improvement of the hydrochemical situation to concentrations that are almost in compliance with the reference limits.
The analysis of the different lines of evidence shows how indoor concentrations, based on what has been observed at the soil, subsurface and ambient air levels, given the dependence of outdoor concentrations on different sources and linked to point, linear and diffuse emission sources present in the area of interest, given the absence of an obvious active volatilization pathway from dissolved/free phase or deep soil, are correlated with outdoor air quality, by virtue of a common matrix between indoors and outdoors, to which is added a component of indoor origin that derives from household products (detergents, deodorizers, fragrances, spray propellant gases), subject to potential accumulation phenomena, which are detected only inside the home or in the Flux Chamber (2,2,4,6,6-pentamethyl heptane compound) always traceable, also in the case of the Flux Chamber, to specific biocide and pest control products.
The analysis and correlation of the environmental data acquired through periodic monitoring and the study of chromatographic profiles, with identification of particular compounds and possible sources, allowed for assessments to be made regarding the existence of the potential vapor migration pathway and the composition of indoor ambient air, an aspect that is particularly critical because of the multiple sources contributing to it, not allowing for unambiguous discrimination of the source of contamination that determines the values found analytically.
In order to further deepen the assessment, with a view to remodeling MISE interventions on interstitial gases with specific reference to recovery from crawl spaces serving residential buildings, following evaluation by the relevant agencies, a specific test is being planned to be performed at the housing unit that will consist of indoor monitoring using a non-stationary storage flow chamber scout detector PID and IR to evaluate gaseous exchanges at specific localized points.

Keywords: Soil gas emergency safety measures, monitoring

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Malamocco-Marghera navigation channel (Venice lagoon): study of operational and structural solutions to achieve a sustainable navigation

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An advanced and multi-disciplinary study is ongoing aiming at identifying possible solutions to achieve sustaniable navigation along the Malamocco-Marghera Channel (hereafter MMC), in the Venice Lagoon, at the same time mitigating the erosion processes affecting the tidal flats surrounding the Channel achieving and maintaining safe navigation conditions. Following Public Tender procedures, North Adriatic Sea Port Authority – Ports of Venice And Chioggia assigned the study to a Consortium led by DHI S.r.l. and formed by DHI A/S, FORCE Technology, HS Marine S.r.l., Cetena S.p.a. and Around Water S.r.l.. The project activities fit into the “Channeling the Green Deal for Venice", a Connecting Europe Facility European funded project (2020-2023) that tackles the present limiteded navigational accessibility of the ports of Venice and Chioggia, fully respecting the environment and the Venice Lagoon. Moreover, seeking synergies between port sustainability and mitigation of human and climate change impacts on endangered habitats is part of the challenge. To achieve this ambitious goal, an integrated approach involving state-of-the-art modelling of navigation and meteomarine conditions including hydrodynamic / sediment transport processes was planned and implemented.

The development of an integrated modelling system (hydrodynamics + waves) capable of reconstructing, over a sufficiently long time and after proper calibration and validation, the spatial and temporal

distribution of the main meteo-marine variables of interest at lagoon scale formed a first and necessary milestone in the development of the study: an integrated 2D model of the entire lagoon, aiming at establishing, for one representative year, the spatial and temporal distribution of water levels, currents and wave conditions was implemented as a combination of DHI's MIKE 21 HD and MIKE 21 SW models.

The effect of navigation on the hydrodynamics and morphology of the MMC and surrounding areas primarily deals with two types of waves induced by passing vessels: primary waves (draw down) and secondary waves (Kelvin wake). Primary waves are bound displacement waves induced by the acceleration of the flow under and around the vessel hull. The secondary wave system consists of diverging and transverse waves in a restricted wedge-shaped region around the vessel.

In the MMC, primary waves showed greater importance than secondary (Kelvin) waves. Primary waves were simulated using a 3D hydrodynamic model (MIKE 3 HD FM) covering the MMC and surrounding areas. The passing vessel is simulated accurately as a moving pressure field boundary condition, where the pressure field is proportional to the draft of the vessel. The numerical model for simulating the draw-down, that has previously been successfully validated against physical model tests, was calibrated against wave data measured by CNR (August 2019 to February 2020) and against new wave data collected by HS Marine in a dedicated campaign.

The propagation of the secondary waves into the tidal flats was simulated using DHI's Spectral Wave model MIKE 21 SW. The implementation of the above modelling (for both primary and secondary waves) made it possible to assess the morphological impact of passing vessels on the nearby tidal flats based on sediment transport rates and sediment budget calculated during a series of events.

The candidate solution will be finally validated through a replication of the integrated and validated modelling system and the execution of additional full mission simulations.

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Remediation of contaminated land using phyotoremediation techniques

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Soil and sediment contamination has become a critical issue worldwide due to its great harm to the ecological environment and public health. One of the premium explosives manufacturing facilities in India, operational since 1958, has some environmental legacy issues. This site has four marshy areas – otherwise known as wetlands – located in the southern part of the premises, downstream of the manufacturing plants due to the topographical features of the areas. Most of the surface water discharged from the plant site passes through these marshy areas. Of the four marshy land areas, Marshy Land-1 (ML-1, around 1.2 acres of land) has consistently reported higher contaminant concentrations of nitrate, nitrite, ammonia, perchlorate, and lead ('Contaminants of Concern'). As a result, the ML-1 area requires remediation with the objective of eliminating or significantly reducing potential shallow groundwater contamination due to surface water runoff and infiltration. The site has developed a conceptual site model (CSM), which revealed that surface water is a primary mode of contaminant transport from the site. Remediation techniques may include a combination of constructed engineered wetland approaches and phytoremediation using indigenous plant species. The plant species are planted in different layers of soil to uptake the contaminants of concern and related nutrients. Several factors influence this phytoremediation process, including types of contaminants, pollutant characteristics, plant species selection, climate considerations, flooding and ageing, the effect of micro & macronutrients, soil parameters, and redox potential. Phytoremediation's environmental and economic efficiency, use, and relevance are described in this work.

Prior to implementing comprehensive ML-1 remediation works, the site installed a series of 12 check dams (as part of the micro-watershed management) in the monsoon gullies upstream of the ML-1 area to

aid in reducing monsoon runoff and detaining water upstream of ML-1. It is estimated that the relatively uncontaminated (fresh rainwater) runoff from upstream areas represents approximately two-thirds of the volume of the total ML-1 runoff. It was identified that preventing/slowing/diverting the upstream runoff would significantly (a) reduce the contaminant mass flux through and out of ML-1 and (b) increase the residence time in the catchment ponds thus enhancing phytoremediation processes.

Following the first harvest cycle in April 2022, the site team assessed the uptake efficacy of the selected plant species and estimated the equivalent of 485 kg of ammonium nitrate (NH_4NO_3) uptake by the harvested shoots/leaves from the contaminated soils/ sediments, and surface water, shallow aquifer/void zone. It is expected that three harvesting cycles will be done in a year. So, as estimated, around more than 1.5 tons equivalent of ammonium nitrate is expected to be remediated in a year. Also, as an additional benefit of this approach, more than 25 tons of carbon dioxide will be captured/sequestered. Similarly, Phyto-stabilization in the root zone is significantly reducing the mobility of lead and preventing its runoff through surface water, migration to groundwater (leaching) or entry into the food chain. It has also been observed that an estimated 12 kg of perchlorate was removed from sediments/soil by Phytoextraction to reduce the concentration of perchlorate in surface water discharge and shallow groundwater.

It is evident that Phytoremediation has the advantage of restoring balance in a stressful environment, but it is important to implement it carefully. This approach can reduce contaminants in both soil and water. It is a low cost and environmentally friendly remediation alternative to more traditional methods. The results already obtained indicate that the selected indigenous species are effective and can be used to remediate soil and shallow groundwater for many contaminants of concern in tropical climates.

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Combining high-resolution characterization and monitoring with statistical methods: a proposal to overcome the limitations of traditional methods

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Traditional characterization methods, such as borehole loggingand laboratory analysis of soil and groundwater samples, are commonly used to define the geological structure and the extent of soil and groundwater contamination. Multi-media sample collection through multiple campaigns is normally required to achieve a satisfactory vertical profile of contamination, all with high costs and long times.
This study proposes a protocol for high-resolution site characterization by means of Membrane interface probe (MiHPT) and Optical Image Profiler (OIP) logs to evaluate the geological structure and the spatial distribution of organic contaminants on the basis of several case studies. In addition to these technologies, data from geophysical mapping (electrical conductivity) were used both before and concurrently to direct probing locations and constrain the survey area extension. In the three sites described, a high-resolution subsurface conceptual model has been obtained with a significantly greater accuracy than that attainable with traditional characterization procedures and with cost savings of up to 30%-40% compared to traditional procedures. As in each study site a single campaign was carried out to identify the contamination sources, significant time savings were obtained compared to traditional methods which always require, for sites of medium to high extension and complexity, several successive investigation campaigns.
The protocol has been refined based on the experience gained in the three sites where it has been applied, and we consider it mature enough to be proposed as a standard for investigating contaminated sites. We aim at proposing a methodology that overcomes limitations in the Italian law on the applicable techniques for data acquisition in contaminated sites. If compliant with the law and proved superior to

standard methods, public administrations will be allowed to request the new approach and approve its results.
MiHPT and the OIP technologies offered significant advantages over traditional investigation methods in all three test sites and yielded pivotal data to a full high-resolution subsurface characterization. Data obtained from the MiHPT and OIP are considered as screening-level data and need to be supplemented with analytical data from a small number of calibration boreholes. This number is around 35% of the boreholes required by standard characterization procedures.
Cost-benefit analysis shows that the application of MiHPT/OIP allows to obtain an accurate and reliable subsurface model with cost savings up to 30%-40% compared to traditional methods aiming at a comparable accuracy (i.e., same number of boreholes, each with 1 m vertical sampling interval). Moreover, the technology allows to collect real-time data, enabling a constant revision and update of the conceptual model. In turn, the investigation plan can be iteratively adjusted to pursue the best efficiency of collected data. This can save significant costs as the investigation fits real site conditions.
Moreover, these technologies can be easily applied, in agreement with Environmental Agencies, in active sites with ongoing remediation projects to fully support risk analysis and remediation strategies. In this context, the proposed protocol aims at turning the spotlight on the need to standardize the application of the described technologies for contaminated site management (i.e. site characterization, periodical monitoring, etc.). If compliant with the law and proved superior to standard methods, public administrations will be allowed to request the new approach and approve its results. Finally, this protocol complies with regulations issued by some local authorities (e.g. Veneto and Emilia-Romagna) which specifically refer to high-resolution characterization.

Keywords: high-resolution characterization, periodical monitoring, MiHPT and the OIP technologies

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Mercury in European river bed sediments and climate change

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Practically all European countries have committed themselves to the minimization of mercury releases when signing the „Minamata Convention“. Further obligations for mercury emission reduction also result from marine protection regulations as the OSPAR and HELCOM Convention, from the UNECE Heavy Metal Protocol and the EU Water Framework Directive, as well as from the EU Industrial Emissions Directive and its related BAT Reference Documents. According to the EEA mercury report mercury presents the biggest risk in rivers, lakes and oceans where it often is present in the most toxic methylmercury form that is readily absorbed by animals, including fish and bioaccumulates further in the aquatic foodchain.

The European Water Framework Directive, which has been adopted by the national legislation of the EU member states, defines the chemical status of water bodies by complying with environmental quality standards (EQS) for some selected chemicals. And yet, some of the regulated parameters typically do not show any exceedance of EQS in European water bodies at present. Other substances are found to cause environmental hazards and the monitoring list is therefore regularly updated. Since there are also some new findings on the potential for water hazards, environmental quality standards are regularly reviewed and changed. In 2013, the specifications for some substances were changed in the Environmental Quality Standard Directive and standards were set for other substances.

Consequently, the European Water Framework Directive requires member states to assess the chemical and ecological status of water bodies. The assessment is based on the EQS Directive (2008/105/EG, amended by 2013/39/EU), which defines the EQS for substances and groups of substances for EU water policy that are valid in all EU countries. The EQS for mercury is defined at 70 ng/L maximum allowable concentration in the water phase and at 20 µg/kg in biota.

These values were derived to protect birds and mammals that feed on fish (e.g. osprey and otter). However, the situation for mercury is different. In Germany, for example, mercury (as also polybrominated diphenyl ethers, BDE) presents a practically ubiquitous problem in the surface water. This is in line with findings from many of the other EU member states: recent monitoring data show that out of approximately 111.000 surface water bodies in the EU nearly 46.000 are not meeting mercury levels set to protect fish-eating birds and mammals (EEA 2018).

Due to the bioaccumulating and toxic properties of mercury, in particular of methylmercury, bioaccumulation and biomagnification of mercury in aquatic and terrestrial foodwebs following these flooding events play an increasing role in the global mercury cycle. Via consumption of animal products and crops bioaccumulated mercury will eventually also lead to human health exposure. Reduction of ecological/human health risks is often the main driver for contaminated site management of mercury contaminated sites/areas. In order to effectively reduce ecological/human risks, human health risk assessment (HHRA) and ecological risk assessment (ERA) are necessary and powerful tools which need to be incorporated in the decision making and design phase for (cost)effective mitigation/ remedial measures. It enables to derive realistic and clear goals, targets and evaluation frameworks.

In our presentation we will discuss the fate & transport and the environmental risks of mercury in fluvial systems in Europe with particular regard to the increased environmental risks of heavy flood events. We will focus on the role of historcial sediment deposits in river courses, backwaters and floodplain soils. Systematic approaches to investigating the mercury inventories and their dislocation in flood events will be presented along with monitoring and analysis of the transport patterns under different hydraulic conditions. We will illustrate this with a number of cases from sites in Spain and the Netherlands. These detailed mapping and inventory studies in our opinion provide essential input for the following risk assessment and risk management steps in order to improve the chemical and ecological status of water bodies.

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Thermal Treatment of PFAS Impacted Soil – Field Demonstration and Scale-Up Considerations

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Soils contaminated by per- and polyfluoroalkyl substances (PFAS) present a unique challenge because the options for treatment are extremely limited. Excavation and off-site disposal/treatment is problematic because the liability for the PFAS contaminants present in soil, and off-site treatment options are uncertain. Even thermal destruction in soil burners may be problematic due to the potential formation of byproducts.

Laboratory-scale thermal treatment studies using PFAS-impacted solids at temperatures be-tween 350 and 400°C have shown great promise; all 28 targeted PFAS compounds were effectively re-moved to near non-detect concentrations. This finding is consistent between studies performed by the TRS Group, Jacobs Engineering, and Kruger. To date, no field-scale demonstrations of thermal treatment of PFAS-impacted soils have been completed.

A field demonstration was conducted on a stockpile of PFAS-impacted soils in Alaska to demonstrate thermal remediation as an effective technology for perfluoroalkyl and polyfluoroalkyl substances (PFAS) removal from ex situ soil stockpiles.

Eielson Air Force Base in Alaska has approximately 150,000 cubic yards of PFAS-laden soils stored in 52 above-grade piles. With funding from the United States Department of Defense, a small pile was treated on site in 2021. Activities included:

• Laboratory soil heating studies – including experiments designed to look for non-targeted compounds and potential by-products formed during heating

• Field demonstration of thermal conduction heating (TCH) in one stockpile using 48 heaters and nine soil vapor extraction wells; a three-month-long operation which brought the soil to temperatures above 350°C

• Extraction of vapors and on-site treatment using cooling, condensation, and granular activated carbon
• Soil sampling and determination of PFAS concentrations before and after treatment

As the first field-scale PFAS soil thermal treatment demonstration, the project focused on providing a detailed understanding of the process. The detailed sampling and analysis demonstrated PFAS reductions and served to identify the fate of precursors and by-products. As part of the off-gas sampling effort, the new U.S. EPA OTM-45 vapor sampling method was deployed.

The TCH field demonstration operated during the fourth quarter of 2021 in Alaska. Despite the very cold ambient temperatures (-38°C), the average stockpile temperature at the end of the demonstration was 413°C with a maximum recorded temperature of 482°C.

The chart below compares baseline and confirmatory sample results for PFOA in the stockpile. All post treatment samples were below PFOA detection limits.

Significant reductions in PFOS concentrations were observed, as well. The comparison of baseline and confirmatory PFOS concentrations are presented int he following chart.

Although operating in Alaska during winter months was challenging, the TCH ex-situ field demonstration was successful and confirmed the previous bench test results. There were significant reductions of PFAS concentrations in soil. Extracted vapors were recovered and treated. The technology is scalable and is more economical with larger treatment volumes.

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Improving site management sustainability and remediation effectiveness by utilizing more robust conceptual site models

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Site management strategies, remediation sustainability, and effectiveness rely on the quality and density of data provided to create a conceptual site model (CSM). Previous studies point out that management decisions must be based on reliable environmental information to achieve remedial goals and promote site re-development(Guilbeault et al., 2005; Souto et al., 2020; Suthersan et al., 2015; WHO, 2021).

This paper showcases the management process of a site impacted by petroleum hydrocarbons and the changes in the strategies used, from investigation to remedial update to increase efficacy and sustainability. The site was under investigation and remediation since 2005 without achieving remedial goals. The investigation process used the combination of the High-Resolution Site Characterization and TRIAD strategies to better assess the overall impacted area and its tridimensional extensions. It also included the appropriate legal framework stablished for the state of São Paulo, Brazil, which states that the different phases of contamination must be properly assessed so that the impacted environment might be restored following legal standards. After the completion of the investigation the remediation strategy was upgraded and optimized.

The new remediation approach first objective was to optimize the well screen positions, based on the data from the hydraulic profiling tool (HPT) and the optical image profiler (OiHPT) data results. Then, the new pump and treat systems recovered more than 9 thousand liters of LNAPL in the same time spam. Moreover, a new remediation and management approach was suggested to increase the sustainability of the project with the use of a combination of approaches, which enabled the stakeholders and legal authorities to conduct the process in a timely manner with a predictable end point at sight which

encompassed the proper application and completion of the applicable legal framework.
A new OiHPT field campaign was used to evaluate the extension of the LNAPL impacted area after this new period of extraction. The impacted area decreased by one-third in area, fluorescence readings decreased from a maximum of 100% in 2019 to 14% in 2021, which indicates that the mass of contaminant present in the area also was significantly smaller.
This study shows that the combination of a dense investigation approach, HRSC and TRIAD in this case, allows the construction of management strategies aimed at defining sustainable solutions to remediate contaminated sites. Even though excavation generates a higher immediate environmental impact, it is a more sustainable approach when its efficiency of mass removal is put into perspective.
In Brazil, especially in the state of São Paulo, remedial actions which focus on mass removal or destruction are mandatory whenever possible, instead of mitigatory, long term management solutions that do not necessarily remove contaminant mass or its risk to natural resources or human health. Upon the use of dense investigation strategies, these more robust remedial strategies can be used and adopted to promote the application of sustainable remediation methods that can have measurable success rates, prior, during, and after its deployment.
Remediation strategies, when aimed at sustainability, have to be focused on integrally managing the contamination mass, targeting its removal or destruction whenever possible, to have its effectiveness measured. Long term mitigation strategies might use less energy and have a smaller footprint. However, considering the fact that the mass of contamination is not being removed/destroyed, the length of its maintenance and efforts results in a lesser sustainable approach as it does not recover the environment or eliminate the risk to natural resources or human health. Moreover, the long-term inefficacy shifts the perspective towards more punctual and precise remedial approaches that address the contamination impacts at any given site based on denser data sets that mitigate the higher footprint and promote real sustainability for long term site management and restoration.

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Valutazione della variabilità oraria delle caratteristiche chimico-fisiche del soil gas in un campo prova ubicato all'interno del SIN di Venezia

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In un campo prova ubicato all'interno del Petrolchimico di Porto Marghera – Venezia, così come in altri siti esterni al SIN, è stata studiata la variabilità temporale nel breve termine delle caratteristiche chimico-fisiche del soil gas attraverso misure in continuo, campionamenti seguiti da analisi di laboratorio e misure ripetute con strumenti automatici da campo. Conoscere la variabilità oraria delle caratteristiche del soil gas risulta fondamentale per contestualizzare la misura e definire correttamente modalità e durata del campionamento, i cui risultati sono frequentemente impiegati per la verifica del rischio derivante da esposizioni di lungo termine ai composti volatili presenti nel sottosuolo.

All'interno di sonde per il monitoraggio del soil gas (micropiezometri fenestrati nella zona vadosa) sono stati installati un PID e un misuratore di pressione differenziale predisposti per misure in continuo. Nelle stesse sonde sono stati prelevati campioni di soil gas con canister in vetro (vacuum bottle) da destinare alla successiva analisi di laboratorio e sono state effettuate misure con strumenti automatici da campo. I campionamenti sono stati condotti a intervalli di tempo ravvicinati, scelti sulla base di una analisi statistica preliminare dei dati meteorologici disponibili.

Le misure condotte nell'ambito della sperimentazione hanno evidenziato come sia le concentrazioni dei composti organici volatili (COV) nel soil gas sia la pressione differenziale fra soil gas e aria presentino una variazione ciclica nelle 24h al netto delle variazioni indotte sul sistema dalle evoluzioni meteorologiche (precipitazioni, fronti di bassa pressione…) . Le misure condotte, sia con la

strumentazione aspecifica in continuo, sia con campionamenti attivi, sembrano evidenziare una notevole influenza delle dinamiche all'interfaccia suolo-atmosfera sulla forzante barometrica (barometric pumping) e quindi sulle concentrazioni di COV nel soil gas, indicando l'importanza della misurazione del differenziale di pressione fra queste due matrici per la corretta interpretazione dei risultati dei monitoraggi.

Keywords: soil gas, pressione differenziale, COV

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Advanced Vapor Intrusion Mitigation Methodologies for Complex Subsurface Conditions

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Over the past two decades, the intrusion of contaminated soil gas into existing and new-construction residential, commercial, and industrial buildings has gained the attention of the scientific community and environmental industry worldwide. Complex sub-slab environments, slab-on-grade foundations and anisotropic heterogeneous geologic settings, and varying fate and partitioning behavior of organic contaminants have necessitated the development of innovative vapor intrusion mitigation strategies. Such strategies include vapor mitigation systems that actively collect and treat contaminated vapors, providing added remedial benefit while also protecting human health. However, with active systems come challenges and complexities that must be considered during their design. This presentation provides insight into several unique, yet common, site constraints that add complexity when designing an effective vapor mitigation system and provides two case studies that demonstrate techniques that can be used to overcome the constraints.

The importance of these principles and design specifications will be discussed through the use of the following case studies:

• In San Jose, California, a site presented several constraints, including a shallow water table, a sub-slab silty clay formation, anisotropic geologic conditions, and extremely high level chlorinated volatile organic compound (VOC) vapor impacts inside five residential buildings from a nearby industrial chemical storage site. However, innovative design using adjustable manifold piping, control interlocks, automated subsurface water level and pressure sensors, and a remote telemetry system provided adequate vacuum propagation through a SVE system, while reducing the amount of water collected. The SVE system was specifically designed to mitigate vapor intrusion inside the residential buildings while concurrently reducing the VOC mass present in the vadose and capillary fringe zones. 2D and 3D pneumatic

modeling was performed using the pilot test data to determine the key SVE design parameters both for the vapor intrusion mitigation and VOC mass/source removal perspectives.

• In the City of Yakima, Washington, a full-scale sub-slab depressurization system (SSDS) in the form of a barrier SVE has been designed and installed and has been effectively operating, comprising two separate slab-on-grade areas, each with different subsurface air intrinsic permeabilities. The site consists of a former oil distribution facility with two adjoining business buildings with non-aqueous phase liquid (NAPL) presence in the subsurface and elevated indoor air and soil vapor VOC and petroleum hydrocarbon concentrations. The barrier SVE system was designed and installed outside the two business buildings to provide sub-slab depressurization underneath the building slabs for vapor intrusion mitigation purposes, given the restricted access inside the business buildings. 2D and 3D pneumatic modeling was performed to determine the key SVE design parameters. The SSDS was designed such that the number of active vapor extraction points (VEPs) and required vacuum and air flow rates could be uniquely controlled for each building and for each VEP, fully automatedly and remotely. Real-time continuous indoor air and sub-slab soil vapor monitoring systems were installed in each building to automatedly control the blowers speed via VFDs in response to the barometric pressure fluctuations, sub-slab vacuum propagation variations, and contaminant soil vapor concentrations. Operational data of the systems as well as the indoor air and sub-slab soil vapor concentrations are monitored in real-time via a remote telemetry system. Such automated vapor mitigation systems can be highly cost effective, energy efficient, and sustainable over the operational life of these systems.

These case studies take an in-depth look at the existing subsurface constraints of each site and the steps taken to overcome the limitations these constraints could have potentially imposed on the effectiveness of the mitigation system. In addition, the remedial effectiveness of each system will be demonstrated through analytical data collected before and during system operation.

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Pile Foundation Options for Development Over Landfill Sites and Their Environmental Impacts

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This absutract describes the main issues in pile foundation design involved in new construction and infrastructure development on the top of existing closed landfill sites necessitated in the urban areas today. As it is known, landfill itself is of different nature, and shows different behavior, when it is closed municipal sanitary landfill, construction debris, toxic or hazardous waste landfill, and causes different possible effects on pile foundations that are constructed to transfer loads from the desired new construction and any infrastructural development running through the landfill refuse down into the underlying soil strata. Landfill sites can undergo significant settlement caused by the decomposition, consolidation, and compression of the landfill material due to the weight of landfill refuse, existing cover soil, and new fill and/or structural loads associated with the proposed development over landfills. This presentation discusses the present state of the art assembled through a number of on ground case studies and suggests a systematic approach that can be developed into the pile foundation design guidelines involving challenges of advanced concrete technology, steel corrosion protection, environmental, geotechnical, site civil, and chemical considerations and the science of landfill characteristics.

To reduce the potential for settlement of proposed buildings, utility corridors and surface improvements, the proposed structures can be supported on the aforementioned pile types with or without the deep dynamic compaction techniques. These pile options are designed to address the potential for landfill disturbance and preserve the integrity of the landfill components and the structures built as part of the proposed development in a manner that is protective of public health and safety and the environment. For each pile options, the recommended embedded length into the underlaying native soil, vertical and lateral capacities, including the effects of down-drag and

settlement on the capacities and the amount of reinforcing steel necessary to resist lateral loads and resulting bending moments will be discussed.

The presentation evaluates the potential of landfill of attacking the concrete due to its chloride (Cl-), sulfate (SO42-), carbon dioxide (CO2) and methane (CH4) content and steel sheet piles due to its corrosive environment [i.e., presence of sulfur-based corrosive gases like hydrogen sulfide (H2S) which can be microbially converted to sulfuric acid (H2SO4), thus producing low pH environments]. The landfill gas emissions and potential migration of gases associated with each of the pile options are considered as well. Other environmental impact considerations for each pile options include:

• the potential for vertical and lateral displacement of soil, refuse, leachate, and groundwater,

• the potential for transport of leachate to groundwater,

• lateral displacement and densification of surrounding soil and refuse,

• the amount of soil and refuse cuttings generated and require handling and management during drilling and pile deployment,

• the ability to prevent voids from forming, and

• the potential for landfill materials (refuse, leachate, and landfill gas) and impacted groundwater to penetrate into the underlaying native soils and aquifers.

For example, for the DDP and ACIP options, because the grout/concrete is injected under relatively high pressure, the grout/concrete penetrates into the voids in refuse and soil surrounding the pile, thereby effectively sealing the interface between the pile and the adjacent soil and refuse and reducing the potential for introducing landfill materials and impacted groundwater into the underlying aquifers both during and after construction. This process helps eliminate the potential for a preferential seepage path along the pile/soil contact. This process also helps prevent the potential landfill gas migration vertically upward and uncontrolled surface emissions through the pile/soil interface.

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In-Situ Thermal Remediation of DNAPL under a Former Manufacturing Facility

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In the period 2017-2019, TRS Europe performed a guaranteed fixed price in situ thermal remediation (ISTR) to address a dense non-aqueous phase liquid (DNAPL) impacted source area at a former manufacturing facility in the Saône-et-Loire department, France. The soil and groundwater beneath the Site had been contaminated by chlorinated volatile organic compounds (CVOCs), namely Tetra-chloroethylene (PCE), Trichloroethylene (TCE), and daughter products. TRS Europe provided a guar-anteed reduction of CVOC concentration in soil to an average of 5 milligrams per kilogram (mg/kg dm) or less, with no soil sample with CVOC concentrations above 10 mg/kg and 90 percent of all samples below 5 mg/kg. During the design and project planning phase, careful consideration was given not only to potential technical obstacles, but also to logistical challenges and the assembly of a cohesive multi-national project team, which would prove critical to the success of the project.

The project team made the following observation based on the data collected before, during, and after the ERH remediation at the Site:

- Average pre-ERH CVOC soil concentrations were approximately 3.364 mg/kg (PCE). Confirmatory sampling indicated that post-ERH soil CVOC concentrations had been reduced to an average 0,56 mg/kg, a reduction from baseline concentrations of approximately 99,98 percent.
- 98 soil samples had CVOC concentrations below the average remediation target of 5 mg/kg. Two soil samples had concentrations between 5 mg/kg and 10 mg/kg.
- The guaranteed soil goals were met.
- Based on regular laboratory analysis of vapor effluent recovered during ERH operations, an estimated 35.383 kg of CVOCs were removed from the treatment volume during ERH remediation.

• A total of 6.009.105 kWh of energy were applied to the ERH treatment volume over the course 341 days. The amount of energy to achieve the remediation goals was less than the design estimate resulting in a cost savings to the client.
• Subsurface temperatures increased from a baseline temperature of 15,4ºC to an average high temperature of 97,4ºC. The maximum recorded individual temperature within the treatment volume was 129ºC, at location TMP-G24 at 9,5 m bgs.
• No injuries or lost time incidents occurred during the project.

While technical difficulties were certainly encountered during the project, addressing the following challenges also proved instrumental to achieve project success:
• Staffing with international teams required additional planning and attention to ensure a continuous flow of information between project team members and the client. Clear and concise communication proved pivotal to the success of this project.
• Local utility regulations, previously unknown to the project team, at one point threatened the progress of the project. Understanding the regulatory frameworks within a country and region where the project takes place is essential.
• Project designs with specific or specialized materials require additional time for procurement. Material availability can vary greatly between countries and regions.

ERH application at the site proved extremely effective at reducing DNAPL and CVOC soil concentrations, with a 99,98% reduction of CVOC soil concentrations from baseline. The ERH remediation was successfully implemented adjacent to and underneath a former manufacturing facility. An important component to project success was establishing relationships with local staff and consultants and leveraging the international team member's strengths.

Keywords: In-Situ Thermal Remediation, DNAPL

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Functionalization of carbon-based materials for Critical Raw Materials (CRMs) removal from aqueous solution

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Critical raw materials (CRMs) are a list of 30 elements considered critical because of their economic importance and high supply risk (COM (2020) 474 final). Critical raw materials are essential prerequisites for the development of strategic sectors such as renewable energy, electric mobility, digital technologies, defense and aerospace (Bobba et al., 2020). In January 2018, the European Commission published a report highlighting the potential for a more circular usage of CRMs in our economy (EC, 2018).

The recovery of elements from wastewater can be achieved with various treatments, including ion exchange, membrane technologies, coagulation/flocculation, electrocoagulation, and adsorption. Among them, adsorption is the most successful and promising way to remove elements from wastewater, owing to its easy implementation, cost-effectiveness, high availability and high removal efficiencies even at low metal concentrations (Park et al., 2016; Yagmur Goren et al., 2022). Moreover, adsorption can avoid the potential release of secondary pollutants to the environment, since it does not involve chemical or organic solvents and allows the reuse of both adsorbate and adsorbent (Perez et al., 2019).

The most widely-used adsorbents are activated carbons (Ahmad et al., 2014; Godwin et al., 2019); however, their production is complex and costly. An alternative to activated carbon are biomaterials. Among biomaterials, second generation carbon based materials (2GCBM), commonly known as “biochar”, are the solid product of the thermal conversion of organic biomass residuals. They have been widely assessed as medium to remove toxic metals, organic pollutants and

nutrients from wastewater (Mohan et al., 2014; Xiang et al., 2020). Native 2GCBM show limited adsorption capacity, but chemical and physical modifications can improve their efficiency by adding functional groups on the surface, increasing the surface area and porosity (Lakshmi et al., 2021). Modification of carbon-based materials with metals, such as iron, generates magnetic 2GCBM (M2GCBM). This new modified carbon show an improved adsorption capacity; moreover, it makes the recovery of the adsorbent from the solution easier and cheaper, by applying a magnetic field (Qu et al., 2022).

This work aims to demonstrate the CRMs recovery from aqueous solution using M2GCBM. Carbon 2G, produced by vine pruning biomass under controlled conditions and functionalized with Fe-Mn (hydr-)oxides, are used as adsorption medium.

Functionalisation was carried out on two different feedstocks, the original vine prunings biomass and 2GCBM, produced through the pyrolysis at 500 °C for 2 h of vine prunings biomass.

The addition of Fe-Mn (hydr-)oxides, both to biomass and 2GCBM, was performed with two methods: i) biomass/carbon + dry ground (hydr-)oxides (solid/solid) and ii) biochar/carbon immersed in a suspension with the (hydr-)oxides (solid/liquid). In the solid/solid method, dried Fe-Mn (hydr-)oxides were added to the feedstock. In the solid/liquid method, a previously weighed quantity of sludge was suspended in deionised water. After stirring the suspension for 15 minutes, a known amount of biomass/carbon was added. A quantity of 10 g of feedstock was soaked in 400 ml of Fe and Mn (hydr-)oxide suspension. The resulting mixture was stirred with the shaker at 225 rpm for 5 hours and was then filtered with the vacuum pump and placed in the oven. The biomass/carbon + (hydr-)oxides samples, functionalised with the two methods, were pyrolysed in a microwave muffle furnace, ramp 20 °C min-1 at 600 °C for 2 hours.

We chose two ratios of biomass/carbon:Fe-Mn (hydro-)oxides per method; for solid/solid the proportions were 90:10 and 80:20 (where the higher amount is the feedstock) while, for solid/liquid the proportions were 70:30 and 55:45. Overall, we produced eight different M2GCBM. The phisico-chemical characterization of the M2GCBM as well as the CRMs recovery test from aqueous solution are ongoing.

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Outdoor cultivation of an autochtonous microalgal strain in pilot-scale: Prototype for urban wastewater treatment

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Microalgae are photosynthetic organisms that can adapt to a wide range of environmental conditions, since they can modify their metabolism producing useful molecules in response to changes in the growth environment. Because of their versatility, microalgae are excellent candidates for application in many biotechnological fields, including wastewater treatment. Urban wastewater (UWW) contains high amounts of organic matter, nitrogen (N), phosphorous (P), heavy metals and pathogenic microorganisms (i.e., Escherichia coli).
During the summer experiment, starting from 1 day of cultivation, dry biomass of Chlorella-like culture progressively increased, reaching 4-fold values after 8 days. The increase in biomass and cell density was accompanied by a PSII maximum quantum yield of 0.6-0.7, i.e. optimal values, indicating a good adaptation of the microalgal isolate to the effluent. In the same 8 days-long period, most of the N was reduced (removal efficiency: 81% for N-NH4+ and 78% for N-NO3-). Conversely, after an initial 74% decrease observed in the first 4 days, at the end of the cultivation period P-PO43- concentration reached similar values to the initial ones. The nutrients removal was in line with growth results, indicating that nutrients assimilation was the prevailing phenomenon at the beginning of the experiment (4-8 days). Differently, after day 8, an excessive air supply likely promoted the contamination by other microorganisms (Ciliophora), which interfered with the growth and nutrients removal performance of microalgae. Surprisingly, E. coli load decreased from 4000 to <2 CFU/100mL. This reduction was accompanied by the observation that microalgae tended to release exopolysaccharides, i.e., molecules responsible for the formation of an extracellular mucilaginous matrix. The production

of these compounds promoted the formation of microalgae aggregates, where other microorganisms, including bacteria, were also trapped, thus supporting the reduction of the E. coli load in the effluent.
Based on results obtained during the summer experiment, winter test was performed without air supply. Dry microalgal biomass remained stable for the first days of cultivation due to the harsh conditions of the winter season (mainly, low temperature), and only slightly increased towards the end of the
experiment. Parallelly, the FV/FM rapidly decreased from 0.6 to 0.1, but it tended to rise again from day 14 of cultivation, reaching values of 0.3 at the end of the experiment (20 days). Results on growth and on PSII photochemistry indicated that Chlorella-like cells were able to reactivate their replicative activity and their photosynthetic metabolism after an initial period of adaptation to low temperatures, suggesting their potential applicability even under unfavourable outdoor conditions. Although the harsh winter period affected the growth of microalgae, nitrates in the effluent were reduced by 88% and ammonium by 30% in 20 days, while negligible removal was observed for phosphates. As observed also during the summer experimentation, microalgae released exopolysaccharides and formed cell aggregates. Ultrastructural observation of algae samples highlighted peculiar extroflections and invaginations of the cell wall, with which particulate material, including bacteria, was embedded. Therefore, we believe that the almost complete removal of E. coli, already by 95% after 3 days of cultivation, was mainly related to microalgal aggregates production. Although further trials are necessary both to validate the aforementioned data and to achieve a more efficient nutrients removal in pilot-scale prototype, the results from present research showed that Chlorella- like can adapt to a wide range of temperatures and to the variability of the effluent composition, suggesting the great potential of this alga as a successful tool for improving depuration treatments of effluents within conventional WWTPs. Moreover, the ability of Chlorella-like to form aggregates and, thus, to reduce E. coli concentration, represents an advantage in the UWW disinfection process, helping to significantly reduce the use of chemical compounds to sanitise the streams before their release into the environment.

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Pot test study to determine the best phytoremediation treatment for TPH contaminated soils using plant species with potential for biofuel production

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Within the framework of the Phy2Climate H2020 Project, whose overall objective is to build the bridge between the phytoremediation of contaminated land with the production of clean drop-in biofuels, an industrial site located in Catalunya (Spain), contaminated by total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH) has been selected as a case study for the development of several pilot tests, first at the laboratory, later in the field.

During the course of the pot tests, morphological changes revealed growth differences among the species and scenarios tested. For instance, focusing on soil additives, the highest plants were obtained for compost and for the mixture of compost, biochar and PGPR (referred to as "All" hereinafter), whereas the plants that showed the greatest height were Sorghum sp. and Helianthus annuus. It was also observed that the amendments used affected some of the physicochemical properties of the soil (moisture content, pH, electrical conductivity, etc.), which varied according to the characteristics of each treatment tested. For instance, all treatments showed optimum to high values of available K, whereas only compost was able to properly supply P, and N deficiency was recorded in all cases. In regards to metals and metalloids, no clear trend was observed but, in any case, concentrations at the end of the pot tests were below the reference levels established by the applicable legislation. TPH removal efficiency was also evaluated, resulting in a TPH decrease that ranged between 87% and 97% in all scenarios, including the control experiments of contaminated soil (with and without amendments). These observations would suggest that the phytoremediation of the TPH-contaminated soil was mainly due to

biodegradation driven by the soil microorganisms rather than the plant species, and that microbial activity was not influenced by neither the plants nor their combination with the amendments. However, at the end of the pot tests, TPH concentrations were still above the reference levels, suggesting that longer treatment periods could be required.

In all, the experiments performed revealed that the studied species showed a good tolerance to TPH and that phytoremediation efficiency may not be a key parameter for the selection of the vegetative species to be applied in the field. Thus, the following other criteria were considered for the selection of the final plant species: 1) biomass production, to comply with the specific objectives established by the project's framework; 2) tendency to develop pests, and 3) shape of the roots, since the development of well-branched roots generally leads to greater phytoremediation efficiency. Consequently, Sorghum sp. was selected to be applied in field because it showed the highest biomass production and a well-branched root. In addition, a crop rotation with Brassica napus was proposed to avoid having bare soil for a season, to ensure that biomass production needs will be met, to limit runoff and leaching of NPK, and to improve soil structure thanks to the use of different crops with different root morphologies.

. For this, the two best-performing plant species in terms of TPH removal and biomass production, Sorghum sp. and Brassica napus, were selected. According to each species' vegetative cycle, a crop rotation system was planned in order to ensure an almost permanent soil cover. The evolution of the field pilot test will be assessed through the periodic monitoring of several climatic and physicochemical parameters. After harvesting, the energy crops' tissue will be analysed as well. Lastly, in order to assess the effect of the phytoremediation strategy on enhancing soil quality, additional parameters will be included in the soil characteristics' analysis to estimate the soil quality index (SQI) based on an adaptation of the method described in Klimkowicz-Pawlas et al. (2019). The in-situ pilot test has just started and is still ongoing, so field results will not be included at this conference's presentation, but the aim is to present them in future RemtechExpo editions, if we have the opportunity to do so.

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Using high-resolution tools and 3-d visualization and animation (3-dva) technology to support environmental investigations

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High-Resolution Site Characterization (HRSC) tools and 3-D Visualization and Animation (3-DVA) technology are being utilized more often to reduce the costs of environmental liabilities caused by chemical spills and releases. HRSC tools provide detailed information about the subsurface geologic setting of a site as well as the magnitude and distribution of chemical contaminants in the subsurface, while 3-DVA technology provides a way to present the massive amount of data generated by the tools.

In early 2022, HRSC tools and 3-DVA technology assisted in the investigation, characterization, and remediation planning of a site in Chicago, Illinois impacted from a release of trichloroethene (TCE) nearly 50 years ago. Specifically, multiple types of data were collected during the subsurface investigation, including, data from a combined Membrane Interface Probe / Hydraulic Profiling Tool (MiHPT) and confirmatory soil and groundwater analytical samples. The data were used to delineate and quantify the amount of contamination present in the subsurface as well as determine the geologic setting of the site. Additionally, several different remediation options were analyzed using 3-DVA technology to make certain that the most cost-effective remediation option was selected. Several methods/technologies were assessed, including, excavation (dig and haul), horizontal fracturing with amendment injection, in-situ chemical treatment via soil mixing, homogenization using large diameter augers (LDA) with steam treatment, and in-situ thermal. Finally, mass estimates were calculated using the statistically modeled data to better estimate the amount of trichloroethene mass present in the subsurface to assist with remedial design and costing.

Although remedial options are still being assessed, it appears that the most cost-effective option will be the use of in-situ thermal – through either electrical resistance heating (ERH) or thermal conductive

heating (TCH). In-situ thermal treatment will likely be the most cost-effective option for several reasons:

1) The majority of the contaminant mass is located in fine-grained dense clay deposits – from both lacustrine (lakebed) and glacial origin. Therefore, strategies that involve soil mixing would be more difficult as thoroughly homogenizing chemical amendments with the dense clay soils would be challenging. Additionally, soil mixing strategies are also likely to yield a significant volume of spoils from soil fluffing, adding to the overall disposal costs. Lakebed deposits are shown in brown and glacial till is shown in gray. Fill material is presented as blue.

2) The amount of contaminant mass is quite high. The 3D volumetric analysis estimated the contaminant mass to be in excess of over 50,000 pounds of TCE. The large amount of mass would require the addition of a significant amount of chemical amendment (and added cost) for soil mixing strategies. Additionally, although horizontal fracturing of the clay soils is feasible, the amount of contamination present renders this method (which relies of the diffusion of injected amendments) impractical due to the time frames required to achieve the treatment goals.

3) The contamination extends to depths of over 22' in two areas. This makes a simpler excavation (dig and haul) operation unfeasible, as both an adjacent building and neighboring truckyard would be impacted from the slope of the excavation walls. Alternatively, sheet piling could be installed to create vertical excavation walls, however, the engineering and implementation of this method are not cost effective.

4) The overall characteristics of the subsurface impacts are well suited for thermal treatment, including, a high contaminant mass in a relatively small footprint, deeper (>20 ft) impacts, and the majority of the contaminant mass present in fine-grained soils.

The 3D models and resulting analysis were delivered to the clients, remediation contractors, and stakeholders as a web-based 3D interactive model. This allowed for a complete understanding of the impacts in three dimensions, an improved remedial design, a reduced chance of project cost overruns, and a greater probability of success.

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Analysis of the economic, environmental and social sustainability of saturated and unsaturated soil remediation technologies with AECOM sustainable remediation tool

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A range of different technological solutions for the remediation of saturated and unsaturated soil were evaluated to be applicable to a site, to reach the remediation goals, based not only on the efficiency of the remedial technologies, but also on their an Economical, Environmental and Social Sustainabilty.

By considering the environmental site-specific context, a wide range of different technological solutions were selected in order to: i) remove the source of contamination (i.e. off-site Dig and Disposal). ii) to treat and reuse the excavated contaminated soil (i.e. Soil Washing, Biopile, Landfarming) and iii) to treat directly the contaminated soil without excavation (i.e. Direct Soil Mixing with ISCO). The choice of one or more effective technical solutions could not be defined solely on the magnitude of the soil-volume to be treated, but each different Remediation Scenarios (i.e. combination of different technologies implemented together to reach the remedial objectives) might have a completely different impact in terms of Economic, Environmental and Social Sustainability, and not only from a mere costs point of view.

Implementing Economic, Environmental and Social Sustainability (EESS) in a decision-making process for the choice of a suitable solution in remediation activities is of fundamental importance and it aims to demonstrate that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected through the use of a balanced decision-making process (Sustainable Remediation Forum in the UK, SuRF-UK, 2010). Present day increasing awareness in sustainability and sustainable-related solutions is a matter of concern and it must be considered when remediation actions shall be implemented, and public community is involved.

The study was developed through the application of the AECOM Sustainable Remediation Tool © . The integration of sustainability principles within the decision-making process of the selection of the remediation technology was conducted by referencing to the best practices of sustainable remediation, such as current national and international guidelines: i) guidelines for assessing the sustainability of soil and groundwater remediation interventions (Sustainable Remediation Forum UK - SuRF-UK, 2010), ii) white paper on sustainability in remediation in Italy (SuRF Italy, 2015), and iii) ISO 18504:2017 (Soil quality - Sustainable remediation) standard for sustainable remediation.

The AECOM Sustainable Remediation Tool © allows for a Multi-Criteria Decision Analysis (MCDA) based on sustainability indicators, weights and measurement criteria selected by considering the site-specific attributes. As a decision-making tool, it provides a ranking of the alternatives examined by calculating a sustainability index (or score), which does not represent an absolute value of the individual solution but a relative value, as result of comparing different remedial strategies in a specific context. During the sustainability assessment of the presented case-study, the tool allowed to take into consideration the site -specific attributes of relevance, for both the stakeholders and the local community, such as: site location in a mixed land use area with presence of neighbouring residential houses, the redevelopment plan of the site for industrial use, and minimize the use of natural resources.

The Economic, Environmental and Social Sustainability Assessment conducted by means of the AECOM Sustainable Remediation Tool© enabled to identify the most sustainable remediation strategy applicable to the Site. This practical application confirmed the suitability and the flexibility of the tool that might be readily implemented in a variety of different Remedial Projects taking into consideration the site-specific constraints and allows to guide the choice toward the most sustainable one. The value of the Sustainability Assessment was intended as a support before the Authorities for the selection of the applicable Remediation Scenario with qualitative and quantitative measurable approach that could be easily communicated and integrated within remediation projects.

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Sure by Ramboll: a tool for sustainability assessment in remediation. Case example for groundwater contamination

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SURE by Ramboll is an on-line tool developed by Ramboll for sustainable remediation assessment, engagement and reporting. SURE is compliant to ISO 18504:2017, ASTM E2893-16 and SuRF-UK; moreover, it supports the correlation with UN SDG's.

The aim of a sustainability assessment is to help compare and select the most sustainable remediation strategy for a project. The output of the assessment can also be used to facilitate communication of the decision-making process with stakeholders, and to record the overall process for compliance support.

For the present study, the tool was applied to demonstrate that the Monitoring of Natural Attenuation (MNA) was the most sustainable remediation alternative, if compared with Pump&Treat (P&T) and Bioremediation for a site where groundwater contamination from hydrocarbons was detected.

The Sustainable Remediation Forum (SuRF) defines sustainable remediation as "a remedy or combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources". This definition follows similar work by the Network for Industrially Contaminated Land in Europe (NICOLE) and the Contaminated Land: Applications in Real Environments (CL:AIRE) organizations.

International Standards Organization (ISO) standard 18504:2017 defines sustainable remediation as "elimination and/or control of unacceptable risks in a safe and timely manner whilst optimizing the environmental, social and economic value of the work.".

As noted by the Interstate Technology Regulatory Council (ITRC) in its May 2011 technology overview of green and sustainable remediation ("GSR"), green remediation approaches have traditionally focused on the use of best management practices to reduce the environmental impacts of a remedial action. Sustainable remediation, by comparison,

incorporates a broader, more holistic perspective, considering not only the environmental impacts of a remedy, but also economic and social impacts (ITRC 2011).
Traditionally, the selection of alternative remediation options have focused primarily on effective regulatory-based risk reduction, technical risk reduction, practicability of implementation, and cost-efficiency. In comparison, sustainability assessment evaluates the potential effects of remedial options in terms of the three domains of sustainability: environment, society, and economy.
The sustainability assessment for the present study was conducted with reference to a 900 m2 area, where groundwater contamination from hydrocarbons was detected. The intervention area was located within a plant which extends for 55.000 m2, and operates in the sector of fine chemical production. The contaminated aquifer is the shallow one, with a depth to water of 3 to 5 meters, characterized by gravel fluvial sediments in a sandy-loamy matrix.
The remediation alternatives compared for the assessment were: Monitoring of Natural Attenuation (MNA), Pump&Treat (P&T) and Bioremediation (BIO). The assessment was based on a total of 33 indicators: 12 for the environmental domain, 14 for the economic domain, 7 for the social domain, weighted respectively 39,5%, 33% and 27,5%.
The relative weight calculated for each category of indicators where it is evident that the categories with the highest impact are: groundwater and surface water for environmental indicators; direct costs and benefits for economy indicators. As per the social indicators, the assigned weights resulted in an equal distribution within the categories. The selected remediation alternatives were scored against each indicator, and the rationale for the scoring was recorded. For each remediation alternative, SURE has calculated the total weighted scores for each category of indicator and each domain, together with a total Sustainability Score.
The sustainability assessment allowed to identify that the MNA was the most sustainable remediation alternative for the area, in particular with reference to environmental indicators.

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Surfactant enhanced extraction of NAPL, globule, and sorbed phase contamination resolving hydro-geo-chemical limitation to contaminant availability

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

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

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

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

Keywords: Surfactant enhanced extraction of NAPL, hydrophobic organic chemical (HOC), petroleum hydrocarbons, chlorinated solvents, PFAS, Pesticides,

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Adsorption performance of hydrochars for chlorfenvinphos removal from water

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Chlorfenvinphos (CVP), 2-chloro-1 vinyl diethyl phosphate is an organic compound of artificial origin used as an organophosphorus pesticide and is harmful for human health due to its neurotoxicity. Also, CVP have been found in wastewater and natural water bodies (Barco-Bonilla et al., 2013). For these reasons, it was included in Decision 2455/2001/EC of the European Parlament and of the Council of 20 November 2001 amending the Water Framework Directive (2000/60/EC) and establishing the list of 33 priority substances in the field of water policy (Mora-Gómez et al., 2022). Hydrochars are carbon-based materials produced by hydrothermal carbonization (HTC) process which includes thermochemical conversion using heat to convert wet biomass feedstocks to hydrochar. The application of hydrochars has been shown as very important for carbon sequestration, energy production, contaminated soil remediation and as potential adsorbents for the removal of organic pollutants from water. These carbon materials have a highly porous structure as well as oxygen-containing functional groups (e.g., –OH, –C═O, and –COOH groups) which play an important role in the adsorption process (Phan et al., 2022). HTC conditions and the type of raw biomass, can influence which functional groups are present on the surface of hydrochar, the size and structural shape changes, and instigate adsorption of organic pollutants (Santana et al., 2022).

Kinetics experiments aimed to investigate the time required to establish the adsorption-desorption equilibrium. Based on the obtained dependence of the equilibrium concentration to initial concentration ratio (Ce/C0) on time (t), adsorption-desorption

equilibrium of the tested compound for both hydrochars was established after 24 h.

Adsorption isotherms: the Freundlich isotherm defines the surface heterogeneity and the exponential distribution of active sites and energies and is applicable to adsorption on heterogenous surfaces (Ayawei et al., 2017). Adsorption of CVP on selected chars is well presented with the Freundlich model with satisfactory determination coefficients (R2=0.959–0.985) for both adsorption isotherms. Adsorption of CVP was nonlinear for HTC_SBS 180 (n=0.339) which indicates that the affinity of sorbent decreases with increasing CVP concentration which indicates a favorable adsorption process, whereas for HTC_MIS 180 adsorption process indicates unfavorable adsorption (n=1.239) (Worch, 2012). Adsorption coeffcients (KF) were 0.105 and 9.356 (μg/g)/(μg/L)n for CVP sorption on HTC_SBS 180 and HTC_MIS 180, respectively, indicating significantly higher adsorption the hydrochar originating from Miscanthus giganteus. Positive correlation was found between the obtained partition coefficients (Kd, calculated at three equilibrium concentrations of 1, 10 and 50% of CVP water solubility, presented in Table 1) and specific surface area (SSA) of the chars (HTC_MIS 180=13.1; HTC_SBS 180=3.87), indicating on a higher sorption affinity of HTC_MIS 180 compared to HTC_SBS 180 due to its larger SSA.

This study investigated the potential of the application of two hydrochars as adsorbents for the removal of CVP during water treatment. Higher sorption affinity was observed for HTC_MIS 180 compared to HTC_SBS 180 due to its larger SSA, as indicated by the positive correlation between the obtained partition coefficients (Kd) and SSA of the two hydrochars. Thus, the significant difference in SSA of these carbon materials, as a result of a different chemical composition of the used feedstock, may be the cause of the disparity between the adsorption capacities of the two hydrochars. Adsorption of CVP for HTC_SBS 180 (n=0.339) indicates a favorable adsorption process, whereas for HTC_MIS 180, the results indicate unfavorable adsorption (n=1.239).

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Technology of oil pollution control and elimination by using method of biological destruction of hydrocarbon compounds

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Bioremediation involves the stimulation of indigenous, non pathogenic and non toxic microbial populations (e.g. by adding nutrients and aeration). Since the soil is not removed, this method is relatively environmental friendly and cost effective. Therefore there is no strict standards for the bioremediation of contaminated soils. However, there are several not obligatory international guidelines that should be followed to obtain the optimum degradation rates of the hydrocarbon organic contaminants (for example in Canada, EPA-USA, Germany). The Technology is based on same principles and approaches.

By using the Technology we provide the biological destruction of petroleum hydrocarbons and petroleum products (e.g. fuel oil, lubes, diesel fuel, naphtha, kerosene, benzenes) on various substrates in various components of the environment (soil, ground, water in rivers or basins);

The Technology may also be used for prevention of the endangered areas of contamination with oil and oil products;

For extraction of oil-oxidizing microorganisms the express method enables to adjust as far as necessary the species composition of destructors for the increase of efficiency of biological destruction process;

For creation of the nutrient aiming the increase of efficiency of the oil-oxidizing microorganisms, the original recipe was developed on the basis of nontoxic substances and microelements, therefore the unlimited use of this nutrient is permitted in all countries worldwide;

Biological destruction of hydrocarbons is accomplished by nonpathogenic, autochthonic, active, dominant strains of microorganisms. Microorganisms are preliminarily taken from the contaminated areas subject to purification. Therefore, they do not introduce imbalance in the species composition of biome as they represent the same biome. This is the factor of acceleration of the natural process of bio-destruction of hydrocarbons;

Through introduction of autochthonic strains which are the first link in destruction of hydrocarbons are accumulated the decomposition products which stimulate activation of next links in the food chain. By microorganisms- destructors the decomposition of hydrocarbons are provided to the finite products H2O (water) and CO2 (carbon dioxide); The extracted oil-oxidizing microorganisms use hydrocarbons as the single source of energy and carbon;
Technology is based on the following concept:
- The mechanism of destruction of organic matters is inherent to any ecosystem;
- The potential of these mechanisms is not spontaneously realized in the nature due to the regularity of the biotic potential of population and restricting factors of the environment (space, food, seasonality, temperature etc.);
- There is the Technology (method) of intensification and scaling-up of those mechanisms during the significant growth of count of organic matters, e.g. in case of oil pollution;
- Increase of potential of the natural mechanisms of destruction of organic matters is possible through adaptation of local microorganisms (destructors) without interference in their species composition and genetic structure.
The effective, economic and eco-friendly treatment of the environment (soil, water, some components of oil industry infrastructure) by means of oil-oxidizing microorganisms extracted from the treated land or water areas without using the synthetic chemicals or introduction of microorganism not inherent for the given land or water area. This method is based on:
- Detailed analysis of the initial contamination state;
- Extraction of strains of most active microorganisms;
- Intensification of destructive opportunities of microorganisms
- Their introduction in the polluted environment and monitoring of the start of the process; □Periodical control of the treatment process effectiveness.

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Development and validation of a clean technology for the integral treatment of metallurgical effluents and tailings neutralization based on the use of calcareous agents

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The Project called: “DEVELOPMENT AND VALIDATION OF A CLEAN TECHNOLOGY FOR THE INTEGRAL TREATMENT OF METALLURGICAL EFFLUENTS AND TAILINGS NEUTRALIZATION BASED ON THE USE OF CALCAREOUS AGENTS” was carried out with the purpose of determining the feasibility of using the tailings from the metallurgical processing-"LEACHING IN VATS" developed by artisanal mining, in the "Cerro El Toro" tailings dam, which is located in the district of Huamachuco, Province of Sánchez Carrión, Department of La Libertad in Perú which has a negative impact through artisanal mining contamination in the communities of Shiracmaca and Coigobamba located in the areas of influence of the project, affecting their agriculture, livestock and their quality of life. Likewise, it is important to point out that the determination of the feasibility of the use of refractory polymetallic gold oxidized and sulfurized tailings was carried out for its use as raw material for the elaboration of a “construction aggregate.

In this sense, it should be noted that the development of the Project involved the development of Study Tests at the laboratory level that were carried out in order to determine the initial environmental characterization of the untreated tailings of "Cerro El Toro" from the process of " cyanidation in trays”, the environmental characterization of the “untreated remedial agent used for the detoxification of the tailings, the environmental characterization of the “treated remedial agent” used for the decontamination of the tailings, the final environmental characterization of the tailings” after submitting the application of the method of remediation of the integral detoxification

treatment of contaminants in metallurgical tailings, the tests for the manufacture of brick specimens made with "construction aggregates made with detoxified tailings and the tests for the manufacture of blocks made with "aggregates of construction" made with detoxified tailings.

The Project proposes the reuse of mining tailings in the form of "Construction Aggregates" through the implementation of the Remediation Method-MRTI-SLFCH that allows compliance with the Soil Environmental Quality Standards (SEQ SOIL).

The Technical-Economic Feasibility of the Study was determined based on the remediation method mentioned above, it is a Technique used in tailings with the purpose of minimizing the concentration of heavy metals such as: barium, cadmium, lead and mercury, which are the metals that constitute the inorganic parameters, whose concentration must be below the values of the Maximum Permissible Limits (LMP) of the Soil Environmental Quality Standard (seq SOIL).

The Justification of the Study seeks to solve the environmental problem of the large volume tailings of "Cerro El Toro" that occupies an area of 69,238.04 m3, for which it is necessary to provide a technological solution to mitigate and reduce environmental pollution in the zone.

The proposed technological solution is to clean the tailings and evaluate technologies that contemplate the use of tailings as an aggregate for construction. That is why, it is proposed to implement a method of remediation of the reprocessing of the tailings until its mineral and reactivity are exhausted" through the integral detoxification treatment of contaminants in metallurgical tailings by the differential flotation technique with air and gravimetric concentration" - also called : "MRTI-SLFCH".

The Technology: "REMEDIATION METHOD-MRTI-SLFCH" which belongs to the Company: "GREEN METALLURGY TECHNOLOGIES S.R.L." and it was used to reduce the concentrations of toxic constituents in tailings from metallurgical cyanidation treatments in rafts that are subjected to a metallurgical flotation retreatment and/or gravimetric concentration in order to sterilize the tailings as much as possible according to the environmental regulations for Extractive soil of the Environmental Quality Standards (SEQ SOIL).

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Critera for the assessment of the environmental damage

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In 2019 the IMPEL Network set up a project named “CAED - Criteria for the Assessment of the Environmental Damage” in order to help Member States and specifically their competent autorities in improving their determination of the environmental damage and its imminent threat.
The CAED project takes guidance on key terms and definitions of Environmental Damage under the Environmental Liability Directive (‘ELD’, 2004/35/CE) as a springboard. It focusses on the technical-administrative procedures and methods necessary to determine the environmental damage caused by environmental incidents, non-compliances, offences and criminal actions.
The CAED report is the first of the IMPEL Network products concerning the ELD implementation and the environmental damage assessment in general, moreover, it is the first European report entirely devoted to the ascertainment/investigation phase of the whole process of the environmental damage assessment.
The CAED project concerns the environmental damage to the natural resources protected by the ELD, namely:
- protected species and natural habitats (included in Habitat and Birds Directives),
- waters (under Water and Marine Strategy Framework Directives)
- and land.
In addition, the project includes areas protected by national legislation (such as protected areas, national and regional parks, wetlands) and international conventions (RAMSAR).
Moreover, the CAED project concerns environmental damage under ELD, which is assessed as "significant" according to the criteria defined in the Directive and further clarified in the Guidelines providing a common understanding of the term 'environmental damage' as defined in Article 2 of Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage, C(2021) 1860 final.

Finally, the CAED project has been included in the ELD Multi-Annual Rolling Work Programme (MARWP) 2021-2024 of the EU Commission as one of the actions for training and capacity building (activity 1.3).
Currently, the main difficulties in enforcing the ELD result in the definition and measurement of "significant adverse effects" that determine environmental damage. There is a lack of corresponding criteria or thresholds and it makes difficult to reach an accurate assessment and an effective remediation.
The ultimate goal of the project is to produce a Practical Guide and Practical Tables including criteria for the determination of the environmental damage and imminent threat of damage, based on reference parameters relating to 'evidence' and 'clues'. Moreover, the activity of the project is to provide training activities on CAED products and well as on other ELD related issues.
The CAED project on 2021 produced practical tools such as a Practical Guide and Practical Tables including:

- check-lists useful for the identification of potential cases of environmental damage and imminent threat of damage and for the screeening and preliminary assessment of ELD cases
- supportive decision-making flowcharts giving guidance for the determination of the clues of the environmental damage,

Those practical tools and guidance aim to enhance competent authorities and practitioner's capability: for example, when assessing the environmental damage of a long-term emission not recognised in time that contaminates land and groundwaters.
This guidance will be an essential tool for the practitions that greatly contribute to assess the damage or imminent threat of damage under ELD regime.

On 2021-2022 the CAED project conducted training activitites on CAED products to various ELD practitioners and stakeholders and organised a Webinar on ELD enforcement.

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Quantarray®-NSZD: a new tool for the assessment of natural source zone depletion

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As researchers continue to identify the impact that natural source zone depletion (NSZD) has on site cleanup timeframes, there is a growing need for methods and tools that provide microbial-based metrics to aid in conceptual site modelling. Through the identification and quantification of the microorganisms and functional genes related to NSZD at hydrocarbon release sites, site and project managers are better able to: 1) identify the potential for NSZD, 2) enhance site-specific models and 3) provide direct microbial data to regulatory bodies as proof of NSZD potential. The Microbial Insights QuantArray®-NSZD is an advanced qPCR method that quantifies a broad spectrum of NSZD microorganisms and functional genes in a single analysis for a more comprehensive and cost-effective evaluation of bioremediation potential. Similarly, the QuantArray®-Petro quantifies a suite of functional genes involved in aerobic and anaerobic biodegradation of BTEX, PAHs, and other petroleum hydrocarbons. Both QuantArray® analyses include over 20 assays performed on a single sample. By incorporating these molecular biological tools into baseline sampling and routine monitoring, and by utilizing the Microbial Insights database for enhanced data analysis, the subsurface microbiome will no longer be an unknown. Within this study, QuantArray®-NSZD was employed to identify the presence of key gene targets related to NSZD at a petroleum hydrocarbon-impacted site.

The QuantArray® is a hybrid technology that combines the highly parallel detection of DNA microarrays with the accurate and precise quantification of qPCR into a single platform. The approach employs nanoliter fluidics for low volume, solution phase qPCR allowing simultaneous quantification of different gene targets and therefore more comprehensive sample assessment. QuantArray®-NSZD is used to quantify 21 different taxonomic and functional gene targets related to natural source zone depletion. Examples of target and functional

genes are: acetogens (AGN), fermenters (FER), methanogens (MGN), acetoclastic methanogens (AMGN), biosurfactant production-based genes (SurG, SurL, SurP, etc.), and metal reducing bacteria (IRB, IRG, IRS). Other methods like multiplex qPCR have been described that achieve some level of parallel quantification, but unlike multiplex qPCR, the QuantArray® employs discrete through-holes for individual qPCR reactions ensuring that reaction kinetics are not compromised.

A petroleum hydrocarbon-impacted site undergoing suspected NSZD was analyzed via chemical and geochemical techniques as well as QuantArray®-NSZD. The goal of these analyses were two fold: 1. to determine if NSZD was occurring, and 2. to identify any correlations between chemical parameters and the measured microbial gene targets.

As demonstrated within this presentation, the bulk of NSZD processes rely on microbial activity. Although the final products (CO2 and CH4) of NSZD can be measured using traditional analyses, only the microbial data can provide insights into the actual functions taking place. At the site discussed, QuantArray®-NSZD data was used to determine that key NSZD gene targets were present and that methane production could be correlated to a specific target.

QuantArray®-NSZD was successfully used to identify and quantify key genes related to NSZD. Often, three lines of evidence are recommended for a clearer understanding of the activity occurring in the subsurface of a contaminated site: chemical, geochemical, and microbiological. The data that is described within this presentation will not only highlight the necessity for multiple lines of evidence, but will illustrate that microbiology is the only line of evidence that can truly connect the other two lines of evidence during processes like NSZD.

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Decisional key elements for a profitable urban mining project on past mettallurgical sites and deposites – the NWE -regeneratis project

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Europe is highly reliant on other nations in the world in order to satisfy its expanding ferrous and non-ferrous metal needs. Through the (re)mining of currently extant potentially contaminated sites abandoned by the metallurgical industries, some of these metals can be recovered and produced in Europe. Urban mining of Past Metallurgical Sites and Deposits (PMSD) opens up new opportunities for sustainable waste management, land and material recovery, human health protection and environmental risk reduction. Even though the social and environmental benefits of the urban mining projects have been assessed, but stakeholders are still often reluctant to start the projects due to the profitability risks associated with the lack of reliable data.

To facilitate the implementation of this kind of urban mining projects, the NWE-REGENRATIS project focuses on the extraction and revalorization of deposited materials from PMSDs. The project partners have developed an innovative methodology called REMICRRAM (REGENERATIS Methodology for Innovative Circularity to Recover Raw materials from PMSD while regenerating the polluted sites) to support the new circular economy for secondary raw materials recovered from brownfields/PMSDs.

This methodology helps the stakeholders to take the decision “to start or not to start” the valorization project on a given site/a PMSD based on the provision of best valorization options. It also facilitate the stakeholders’ decision by identifying the other drivers (economic, social and environmental).

The objective of REMICRRAM methodology is to encourage and guide those who are interested in the revalorization of PMSDs (e.g. brownfield owners, project managers, local authorities), to fully characterize a PMSD site and its economic potential for the recovery

of materials, metals, soil and land. To summarize, NWE-REGENERATIS offers an accurate perspective of a PMSD, which is essential for developing a sustainable development of the project on it.

The REMICRRAM methodology consists of 3 phases:
- Phase 1: A quick screening software to evaluate the valorization potential of a site/PMSD for the recovery of materials, metals, soil and land (SMART PHOENIX). In case of high potential, the user can proceed to the next phase;
- Phase 2: A Decision Support Tool (DST) based on artificial intelligence and algorithms to choose the best valorization options for materials and metals present on site (SMARTIX);
- Phase 3: The structure of an evidence based business case in order to facilitate a cost benefits analysis focusing on the efficiency, effectiveness, economic, social and environmental potential of a site-specific urban mining project.
After applying the REMICRRAM methodology, the user decides whether or not to initiate an urban mining project on the site. At this point, the user will have different scenarios for the site valorization. This step helps the user to choose the best valorization option for site/materials by identifying other drivers such as: biodiversity, green energy, ecosystem services, social benefits, economic benefits, environmental revenues, etc.

The developement of the REMICRRAM methodology is entirely based on the discussion between different experts (involved in the project) associated with the fields of material recovery, consultancy, civil engineering, academia, biomass production, and artificial intelligence. Each phase of the REMICRRAM is designed based on the real cases studies. This methodology provides transparent and evidence-based scenerios for optimal material, metals, soil and land reclamation. It opens up new pathways to the circular economy with a more sustainable approach while encourging stakeholders to initiate urban mining projects by allowing them to asses the potential of their sites through different prospectives to avoid profitability risks before launching the project on site.

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Mass discharge calculation for rehabilitation of industrial site

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Environmental studies in the subject area, located in the state of São Paulo, Brazil, started in 2003. The studies consisted of a series of environmental investigations that enabled the detailed mapping of the site's environmental scenario and detected changes in the environmental quality of the local groundwater. Quality alterations were primarily due to the presence of perchloroethylene (PCE) in two distinct areas: downgradient of the former settling ponds (which were part of the WWTP), at the southern portion of the industrial site, near the local creek; and at the former degreasing area, at the central portion of the production area.

Considering the scenario identified, an Integrated Remediation System was implemented in the area, using several techniques: Bioremediation, Multiphase Extraction (MPE), In Situ Chemical Oxidation (ISCO) and Hydraulic Barrier. These systems removed/destroyed PCE from the primary centers of mass identified and contained its migration to the local receiving water body. The action of these systems helped reduce the concentrations of the identified pollutants to levels below the Site Specific Target Levels (SSTLs) and contributed to stabilize the local environmental conditions, until their operation was no longer necessary. The decision to discontinue the operation of the Hydraulic Barrier was based on mass discharge calculations that assessed the receiving body's capacity to assimilate a potential influx of PCE.

Mass discharge calculations for PCE estimated that theoretically even if the entire existing PCE plume front were to reach the receiving water body at PCE concentrations of 500 µg/L, water body quality would not be altered to the point of changing its classification. In terms of mass, this would represent an annual release of 1.8 kg of PCE.

From the practical side, it was known that the average concentration of PCE in the water captured by the hydraulic barrier was about ~315 µg/L restricting the potential mass discharge to 1.1 kg/year of PCE, which is approximately 40% below the yearly threshold level estimated for this receptor (i.e.: 1.8 kg/year). Therefore, calculations showed that the discontinuance of the hydraulic barrier – which was the last remedial system in operational in the area – would not result in unacceptable levels of impact to the surface water. Thus, with the local environmental agency acceptance, the hydraulic barrier was shut down and several rounds of surface water monitoring were carried out. As no impacts were detected (as predicted) the area was officially declared as remediated for industrial use.

Keywords: rehabilitation of industrial site, Bioremediation, Multiphase Extraction (MPE), In Situ Chemical Oxidation (ISCO) and Hydraulic Barrier

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Remedial safety in in-situ chemical oxidation, crucial to success

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Health, Safety & Environmental (HSE) practices for site remediation programs vary by location, work type and site maturity This paper looks at the development of safety-first work practices at remediation sites where In-Situ Chemical Oxidation (ISCO) is selected. ISCO programs combine powerful (hazardous) chemicals and convey them to subsurface (typically) under pressure and present unique HSE challenges compared to other remedial methods, with ISCO often classified as one of the highest risk in-situ activities. This paper attempts to identify practices for consideration in development of site-specific plans, including chemical storage and handling, tail gate meetings, and stop work authorization.

HSE practices evolved in the late 1980s in response to the need to provide protection from the various Site hazards and unexpected releases. In the 1990s, employers developed company-specific programs to protect workers involved in hazardous waste operations. These programs varied globally throughout the industry but minimally included; provision of various levels of worker training, mandated selection and use of appropriate Personal Protective Equipment (PPE) and effective planning, as in the creation of Health and Safety Plans. Since 2000, the industry has shifted toward a behavior-based safety-first focus, empowering individuals' responsibility for safety – "I am responsible for the safety of myself and the team."

Safety practices remain important for the protection of all workers, as well as the general environment, the public, and compliance with professional expectations for work practices. This remains paramount for ISCO where the consequence of poor practices is substantial. ISCO, which uses large volumes of potentially hazardous, flammable and/or

corrosive chemicals, combined with pressurized injection scenarios, chemical compatibility issues, proper storage , requires detailed HSE planning to address these concerns.

Safe work practices can be improved by sharing the compendium of previous knowledge so as not to repeat the mistakes of the past. Rather than simply anecdotally sharing experiences, we will explain both why safety-first work practices are needed, as well as showing consequences of inadequate or incomplete practices. Focus will be given to persulfate, however the information provided will be relevant to any injected material (e.g., other ISCO agents, bioremediation amendments, fracturing slurries, and solids).

This paper will discuss the top four historical risks of injection; impacts to storm sewers (specifically), impacts to other utilities, error and omissions, and contingency planning. The top three skills for injection projects, and associated risk mitigation strategies will also be presented; planning, executing, and correcting.

What you can do?

• Engage all individuals at the implementation site, to create a true team atmosphere. Project success depends on a united approach toward preservation of safety and minimizing risk to the team, the Site, and the environment.

• Empower teams to find, respond to and correct problems during all phases of activity from planning, through execution and closure.

• Vigilance of everyone during all phases of the works, especially during implementation, to eliminate deficiencies and detect unwanted conditions.

• Share information on incidents, near-misses, and continuous improvements within the industry to increase the state-of-the-art processes, provide safe procedures for all and facilitate the completion of safe and effective remedial programs into the future.

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Sustainable resilient remediation

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Globally, we're feeling the effects climate change, rapid urbanization, and loss of biodiversity. The rate at which we're seeing devastating large-scale events such as droughts, floods, and wildfires is becoming more frequent. The demand has never been greater to help our cities and communities create healthier lives and become better stewards of our natural resources and a more resilient future.

Evaluation and implementation of remedial solutions for contaminant treatment at impacted sites has long been a balance of cost efficiency, technical effectiveness, and community acceptance. Many phases of evolution have taken place within the remediation industry due to technological developments, higher focus on emerging contaminants and new contaminant types, regulatory changes, economic factors, and, most recently, sustainability and resiliency considerations.

Generally, sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Definition; 1987 Report of the World Commission on Environment and Development). Within sustainability is resilience, or the capability to anticipate, prepare for, respond to, and recover from significant multi- hazard threats with minimal damage to social wellbeing, the economy, and the environment (ASTM). Inherently built into the practice of remediation is the process of improving environmental conditions for future generations and responding to hazards to human health and the environment.

The sustainability benefits of a cleanup remedy are best evaluated at the outset of design with a focus on five primary elements: 1) total energy and renewable energy use, 2) air pollutants and greenhouse gas emissions, 3) water use and impacts to water resources, 4) materials management and waste reduction, and 5) land management, biodiversity and ecosystems protection. This evaluation is commonly referred to as green remediation.

Truly sustainable remedies integrate

both social and economic sustainability components. Often it is possible to implement a sustainable remedy that addresses both the wants and needs of a community while also benefiting the local economy or environment. For example, a desire for more green space may align with a nature-based solution that also benefits the environment (e.g., vegetated soil covers, phytoremediation), or the need for a community meeting space may be fulfilled by repurposing a vacant building, thus eliminating the cost and material needed to create a new structure. Further, economic improvements to the community can be fostered by using local vendors for such projects. Often, remediation coupled with redevelopment can lead to improved economic and social benefits. Sources of the benefits that can be pursued while planning remediation are detailed in ITRC's Sustainable Resilient Remediation (2021) and in CLAIRE 2020. When applying social and economic practices, there are several approaches that can be used to assess benefits and potential impacts: best management practices, such as ASTM's Standard Guide for Integrating Sustainable Objectives into Cleanup (ASTM E2876, 2013), BMPs coupled with a simple scoring system, or Multi-Criteria Decision Analysis (Harclerode et al. 2015).

Arcadis' programmatic approach to SRR integration provides a framework to go beyond industry standards to leverage digital tools, identify site-specific needs, and develop innovative methods to outline a tailored approach to meet project objectives. We support this framework through a culture of innovation, a whole systems view, and continuous stakeholder dialogue to incorporate and meet rising social considerations. These frameworks facilitate effective management of sustainability by clearly identifying ambition levels, prioritizing goals in decision making processes, outlining implementation benchmarks, and communicating the results in user-friendly dashboards as part of the regular reporting process. Through this, we will continue to unlock sustainable opportunities from scientific, regulatory, and stakeholder perspectives to fully realize the triple bottom line.

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Incorporating Resilience and Adaptation into the SuRF-UK Sustainable Remediation Framework

SuRF-UK Steering Committee

Climate change is one of or the biggest challenge facing society. It is driving changes to the climate system such as disturbance in the hydrological cycle, rising sea levels and more frequent extreme weather events. In the contaminated land sector, projects need to be able to adapt to the new and changing environment in a way that moderates the harm and exploits any benefits; but also be resilient with the capability to anticipate, prepare and respond to the multi-hazard threats presented by climate change and minimize the damage to social, environmental, and economic well-being.

A number of recent publications have begun to consider the impact of climate change and subsequent risk management implications on both the fate and transport of contaminants and the influence of impacts on different remediation technologies. These led to the development of guidance linking resiliency to climate change to "green and sustainable remediation" by the Interstate Technology and Regulatory Council (ITRC) in the USA. Aligned with these developments SuRF-UK has developed outline guidance (currently under review) about the current provision for incorporating climate change and broader considerations of resiliency in the context of the SuRF-UK Framework. This guidance comprises into four parts.

1. Project Lifecycle – when setting the sustainability objectives, select the headline indicator category, "Project Lifespan and Flexibility" that includes four sub-indicators that directly address issues of resiliency to climate change, financial or societal impacts
2. Part A of the Framework, setting remediation specifications – the extent to which resilience needs to be incorporated should be clearer at this part of the project; there are several UK-specific resources that could be used to inform a climate change vulnerability assessment to help define potential future risks
3. Part B of the Framework, setting remediation technology approach – here it is possible to consider the vulnerabilities of the different selected technologies to impacts of climate change

4. Sustainable Management Practices (SMPs) – these relatively simple, common-sense actions that can be implemented at any stage of a contaminated land project or portfolio of works; SMPs that enhance the resiliency of a project could include incorporating natural attenuation into the project strategy, this would ensure that the fate and transport of contaminants were considered in the event the primary risk management mechanism failed.

Ultimately, climate change and financial and institutional changes can introduce risks to projects and thereby undermine the effectiveness of certain risk management options. This presentation will describe how the SuRF-UK Framework allows evaluation of resilience to be built into projects through incorporation of indicators at an early stage of the project and at the point of remedial option selection. Furthermore, the framework allows for the adoption of SMPs that can be implemented throughout the project lifecycle to maintain durable and effective risk management in a dynamic environmental, economic and social context.

Environmental monitoring protocol of the Capo Frasca military training site, West Sardinia

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This work is the result of the technical-scientific agreement between AM (Aeronautica Militare italiana) and ISPRA (Italian Institute for Environmental Protection and Research) to assess the impact on the environmental matrices due to the training activities carried out at the Capo Frasca military firing range (PCF), located in the western coast of Sardinia. The goals of the agreement include the drafting of a protocol of environmental investigations aimed at the integration of the "Disciplinary for the environmental protection of the Capo Frasca Polygon" (Chapter IV, point 3) in order to make it consistent with the "Permanent monitoring plan on the components of all environmental matrices in relation to the activities carried out in the polygon" as required by c. 4 bis, art. 241-bis of Legislative Decree 152/06. Specifically, the envirnmental monitoring protocol includes two phases:

- the determination of a quality baseline of the environmental matrices;

. a monitoring program articulated (in time and space) according to: i) the results of the baseline and the conceptual model of the PCF; ii) the activities carried out therein.

In the 1,417 ha large PCF, located at the Capo Frasca promontory , the following activities are carried out: i) national and international training activities; ii) testing and standardization of air / ground shooting techniques and tactics that envisage the use of inert and / or dummy ammunition only; iii) shooting activities with light land ammunition. These activities are run in specific training/target areas. Taking into account the available environmental data (AB&C studio, 2016; Golder Associates, 2016), the environmental monitoring protocol was based on a preliminary conceptual model focussing on:

i) source of potential contamination; ii) transport mechanisms and migration routes of contaminant; iii) targets and exposure routes.
The environmenal monitoring protocol includes two sections:
Planning of baseline investigations: these are aimed at verifying the state of the environmental matrices within the operational areas, potentially impacted by training activities, with particular reference to the target areas, used in the present and in the past. Baseline investigations for soils in the PCF operational areas were planned at three levels:
1. wide area (AV): a grid made up of 24, 500X500 m wide meshes has been identified, covering the entire plateau of the operational area. Within each mesh, the sampling of a composite sample of top soil (depth 0,2 m) and a surface soil (depth 1 m) were planned :
2. Current training area (AE): a grid of 35 200X200 wide meshes has been identified to cover the current target areas T1, T2, T5, T7 and the approach corridor on the western part of the range . Within each grid mesh, sampling activities will be conducted in the same manner as in the wide area.
3. Dismissed training area (AD): a grid consisting of 44 50 x 150 wide meshes has been identified to cover the now dismissed target areas T12, T4, T3. Within each mesh of the grid, sampling activities will be conducted in the same manner as in the large area, after removal of the numerous shells scattered in the area. For these areas it was decided to increase the sampling density (smaller mesh) as they have never been subject to characterisation.
The realization of three, 15m-deep piezometers was planned, nevertheless the geological and geomorphological scenario of the site makes unlikely that groundwater will be found at the target depths .
The safety data sheets of the ammunition used in the training area, provided information to complete the list of contaminant of concern (e.g. metals, Pentrite, Centralite, nitroguanidina, difenilammina, dibutiftalato, dinitrotoluene, nitroglicerine)

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Transparent Tailings initiative: monitoring and early warning system for Tailings facilities

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Chile, according to the latest update of the Tailings Deposit Cadastre of the National Geology and Mining Survey (SERNAGEOMIN), has a total of 757 tailings deposits, which would correspond to almost 11,000 million tons of tailings. . If an increase in mining production close to 25% is also considered by 2035, the current generation of tailings could almost double from 600 million tons per year (2014) to 1,100 million tons per year (2035). Therefore it is crutial to focus efforts on the development of a safe and cutting-edge mining activity, which includes, of course, safe management of tailings deposits.

There is now a general consensus on the bottom line: addressing mining challenges by working collaboratively to agree on minimum monitoring standards for all tailings facilities. With this focus, since December 2016 the Transparent Tailings, a public-private initiative, has had the support of mining companies, authorities and communities, for the development of a standardized monitoring and early warning system for tailings deposits, which, through an information management platform, will provide quality, reliable and timely information on the performance of the deposits regarding their physical and chemical stability. The ultimate purpose is to strengthen preventive operational management, improve communication and response between the parties in eventual emergency situations.

The objective of the Tranque Program proposal is to provide a national solution to the monitoring of tailings facilities and their suroundings waters bodies, considering tailings characteristics and the environmental conditions of the site. The monitoring system: i) identify impacts on the waters surrounding a tailings deposit, ii) identify whether an impact means a risk to the health of people or the environment, iii) provides timely information on anomalies in the

physicochemical characteristics of the water, and iv) identify future anomalies.

As key element to determine the impacts of tailings facilities on quality of surrounding waters critical variables are defined, including, online physical-chemical variables and lab analysis of critical variables. Table 1 details critical variables for chemical (environmental) tailings facility stability.

Currently the system is being implemented at a full scale on one tailings facility from Antofagasta Minerals and partially in Las Tortolas Tailings facility from AngloAmerican and Ovejería from CODELCO.

In parallel an intensive process for designing the monitoring and control room for the central system has been implemented together with SERNAGEOMIN; as a result of this process a detailed technical and administrative process description, a control room design and an estimation of operational and maintenance costs will be obtained during 2019. Iť s expected to implement the monitoring and control room in the central SERNAGEOMIN offices during 2020.

Full transparency to communities and authorities is expected to occur during 2020, once the data analysis tools have been validated with monitoring data coming from the three pilot tailings facilities.

Important progresses has been achieved in Chile regarding transparent and preventive tailings management, for environmental stability, driven by a public private initiative composed by relevant representatives of the private and public mining sector and other related organizations. The developed system is succesfully being implemented in several tailings dams. This system will provide to the involved parties, authorities and mining companies, and in the nearby future communities, better, reliable and real-time information about the dams' behaviour in terms chemical (environmental) stability.

In 2018, the Chilean government has highlighted and recognized the results of the Transparent Tailings Initiative, by announcing the inclusion of the developed system in the Chilean National Policy for Tailings for the monitoring of the 112 active mine tailings.

These achievements are the result of an innovative, collaborative and voluntary effort made by mining companies and public agencies, in order to solve complex challenges and develop public goods and benefits.

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Aerobic cometabolism for treatment of traditional and emerging groundwater contaminants

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Aerobic cometabolism of organic pollutants has been studied for more than 50 years, yet this process is rarely considered by practitioners as a primary remediation approach or as a critical component of natural attenuation. However, recent laboratory and field studies suggest that aerobic cometabolism can be highly effective for a broad suite of traditional and emerging contaminants, including many chlorinated volatile organic compounds (cVOCs), 1,4-dioxane (1,4-D), 1,2-dibromoethane (EDB), 1,2,3-trichloropropane (TCP), and N-nitrosodimethylamine (NDMA) alone or in mixtures. In addition, new evidence indicates that cometabolism may be an important yet largely unrecognized component natural attenuation for cVOCs. This approach is particularly attractive at sites in which initial contaminant concentrations are low and/or where the production of secondary products from anaerobic treatment approaches (e.g., sulfide, methane, dissolved metals) is undesirable. This presentation will provide an overview of the fundamentals of cometabolic processes and examples of successful in situ and ex situ field applications of this technology for treating traditional and emerging contaminants.

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Stabilization of PFAS contaminated soil to minimize cost for construction works and carbon footprint for widely contaminate and active areas

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The management of soil contaminated with per- and poly-fluorinated alkyl substances (PFAS) is a major challenge worldwide. Traditional remediation processes are not applicable due to the inherent chemical stability of the PFAS substances. Landfill disposal, a common practice in Europe for other soil contaminants, has its own challenges for PFAS contaminants because disposal of PFAS soil in a landfill creates a concentrated point source of these toxic and water soluble substances, which creates a risk to human health and the environment through transfer via the landfill leachate.

For construction works within large areas with PFAS concentrations, as well as active sites, these soils become an expensive part of construction works. Excavated soil needs to be transported to landfills or incinerated, creating both a large cost as well as a large carbon footprint. As additional cost and environmental liability new “clean” soil needs to purchased and transported, and deposited in contaminated areas, becoming contaminated as soon as they reach the ground, without remediating the area in any detectable way.

As both an economical and more environmentally friendly solution, Envytech has, in cooperation with the Swedish Defence Estate Agency (SDEA), carried out stabilization of PFAS contaminated soil arising from construction works within a large contaminated active firefighting training area using Rembind by Rembind PTY Ltd. As the works begun, permission to stabilize and reuse of soil was not yet granted, and approx. 1000 tonnes of PFAS contaminated soil were transported to a landfill where stabilization was carried out.

For the second stage of the works, EPA had granted the SDEA permission to reuse stabilized soil if minimization of PFAS leachability could be achieved and documented.

By presenting the results from theses two stabilizations of PFAS contaminated soils we will verify that 1) stabilization could minimize

PFAS leachability of excavated soils enough for the EPA to grant permission for reuse of treated soils on site, 2) Stabilization can vastly reduce the costs by minimizing the costs of transporting contaminated material to landfill, where a point source can be created, and by minimizing the need to purchase and transport new fill material, and 3) minimize the carbon footprint.

As a first step for proving the efficiency of the product to stabilize the different soils and concentrations, soil samples were taken out and analyzed for the Swedish SLV SUM PFAS11 concentrations. A two step leachability test, L/S2 and L/S8 was conducted on all samples, to measure the amount of PFAS the untreated soil leach over time.

To evaluate the effect and cost for stabilization of the different soil samples, separate samples were taken out, and depending on contamination level, stabilized with two different percentages of Rembind, one higher and one lower. This to evaluate what different percent stabilization product would be needed to minimize leaching of PFAS for each sample.

From the results achieved, the soils were stabilized, first batch at a landfill, and the second on-site as permission had been granted from the EPA to use stabilized soils for backfill material, if proven that minimization of PFAS could be achieved.

Approx. 1000 tonnes of PFAS contaminated soil were transported to a landfill where stabilization was carried out, and where permission for depositing had been granted for treated soil where leachability could be decreased >80%. Envytech carried out the stabilization works and the soil was deposited as leachate was decreased up to 99%.

For the second stage of the works, the soil was stabilized on site, and results proves that minimizatio of leachability was achivied with > 97%. The stabilized soil was approved to be reused on site and was used as back fill.

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Surface Active Foam Fractionation (SAFF) in combination with Electrochemical Oxidation: Effective PFAS removal from water using only air, creating zero waste

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EPOC Systems, an Australian environmental engineering company and Envytech, their European technology partner, have been working in recent years to develop a PFAS separation and concentration process based entirely on the surface active power of rising air bubbles in a water column. This PFAS treatment method uses no consumables or additives.

Envytech have successfully operated more then10 full scale SAFF projects since 2021, treating collected water from fire fighting activities as well as over 250 000 m3 of PFAS contaminated leachate. The projects conducted on heavily contaminated and complex waters have shown to produce approx. 200-400 liters of PFAS hyper concentrate from every 30 000 m3 treated.

Envytech have carried out a proof of concept study where a bench scale trial was carried out to evaluate a soil washing method combining SAFF, traditional soilwashing steps and tailor made additives, developed by Envytech in cooperation with EPOC systems. The method trial proved that the added tailor made wash solvent was effective at desorbing many PFAS from highly contaminated soils with particle sizes varying from super fines to coarse. The trial also showed that SAFF could be used to treat the wash water from PFAS, without removing the tailor made wash solvent, allowing it to be reused.

Envytech will during the summer of 2022 conduct a new bench scale soil washing trial, involving 4-8 different soils from an airport where a clint wish to evaluate the potential for soil washing as a remediation method. The 8 different soil samples will all be sampled as will the leachate from all samples, and the aim if the study is to evaluate if the different soils can be effectively treated with the Envytech EPOC soil washing and water treatment method.

To be able to compare results from the soil washing with the option of stabilization of PFAS impacted soils, all 8 samples will be stabilized with Rembind - a patented stabilization product from Rembind Pty.
By presenting results from the two soil washing bench scale trials, we will show if the developed soil washing and water treatment method is a possible option for a sustainable way of treating PFAS contaminated soils of various particle sizes. We will also show the effect in comparison to stabilization.
The project involves a total of 8 soil samples collected at an airport where PFAS contaminated soil have been verified in several areas, thorough several different soil types, containing various particle sizes and contamination levels.
As a first step, the soil samples will be analyzed for PFAS22 content. A two step leachability test, L/S2 and L/S8 will then be conducted, to measure the amount of PFAS the untreated soil leach over time.
The results from the study will be available in the beginning of September. The following data is expected to be presented at the presentation:

- Initial concentrations of PFAS for 8 different soils from 8 different locations within an airfield
- Leachability of PFAS for all 8 samples
- Effects of Stabilization with Rembind, 2 different percentages Rembind for each samples.
- Soilwashing of 4 samples using A) water, B) one chemical and an additive, and 3) a patented desorption product
- Evaluation of effect of PFAS desorption due to contact time with the different wash waters for 4 samples
- Evaluation of final PFAS concentrations in various particle sizes for 4 different soils after soil washing
- Evaluation of leachability for 4 soil washed samples
- Possible effect of Stabilization with Rembind on washed samples – if concentrations show that this could be needed to reach target criterias.
- Evaluation on SAFFs potential to remove PFAS from wash water, and status of the wash additives to remain in solution.

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Evaluation of the PFAST method – Perfluorinated Assisted Soil Treatment on different soils from an airport in Sweden, using Surface Active Foam Fractionation (SAFF) in combination with different additives to perform PFAS soil washing

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EPOC Enviro, an Australian environmental engineering company and Envytech, their European technology partner, have been working in recent years to develop a PFAS separation and concentration process based entirely on the surface active power of rising air bubbles in a water column. This PFAS treatment method uses no consumables or additives.

Envytech have successfully operated more than 10 full scale SAFF projects since 2021, treating collected water from industrial and fire-fighting activities as well as over 250 000 m3 of PFAS contaminated leachate. The projects conducted on heavily contaminated and complex waters have shown to produce approx. 1-2 litres of PFAS hyper concentrate from every 150m3 treated.

Envytech have carried out a proof of concept study where a bench scale trial was carried out to evaluate a soil washing method combining SAFF, traditional soil washing steps and tailor made additives, developed by Envytech in cooperation with EPOC Enviro. The method trial proved that the added proprietary wash solvent was effective at desorbing many PFAS from highly contaminated soils with particle sizes varying from super fine to coarse. The trial also showed that SAFF could be used to remove essentially all of the PFAS transitioned in to the wash water, without removing the proprietary wash solvent, allowing it to be returned to the beginning of the soil washing process and reused.

During the summer of 2022, Envytech will conduct a new bench scale soil washing trial, involving 4- 8 different soils from an airport where a client wish to evaluate the potential for soil washing as a remediation method. The 8 different soil samples will all be analysed for PFAS, as will the leachate generated by the washing process. The aim if the

study is to evaluate if the different soil types can be effectively treated with the Envytech/EPOC soil washing and water treatment method.
To be able to compare results from the soil washing with the option of stabilization of PFAS impacted soils, all 8 samples will be stabilized with Rembind - a patented stabilization product from Rembind Pty.
By presenting results from the two soil washing bench scale trials, we will show if the developed soil washing and water treatment method is a possible option for a sustainable way of treating PFAS contaminated soils of various particle sizes and permanently removing PFAS from the environment. We will also compare soil washing with stabilization to evaluate which process offers the most potential for broad scale PFAS impacted soil management and remediation.
The results from the study will be available in the beginning of September. The following data is expected to be presented at the presentation

- Initial concentrations of PFAS for 8 different soils from 8 different locations within an airfield
- Leachability of PFAS for all 8 soil samples
- Effects of Stabilisation with 2 different percentages of Rembind for each sample.
- Soilwashing of 4 samples using A) water, B) one chemical and an additive, and 3) a patented desorption product
- Evaluation of the effect of PFAS desorption from soil due to contact time with the different wash waters for 4 samples.
- Evaluation of final PFAS concentrations in various particle sizes for 4 different soils after soil washing
- Evaluation of leachability for 4 washed soil samples
- Possible effect of Stabilization with Rembind on washed samples – if concentrations show that this could be needed to reach target criteria for beneficial on site reuse.
- Evaluation of SAFFs potential to remove PFAS from soil wash water, and concentrations of
the soil wash additives which remain in solution.

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Significant damage facts and experience of remediation/reforestion of damage forest in Georgia

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Law of Georgia on Environmental Liability adoppted on March 1 of 2021 year. State Government before today implementation a remediations and reforestations damage territory by himself and didn't have a special regulations for remediation/reforestation of damage territory by legal entitys or by some different acdinets. Information that will be presented in Article it is one of the biggest damage on the territory of Georgia in 2008 years. Fire was spread on the 1,260 hectars in Samtskhe-Javakheti Region on the territory of National Forest Agency and Agency of Protected Areas (Borjom-Kharagauli National Park, around of village Daba). Reforestation started by National Forest Agency and by State budget.

In results, whole part of significant damaged territory (1,100 ha) was reforestation and planted coniferous and broadleafs species for same composition of forest that was before fire and bases modern forest legislation. Most of important was renovation of forest by the National Forest Agency was spend very big energy and budget and succes came only after two times but plan of remediation finnaly stage was implemented and covered whole part. Meadows and the territory of Borjomi-Kharagauli National Parks burned forest were remediation without any special activities.

The fire started on August 16 and lasted for 26 days, capturing the territory of state forest fund with the area of 950. ha (Charkhistskali, Tba and Tsagveri forestries of Borjomi-Bakuriani Forest District). The area of about 250 ha was completely destroyed (Tba Forestry, the territory adjacent to the village Daba), and the remaining part was severely damaged. On the territory of Borjom-Kharagauli National

Park (Agency of Protected Areas) was destroyed 150 hectars of coniferous forest.
For assesment of damage territory, there was a Commission formed by the representatives of government agencies, academia and NGOs under the Decree (N252, 29.08.2008) of the Prime Minister of Georgia for assessing the impact on environment as the result of warfare in August 2008 .
In this case in article presented remediation/ reforestation example of siginificant damages by State budget and by the Ministry of Environment and Agriculture (MEA, NFA) but in otherwise case damage need to control and monitoring of process of remediation/reforestation plan by the National Environment Agency and implemente by companies step by step with agree Georgian legislation. Finnaly, implementation the Law of Georgia on Environmental Liabilitywill be help to implementation of remediation plans for significant damaged part in whole Georgia.

Keywords: The Ministry of Environment protection and Agriculture, LEPL National Forest Agency(NFA), LEPL Agency of Protected Areas (APA), remediation, reforestation, significant damage, red list.

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Assessment of the "Mindset" and culture for circular economy with the use of it: A case study in the Electronic Waste Industry in Brazil

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The Circular Economy (CE) represents a new anthropic model that provides the cyclical and responsible use of resources (Moraga et al., 2019). Systems aimed at circularity are guided by a strategy of regenerating natural capital, eliminating waste and pollution, and maintaining products and materials in the use phase (Ellen MacArthur Foundation, n.d.). Thus, they demand from companies the need to reassess their mindset and culture as a means to obtain consistent results when transitioning to this new economic model.

The Electronics Equipment industry has become a central focus regarding the transition to EC, especially due to the increasingly latent scarcity of materials, alarming amounts of waste generated and the low recovery rate in the current scenario. In the electronics end-of-life (EoL) sector, Brazil is going through a phase of adaptation to circularity, with recent regulations implemented in favour of collection and treatment for value recovery and reduction of environmental impacts.

This article aims to map the mindset of leaders and employees in the EoL electronics industry, using Information Technology (IT) by diagnosing the organizational mindset when transitioning to a circular economy. The study presents the use of the FlashPlayHR® tool which is intended to assess the mentality related to soft and hard skill aspects of leaders and employees.

The main results of the application of the soft skill test by the FlashPlayHR® platform on Industria Fox employees. Industria Fox has an organizational culture focused on circular economy (hard skills) and the characterization before the test is applied coincides with the results obtained at www.flashplayHR.com.br : a mentality of "model transition". Most employees (56%) were focused on soft skills profile

in “development(ii) and adaptive(ii)”, concerning the model Brito (2021), which is a characteristic of an organization undergoing the transition from “linear to circular”. The classification as a company in “development(ii)” and “adaptation (ii)” was highlighted by the leadership and planning groups, with 60% and 54%, respectively, of the results in the “development” (ii) profile. On the other hand, half of the employees working in the most operational group presented profiles of “Adaptability (ii) and Linearity (i)” with balanced percentages. However, the linearity profile becomes important in localized tasks.

The present study brought an innovative approach to applying an Information Technology tool for strategic human resources to carry out a mindset mapping regarding the Circular Economy process. It also helps in the integrated planning of the areas. The study shows, by identifying the mindset of employees, that Industria Fox has characteristics of “development” (ii) and “adaptation” (ii). The non-appearance of the “circular, systemic”(iii) , “resilient” profile (iii) demonstrates the need for investments in the training and qualification of the technical team in the soft skill and hard skill aspects at different organizational levels, promoting support for the continuous transition.

The limitations of the present study stem from the fact that it was restricted to the analysis of soft skills in a controlled group of a case study in an industry. Other evaluations were carried out with a general public. Therefore, future studies can address the specific knowledge skills of employees in terms of CE and integrate such results with the identified soft skills and consider more case studies in different industries. The tool used (FlashPlayHR®) proved to be useful to point out the diagnosis of mindset related to the soft skills and hard skills of the employees in the perspective of "linear to circular", particularly, in the sectors of leadership,

planning and execution of the studied company, which can be applied in other different productive sectors.

Keywords: Circular Economy, Electronic Waste Industry

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