# intersoil'2024

International Conference on Soils, Sediments and Water

## Santé des sols : c'est grave docteur ?

## Bodemgezondheid: hoe ernstig is het, dokter?

## Soil health: is it serious, doctor?

**5 & 6/12/2024**

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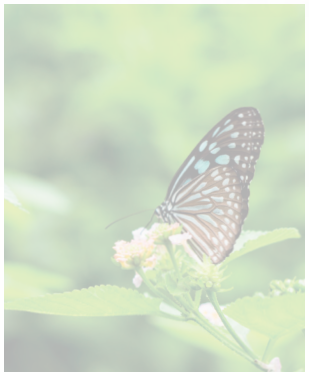
Good Soil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## Jeudi 5 décembre 2024

08h30
Accueil des participants

09h15
Discours de bienvenue
*Saïd El Fadili, Chef de la sous-division Sols - Bruxelles Environnement*

09h30
Vision Européenne
*Bavo Peeters, Chargé de mission protection des sols et utilisation durable des terres - Commission européenne*

10h00
Région Flamande
*Martien Swerts, Responsable d'équipe Sol et Environnement - Département Environnement & Johan Ceenaeme, Expert senior Sols et Coordinateur politique - Département Gestion du Sol, Agence Publique Flamande des Déchets - OVAM*

10h30
Région Wallonne
*Esther Goidts, Conseiller principal & Michel Amand, Directeur - Service Public de Wallonie (SPW), Agriculture Ressources naturelles & Environnement*

11h00
Pause-café

11h30
Région Bruxelles
Stratégie Good Soil : Comment rendre les sols bruxellois sains d'ici 2050 ?
*Wouter François, Chef de service - Bruxelles Environnement*

12h00
Discussions - Panel « Santé des sols »
*Modérateur : Bernard Deltour, Avocat associé - Industrious*

13h00
Déjeuner

## Comment objectiver la notion de santé des sols ?

14h00
IQSB – Comment aménager le territoire bruxellois en tenant compte de la qualité des sols et de leurs services écosystémiques ?
*Lydie Sombré, Chargée de projets & François Henry, Chef de projets - Bruxelles Environnement (Belgique)*

14h20
L'IQSW : un outil pour objectiver les services que les sols nous rendent
*Clélia Van de Casteele, Chargée d'études de sol - ARIES Consultants (Belgique)*

14h40
Comment intégrer les sols dans les stratégies de territoire ?
• *Cécile Grand, Chef de projets - Agence de l'Environnement et de la Maîtrise de l'Energie, ADEME (France)*
• *Florence Baptist, Directrice - Soltis Environnement (France)*

15h00
La complexité de l'évaluation de la santé des sols et une discussion sur les bonnes pratiques de gestion des sols
*Julie Estival, Cheffe de projets Agro environnement - Tauw Group (France)*

15h20
Pause-café

## Comment réussir le Zéro artificialisation nette des sols ?

15h50
Zéro artificialisation nette et défi de réindustrialisation
*Juliette Sohm Associate, Lawyer at the Paris Bar, Environment & Sustainability - Osborne Clarke (France)*

16h10
Évaluer la qualité écologique des sols au service de l'aménagement durable du territoire
*Battle Karimi, Directrice Scientifique - Novasol Experts (France)*

16h30
Réhabilitation écologique de friches polluées : développement d'un outil opérationnel d'évaluation des fonctions des sols urbains à l'échelle du projet d'aménagement
*Xavier Marié, Gérant - Sol Paysage (France)*

16h50
Un outil cartographique pour optimiser et gérer durablement les friches urbaines
*Fabiana Fabri, Titulaire de la Chaire UsinoVerT Usines & Territoires, Enseignante-Chercheuse en géographie et analyse environnementale - Institut polytechnique UniLaSalle, Rouen (France)*

17h10
Questions/Réponses & conclusions

17h30
Fin de la 1ère journée


## Donderdag 5 december 2024

08:30
Welkom van de deelnemers

09:15
Welkomstwoord
*Saïd El Fadili, Onderafdelingshoofd Bodem - Leefmilieu Brussel*

09:30
Europese visie
*Bavo Peeters, Ambtenaar bodembescherming en duurzaam bodemgebruik - Europese Commissie*

10:00
Vlaams Gewest
*Martien Swerts, Teamverantwoordelijke Bodem en Omgeving - Departement Omgeving & Johan Ceenaeme, Senior Bodemdeskundige en beleidscoördinator - Afdeling Bodembeheer, Openbare Vlaamse Afvalstoffenmaatschappij (OVAM)*

10:30
Waals Gewest
*Esther Goidts, Senior-adviseur & Michel Amand, Directeur - Waalse Overheidsdienst (WOD), Landbouw Natuurlijke grondstoffen & Milieu*

11:00 Koffiepauze

11:30
Brussels Gewest
Good Soil-strategie: hoe maken we de Brusselse bodem gezond tegen 2050?
*Wouter François, diensthoofd Leefmilieu Brussel*

12:00
Discussies - Panel “Bodemgezondheid”
*Moderator: Bernard Deltour, Partner - Industrious*

13:00 Lunch

## Hoe kunnen we het begrip bodemgezondheid objectiveren?

14:00
IBKB - Hoe kunnen we bij de planning van het Brussels grondgebied rekening houden met de kwaliteit van de bodem en zijn ecosysteemdiensten?
*Lydie Sombré, Project Manager & François Henry, Project Manager - Leefmilieu Brussel (België)*

14:20
De SQIW: een instrument om de diensten van bodems te objectiveren
*Clélia Van de Casteele, Bodemonderzoeker - ARIES Consultants (België)*

14:40
Hoe kan de bodem geïntegreerd worden in regionale strategieën?
• *Cécile Grand, Project Manager - Agence de l'Environnement et de la Maîtrise de l'Energie, ADEME (Frankrijk)*
• *Florence Baptist, Director - Soltis Environment (Frankrijk)*

15:00
De complexiteit van het beoordelen van bodemgezondheid en een discussie over goede bodembeheerpraktijken
*Julie Estival, Projectmanager Agromilieu - Tauw Groep (Frankrijk)*

15:20 Koffiepauze

## Hoe kunnen we een stop beton bereiken?

15:50
Stop beton en de uitdaging van herindustrialisatie
*Juliette Sohm Associate, advocaat bij de balie van Parijs, Milieu & Duurzaamheid - Osborne Clarke (Frankrijk)*

16:10
Beoordeling van de ecologische kwaliteit van bodems voor duurzame ruimtelijke ordening
*Battle Karimi, wetenschappelijk directeur - Novasol Experts (Frankrijk)*

16:30
Ecologische sanering van verontreinigde braakliggende terreinen: ontwikkeling van een operationeel instrument voor de beoordeling van de functies van stedelijke bodems op de schaal van het ontwikkelingsproject
*Xavier Marié, Manager - Sol Paysage (Frankrijk)*

16:50
Een karteringsinstrument om stedelijke braakliggende terreinen te optimaliseren en duurzaam te beheren
*Fabiana Fabri, Houder van de leerstoel UsinoVerT Usines & Territories, docent-onderzoekster in geografie en milieuanalyse - Institut polytechnique UniLaSalle, Rouen (Frankrijk)*

17:10 Vragen/Antwoorden & Conclusies

17:30 Einde van dag 1


## Thursday December 5, 2024

08:30
Attendee's welcoming

09:15
Welcome speech
*Saïd El Fadili, Head of the Soils sub-division - Brussels Environment*

09:30
European Vision
*Bavo Peeters, Policy officer Soil protection & Sustainable Land use - European Commission*

10:00
Flemish Region
*Martien Swerts, Soil and Environment Team manager - Environment Departement & Johan Ceenaeme, Senior Soil expert and Policy coordinator - Soil management department - Public Waste Agency of Flanders (OVAM)*

10:30
Wallonia Region
*Esther Goidts, Senior advisor & Michel Amand, Director - Public Service of Wallonia (SPW), Agriculture Natural resources & Environment*

11:00
Coffee break

11:30
Brussels-Capital Region
Good Soil Strategy: How to make Brussels soils healthy by 2050?
*Wouter François, Head of department - Bruxelles Environnement*

12:00
Discussions - "Soil health" panel
*Moderator: Bernard Deltour, Partner - Industrious Law Firm*

13h00
Lunch

## How to objectify the notion of soil health?

14:00
IQSB – How to develop the Brussels territory taking into account the quality of the soil and its ecosystem services?
*Lydie Sombré, Project Manager & François Henry, Project Manager - Brussels Environment (Belgium)*

14:20
WSQI: a tool for objectifying soil ecosystem services
*Clélia Van de Casteele, Soil Studies Manager - ARIES Consultants (Belgium)*

14:40
How to integrate soils into territorial strategies?
- *Cécile Grand, Project Manager - French Agency for Ecological Transition, ADEME (France)*
- *Florence Baptist, Director - Soltis Environment (France)*

15:00
The complexity of evaluating soil health and a discussion on good soil management practices
*Julie Estival, Agro environment Project Manager - Tauw Group (France)*

15:20
Coffee break

## How to achieve zero net land artificialization?

15:50
Zero net artificialization and the challenge of reindustrialisation
*Juliette Sohm Collaboratrice, Avocate au Barreau de Paris, Environnement & Développement Durable - Osborne Clarke (France)*

16:10
Evaluate the ecological quality of soils for sustainable land development
*Battle Karimi, Scientific Director - Novasol Experts (France)*

16:30
Ecological rehabilitation of polluted wastelands: development of an operational tool for assessing the functions of urban soils at the scale of development project
*Xavier Marié, Company Manager - Sol Paysage (France)*

16:50
A cartographic tool to optimize and sustainably manage urban wastelands
*Holder of the UsinoVerT Chair in Factories & Territories, Teacher-Researcher in geography and environmental analysis - UniLaSalle Polytechnic Institute, Rouen (France)*

17:10
Questions/Answers & conclusions

17:30
End of day 1

# Importance de la gestion intégrée et durable des sols à Bruxelles

Saïd El Fadili, Directeur - Bruxelles Environnement – Leefmilieu Brussel
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Les sols sont une ressource non renouvelable et limitée, dont la formation de quelques centimètres requiert plusieurs milliers d'années. Ils sont de ce fait particulièrement précieux. Ils constituent un écosystème vivant essentiel, complexe, multifonctionnel et indispensable au niveau environnemental et socio-économique. Ils rendent des services écosystémiques essentiels aux populations locales et au niveau mondial, tels que la fourniture de ressources alimentaires et de matières premières, la régulation du climat grâce à la séquestration du carbone, la purification de l'eau, la régulation des nutriments ou la lutte contre les organismes nuisibles. En outre, ils servent de plateforme aux activités humaines et limitent les risques d'inondation et de sécheresse. Ces services sont cruciaux pour la vie humaine et la survie des écosystèmes, afin que les générations actuelles et futures puissent subvenir à leurs propres besoins.

Or, la législation bruxelloise actuelle se limite à la prise en charge des pollutions chimiques des sols, en vue de les décontaminer et de les réserver presque uniquement aux seules fonctions de support pour des bâtiments et autres infrastructures. Cette approche néglige la prise en considération des sols dans leurs dimensions physique et biologique et, par conséquent, ne prend pas (ou insuffisamment) en compte la valeur des services écosystémiques qu'ils fournissent . La gestion intégrée et durable des sols poursuivie par le présent projet a donc pour objectif d'intégrer, en plus des composantes chimiques, les propriétés physiques et biologiques des sols et de traiter l'ensemble des dégradations qu'ils subissent (compaction, érosion, pertes en matière organique, en nutriments et en micro-organismes,…).

Les différentes campagnes d'analyse, réalisées par Bruxelles Environnement en 2021 et 2022, montrent que 50% de sols bruxellois sont dégradés et la Région ne peut négliger le risque qu'entraîne l'aggravation de cette situation. La Région a besoin d'intégrer la politique de protection, de gestion durable et de restauration des sols dans le modèle socio-économique proposé par la Commission européenne.

L'absence de cadre juridique bruxellois en matière de gestion intégrée et durable des sols, adapté et cohérent, est identifiée par les parties prenantes comme la principale cause favorisant la poursuite de la dégradation des sols bruxellois.

Investir pour éviter la dégradation des sols et pour restaurer les sols dégradés est économiquement cohérent, car en règle générale les bénéfices excèdent largement les coûts et selon la stratégie 2030 sur les sols de la Commission européenne les coûts de la restauration sont dix fois plus élevés que les coûts de prévention.

La protection des sols, leur utilisation durable dans le contexte d'une économie circulaire, ainsi que leur restauration doivent être intégrées dans toutes les politiques sectorielles pertinentes et cohérentes afin de prévenir toutes nouvelles dégradations, de garantir un niveau uniformément élevé de protection (et, le cas échéant, de restauration) et d'éviter les chevauchements, les incohérences et les contradictions au sein de la législation et des politiques de la Région.

**1. Gestion intégrée et durable des sols pour lutter contre les changements climatiques**

La dégradation des sols entrave la capacité de la Région à atteindre ses objectifs en matière d'environnement, de développement durable et de climat. Ainsi, par exemple, en l'absence de mesures supplémentaires pour améliorer la qualité des sols bruxellois, il sera difficile, voire impossible, d'atteindre les objectifs de neutralité carbone et d'adaptation aux changements climatiques en 2050 comme en atteste la Commission européenne dans sa stratégie 2030.

Les sols vivants renforceront la résilience de la Région et réduiront sa vulnérabilité aux changements climatiques. Les sols de la planète constituent le plus grand réservoir terrestre de carbone (3 à 4 fois plus que la végétation et l'atmosphère réunies). Les sols sains sont essentiels à l'atténuation du changement climatique car ils absorbent environ 25 % de l'équivalent carbone issu chaque année de l'utilisation des combustibles fossiles au niveau mondial. Les espaces verts, l'agriculture, les bois et les forêts contribuent de façon essentielle à l'absorption du carbone de l'atmosphère grâce au captage et au stockage du carbone dans les sols et dans la biomasse.

La Commission européenne déclare qu'on ne peut réussir les stratégies relatives à la biodiversité, l'alimentation et surtout la neutralité carbone en 2050 que si nous avons d'ici là 100% de sols sains. Plus concrètement, la Commission estime que pour parvenir à la neutralité carbone en 2050, il faudra non seulement mettre un terme à la destruction des sols riches en carbone mais aussi enrichir les sols en carbone. La Région pourra soutenir l'initiative mondiale « 4 pour 1000 » afin d'augmenter la teneur en carbone organique des sols (agricoles, forestiers et des espaces verts). Compte tenu de leur rôle crucial dans le cycle de l'eau, les sols constituent également un allié indispensable pour l'adaptation au changement climatique. Une forte capacité de rétention d'eau des sols limite les effets des inondations et diminue l'impact négatif des sécheresses.

Enfin, des bonnes pratiques concernant le stockage du carbone et le maintien de l'eau dans les sols (agroécologie, agroforesterie, agriculture de conservation, gestion des paysages, gestion des déchets verts, paillage, etc.) seront mises en place.

**2. Gestion intégrée et durable des sols pour lutter contre le déclin de la biodiversité**

Les sols vivants abritent 25% de la biodiversité mondiale et tous ces micro-organismes jouent un rôle essentiel pour assurer l'ensemble des services écosystémiques. La présence d'une faune dans les sols augmente significativement le rendement, la biomasse et la diversité des plantes. Plus généralement, l'impact de la faune du sol sur la production primaire peut être vu au travers de ses effets sur les fonctions de recyclage des nutriments, d'entretien de la stabilité/structure du sol, de contrôle des parasites et de support de biodiversité. Un sol vivant favorisant une biodiversité riche et variée ne doit pas être forcément un sol riche en nutriments et en matière organique car l'objectif est d'avoir une diversité des sols pour assurer une diversité des plantes. Par exemple, un sol vivant riche dans une zone humide permet le développement d'espèces végétales telles que la reine des prés qui est extrêmement utile aux insectes butineurs, tandis qu'un sol pauvre favorise l'apparition d'orchidées sauvages, etc.

La faune du sol représente donc un atout pour la croissance et la diversité des plantes. Pourtant, cette faune s'appauvrit en raison de pratiques de gestion des sols non durables et de la fragmentation des habitats naturels. Cet appauvrissement agit sur les interactions biologiques et induit un plus faible niveau de services rendus, notamment concernant la pollinisation ou le contrôle des ravageurs, la disponibilité en nutriments ou la stabilité des sols. Les pratiques de gestion durables des sols devraient aider à maintenir, voire améliorer, la faune du sol et par conséquent la diversité des plantes.

La présente ordonnance vise dès lors à restaurer la faune du sol, à surveiller son évolution et son étendue.

**3. Gestion intégrée et durable des sols en faveur de l'économie circulaire**

Enfin, la gestion circulaire des sols déjà scellés (entre 17.000 et 26.000 bâtiments abandonnés) pourrait aider à freiner l'imperméabilisation des sols et ainsi à mieux lutter contre les inondations et le déclin de la biodiversité. La Stratégie UE projette, à ce titre, « zéro artificialisation nette » en 2050. A l'échelle de la Région, 65 hectares de sols sont imperméabilisés par an. Sans mesures contraignantes destinées à limiter l'occupation de nouvelles terres et à favoriser leur restauration, leur remise en culture et leur recyclage, il sera impossible d'atteindre l'objectif consistant à mettre fin à l'augmentation nette de l'artificialisation des terres d'ici 2050.

**4. Mise en place concrète de la gestion intégrée et durable des sols**

Il est nécessaire de connaitre la qualité des sols bruxellois et le présent projet d'ordonnance poursuit cet objectif car seule une information complète peut aider à identifier et restaurer les dégradations et à gérer durablement les sols bruxellois.

Le but est de mettre en place une procédure d'identification et de traitement des sols dégradés et d'aider les propriétaires et les exploitants à mieux choisir les usages pour leurs sols en fonction des services écosystémiques qu'ils sont susceptibles de fournir. Par exemple, un sol vivant sera, dans la mesure du possible, réservé à l'agriculture, la biodiversité et la régulation des cycles de l'eau et du carbone, tandis qu'un sol non vivant sera destiné aux constructions.

En outre, il y a lieu d'encourager les utilisateurs des terres à prendre des mesures de prévention afin d'empêcher la dégradation des sols, de préserver les sols et de les gérer de manière durable pour les générations futures.

Pour ce faire, il est nécessaire de prévoir des mesures de soutien et d'incitation financières suffisantes en faveur de la protection, de la gestion durable, de la préservation et de la restauration des sols.

De même, des guides techniques verront le jour afin d'aider les acteurs concernés à gérer de façon intégrée et durable les sols bruxellois.

Des partenariats seront renforcés avec les acteurs de planification et d'urbanisation, les communes, les opérateurs publics, les experts ou les entrepreneurs en gestion ainsi qu'avec les notaires et les fédérations sectorielles.

Enfin, il est utile et nécessaire de mettre en place des initiatives qui visent à améliorer la sensibilisation et la compréhension du public en ce qui concerne l'incidence positive des fonctions des sols et de la protection et la de restauration des sols, ainsi qu'en matière de santé publique et de durabilité environnementale. La sensibilisation du public à l'égard des fonctions des sols et sa compréhension du sujet sont fondamentales pour garantir le succès du présent projet d'ordonnance. La participation des citoyens, et en premier lieu des propriétaires et gestionnaires terriens, des agriculteurs et des forestiers, en tant qu'acteurs principaux de la gestion des sols est aussi un enjeu fondamental. Pour ce faire, il est préconisé de renforcer le dialogue avec le grand public en ce qui concerne la santé des sols et l'urgence environnementale, de soutenir les initiatives locales sur la protection et l'utilisation durable des sols.

**Good Soil Strategy: How to Make Brussels' Soils Healthy by 2050?**

Wouter François, Head of service - Brussels Environment

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The Good Soil strategy, adopted by the Brussels government in May 2024, aims to lay the first foundations for integrated and sustainable soil management in the specific urban context of the Brussels-Capital Region. This strategy not only aims to address soil contamination but also to consider all soil threats and promote soil ecosystem services. Among other things, it seeks to ensure a balance between soil management and the various socio-economic functions of the Region based on the principle of "the right soil for the right use". Several measures from this strategy are already being implemented, and a thorough implementation is being prepared, with partnerships forming a central element. The perspective is to continue improving the living environment by responding to the major challenges our society faces in terms of environment, climate, urban planning, and socio-economics.

**IQSB – How to develop the Brussels territory taking into account the quality of the soil and its ecosystem services?**

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ir. François Henry, Project Manager – Brussels Environment (Belgium)
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Launched as part of the Good Soil strategy, the Brussels Soil Quality Index (BSQI) is the tool of choice to study soil quality in Brussels. An IQSB study is aimed at professionals involved in the development of urban planning projects and results in a quantitative indicator describing the quality and health of the soil of different areas within a site. Its main aim is to help project developers, as early in a project as possible, to match planned uses and functions with the actual quality of the soil on site.

To do so, it measures various soil parameters to assess the physical, biological and chemical state of a site, its capacity to provide ecosystem services, and the level of degradations it may have sustained. It also provides sustainable management guidelines to help keep the soil in the best possible health so that it can provide the maximum number of ecosystem services.
In short: the goal of this indicator is to put the right use on the right soil, by allocating as much good-quality soil as possible to the uses that require it (such as nature, agriculture, water cycle management, etc.), and by limiting as far as possible infrastructure and construction to already degraded soils.

# IQSW: a tool for objectifying soil ecosystem services

Clélia Van de Casteele[1], Arnaud Delfairière[1], Louis Vandebroek[1], Yannick Agnan[2], Brieuc Hardy[3]

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A healthy soil can provide ecosystem services such as food and biomass production, regulation of the water cycle, habitat for biodiversity and carbon storage. In Wallonia, the Soil Decree sets out the framework for diagnosing and limiting pollution-related soil degradation, but there is no tool for assessing a soil's capacity to provide ecosystem services, including its physical, chemical and biological dimensions.

The IQSW project ('*Indicateur de Qualité des Sols Wallons*', Walloon Soil Quality Indicator) aims to develop two tools to assess the quality of Walloon soils:

- IQSW-pro: an indicator for improving soil quality or guiding soil use in line with its current state of quality, for use by any public or private player who exploits, uses, protects or restores (or even creates) soil. It is intended to cover every soil use, namely agricultural, forestry and urban.
- IQSW-citizen: an indicator to raise public awareness of the importance of soil conservation, based on simple tests.

**IQSW-pro**

Stakeholders are involved in the IQSW-pro development steps. In order to characterise soil in all its heterogeneity, IQSW will include physical properties (including texture, structure and hydrological properties), chemical properties (including nutrient richness and organic matter) and biological properties (abundance, diversity and activity of soil fauna and micro-organisms). The results of measuring these properties will be combined and processed to obtain an 'ecosystem service score' that objectively measures the soil's ability to provide a given ecosystem service.

**IQSW-citizen**

The philosophy behind the IQSW-citizen is to be as flexible as possible, depending on the needs and interests of the user. Depending on the information they need about their soil, people can choose between different thematic paths linked to ecosystem services (for example, the user will follow a fertility path if he wants to plant a vegetable garden).

The field tests are organised into several levels, depending on the user's needs and interests:

- Level 1 tests: minimum package of tests and observations,
- Level 2 tests: more 'advanced' protocols (longer, requiring equipment, etc.) to refine the conclusions of the first level or acquire additional information,
- Level 3 tests: referral to related tools and possible laboratory analyses.

Diagnosis is first carried out at field level, in order to identify the various factors impacting the soil and to distinguish homogeneous areas. Once the test area has been defined, we gradually zoom in on an observation quadrat, before extracting a clod and manipulating the soil itself.

The results are then interpreted according to the selected path (e.g. fertility), based on a traffic light system (green-orange-red). Based on the results, recommendations will be made to citizens on how to improve their soil and thus promote ecosystem services.

While IQSW-pro is still at the conception stage, IQSW-citizen will be tested in autumn 2024 in order to validate protocols and the resulting interpretations. This questioning will be fuelled by feedback from a panel of testers, enabling the tool to be fine-tuned to suit end-users' expectations while ensuring its scientific relevance.
Once validated, the methodological guide can be widely broadcasted. This will be accompanied by an interactive platform for encoding the results.

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# How to integrate soil into territorial strategies?

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To overcome the lack of soil data for assessing soil functions in urban areas, the guide will present different approaches that can be carried out setting a global sampling strategy which can be very costly (at a scale of 1/10,000 where possible) to more targeted strategies focusing on areas of interest, reducing the number of samples (e.g., renaturation zones).

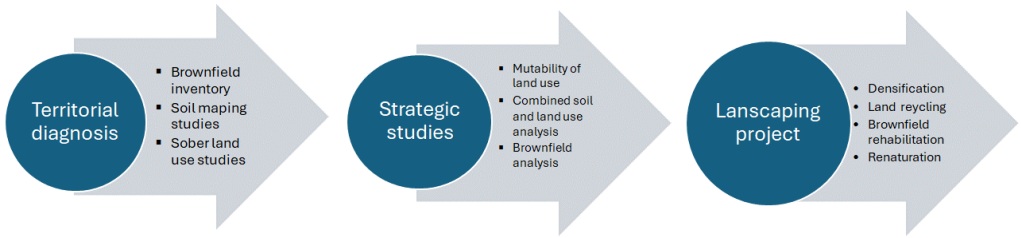
The aim of the work is to provide a guide for the stakeholders involved in land-use planning, so that they can be directed towards appropriate methods for considering soil functions in urban or rural areas and integrating soil considerations into planning documents.

**Abstract**

The Climate and Resilience Law of August 2021, with its qualitative and quantitative definitions of soil artificialisation, introduces a new legal approach to soil. It defines artificialisation as "*the lasting alteration of all or part of a soil's ecological functions, particularly its biological, hydric and climatic functions, as well as its agronomic potential through its occupation or use*". This law sets an intermediate target to halve the consumption of natural, agricultural, and forest land by 2031, compared to the consumption measured between 2011 and 2021, and a goal of achieving zero artificial land take by 2050. From 2031, new regulation based on the measurement of land use (coverage and uses) and on a codification[1] of urban areas will be implemented. However, these regulations only partially account for soil functions, potentially leading to significant negative impacts if not fully considered (e.g., urban densification in areas with high-quality soils, restoring soils without addressing issues like flooding or ecological fragmentation).

In addition to the environmental issues associated with land-use planning, urban areas must adapt to the consequences of climate change and meet biodiversity preservation and restoration objectives (Climate Law - Biodiversity Plan). Renaturation of brownfields or areas with significant ecological concerns presents an opportunity to make territories more resilient, offering a range of environmental, social, and economic benefits. These priority areas for renaturation represent a real chance to create natural spaces within cities (urban parks, community gardens, green belts, biodiversity reservoirs). To achieve this, it is essential to restore soil ecological functions and the ecosystem services they support.

[1] According to the nomenclature of the decree of 27 November 2023- article appendix R 101-1 of urban planning regulation




*Picture 1 : soil analysis in land planning processes*

Soil functions should therefore be integrated at the urban planning scale as well as at the operational scale development projects) through soil properties analysis (***Picture 1***). This would (1) complete territorial diagnostics with soil information, (2) integrate soil functions into NNLT (No Net Land Take) strategies, which are usually based on measuring land use and occupation, and (3) provide a better understanding of which soil functions need to be renatured or restored (pedological and ecological engineering actions).

To promote best practices for understanding soil functions, several methodologies have been developed that can be applied at different scales. To assist stakeholders involved in land-use planning in implementing these new methods, ADEME, in collaboration with SOLTIS Environnement, has developed a guide to help stakeholders carry out appropriate soil diagnostics.

For regional land-use planning, the MUSE methodology can be used to map the multifunctional potential of soils at a large scale (1:250,000). Based on various documentary data, this method offers indicators for four key soil functions, with different approaches for rural and urban areas (agronomic potential, water infiltration potential, carbon storage potential, soil biodiversity index). Although better suited to regional scales, this methodology can provide initial guidance, identifying areas that need further study (e.g., areas for densification, preservation, renaturation, or restoration) where ecological soil functions must be examined in greater detail through field data collection (e.g., agro-pedological diagnostics). As a simple additive methodology, it also accounts for additional constraints essential for a realistic assessment of soil functions (e.g., hydromorphy, slope, salinity, and contamination).

For landscaping projects, other methods have been developed based on more detailed soil diagnostics, involving observation, sampling, and analysis. These methods typically integrate physical, chemical, and biological soil properties (e.g., pH, texture, nitrogen content, presence of biological activity), which are then translated into 'soil function indicators' and interpreted according to national or local standards.

For urban land-use planning, the results produced by the MUSE methodology are not sufficient for supporting decision-making. Moreover, the databases used in this methodology are rarely available in urban areas. On the other hand, soil diagnostics can be too costly for local authorities. To address this issue, the guide presents different approaches, including comprehensive sampling strategies (at a scale of 1/10,000 where possible) or focusing on areas of interest to reduce the number of samples (e.g., renaturation zones).

In general, this guide aims to provide better support for stakeholders involved in land planning, helping them integrate soil functions into planning documents.

***Keywords***

*Soil, soil functions, artificialization, land planning, soil diagnostics, landscaping, no net land take (NNLT), land use efficiency, ecological soil function, soil ecosystem services.*

# The complexity of evaluating soil health and a discussion on good soil management practices

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**Key words:**
Desealing soils / Mitigating erosion / Mitigating compaction / Green cities / Treatment of polluted soils / Biodiversity / Capacity of the soil to retain water / Soil monitoring law

**Innovative content:**
The communication will show 2 recent case studies (2024) with feedback on soil health assessment, using an approach based on the preservation and enhancement of selected soil ecosystem services. The 2 cases are very different and complement each other, illustrating the complexity of determining a 'healthy soil' and exemplifying how good soil management practices are guided by this type of evaluation. Finally, the communication will also discuss the approach adopted by the European Commission in the new Directive on Soil Monitoring and Resilience.

**Abstract:**
A healthy soil can have a wide scale of natural functions, and good soil health is important for our society. However, it appears that assessing all the functions of the soil is a tremendous work, and maybe not necessary at the scale of a specific project. Thus, one approach to determine soil quality is to select the most interesting ecosystem services (based on the environment initial state and the future use of the site), and to assess only corresponding soil functions. For example, fertile soils are needed for food production while poor soils are sometimes needed for renaturation. Therefore, there is not one approach to do research on 'healthy soils', since each ecosystem service requires different soil conditions. In this way, soil quality is not absolute but relates to certain ecosystems services (and of course pedoclimatic conditions).

In this presentation we will discuss the complexity of evaluating 'healthy soils' and the different parameters that could be included in such a research study, depending on the ecosystem services selected. This discussion will be illustrated by two different case studies to show different designed and performed research.

The first case study is about management of two municipal parks in the city of Deventer, The Netherlands. At both parks, different events are organized, like festivals and art events. These events might have a negative impact on the soil quality and might have resulted in the compaction of the soil. In this research the following parameters have been measured or

analyzed to be able to make a good assessment of the soil quality: soil resistance (penetrometer), soil biota (worms), water permeability (k-value), organic matter content and stability, pH, CEC and nutrients. Based on this outcome we advise measures to prevent further soil compaction and improve the soil quality, such as monitoring the soil resistance before and after every event, plowing the field and advise change in the land use (type of event, frequency).
The second case is about the transformation of a former textile factory, in the North-East of France. The project owner wants to build a photovoltaic power plant, but faces certain constraints / opportunities due to the environment and to the history of the site. Former industrial activities led to soil contamination; whereas the area shelters various ecological habitats, with biodiversity of national importance on some places (particularly wetlands). Moreover, a river runs alongside and the area is a flood zone in case of heavy rains. The research focused on the following parameters that have been measured to assess soil quality: soil structure and type (pedology), flora inventory, and chemical analysis (pH, organic matter content, hydrocarbons, volatile compounds, metals, cyanides, PCB). The results have guided our recommendations: on site remediation on the most impacted areas, project design minimizing the degradation of wetlands and preserving the hydraulic functions of the flood zone (testing several layouts), monitoring biodiversity during and after the construction phase, promoting plant species that are interesting both for ecological habitats and flood zone functioning, ...

Finally, we would like to discuss the approach proposed by the Soil monitoring Law that heads more towards threats posed to the soil. Salinization, erosion, soil sealing, etc. are phenomena widely observed throughout Europe, making the definition of 'healthy soils' a more consensual one than one focusing on the characterization of site-specific ecosystem services. However, this approach may be difficult to adopt by stakeholders and might not promote the vital benefits of the soil.

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# Zero net artificialisation and the challenge of reindustrialisation

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The purpose of this presentation is to review the French ZAN system and to explain how the law attempts to reconcile land conservation with the objective of reindustrialisation.

## 1) Overview of the French ZAN system

In this communication, we will recap the French 'zero net artificialisation' system introduced by the 'Climate and Resilience' Act of 22 August 2021, which set the objective of achieving 'zero net artificialisation' (ZAN) of land by 2050, with an intermediate objective of halving the consumption of natural, agricultural and forest areas (ENAF) over the period 2021-2031 compared with the previous decade. This gradual trajectory is to be set out in local planning and urban development documents. In concrete terms, between now and 2031, the text authorises the urbanisation of 125,000 hectares.

The system is accompanied by a nomenclature for the artificialization of land, which includes 5 categories of artificialized surfaces (for example, waterproofed surfaces due to buildings) and 5 categories of non-artificialized surfaces (for example, natural surfaces or surfaces used for crops).

ZAN and its nomenclature take a quantitative approach, based on the stock of land, rather than a qualitative approach to soil. The notion of functionality no longer appears in the nomenclature, contrary to what the law stipulates in terms of artificialisation, namely: '*The lasting alteration of all or part of the ecological functions of a soil, in particular its biological, hydric and climatic functions, as well as its agronomic potential through its occupation or use*'.

ZAN still needs to be improved if it is to become a genuine tool for improving soil condition.

For the time being, the implementation of ZAN has only been the subject of adjustments designed to reconcile sober land use and the economic development of the regions. We will look at these challenges mainly through two laws:

- The law of 20 July 2023 aimed at facilitating the implementation of objectives to combat the artificialization of land and to strengthen support for local elected representatives;
- The Green Industry Act, aimed at speeding up the country's re-industrialisation and making France the green industry leader in Europe.

These laws provide tools for land recycling and allow exceptions to ZAN for certain strategic projects.

## 2) Tools for industrial land recycling

One of the prerequisites for reindustrialising France is being able to mobilise the land needed to set up new economic activities.

However, this economic policy objective is in direct conflict with the of achieving "zero net artificialisation of land" by 2050. The Green Industry Act seeks to facilitate and accelerate the mobilisation of industrial land.

The law introduces a number of technical measures to facilitate the mobilisation of industrial land by broadening the scope for interested third parties to substitute for the operator: under the so-called "third party applicant" procedure, an interested third party may ask the Prefect to substitute for the last operator of an ICPE to carry out remediation work.

One of the measures provides a significant relief for former operators in the event of a third-party procedure. In cases of default of the third-party, the last operator is only responsible for ensuring the safety of the site and not for its full remediation. Which means that in the event of a third-party procedure, the last operator will be relieved of its rehabilitation obligation.

As far as land is concerned, these measures must combine with the action of the Banque des Territoires, which is due to invest €1 billion between 2023 and 2027 to create 50 pre-developed "turnkey" sites by cleaning up brownfield sites.

3) Exceptions to ZAN for specific projects

The law of 20 July 2023 provides for the consumption of natural, agricultural and forestry areas (ENAF) by projects of national or European scope (PENE) of major general interest to be accounted for at national level, rather than regional or local level. For the decade 2021-2031, the envelope dedicated to the consumption of space by PENEs is 12,500 hectares.

Under the terms of article 19 of the Green Industry Act, the Administration may, by decree, designate a project as being of 'major national interest' (PINM), by initiating a procedure to make town planning documents compatible with the project and be included in the national artificialisation envelope of 12,500 hectares reserved for major national and regional projects. New industrial projects already account for 30% of the first 167 projects selected to escape the ZAN, unveiled in April by the Ministry of Ecological Transition.

Ultimately, reindustrialisation is likely to lead to competition for land as part of the implementation of ZAN, and appropriate compromises will have to be found between reindustrialisation and respect for planetary limits. This raises questions about how to reclaim derelict land, and how to make use of vacant buildings to achieve the objective of using land sparingly. Bringing industry and logistics closer to city centres, as part of a strategy to reduce the carbon footprint of transport, is also a key issue, and will require support from the public authorities, which will need to provide low-cost industrial sites.

The necessary revision of the ZAN or - in any case - of French law, to include a qualitative approach to soil, will reinforce this logic of recycling industrial land and lead to the development of tools for identifying and prioritising efforts to regain ecological functionality where such efforts will be most effective.

A new law on ZAN has been announced for the first half of 2025, to be continued…

# Assessing the soil ecological quality of soils to improve the sustainability of urban development

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**Title:** Assessing the soil ecological quality of soils to improve the sustainability of urban development

**Keywords:** Ecological Quality – Urban planning – Sustainable management – Renaturation – Circular economy

**Abstract:**
Paris La Defense is one of the most artificialized and impermeabilized area in France and Europe. To meet environmental and social objectives, the Public Development Agency (PDA) provides an intensive renaturation of the area, including the implementation of a large brown and green frame between the Terraces of the Nanterre University and the Parc du Chemin de l'Ile that line the Seine river. To plan a sustainable urban development and better integrate soils into their strategy, the PDA has initiated a step of evaluation of the ecological quality of available soils on the area. The objective of the microbiological and ecological diagnosis of these soils is to assess their quality, fertility and sustainability as a key criterion for their reuse on site or in other site of the PLD area concerned by future landscaping. Three sites with different uses and characteristics were here investigated: i- the footprint of a future city stadium located on an urban vegetated wasteland, ii- a 30-years old urban farm, iii- a motorway interchange hosting both soil storage embankments and unused vegetated zones.

For each site, a specific and appropriate strategy was designed to sample soils and deploy the indicators of soil ecological quality. The results provided different information for the PDA:

i- The detection of soils of satisfactory and sufficient ecological quality to be reused on site;
ii- The assessment of the possibility of re-use soil deposits in future development;
iii- The identification of inappropriate soil management practices that have led to an alteration of soil quality;
iv- The identification of the most appropriate uses of evaluated soils for the future;
v- The proposition of actions to improve the quality of soil of poor quality.

All the conclusions and recommendations are valued by the PDA to optimize the choice of future uses and landscaping, to improve the traceability of the soils and materials used, and to implement a management that improves and does not degrade the ecological value of these new urban landscape.

# Réhabilitation écologique de friches polluées : développement d'un outil opérationnel d'évaluation des fonctions des sols urbains à l'échelle du projet d'aménagement

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## Caractère innovant du sujet

Développement et application d'un outil d'évaluation fonctionnelle basé sur une synthèse bibliographique de la littérature scientifique et technique afin (1) de sélectionner les indicateurs les plus robustes et opérants pour évaluer les fonctions des sols ; (2) d'adapter les référentiels des indicateurs sélectionnés à des contextes urbains ; (3) de proposer une méthode adaptative aux besoins du projet et dont les résultats soient facilement appropriables par un non-sachant.

## Objectif

L'objectif principal du projet est d'évaluer les fonctions de sols de friches polluées, avant et après travaux de réhabilitation écologique, sur la base de diagnostics de terrain écologiques et agropédologiques.

## Résumé

La politique du « zéro artificialisation nette » (ZAN) issue de la Loi Climat et Résilience conduit les territoires à la réhabilitation de leurs friches pour lutter contre la dégradation des sols naturels et permettre la refonctionnalisation de sols artificialisés susceptibles d'accueillir de nouveaux espaces de nature en ville. Cependant, l'évaluation des fonctions dans ces sols urbains, très spécifiques et souvent pollués, reste peu éprouvée du fait de l'absence d'outils opérationnels et adaptés aux friches. Dans ce contexte, le projet « Friches Réhabilitation » soutenu par l'ADEME vise à contribuer à l'établissement d'indicateurs fonctionnels et de référentiels d'interprétation associés, spécifiques aux caractérisations en milieu urbain et à l'état souhaité de refonctionnalisation des sols.

Trois friches urbaines situées respectivement à Maubeuge, Rouen et Avranches, ont fait l'objet en 2022 d'un diagnostic initial de fonctionnalité, préalable aux travaux de réhabilitation et en 2024 d'un diagnostic final. Sur chacune des friches ont été définis des points d'étude contrastés en termes d'historique, d'usage passé et à venir. Un point d'étude de référence fonctionnelle a également été sélectionné sur chacune des friches (ex : sol naturel à proximité présentant a priori le plus haut niveau de multifonctionnalité localement). Le groupement Sol Paysage – mandataire – et ARCHIMED environnement – co-traitant – ont réalisé sur ces points d'étude des diagnostics agropédologiques, sites et sols pollués et écologiques. Ainsi, une trentaine de paramètres physiques, chimiques et biologiques des sols ont été mesurés à la fois sur le terrain et à partir d'échantillons en laboratoire. Sur la base de la littérature scientifique et technique disponible. Ces différents paramètres ont été agrégés pour caractériser 7 fonctions : (1) Habitat pour les organismes du sol ; (2) Stockage du carbone ; (3) Capacité d'infiltration de l'eau ; (4) Capacité de rétention de l'eau ; (5) Potentiel d'enracinement – ancrage physique des végétaux ; (6) Rétention et fourniture en éléments nutritifs ; (7) Recyclage et transformation de la matière organique. D'après les référentiels disponibles, un score de 0 à 3 a été associé à chaque valeur de paramètre. Chaque fonction est ainsi évaluée sur la base de la moyenne du score des paramètres la caractérisant, et représentée sous forme de diagramme.

Les résultats obtenus sur les trois friches mettent en avant la complémentarité des observations pédologiques faites sur le terrain aux données issues d'analyses en laboratoire. L'analyse de chacun des paramètres permet une interprétation fine du fonctionnement du sol, en cohérence avec les données historiques des sites et les milieux écologiques observables avant réhabilitation (développement du couvert végétal, état de surface, écoulement des eaux…) ainsi que les travaux réalisés. Les gains de fonctionnalité sont en effet fortement dépendants de la modalité de sol mise en œuvre (nature des matériaux, épaisseur, compaction, couvert végétal…). La fonctionnalisation de sols reconstitués étant un processus relativement long, cette première évaluation post-travaux constitue en réalité un nouvel état initial qu'il serait pertinent de réévaluer 3 à 5 ans après la fin des travaux.
La méthode de scoring développée permet quant à elle d'illustrer de façon synthétique et didactique le fonctionnement des sols et de les comparer entre eux, notamment à un sol choisi comme référence. Le choix de ce site de référence s'avère pertinent afin d'identifier au mieux le gain de fonctionnalité envisageable. Ce retour d'expérience illustre également l'importance de l'expertise en ingénierie qui reste indispensable pour assurer la cohérence et la réussite du projet paysager écologique en apportant les préconisations techniques les plus adaptées aux ambitions de fonctionnalité visées.

**Mots clés**

ZAN ; artificialisation ; sites et sols pollués ; évaluation fonctionnelle ; renaturation ; diagnostic agropédologique ; ingénierie pédologique.

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## Ecological rehabilitation of polluted wastelands: development of an operational tool for assessing the functions of urban soils at the scale of development projects

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**Abstract**

The "Zero Net Land Take" (ZAN) policy introduced by the French Climate and Resilience Law is leading local authorities to rehabilitate their brownfield sites to deal with the degradation of natural soils and enable the re-functionalization of artificial soils that could be used to create new urban nature areas. However, assessing functions in these particular and often polluted urban soils remains untested due to the lack of operational tools adapted to brownfields. Thus, the ADEME-supported "Friches Réhabilitation" project aims to contribute to the establishment of urban functional indicators and associated interpretation guidelines.

Three urban wastelands, located in Maubeuge, Rouen, and Avranches respectively, were studied in 2022 before soil rehabilitation, and in 2024 after soil rehabilitation. For each site, contrasting study points were defined depending on pollution history due to past land-use, and also depending on future land use defined in the rehabilitation project. A functional reference point was also selected for each site (e.g. nearby natural soil with the highest level of local multifunctionality). The project team made up of "Sol Paysage" and "ARCHIMED environnement" companies, carried out a diagnosis for each point: fauna and flora diagnosis, description of soil profiles, soil pollution analyses. About thirty

physical, chemical and biological soil parameters were measured in the field and in laboratory. Based on available scientific and technical literature, these different parameters were aggregated to assess 7 ecological soil functions: (1) Habitat for soil organisms; (2) Carbon storage; (3) Water infiltration capacity; (4) Water retention capacity; (5) Rooting potential and physical anchoring for plants; (6) Retention and supply of nutrients; (7) Recycling and transformation of organic matter. Based on the available guidelines, a score from 0 to 3 has been assigned to each parameter value. Each function was thus evaluated based on the average score of the parameters characterizing it, and represented in diagram form.

The results obtained on the three brownfield sites highlight the complementarity of soil observations made in the field and data from laboratory analyses. The analysis of each parameter enables a detailed interpretation of soil functioning, in line with the historical data for the sites and the ecological environments observable before rehabilitation (development of plant cover, surface condition, water runoff, etc.) as well as the work carried out. Functionality gains are highly dependent on soil engineering applied during the rehabilitation process (type of soil material, thickness, compaction, plant cover, etc.). As the functionalization of reconstituted soils is a relatively lengthy process, this assessment just after rehabilitation work is a new initial state that should be reassessed 3 to 5 years later.

The scoring method developed enables us to illustrate the functioning of the soils in a synthetic and didactic way, and to compare them with each other, in particular with a soil chosen as a reference. The choice of this reference site proves to be relevant to identify the possible gain in soil functionality. This feedback also illustrates the importance of engineering expertise, which remains essential to ensure the coherence and success of the ecological landscaping project, by providing the technical recommendations best suited to the functional ambitions being pursued.

# A mapping tool to optimize and sustainably manage urban brownfields

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**Keywords** Brownfield, Urban Green Infrastructure, Site Suitability Analysis, Multifunctionality, Spatial Planning

The spatial expansion of cities results in the loss of natural resources. It is therefore crucial to maintain ecological performance by balancing the land used for human purposes with efforts to restore or protect natural habitats. Promoting reasonable land development while reducing land use challenges is a fundamental component of sustainable development (Wei & Ewing, 2018). The EU declared its policy of No Net Land Take by 2050, which France adopted in its national law with the policy "Zéro Artificialisation Nette" to encourage the reuse of developed lands (Science for Environment Policy, 2016). To follow these policies, the brownfields need to be redeveloped and given new life (Loures, 2015). It is recognized that brownfield redevelopment could bring a range of environmental, economic and social benefits (Wang et al., 2011). The integration of green infrastructure in brownfields, presents an attractive nature-based solution for addressing environmental concerns at brownfields (Hou et al., 2023). But is there a practical tool to prioritize brownfields for transformation into multifunctional urban green infrastructure? This question becomes crucial as costs involved in brownfield redevelopment can be significant (Bacot & O'Dell, 2006) and to avoid random allocation. In this study, we propose a GIS-based multi-criteria model to guide practitioners and researchers in identifying and prioritizing brownfields suitable for transformation into green infrastructure. The Green infrastructure decision-support tool derived from Feng et al. (2023). The Coupling Coordination Degree Model is a widely used method in environmental studies to determine the interaction and coordinated evolution of different systems, particularly in the chinese literature. Numerous scientific papers have used the CCDM to integrate complex systems across a range of disciplines, demonstrating its versatility and applicability ( Li Y. et al., 2012; Li T. et al., 2022; Shi et al., 2020; Tang, 2015; Xing et al., 2019) . Despite its widespread use and high citation rate in the Chinese literature, this methodology has not penetrated the academic literature of other countries to any significant extent. Our study sheds light on the effectiveness of the CCDM by demonstrating its utility in analysing the complex relationship between site suitability and urban ecological demands. The model is implemented in three phases. During the first phase, site suitability analysis of each brownfield assessed with seven criteria. In the second phase urban ecological demands was considered that could be addressed through green infrastructure planning. Finally, the coupling coordination model is used followed by an analysis of their matching degree through quadrant division. A total of 84 brownfields were selected for integration into green infrastructure within the Rouen metropolis (Pirouzi et al., 2024). Among these, 15 brownfields were designated as high-priority sites, while 28 sites were categorized as medium priority, and 41 sites as low priority. For future studies, it is necessary to collect socio-economic data to assess the sustainability of the interaction between brownfield regeneration and the development of multifunctional green infrastructure. This approach can be used as part of a spatial planning process, applicable to any city that faces similar problems. It provides support to identify suitable areas for green infrastructure

expansion and to conduct different scenarios that can easily be assessed by planners and developers at the beginning of the planning process.

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# intersol'2025

24e Edition

**Congrès-Exposition International sur les Sols, les Sédiments et l'Eau**

*International Conference-Exhibition on Soils, Sediments and Water*

## Pollution des sols : peut-on vivre avec ? Vers une stratégie intégrée !

- Sous nos pieds, comprendre le sol et le sous-sol ?
- Actualités juridiques, réglementaires et normatives
- Évaluations des risques sanitaires et environnementaux
- Gestion des pollutions : traiter ou vivre avec ?
- Stratégie intégrée pour la gestion pérenne des sols et des sous-sols
- Innovation : session jeunes chercheurs, créateurs, startups

## Soil pollution: can we live with it? Towards an integrated strategy!

- Under our feet, understand the soil and the subsoil?
- Legal, regulatory and normative news
- Health and environmental risk assessments
- Pollution management: treat or live with it?
- Integrated strategy for the sustainable management of soils and subsoils
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## Vendredi 6 décembre 2024

08h30
Accueil des participants

### Comment appliquer les principes d'économie circulaire aux sols ?

09h15
Méthode d'analyse et de prospective pour une gestion durable des terres excavées sur le territoire de la Métropole de Lyon
*Julie Paciello, Responsable d'études Gestion des ressources - Cerema (France)*

09h35
Aménagement d'un nouveau quartier urbain sur la friche industrielle de l'ancien Laminoir de Dudelange à Luxembourg
*Emmanuelle Thiltges, Chef de projets, chef de service adjointe, associée - ENECO Ingénieurs-Conseils (Luxembourg)*

09h55
Les nouveaux défis et certaines opportunités de valorisation des matières présentes sur les sites pollués identifiés dans le cadre de Remind Wallonia
*Claudia Neculau, Coordinateur Projets - Remind Wallonia (Belgique)*

10h15
Application des principes de l'économie circulaire à la gestion des terres excavées - Retour d'expérience du Grand Paris Express
*Thomas Gaudron, Responsable terres excavées & économie circulaire - Société des Grands Projets (France)*

10h35
Apport de différents composts sur les fonctionnalités du sol et le devenir des polluants organiques
*Papa Mamadou Sitor Ndour, Post-doctorant - Unité de Chimie Environnementale et Interactions sur le Vivant (UCEIV), Université du Littoral Côte d'Opale (France)*

10h55
Pause-café

## Comment gérer durablement les pollutions du sol ?

11h25
La caractérisation des risques pour les écosystèmes : un levier pour dynamiser les usages environnementaux des friches
*Benjamin Pauget, Responsable R&D, Associé - Tesora (France)*

11h45
Une approche durable pour le traitement in situ des contaminants CHC profonds sous-jacents à un site de fabrication en Allemagne à l'aide du ZVI et de la bio-augmentation
*Gordon Bures, ingénieur en assainissement - Sensatec GmbH (Allemagne)*

12h05
Stabilisation de la zone source de PFAS : une solution zéro déchet à un problème mondial
*Kris Maerten, Responsable Technique Europe - Regenesis (Belgique)*

12h25
Questions/Réponses

12h45
Déjeuner

13h45
Traitement in situ par oxydation chimique (ISCO) avec les réactifs de Fenton dans la zone insaturée et saturée, comprenant des remblais très hétérogènes, rendue possible grâce à la technologie SPIN®
*Lionel Counet, Ingénieur Projet - Injectis (Belgique)*

14h05
Une solide analyse multi-approches de données pour identifier les sources et l'étendue des impacts des PFAS
*Matar Thiombane, Consultant Senior - ERM (Belgique)*

14h25
Etude de sol descriptive innovante sur les sols pour la contamination complexe par les PFAS dans le sol, les eaux souterraines et béton sur le terrain d'entraînement des pompiers flamands
*Wim Vansina, Chef de projet - Witteveen+Bos Belgium (Belgique)*

14h45
Assainissement amélioré des sols contaminés par le LNAPL à l'aide d'émulsions d'alcool dans un biopolymère
*Bexultan Sabyrbay, Chercheur - Bureau de Recherches Géologiques et Minières, BRGM (France)*

15h05
Remédiation des sols hétérogènes contaminés par les PFAS : Optimisation de la désorption par un mélange solvant/bio-polymère
*Ali Batikh, Doctorant - Colas Environnement (France)*

15h25
Pause-café

15h55
Assainissement durable in situ d'un panache de CHC pour un réaménagement accéléré des friches industrielles. Une étude de cas allemande
*Michael Mueller, Directeur commercial, EMEA - Evonik Operations GmbH (Allemagne)*

16h15
L'utilisation de résines échangeuses d'ions sélectives Lewatit® pour l'élimination des contaminants émergents : PFAS et autres
*Dirk Steinhilber, Responsable développement commercial et applications - Lanxess (Allemagne)*

16h35
Questions/Réponses & conclusions

17h00
Fin du colloque


## Vrijdag 6 december 2024

08:30
Welkom van de deelnemers

### Hoe kunnen de principes van de circulaire economie worden toegepast op de bodem?

09:15
Analyse- en prognosemethode voor het duurzaam beheer van uitgegraven bodem in de agglomeratie Lyon
*Julie Paciello, Hoofd Studies Grondstoffenbeheer - Cerema (Frankrijk)*

09:35
Ontwikkeling van een nieuwe stadswijk op het braakliggende terrein van de voormalige walserij van Dudelange in Luxemburg
*Emmanuelle Thiltges, projectmanager, adjunct afdelingshoofd, medewerker - ENECO Ingénieurs-Conseils (Luxemburg)*

09:55
Nieuwe uitdagingen en kansen voor de recyclage van materialen uit verontreinigde sites geïdentificeerd in het Remind Wallonië project
*Claudia Neculau, Projectcoördinator - Remind Wallonië (België)*

10:15
De principes van de circulaire economie toepassen op het beheer van uitgegraven bodem - Feedback van het Grand Paris Express project
*Thomas Gaudron, Manager uitgegraven aarde & circulaire economie - Société des Grands Projets (Frankrijk)*

10:35
Bijdrage van verschillende composten aan de bodemfunctionaliteit en het lot van organische verontreinigende stoffen
*Papa Mamadou Sitor Ndour, Post-doctorant - Environmental Chemistry and Life Interactions Unit (UCEIV), Université du Littoral Côte d'Opale (Frankrijk)*

10:55 Koffiepauze

## Hoe kan bodemverontreiniging duurzaam beheerd worden?

11:25
Karakterisering van de risico's voor ecosystemen: een hefboom voor het stimuleren van milieuvriendelijk gebruik van oude bedrijfsterreinen
*Benjamin Pauget, R&D Manager, Partner - Tesora (Frankrijk)*

11:45
Een duurzame aanpak voor de in situ behandeling van diepe CHC-verontreinigingen onder een productiesite in Duitsland met ZVI en bioaugmentatie
*Gordon Bures, Saneringstechnicus - Sensatec GmbH (Duitsland)*

12:05
PFAS bronzone stabilisatie: een zero waste oplossing voor een wereldwijd probleem
*Kris Maerten, Technisch Manager Europa - Regenesis (België)*

12:25
Vragen en antwoorden

12:45 Lunch

13:45
In situ chemische oxidatie (ISCO) met Fenton's reagent in de verzadigde en onverzadigde zone van een heterogene, antropogene geology gebruik makend van de SPIN® injectie technologie
*Lionel Counet, Projectingenieur - Injectis (België)*

14:05
Een robuuste multi-aanpak gegevensanalyse om de bronnen en de omvang van PFAS-impact te identificeren
*Matar Thiombane, Senior Consultant - ERM (België)*

14:25
Innovatief beschrijvend bodemonderzoek naar complexe PFAS-verontreiniging in bodem, grondwater en beton op het Vlaams oefenterrein van de brandweer
*Wim Vansina, Project Manager - Witteveen+Bos België (België)*

14:45
Verbeterde sanering van met LNAPL verontreinigde bodems met alcoholemulsies in een biopolymeer
*Bexultan Sabyrbay, Onderzoeker - Bureau de Recherches Géologiques et Minières, BRGM (Frankrijk)*

15:05
Sanering van heterogene bodems verontreinigd met PFAS: optimalisatie van desorptie door een mengsel van oplosmiddel en biopolymeer
*Ali Batikh, doctoraatsstudent - Colas Environnement (Frankrijk)*

15:25 Koffiepauze

15:55
Duurzame in situ sanering van een CHC-pluim voor versnelde herontwikkeling van brownfields. Een Duitse casestudie
*Michael Mueller, Verkoopdirecteur EMEA - Evonik Operations GmbH (Duitsland)*

16:15
Het gebruik van Lewatit® selectieve ionenwisselaarharsen voor de verwijdering van opkomende verontreinigende stoffen: PFAS en andere
*Dirk Steinhilber, Hoofd Bedrijfsontwikkeling en Toepassingen - Lanxess (Duitsland)*

16:35
Vragen/Antwoorden & Conclusies

17:00
Einde van de conferentie


## Friday December 6, 2024

08:30
Attendee's welcoming

### How to apply circular economy principles to soils?

09:15
Method of analysis and forecasting for sustainable land management excavated in the territory of the Metropolis of Lyon
*Julie Paciello, Research Manager Resource Management - Cerema (France)*

09:35
Development of a new urban district on the industrial wasteland of the former Dudelange Rolling Mill in Luxembourg
*Emmanuelle Thiltges, Project Manager, Deputy Head of Department, Associate - ENECO Ingénieurs-Conseils (Luxembourg)*

09:55
New challenges and certain opportunities for the recovery of materials present on polluted sites identified within the framework of Remind Wallonia
*Claudia Neculau, Project Coordinator - Remind Wallonia (Belgium)*

10:15
Operational deployment of the principles of the circular economy to the management of excavated soil - Feedback from Grand Paris Express
*Thomas Gaudron, Head of excavated land & circular economy - Société des Grands Projets (France)*

10:35
Contribution of different composts on soil functionalities and the fate of organic pollutants
*Papa Mamadou Sitor Ndour, Post-doctoral student - Unit of Environmental Chemistry and Interactions on Living Things (UCEIV), University of Littoral Côte d'Opale (France)*

10:55
Coffee break

## How to sustainably manage soil pollution?

11:25
Characterizing risks for ecosystems: a lever to boost the environmental uses of wastelands
*Benjamin Pauget, R&D Manager, Partner - Tesora (France)*

11:45
A Sustainable Approach for the in-situ Treatment of Deep CHC Contaminants Underlying a Manufacturing site in Germany using ZVI and Bio-augmentation
*Gordon Bures, Remediation Engineer - Sensatec GmbH (Germany)*

12:05
PFAS source zone stabilization: a zero-waste solution to a global problem
*Kris Maerten, Technical Manager Europe - Regenesis (Belgique)*

12:25
Questions/Answers

12:45
Lunch

13:45
In situ chemical oxidation (ISCO) treatment by Fenton's reagents in the saturated and unsaturated zone of a heterogeneous, man-made geology using the SPIN® injection technology
*Lionel Counet, Project Engineer - Injectis (Belgium)*

14:05
A robust multi-approach data analysis to identify sources and extent of PFAS impacts
*Matar Thiombane, Senior Consultant - ERM (Belgium)*

14:25
Innovative descriptive soil study on soils for complex PFAS contamination in soil, groundwater and concrete at the training ground of the Flemish fire brigade
*Wim Vansina, Project Manager - Witteveen+Bos Belgium (Belgium)*

14:45
Enhanced remediation of LNAPL-contaminated soils using alcohol-in-biopolymer emulsions
*Bexultan Sabyrbay, Researcher - French Geological and Mining Research Office, BRGM (France)*

15:05
Remediation of heterogeneous soils contaminated by PFAS: Optimization of desorption using a solvent/bio-polymer mixture
*Ali Batikh, PhD student - Colas Environnement (France)*

15:25
Coffee break

15:55
Sustainable In-Situ Remediation of a CHC Plume for Expedited Brownfield Redevelopment. A German Case Study
*Michael Mueller, Business Manager, EMEA - Evonik Operations GmbH (Germany)*

16:15
The use of selective Lewatit® ion exchange resins for the removal of emerging contaminants: PFAS and beyond
*Dirk Steinhilber, Manager Business development and applications - Lanxess (Germany)*

16:35
Questions/Answers & conclusions

17:00
End of the congress

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# Méthode d'analyse et de prospective pour une gestion durable des terres excavées sur le territoire de la Métropole de Lyon (France)

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**Abstract**

Every year In France, an estimated 150 million tonnes of excavated materials are excavated on construction sites. Circular management of these excavated materials represents a major environmental challenge, both in terms of preserving non-renewable natural mineral resources and reducing and recovering of waste. Under the 2010 Waste Ordinance, the law Energy Transition for Green Growth Law (2015) and, more recently, the Anti-Waste for a Circular Economy Law (2020), project owners are constraint to ensure that the excavated materials are properly prevented and managed.

As the local authority responsible for coordinating the ecological transition, and also as project owners, the Lyon Metropole wants to act on the management of excavated materials within its territory. Since autumn 2023, the Lyon Metropole and Cerema has been working together to achieve two objectives:

- To draw up an inventory of excavated soil.
- To propose an action plan for planning the resource in order to create a sustainable management.

The analysis and forecasting method was organized in five stages:

1. Mapping the lithological nature of the excavated materials and providing potential uses for reuse or recycling.
2. Identify local autorized recycling, recovery or disposal facilities and estimate their annual treatment capacities.
3. Estimate the volume of excavated materials annually on construction sites.
4. Project the excavated materials (qualities, quantities, localization) over a five or ten year timeframe.
5. On the basis of the previous steps, develop a roadmap for the management of excavated materials – in the form of an action plan.

This method, which can be reproduced and transposed to other territories, excludes the excavated materials from polluted sites and soils.

The purpose of this presentation is to outline the method, the results and the main actions selected, under the theme « How to applied the principles of the circular economy to soils? »

# Development of a new urban district on the brownfield site of the former rolling mill in Dudelange, Luxembourg

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For more than two decades, Luxembourg has been confronted with both a high demand for space and a growing population due to its economic strength. The resulting intense construction activity generates a large amount of inert waste, including excavated soil, which can only be recycled to a limited extent due to the high building density.

The relatively small country has a rich industrial past, which has left a number of large industrial brownfield sites, particularly in the southern part of the country. The 32-hectare site of the former rolling mill in Dudelange, located right on the French border, is one of them. This brownfield site was selected by the Fonds du Logement as early as 2007 to create a new neighborhood offering sustainable and affordable living. This new urban district, called “Neischmelz”, will also integrate two older, immediately adjacent districts.

The numerous investigations carried out in the soil, soil air and groundwater revealed a range of environmental pollution, but this was predominantly local and heterogeneous in distribution and mainly comprised low-volatility substances, principally PAH, TPH and metals. The origins of the pollution can be traced back to both the historical activities at the site and the intrinsic quality of the backfill material used in the past. In addition, there are construction-related issues due to underground infrastructures such as former tunnels, supply channels and large foundations, as well as a very heterogeneous load-bearing capacity of the backfill material.

All these constraints were taken into account during the design phases of the project, in a long, intensive, interactive and ultimately successful collaboration between various stakeholders (Fonds du Logement, administrations, municipality, architects, engineering consultants, etc.). As a result, the first works could not begin until 2024, almost 20 years after the final cessation of industrial activities in 2005 and 13 years after the first master plan was drawn up in 2011.

Since it was not possible, due to the size of the site and the technical limitations mentioned, to simply remove and replace all the contaminants associated with the site's industrial past, the conversion concept required a site-specific approach to managing the soil contamination. This also entailed certain restrictions, such as avoiding direct contact with the soil by applying a protective layer with healthy soil, avoiding basements and private gardens, applying impermeable surface sealing, no groundwater abstraction and special works in advance of the infrastructure development.

These works will both create a distance layer of a certain thickness with materials adapted to the sensitivity of the planned uses (green space/school, residential, services/mineral surfaces) and also enable the maximum utilization of processed excavation and demolition material. The aim is to minimize both the environmental impact for the new use and the risks to the stability of the buildings, while keeping the project costs within budget.

The implementation of these management measures required a long administrative and regulatory preparation with the relevant authorities (cessation of activities, application for approval in

accordance with the amended law of June 10, 1999, adjustments to the application of the current methodology in the Grand Duchy of Luxembourg pending the complete revision of the methodology for the management of contaminated sites and soils, which has been in progress for several years).

The concept was defined on the basis of the planned special development project in order to achieve the balance between excavation and backfilling as far as possible and to limit the amount of excess excavated material after completion of the first development phase. The reuse of crushed concrete and crushed gravel (slag) during the development phase (e.g., for road construction and for trenches associated with the laying of supply lines) and subsequently during the construction phase (e.g., substructures of buildings) is also being investigated in order to further improve the environmental balance of the construction site.

On the site itself, only a small amount of uncontaminated excavated soil is available, since most of the site was filled in the past with material from the former iron and steel industry. However, to cover the remaining contamination, especially with metals and PAHs, natural soil from neighboring construction sites is used as a distance layer. This soil was originally intended for disposal at an inert waste landfill and now serves as a one-meter-thick distance layer to protect against residual contamination and to restore typical soil functions in the area of future green spaces.

ENECO Ingénieurs-Conseils S.A.'s concept for the redevelopment of the former Dudelange rolling mill site was based on its experiences with other steel industry brownfields, notably the Micheville site, located in Villerupt, Audun-Le-Tiche and Russange in France – only 10 km flight distance from Dudelange. Nearly 30 ha of the site will be redeveloped to create a new mixed-use urban district as part of an Opération d'Intérêt National (OIN).

At the Micheville site, several work phases were carried out between 2015 and 2024 under the direction of the Etablissement Public Foncier de Grand-Est (EPFGE) and the Etablissement Public d'Aménagement Alzette/Belval (EPA) to overcome ecological and geotechnical constraints. Using a methodology comparable to that now being applied at the “Neischmelz” site in Dudelange, it was possible to prepare a brownfield area of around 147,000 m2 ready for construction before the actual development and construction phases began.

Despite the different legal requirements in France and Luxembourg, we were able to identify the technical and economic difficulties at an early stage and overcome them accordingly through this transnational exchange of experiences. This will help to overcome recurring planning and financial challenges in the long-term process of redesigning this type of brownfield site, including the “Neischmelz” site in Dudelange.

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NextGenerationEU

Wallonie

REMIND Wallonia

# New challenges and certain opportunities for the recovery of materials present on polluted sites, identified within the framework of Remind Wallonia

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**Key words**: Recovery / Secondary raw material / Resource management / Removal from waste status

**REMIND WALLONIA** is a sector-based technology platform in Wallonia (Belgium), contributing to the resilience and development of the mineral industry.

REMIND WALLONIA's ambition? To make Wallonia the "Mineral Valley" of North-West Europe by 2030, by setting up an ecosystem dedicated to the circularity of mineral materials (aggregates, sands, concretes, clays...) with a view to:

- Imagine new materials through synergy and co-creation (open innovation);

- Set up new product value chains, while retaining as much added value as possible in Wallonia (short circuits).

7 research & development projects are currently active within REMIND WALLONIA, led by 15 industrial compagnies, with scientific support from 2 universities and 2 research centers, and financial support from Wallonia REGION
These projects focus on 4 strategic areas: sustainable construction materials, high-performance concretes, alternative binders and carbonated materials.
REMIND's innovative concept enables the partners involved to develop synergies, innovative projects and virtuoso circular loops.
The presentation will focus on three flagship projects: WASTES2CEM, CIBER and C-GROUT The progress of each project will be highlighted, along with current challenges and future opportunities.

## 1. WASTES2CEM project

**HOW CAN CEMENT MANUFACTURERS REDUCE THEIR ENVIRONMENTAL IMPACT BY PRODUCING CLINKER AND CEMENT LOCALLY FROM SECONDARY MINERAL MATERIALS?**
The main challenge facing cement manufacturers in Wallonia today is both to remain competitive in the face of competition from imported clinker, and to meet their commitments to reduce CO2 emissions.
To meet these challenges, the WASTES2CEM project will work on two complementary aspects: on the one hand, the partial replacement of limestone in clinker raw meal by a locally sourced secondary mineral material, and on the other, the reduction of clinker content in cement via the addition of reactive additions derived from secondary mineral materials.
The two secondary mineral materials studied are different and will have to be processed by mineralurgical techniques to meet cement manufacturers' specifications.
These materials currently constitute a historical deposit: their recovery in a cement plant will also free up land that will be used for other purposes (economic zone, housing, natural zone...).
**This project:**
- aims to reduce dependence on imported clinker;
- aims to free up land for other uses (economic, housing, natural areas).
**Partners:** Remind, CCB, Duferco Wallonie, DC Environment, CTP, ULiège-PEPs, UCLouvain

## 2. CIBER project

**HOW TO USE DECONSTRUCTION FLOWS AND AGGREGATES TO PRODUCE HIGH VALUE-ADDED PRECAST CONCRETES AND LARGE-SCALE MODULAR BLOCKS?**

In view of the high consumption of natural aggregates in the construction sector, the increasing use of recycled aggregates is becoming a necessity.

Wanty company and Dufour company, who have developed a process for recycling deconstruction flows, will be working with Roosens Bétons company to improve the quality of the aggregates produced, so that they can be used in higher value-added outlets such as precast concrete for large-scale structural components (bridge decks, lintels, hourdis, floors, modular deconstructable blocks).

The CIBER project, beyond its use in structural parts already on the market, will seek to develop new, more innovative structural construction elements in the form of large-scale modular blocks, with the aim of improving implementation and deconstruction methods (eco-design concept) to enable their reuse.

This Cradle-to-Cradle approach will make it possible to envisage a circular valorization, not only of aggregates, but also of finished products via their reuse, in the construction sector.

**This project contributes to:**

Circular valorization of recycled and finished products;

Greater flexibility, easier dismantling and reusability.

**Partners**: Remind, Wanty, Dufour, Cogetrina, Roosens Bétons, CTP, ULiège PEPs, ULiège GeMMe, UCLouvain

## 3. C-GROUT project

**HOW TO REPLACE CONVENTIONAL CONCRETE WITH SPECIAL, CIRCULAR CONCRETES MADE FROM MINERAL WASTE AND BY-PRODUCTS ON OFFSHORE WIND TURBINE SITES?**

The offshore wind energy sector has been enjoying significant growth for many years, driven by European authorities and companies thanks to its positive impact on reducing greenhouse gas emissions.

This offshore market has been identified by the C-GROUT project partners as a real opportunity, especially as it is perfectly in line with their core business and development strategy.

The C-GROUT project aims to manufacture special circular concretes for the offshore wind energy sector. The use of recycled materials to replace certain concrete components will deliver economic, ecological and technological gains that will strengthen the positioning of the project partners in this sector.

The need to develop a specific and innovative crushing technology will also enable the research results to add value across a number of sectors.

**This project:**

- Contributes to reducing the environmental footprint of wind farms;
- Has a transversal and multi-sectoral added value.

**Partners:** CTP, ULiège, UCLouvain, Remind, Euroquartz, Lessines Industries

# Operational deployment of the principles of the circular economy to the management of excavated soil - Feedback from Grand Paris Express

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In charge of the construction of additional 200 kilometers of metro lines, mainly underground, *Société des grands projets*, previously known as *Société du Grand Paris* and French public project owner, has to deal with the production of nearly 47 million tons of excavated soils overall the *Grand Paris Express* project over ten years, in Paris area, France.
To overcome the challenges associated to this large amount, *Société des grands projets* has studied innovative solutions to improve excavated soils management from the start of the project studies. To reach the objective of reusing and recycling 70% of excavated soils, *Société des grands projets* entered a proactive approach of circular economy with the support of stakeholders sharing the same ambitions.

8 years after the opening of the first large construction sites, at two thirds of the earthworks realized and 32 million tons of soil excavated and managed, the following feedback is presented to show-up best environmental practices tested and used on the project, split between the different pillars of the circular economy, as described by ADEME, French public agency in charge of ecological transition.

1. Offer part – Sustainable extraction, processing and supply

We transpose this scope to push for a better design incorporating more materials issued from reuse and recycling and by demonstrating the possibilities by the diffusion of eco-products catalogues and toolkits. For this purpose, we work since 2018 with renowned academic laboratories, such as *Institut Mines Telecom Nord Europe*, to characterize representative samples of our excavated material and to test incorporating larger and larger parts of them in the formulations of standard construction products (concrete, road construction, backfilling grout, fertile soil) to obtain the same product performances. 80 formulas were tested. Several calls for innovative projects were launched, ending with partnerships with dozens of industrial platforms. To enhance the use of eco-products with excavated materials, a catalogue of products proposed by our partners was diffused in 2021, as the guide *Matières à faire* in 2022 to support project owners.

2. Offer part – Products and process eco-design

Products used for the construction of the metro infrastructures are mainly new but questioning their environmental impact on the same basis as cost, delay or quality is a new approach developed by our teams. Anticipating change of use and end-of-life steps will improve product longevity and avoid waste production and new resources consumption. For this purpose, we created a set of indicators, called Circulence®, measuring the circularity of a product, design or scheme. It allows to assess and reward best practices at the call-for-bids stage, to follow-up bidders' commitments once deployed on the project. Applied to soil management, treatments pyramid (reuse > recycling > disposal), logistic scheme (less distance, better transport modes) or the incorporation of reused and recycled materials were questioned on several contracts.
Besides, several experiments using excavated material were supported by *Société des grands projets*, such as the production of mud bricks, fertile soil, concrete binder or precast products.

3. Offer part – Local and industrial ecology

*Grand Paris Express* project is a local project, developed for the communities of Paris greater area. Using the existing economic network and enhancing local cooperation are natural factors to reach a better environmental performance. For this purpose, we created RELIEFS, a network grouping all stakeholders of *Grand Paris Express* project soil management: engineering companies, earthworks and construction companies, recycling and waste managers, …, a place where to exchange on project news and best practices.

We develop partnerships with local communities to jointly promote use of eco-products demand, by reviewing call-for-bids technical specifications and sharing knowledge.

4. Offer part – Service economy

Sharing tools and construction equipment on site is a today well-developed practice of the construction companies. It avoids multiple demobilizations and mobilisations, every time a new construction company is involved on site. For soil management purpose, after identifying in 2012 the lack of a traceability digital tool on the market, *Société des grands projets* made the choice of developing its own software dedicated to this purpose, initially for its own use. Ensuring a real-time data consolidation and follow-up, avoiding paper loss and ensuring an unique process on all its construction sites (up to 500), TrEx tool is now linked with in-house tools of all construction majors and mandatory governmental reporting applications. It safeguards the use of duly authorized platforms (check prior to granting access) and allow the follow-up of the reuse and recycling objective. *Société des grands projets* enters discussions with other project owners to share TrEx, avoiding the development of several tools with similar functions.

5. Demand and user behaviour – Responsible consumption

In order to limit material, water and energy consumption during construction and once in operation, design and construction have to be requestioned at each step of the process. Carbon footprint is a project key indicator that is yearly reported within our Sustainability report. Transposed to soil management, we endeavour to optimize transportation by limiting soil moisture, adopting massified means and using local management sites.

The use of small and medium companies has to be enhanced for a better acceptance of local communities. That's why at least 20% of each contract is redirected to these companies. 10% of working hours are dedicated to vocational integration.

6. Demand and user behaviour – Extending longevity

Encouraging the reuse and anticipating the end-of-life of material, equipment and building need the change of mindsets and practices. Beyond the usual search of the balance between excavation and backfilling on-site, we are actively looking for external partners, public as private, to contribute to their projects by providing extra-materials. To this extend, we also provided a technical support to the mapping of *Normandie* and *Ile-de-France* regions soils to enhance offsite reuse, initiative called GeoBapa.

To accompany transition to new habits, we regrouped a set of contractual clauses dedicated to circular economy and ready-to-use in all our construction contracts, at every step of the project: deconstruction, earthworks, civil engineering, building, urban planning.

7. Waste management – Optimizing waste production, recycling and management

This last pillar is the best known and used and it was naturally the first to be studied by the *Société des grands projets* due to the large amount of excavated material. For better practices, we had to better know the resources we have. That's why an extensive campaign of drilling and core sampling was conducted all the path of the future network. Their results were used to evaluate reuse and recycling potentials by the engineering companies, both translated in objectives in our construction contracts. We included reuse objectives inside few applications of our works (backfilling, tunnel filling for levelling, fertile soil).

Circular economy is a relatively new wording but the practices it regroups are not. All of the above-listed initiatives were consolidated in the framework for circular economy published in 2024 by the *Société des grands projets*. Beyond a catalog of initiatives list, our strategy to optimize material, water and energy was widely shared to encourage all our partners to constantly propose leading edge solutions for a better environmental impact.

# Contribution of different composts on soil functionality and the fate of organic pollutants in a brownfield

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**Abstract:**

The contribution of different composts (leaf, manure and fragmented rameal wood: FRW), produced locally in compliance with the principles of a circular economy was tested in soil functionalities, the fate of different organic pollutants (polycyclic aromatic hydrocarbon: PAHs, total petroleum hydrocarbon: TPH and dioxins/furans) and their possible transfer into vegetables in the context of brownfield reconversion into an urban farm. Our results showed that the revegetation led to an increase in the diversity and richness of soil bacterial communities and the application of manure and BRF composts modified the microbial interaction networks by increasing the frequency of fungi-to-bacteria interactions. The three composts also improved the soil metabolic potential and functional richness as well as certain soil ecosystem functions (nutrient recycling, C storage, maintenance of fertility, etc.). A 36% decrease of TPH concentration was obtained after six months of cultivation. However, the application of composts had no effect on the concentration of the different organic pollutants in soils. Among the vegetables tested (tomato, beetroot, carrots, zucchini, chard and potatoes), only chard accumulated TPH and PAH above the concentration measured in the vegetable, without any significant effect of the amendments.

**Introduction:**

The rehabilitation of urban brownfields is now considered a promising strategy for the sustainable transition of metropolitan areas in Europe (Rey et al. 2022). Soil revegetation can limit the dispersion of pollutants and improve soil fertility and ecosystem services, in addition to the aesthetic and landscape interest. More recently, a new alternative is emerging in the management of brownfields, namely the establishment of urban farms based on circular economy principles. Such farms can encourage the support from local populations and public authorities. However, one of the obstacles to their development is the lack of feedback on such practices, particularly on the fate of pollutants, the soil quality and the possible transfer of pollutant in vegetables. This study aims to evaluate the contribution of different types of composts, produced locally in compliance with circular economy from different OM (plant leaves, animal manure and FRW) on soil quality and pollutant fate in a brownfield site undergoing conversion into a shared urban.

**Materials and methods:**

The brownfield located at rue de Soubise in Roubaix FRANCE (50°41'21" N; 3°10'15" E) was subjected to a land reconversion project funded by the European Metropolis of Lille (MEL) which aimes to create an urban farm managed by local associations. After soil excavation, technosols were created and in situ experiments were conducted to study the quality of technosols characterized by residual multi-contamination by organic and inorganic pollutants. Different types of composts (from leaves, manure and FRW) were applied to miniplots of 300 $m^2$ at a rate of 150, 300 and 225 tons per hectare respectively, and a mix of different vegetables was cultivated over a period of 6 months. Soils were sampled and microbial biomass (PLFA profiling), diversity and complexity (16S and ITS metabarcoding) and functions (Biolog™) were assessed before and after the cultivation period. The potential impact of the different composts on delivering ecosystem services was also tested according to the method described by Burges et al. (2016). The TPH, PAH and dioxins/furans were tested in vegetables harvested.

**Results and discussion:**

The diversity of bacterial communities, as well as the complexity of microbial interaction networks, increased significantly with soil revegetation. This could be explained by a stimulation of bacterial populations through root exudates as reported in previous studies (Li et al. 2014; Garaiyurrebaso et al. 2017). The addition of different composts improved soil fertility and particularly increased nutrient contents (organic C, N and available P), soil microbial biomass and metabolic potential. Notably, the application of manure and BRF composts increased the frequency of positive interactions between bacterial and fungal populations by 18 and 37%, respectively, suggesting better cooperation between these two microbial groups and consequently a better soil microbial functioning. The amendments allowed an increase in the relative abundance bacterial genera (*Streptomyces, Agromyces* and *Iamia)* belonging to the Actinobacteria phylum, described for their capacities to degrade soil organic matter (Jia et al. 2022; Jian et al. 2022; Zheng et al. 2022). Regarding pollutants, a significant reduction of 36% was obtained for TPH after 6-month crop growth but the application of composts had no effect on their concentrations. In the tested vegetables, an accumulation of TPH, PAH and dioxins/furans was detected, without any significant effect of the amendments. Nevertheless, except for chard, the concentrations of dioxin/furans remain lower than those measured in marketed vegetables (Hoogerbrugge et al. 2003) and those of TPH and PAH were similar to those of vegetables grown in unpolluted soils. Overall, soil quality increased by 20, 25 and 40% with the application of leaves, manure and FRW compost (Fig. 1).

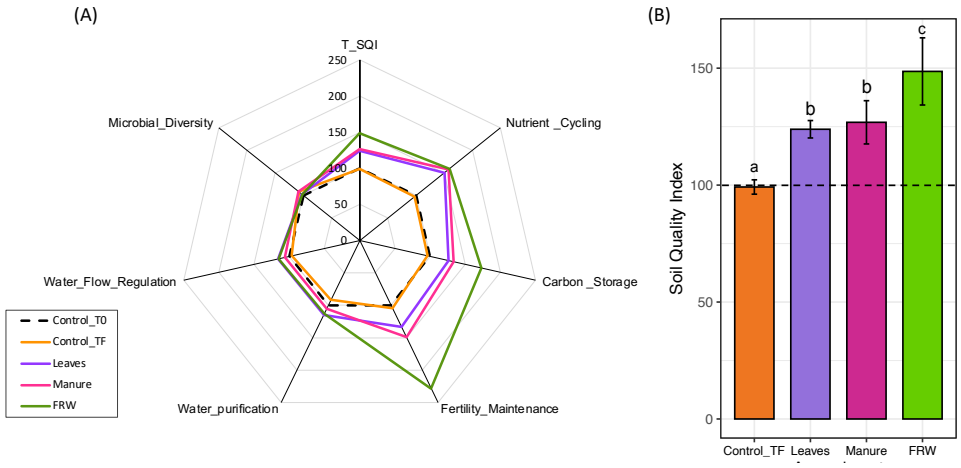


Figure 1: Evolution of ecosystem services and overall soil quality of the ZC plot after revegetation and amendment with the three different types of compost.

**Conclusion and perspectives:**

Our results demonstrate the interest in using composts, particularly those based on manure and FRW, in a perspective of soil refunctionalization and the improvement of its ecosystem services. Despite the transfer of organic pollutants in the harvested vegetables, their concentrations are similar to those of vegetables grown in unpolluted soils (except for the TPH and PAH measured in chard).

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# La caractérisation des risques pour les écosystèmes : un levier pour dynamiser les usages environnementaux des friches

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De nombreuses friches présentent une situation de blocage de reconversion d'usage lorsque la valeur du foncier est dégradée (site orphelin, milieu rural ou de faible activité socio-économique). Il existe pourtant plusieurs autres voies de valorisation à enjeux environnementaux. Ainsi, certaines friches peuvent trouver une seconde vie à travers des projets de revégétalisation favorisant la biodiversité et leur intégration dans le paysage. Le blocage vient alors de la difficulté à se prononcer vis-à-vis du risque qu'elles représentent pour les écosystèmes.

Le projet TRIPODE, mené par L'INERIS et Tesora et soutenu par l'ADEME, a pour objectif de fournir aux acteurs des sites et sols pollués un outil opérationnel d'évaluation du risque pour les écosystèmes (ERE). Un de ses enjeux est d'améliorer la méthode décrite dans la norme ISO 19204 (approche TRIADE de la qualité du sol) et d'assurer son opérationnalité. Ces travaux ont conduit à la production d'un guide technique présentant des recommandations d'aspect pratique ayant trait à la mise en application de la norme et à destination des bureaux d'étude. Le but est d'assurer la démocratisation et la transférabilité de la norme aux acteurs de l'évaluation des risques sanitaires et environnementaux site pour garantir son opérabilité et son acceptabilité par les maîtres d'ouvrages et l'administration.

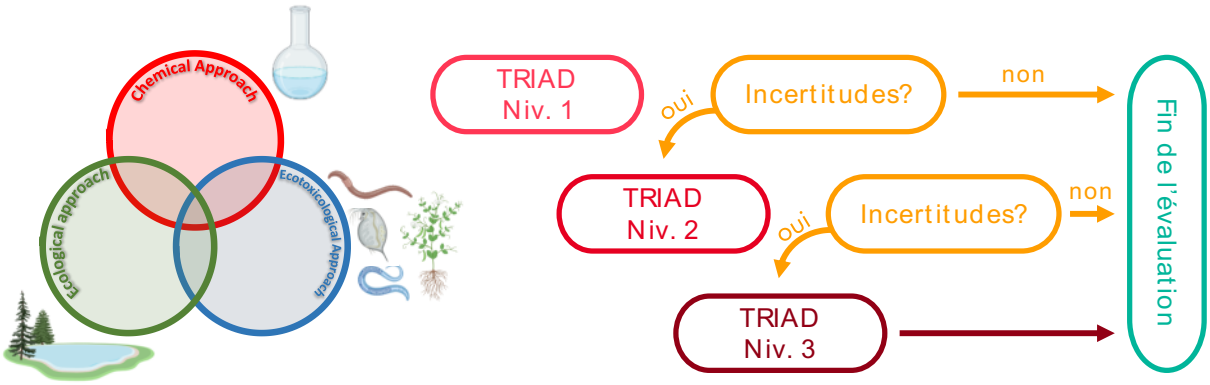


*Figure 1 : les trois approches du risque pour les écosystèmes utilisés dans la norme ISO 19204 TRIADE.*

La méthodologie TRIADE est une méthodologie d'évaluation des risques pour les écosystèmes décrite dans la norme ISO 19204-2017. C'est une approche complète et structurée qui permet de mettre en évidence un risque environnemental lié à la présence de contaminant dans les sols. Cette procédure permet d'identifier, d'évaluer et de gérer les impacts potentiels sur les écosystèmes terrestres, en prenant en compte les caractéristiques propres au site et les substances chimiques présentes. Cette évaluation repose sur trois piliers (approches) fondamentaux

- L'approche chimique consiste à caractériser et quantifier les contaminants présents dans les sols du site d'étude.

- L'évaluation écotoxicologique des sols est principalement réalisé grâce à des essais en laboratoire pour déterminer la toxicité d'un sol pour une ou plusieurs espèce(s) en caractérisant l'effet toxique.

- L'approche écologique consiste à évaluer la qualité écologique du milieu d'étude. Cette approche va intégrer l'ensemble des voies d'exposition des organismes aux contaminants présents dans les sols.

Une fois ces trois approches réalisées, les données recueillies sont intégrées et confrontées entre elles pour évaluer le niveau de risque pour les écosystèmes (ERE) associé à la contamination des sols. L'objectif de cette confrontation est de travailler dans une optique de faisceau de preuve (Line of Evidence, LoE). Si tous les indicateurs des différentes approches apportent des conclusion similaire, l'évaluation des risques environnementaux est alors conclusive (absence ou présence de risques). Si des divergences notables entre les différentes approches il conviendra alors de poursuivre la démarche en effectuant une itération avec des indicateurs plus complexe.

Le site d'étude du projet est situé à proximité d'une voie de chemin de fer. Aucune ancienne activité n'est identifiée sur le site dans les bases de données BASOL/BASIAS/SIS. La zone d'étude se trouve dans un périmètre naturel protégé (ZNIEFF2 et Natura2000). Les usages actuels sont fixes et aucune modification n'est prévue, le site étant actuellement en zone naturelle. La zone témoin a été sélectionnée dans une optique de rester sur le site d'étude.
La confrontation des 3 LoE, intégrant les réponses des indicateurs du TIER2, permet de calculer une note globale de TRIADE de 0.18±0.12. Cette fois, le faible score couplé à un écart type faible, permet de conclure sur une absence de risque environnemental sur la parcelle d'étude pour l'usage naturel en cours.

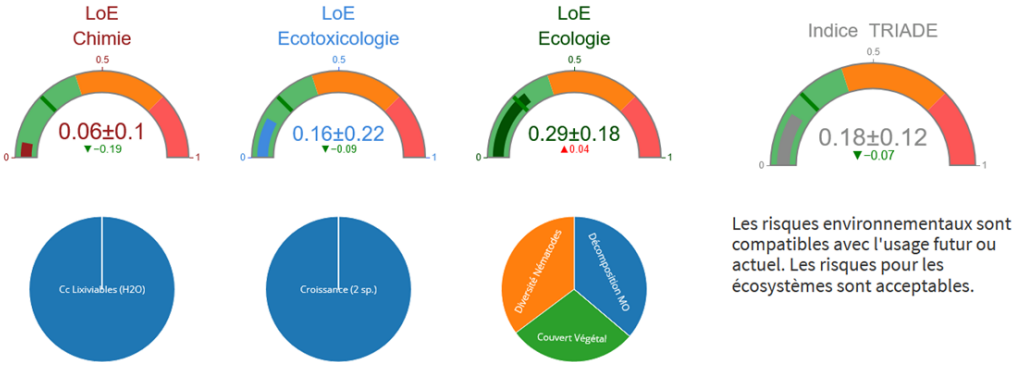


*Figure 2 : Notation des risques environnementaux*

L'utilisation de la TRIADE et d'outils complémentaires (chimie, écotoxicologie, écologie) a permis de démontrer une absence de risques pour les écosystèmes sur un site présentant pourtant une contamination des sols en Pb (120 $mg/kg^{-1}$). Ainsi la TRIADE permet d'apporter des éléments de réponse permettant non seulement d'optimiser les opérations de gestion des sites à passifs environnementaux mais également de valider et de sécuriser la compatibilité des risques environnementaux avec les usages actuels et/ou futur des sites.

# A Sustainable Approach for the in-situ Treatment of Deep CHC Contaminants Underlying a Manufacturing site in Germany using ZVI and Bio-augmentation

**Intersoil 2024, Brussels, Belgium**

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**Background/Objectives**
Due to its heavy industrialization and densely populated urban areas, *in situ* remedial approaches are often the most practical and cost-effective means of mitigating contamination at industrial sites in Germany. Site owners are frequently faced with untenable cost burdens or disruptions to commercial operations when considering traditional remediation technologies. The Dexion plant in Laubach, Germany manufactures industrial shelving and modular storage systems whereby past activities associated with metal degreasing and enamel/paint coating operations have resulted in deep subsurface CHC impacts (to 22 m depth bgs) which largely underlie the existing plant facilities. Soil excavation and ex situ remedial options were initially considered but deemed impractical due to the necessity of removing (i.e. demolishing) much of the plant infrastructure to gain access to contaminated sediments, lost manufacturing capacity, and exorbitant costs. Pump and Treat measures only provide limited effectiveness due to the low permeability of underlying silty clay soils. An *in situ* remedial alternative approach was therefore investigated to sustainably mitigate CHC contaminants using the targeted emplacement of treatment reagents. The objectives of the work were to:

1. Conduct a field pilot to determine the most favorable treatment process for the given site conditions and contaminant concentrations, and
2. Implement the selected remedial process/technologies for achieving full scale site remediation.

**Approach/Activities**
A field pilot trial was conducted in two separate contaminant plume areas at the site to evaluate and compare the performance of in situ chemical oxidation (ISCO) to in situ bioremediation (ISB) with biological augmentation. The results after 2 years monitoring indicated that both approaches had reduced ∑CHC concentrations by approximately 60%, although rebound effects were apparent in the ISCO trial (after depletion of the persulfate oxidant) which was not the case for the ISB trial. Therefore, a remedial approach for full scale *in situ* treatment of the site was developed using in situ chemical reduction (ISCR) with ISB. Targeted Solids Emplacement ("TSE")™ technology using direct push drilling and specialized mixing and pumping equipment was applied for full-scale treatment using Evonik's EHC® amendment in order to emplace 40 metric tonnes of amendment into low permeability soils located under the plant infrastructure. After injection of the EHC amendment (a mixture of organic carbon and micro-ZVI), each of the 40 injection points were constructed as injection wells for the infiltration of lab cultivated microorganism cultures containing the species Dehalococcoides Mccartyi (DHC-M) to further stimulate anaerobic dechlorination. This was followed by a comprehensive groundwater sampling program.

**Results/Lessons Learned**
Groundwater monitoring results from a network of 13 monitoring wells and 40 injection wells within and proximate to the contaminant plume have demonstrated a median reduction of 75% total CHCs in the first year following injection, despite the low permeability of clay soils. The effectiveness of ongoing contaminant degradation since the beginning of pilot scale work is attributable to a large extent by the mode of amendment emplacement (soil fracturing), which provides a greater radius of emplacement and shortening of diffusion pathways for treatment, and the longevity of EHC. The effectiveness of DHC-M bio-enhancement, which has not yet reached its full potential based on the results of qPCR analysis, is thereby also improved. Ongoing groundwater monitoring in the context of Remedial Process Optimization has identified a few isolated areas of contaminant rebound where additional treatment may be necessary.

**PFAS source zone stabilization: a zero-waste solution to a global problem**

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Per- and polyfluoroalkyl substances (PFAS) contamination in soils and groundwater is a widespread issue, particularly associated with Aqueous Film Forming Foams (AFFF) used at fire training facilities. When discharged onto a permeable surface, PFAS will move downward through the soil column by dissolution into infiltrating precipitation (rainfall). PFAS will then bind to the soils through air-water interface accumulation and soil sorption. Due to recalcitrance of PFAS to natural degradation, this can result in the long-term retention of significant reservoirs of contaminant mass in the soils under the discharge location.

Leaching of this sorbed contamination may result in PFAS discharge to groundwater, plume creation and risk to downgradient receptors. The mobility of the PFAS compounds, combined with the toxicity of longer chain compounds, means that these source areas can create and maintain widespread environmental risk long after the discharge event has occurred.

The risk to downgradient receptors from this contaminant mass can be removed by prevention of significant PFAS mass flux from soil and within groundwater. This can be achieved through the *in-situ* application of a multi-format colloidal activated carbon technology (SourceStop$^{TM}$). The solid formulation comprises a solid composite aggregate material of colloidal activated carbon and powdered activated carbon. This can be applied by simple *in situ* mixing using an excavator or continual flight auger. The aggregate is designed to disintegrate easily upon mixing, releasing the colloidal activated carbon which improves distribution and coating of the impacted soils. The treatment results in stabilisation of the PFAS contamination bound to the soils in the vadose zone. This minimises the leachability of the PFAS contamination in the soils and prevents further discharge into the groundwater. The liquid formulation comprises 1-2µm colloidal activated carbon particles suspended in water that are injected into the capillary fringe and saturated zone within the source area. This coats the aquifer material with a thin layer of activated carbon, which adsorbs and retards the transport of groundwater contamination, preventing further plume development. The result is enhanced attenuation of the contaminant plume, eliminating the risk to downgradient human or environmental receptors.

*In situ* treatment using this approach avoids the need for disposal of contamination or filtrate to landfill or for destruction, minimising wider potential exposure. By avoiding soil disposal or the use of long-term pumping equipment, the cost and carbon footprint of the remediation is minimised.

This presentation will explain the processes through which the source area can be treated and how they can be tailored to each site. Laboratory data will demonstrate sorption efficacy and leachability reduction. Onsite application approaches will be shown and discussed. This presentation will be of interest to practitioners, site operators and regulators interested in how to practically and safely manage PFAS contamination.

# In situ chemical oxidation (ISCO) treatment by Fenton's reagents in the saturated and unsaturated zone of a heterogeneous, man-made geology using the SPIN® injection technology

Lionel Counet[1], Jeroen Vandenbruwane[2], Bram Vandekerhove

In general, it is not recommended to carry out a treatment of the unsaturated zone by injections and even less when it comes to implementing a treatment by chemical oxidation (ISCO).

Indeed, the reactions stimulated by the injections need an optimal and prolonged contact between reagents and contaminants to reach good results, which is more when the degradation is done by chemical reaction as is the case of the ISCO where it is the direct contact between pollutant and reagents which makes the success of the treatment. This contact is optimal in an aqueous phase, so when the injections are carried out below the water table, in the saturated zone. If this is not recommended, it does not mean that chemical oxidation in an unsaturated environment (soil treatment) does not work at all. You simply have to know what you have to start with and remain aware of the risks of results. And if the oxidant is injected well with the most homogeneous distribution possible then we can expect satisfactory results.

Our client opted for this "complementary" ISCO treatment in order to guarantee the client the desired objectives. Indeed, the ISCO supported an ongoing treatment of the same area by venting/sparging as well as a Pump & Treat. Venting alone does not obtain the expected yields given the very high heterogeneity of the backfill (>10m) with more compact, impermeable passes containing significant concentrations of volatiles (chlorinated solvents). SPIN® technology was chosen to guarantee the most homogeneous distribution possible of the entire heterogeneous horizon treated and this, based on a successfully completed pilot.

In addition to the injection technique, the injected volumes can maximize contact and therefore the chances of success. To limit the costs of the reagents, it was decided to choose an inexpensive but very reactive oxidant: the Fenton reaction. To minimize costs, the injection work was carried out in 3 phases with monitoring of concentrations between each phase. To optimize the injection campaigns and successfully complete the project within the allotted time, the pilot allowed the injection to be optimized in 2 steps with several machines to also limit the risks due to the high reactivity of the contact of the reagents. It has been proceeded to injections in 2 steps: on the way down, the injection of iron and citric acid, and on the way up (delayed, the next day), hydrogen peroxide.

The presentation will highlight the different phases of the works, and how to obtain good results based on good work upstream and good collaboration with the decontamination company and the trust of the end customer.

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# A robust multi-approach data analysis to identify sources and extent of PFAS impacts

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**Background/Objectives**: At an active industrial plant in Belgium, a multi-level approved remedial strategy has been developed to address a complex mixture of impacts present in both soil and groundwater. Initial Contaminants of Concern (COC's) included chlorinated solvents, chlorobenzenes, chlorotoluenes and nickel.

Since several years, PFAS (Per- and Polyfluoroalkyl Substances) have been gaining a lot of attention from local environmental authorities. In December 2023, Walloon Region regulators released a guideline specific to PFAS investigation. For ongoing site investigations/remediation projects, local environmental authorities request PFAS investigation when the historical research of the site reveals PFAS usage/storage or production.

The PFAS preliminary investigation performed on Site, revealed PFAS impacts due to the former use of firefighting foams containing PFAS. Delineation of these impacts has been requested by the environmental authorities. Due to the presence of multiple industrial facilities in this particular area, several PFAS source contributors may be present making a clear delineation of PFAS contamination associated to the Site very challenging.

**Approach/Activities**: A robust historical study, a multi-criteria data analysis combined with a multivariate data modelling have been developed to identify potential PFAS source areas and delineate PFAS impact associated to the Site. Despite the complexity of the project, this study contributes to understand the multifaceted PFAS patterns and identify their possible sources.

**Results/Lessons Learned**: Multi-criteria data analysis and robust fingerprinting approaches allowed to emphasize two major points:

• PFAS impacts On-Site are related to historical use of Aqueous Film Forming Foam (AFFF); and
• PFAS impacts found on neighboring site are not related to Off-Site migration. Fingerprinting tool clearly identified predominance of C4 PFAS (PFBA, PFBS and PFBSA) and fluorotelomer sulfonic acid compounds (FTS) in neighboring facility, which constitute a different signature from the signature of PFAS impacts found On-Site.

The results from this study provide a robust scientific baseline for PFAS contamination sources discrimination and a powerful argument for the Site's PFAS impact delineation. This study is important because it will represent a fundamental steppingstone approach for PFAS source discrimination by exploratory data analysis and build a long-overdue local picture of PFAS status in Belgium that may support authorities' decision-making on these emerging contaminants.

# Innovative characterization study for a complex PFAS contamination in soil, groundwater and concrete at a Firefighting Training Site in Flanders

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A former firefighting site has been contaminated with PFAS. To complete the characterization of the contamination, advanced investigative methods were applied. The outcomes of these various techniques are discussed in this abstract.

Following an initial source investigation using traditional drillings and monitoring wells, significant concentrations of PFAS were detected with soil concentrations reaching up to 5,620 µg/kg.dw for the sum of PFAS and groundwater concentrations up to 390,000 ng/l. Recognizing the subsurface heterogeneity, which includes layers of varying permeability such as sand, clay and gravel a High-Resolution Site Characterization approach was initiated. This approach involved HPT (Hydraulic Profiling Tool) measurements to estimate soil permeability and heterogeneity, and targeted, vertical groundwater profiling using the GWP (Groundwater Profiler). The combination of HPT and GWP data delivers a screening of not only the variation in concentrations but also the variation of the contaminant mass flux. The screening data is used as a guide to conduct detailed flux measurements to provide a more efficient and focused remediation planning.

Heterogeneity in permeability was observed in the vertical profiles, but these variations were not found at the same depth across different profiles, and were instead related to the local heterogeneity of the Brussels Formation, characterized by the presence of sand-limestone banks. Based on the results, the contamination appeared to extend beyond the boundaries of the source location, leading to a decision to sample all groundwater extraction wells in the broader vicinity of the site and to place monitoring wells at the boundaries of the delineated “No Regret zone”. This to ensure the zone was initially defined sufficiently broadly. In Flanders, No Regret measures are precautionary actions imposed within a 500 m perimeter upon detection of PFAS contamination or around potential PFAS-suspected locations.

To support the conceptual site model (CSM), the results were integrated into a 3D model and a groundwater model was developed. To ensure the soil investigation and remediation were sufficiently future-proof, additional analyses were performed for 'non-measurable PFAS' (TOP assay) and ultra-short-chain PFAS.

TOP assay results at the source zones indicated that the longer chain PFOS and 6:2 FTS (C8) were measured at lower concentrations after oxidation. A significant increase was observed in individual components PFBA (C4), PFPeA (C5), PFHxS (C6), PFHpA (C7), and the sum of PFAS after TOP Assay was also significantly higher.

At the source zones, elevated concentrations of ultra-short-chain PFPrA and PFPrS were measured. Relative to the total PFAS concentrations in this zone (190,000 ng/l), the detected concentrations (1,300 ng/l) were relatively low.

Therefore, it can be concluded that, compared to the regular PFAS analysis, the ultra-short chains were only found in limited amounts, but there were non-measurable precursors present in the regular PFAS range (from C4), especially in the source zone where extensive fire foam exercises were conducted. Other components present in fire foam (glycol) were investigated, but these components were not detected.

The presence of PFAS in concrete was also investigated, which posed a specific risk. Concentrations of up to 360 µg/kg.dw for the sum of PFAS were measured, with leaching values up to 8,800 ng/l.

The goal of this integrated approach was to develop a robust Conceptual Site Model that offers sufficient certainty for the future and the remediation approach. A significant role was played by the client, who, as the problem owner, invested in innovative investigation techniques and provided sufficient budget during the investigation phase.

Proactive communication with external stakeholders, such as local residents, also proved to be very important during the investigation, despite the difficulty of communicating effectively during long-term investigations due to the complex nature of the matter and the challenge of sharing interim results.

# Enhanced remediation of LNAPL-contaminated soils using alcohol-in-biopolymer emulsions

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Environmental pollution, notably soil contamination, is one of the urgent problems at present. Light refined petroleum products (gasoline, diesel, engine oil, etc.) which represent light non-aqueous phase liquids (LNAPL) are among the most widely spread environmental pollutants. The primary source of soil and water pollution by petroleum hydrocarbons is anthropogenic activity. These are the activities of enterprises in the oil refining and petrochemical industries, wastewater from industrial enterprises, accidents and fires at oil storage facilities and refineries, and numerous oil spills as a result of malfunctions of pipelines and tankers. Every year, the volume of polluted territories with oil products constantly increases, threatening the world with an ecological catastrophe. Penetration of LNAPL into the soil or groundwater makes it unsuitable for plant, animal, and microorganism life. Therefore, searching for effective ways to dispose of hydrocarbon pollution is critical. One of the most widely known LNAPL remediation methods is pump-and-treat (PT), which is considered inefficient due to prolonged operation and low recovery efficiency of around 60%. Injecting non-Newtonian fluids such as aqueous polymers presents a significant industrial application interest for in situ remediation of contaminated soil, especially for aquifers with significantly high permeability and strong heterogeneity. However, after flushing with the polymer solution, there will still remain some LNAPL ganglia trapped in pore space that cannot be mobilized anymore. In addition, there are some limitations on the use of high-viscosity fluids. For instance, injecting a high-viscosity polymer solution during soil remediation may increase the injection pressure, leading to injection difficulties or soil uplift. Consequently, developing eco-friendly, sufficiently viscous, and biodegradable fluid is highly in demand. Therefore, in this study, we show how the injection of polymer-surfactant-alcohol emulsion can improve the recovery of residual LNAPL (here diesel fuel) in porous media.

In this study, we prepared a new formulation using biopolymer Xanthan Gum (XG), eco-friendly surfactant sodium dodecyl sulfate (SDS), and water-insoluble biodegradable alcohol “1-pentanol”. This mixture forms a stable emulsion in which the alcohol is dispersed in an aqueous solution. Batch experiments were conducted in small glass vials to test the mechanisms of alcohol partitioning in the presence of aqueous and diesel phases. To evaluate the performance of the emulsion, the recovery of diesel was tested in one-dimensional 30 cm long silica sand-pack columns. The 1D column experiments consider different fluid injection methods such as direct and post-injection. The concentration of diesel fuel in the effluent was measured using refractive index analysis. Furthermore, the effectiveness of the emulsion will be assessed using a Hele-Shaw cell to evaluate the diesel displacement mechanism at the pore scale.

Batch experiment results demonstrated that water-insoluble 1-pentanol in the presence of aqueous and diesel phases promotes partitioning into the diesel phase. As a result, swelling in the volume of the diesel phase was noted, which is typical for the LNAPL mobilization mechanism. Moreover, when 1-pentanol was mixed with XG-SDS solution, it formed stable cloudy emulsions. The new XG-SDS-1-pentanol emulsion was named “COCKTAIL” due to its cloudy white color. Further, we studied the direct injection of COCKTAIL emulsion for diesel removal in the 1D column experiments. We compared the diesel removal efficiency results through direct injection for COCKTAIL emulsion and a combination of XG solution at different concentrations (1 and 2 g/L) with SDS (5 g/L) as a function of pore volume (PV). Increasing polymer (XG) concentration in solutions correlates with an increase in the recovery factor, with values of 83.4% and 88.3% for XG concentrations of 1 g/L and 2 g/L,

respectively. Nevertheless, after flushing with the polymer solution, residual LNAPL ganglia still remain trapped in pore spaces, hindering further mobilization. Combining SDS surfactant with XG solution significantly enhances LNAPL recovery efficiency compared to injecting XG alone. The addition of SDS at a concentration of 5 g/L has a more pronounced effect at a higher XG concentrations, resulting in an increase in recovery efficiency of 4.9% for 1 g/L XG and 5.6% for 2 g/L XG. The primary mechanism for enhancing LNAPL recovery by SDS surfactant in XG solutions is the mobilization of contaminants rather than their solubilization. This implies a reduction in IFT between the XG+SDS solution and diesel oil, facilitating enhanced diesel mobilization. Notably, employing the newly developed COCKTAIL emulsion yields the highest LNAPL recovery results, reaching up to 100 %. The primary displacement mechanism during COCKTAIL emulsion injection is the 1-pentanol partitioning into the diesel phase, causing it to swell and mobilize simultaneously. Using a viscous polymer solution combined with partitioning alcohol helps overcome soil heterogeneity and facilitates the targeted delivery of alcohol droplets to residual LNAPL in low-permeability areas within porous media.

The remediation of diesel-contaminated porous media using post-conventional methods involved a sequential process of water flooding (WF) followed by COCKTAIL emulsion injection. The waterflooding step served as the primary phase for the initial removal of pure free product, akin to the pump-and-treat technique. To examine the influence of LNAPL residual saturation on post-treatment using our emulsion, a column experiment was conducted, producing varied residual LNAPL saturations during this stage. The results demonstrated that the recovery factor reached 64.3% and 79% under less favorable and optimal conditions, respectively. The LNAPL residual saturations obtained were 21%, 26%, 29.6%, and 35.7%. Beyond approximately 2 pore volumes of water injection, no further recoveries were observed in the effluent. The low recovery factor in this stage is attributed to the development of capillary and viscous fingering in the porous medium. Following the post-treatment via COCKTAIL emulsion injection, the recovery factors significantly improved, reaching 100%. These results underscore the exceptional performance of the newly developed emulsion in eliminating all residual LNAPL after waterflooding. Moreover, the initial LNAPL residual saturation was found to have a non-significant impact on the final recovery rate during COCKTAIL emulsion injection.

**Conclusions and perspectives**

Based on the results obtained the following conclusions can be drawn:

- Using a combination of swelling alcohol and a polymer solution is an effective approach to enhance the recovery of residual LNAPL in heterogeneous porous media.
- The new COCKTAIL emulsion exhibited an improved recovery of 100% during direct treatment in 1D columns.
- Post-injection of COCKTAIL emulsion after waterflooding enhanced diesel removal up to 100%.
- The primary remediation mechanism through COCKTAIL emulsion in porous media is the swelling of residual diesel ganglia, leading to their subsequent mobilization.
- The combination of a polymer solution with partitioning alcohol facilitates targeted delivery of the alcohol to low-permeability areas in porous media, thereby promoting the swelling mechanism.

Future perspectives include studying the swelling mechanism of diesel ganglia at a pore scale using a Hele-Shaw cell. Furthermore, we aim to reduce the alcohol content of the COCKTAIL emulsion to minimize flushing costs.

# Remediation of heterogeneous soils contaminated by PFAS: Optimisation of desorption by a solvent/bio-polymer mixture

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Since the 1950s, the production of poly- and perfluoroalkyl substances (PFAS) has been ongoing. The primary application of PFAS involves its use as a low-viscosity sealant in aqueous film-forming foam (AFFF), which is employed for the suppression of hydrocarbon fires. The irrational usage of AFFF at firefighting sites has led to contamination of both soil and water systems, indicating a significant and complex public health and ecological risk. Enhancing PFAS remediation technologies is of significant importance. The traditional remediation methods may be insufficient due to the robust nature of C-F bonds, the properties of surfactants, as well as the solubility and adsorption characteristics of these compounds. Nevertheless, in situ soil flushing with solvents appears to be a promising approach due to its demonstrated effectiveness in desorbing and recovering PFAS from contaminated soils. Nonetheless, the applicability to heterogeneous and complex porous media remains constrained due to the preferential flow pathways and insufficient interaction between contaminants and the fluid.

This study investigates the usage of non-Newtonian fluids whose viscosity changes with applied shear rates as a novel approach to enhance the effectiveness of the soil-flushing method. Due to their capacity to change the flow characteristics with heterogeneity in the soil, this could extensively increase the interaction of these fluids with contaminants. A mixture of alcohol and biopolymer (AP) was prepared and utilized under-regulated laboratory conditions, taking into account its efficacy in recovering PFAS from contaminated soils. The incorporation of alcohol into this mixture was attributed to its capacity to enhance the solubility of PFAS species, whereas the biopolymer constituent was chosen for its shear-thinning behavior, which facilitates effective distribution within heterogeneous porous media.

Rheological behavior of the AP mixture for different concentrations of the biopolymer was carried out and revealed that the alcohol didn't alter the shear thinning behavior of the polymer. Sorption and desorption batch experiments experiment were conducted for a mixture of PFAS including PFOS, PFOA, PFHxS, and PFBS at a concentration of 5mg/L, which represents an average concentration of these compounds in groundwater. A representative of classical alluvial French soil, was used in the experiments with a composition of 92% of sand, 5% of clay, and 3% of organic matter Subsequently a series of 1D column experiments were carried out to evaluate the effectiveness of the formulation proposed in the recovery of the PFAS from the soil. 1D-column results revealed overshoots in PFAS breakthrough curves during alcohol and AP mixture injection, due to over-solubilization. The AP mixture could recover 99% PFOA, 98% PFBS, 97% PFHxS, and 92% PFOS.

These results indicate a synergistic effect between the addition of alcohol and biopolymer in one flushing solution. Alcohol increases PFAS solubility and thus enhances desorption from soil particles, while biopolymer enhances fluid distribution in highly heterogeneous soils. This effect of duality in functionality helps to reduce the risk of residual concentrations and improves general remediation effectiveness.

It highlights perspectives for the extended use of AP mixture in real field conditions. The rheological properties can be adjusted, which allows the design of specific characteristics of each contaminated site, and it is a promising technology to be applied in a wide range of soil types. Besides, biopolymer application is a very "green" product and is fully in line with sustainable remediation because it minimizes the risk of secondary effects.

These results offer new insights into the application of non-Newtonian fluids to environmental remediation, especially regarding the complex challenges offered by PFAS contamination. This work has optimized the effectiveness of soil flushing operations and up-scaled these methodologies, thus this research is in advancement for developing new low-cost, environmentally compatible strategies for a major class of contaminants of emerging concern.

The presentation will give profound insight into the performance-controlling mechanisms of the AP mixture, focusing on its rheological behavior and interactions with contaminants. This work discusses various challenges and opportunities regarding how laboratory-scale results could be scaled up to practical applications and how that could be extrapolated to the broader perspective on using non-Newtonian fluids within environmental remediation.

# Sustainable In-Situ Remediation of a CHC Plume for Expedited Brownfield Redevelopment. A German Case Study

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**Innovative nature:** Integrating Green and Sustainable Remediation (GSR) metrics into full-scale project design and implementation.

**Objectives:** i) Embed a sustainability assessment into the remediation analysis, ii) Quantitatively comparing site renovation sustainability options, iii) Attain environmentally friendly in-situ remediation, iv) Reach stakeholder remediation goals.

## Background/Objectives

In urban areas, brownfield redevelopment projects are often carried out under tight deadlines. In the past, traditional remediation technologies such as excavation & offsite disposal, or pump & treat, have been employed. This is usually because these approaches require a limited amount of time to be designed and implemented. However, such remediation activities may cause greater impact than the contamination that they intend to address. Green and sustainable remediation (GSR) technologies can substantially reduce the environmental footprint of remediation and maximize overall net benefits. Compared with traditional methods, they can typically reduce the life-cycle greenhouse gas (GHG) emissions by ~50–80 % (Hou et al., 2023).

The case study location is a large urban brownfield site that was previously used as a military installation. Real estate re-zoning required the remediation of two shallow chlorinated hydrocarbon (CHC) groundwater impacts, with contaminant plumes extending underneath significant stretches of the residential housing units under construction. The objectives of this case study were to:

1. Assess common GSR claims, based on a real-case full-scale in-situ remedy in Germany using a public-domain GSR assessment tool;
2. Demonstrate the efficacy of a commercially available in-situ amendment to achieve expedited site closure, with above ground brownfield redevelopment activities occurring in a parallel work stream.

## Approach/Activities

An environmentally friendly reagent application technology was utilized, applying the EHC® ISCR amendment to facilitate expedited brownfield redevelopment. Following a one year monitoring program after the pilot test, injection of 200 metric tons of amendment across a total source area of 6,500 $m^2$ (16,5 hectares) was completed over a course of seven months. EHC represents a mixture of recycled materials such as industrial (for the micro-scale ZVI) and agricultural waste (for the organic carbon component). A rigorous and lengthy post-treatment sampling program has been implemented, utilizing a large monitoring network to assess the efficacy of the remedy over the next three to five years. In-situ remediation environmental footprint factors were compared to two conventional remediation technologies, including $CO_2$ data related to amendment production, overall energy use, and fuel consumption for both on-site and off-site activities.

**Results/Lessons Learned**

Several take-aways were discerned from both the pilot and full-scale activities. These include the conclusion that a single amendment injection may allow for achieving stringent remediation goals (i.e. from 12 mg/L to 20 µg/L total CHC) in treatment areas, where the length of effectiveness was >20 months.

GSR metrics performance showed up to 86 % less GHG emissions compared to the two conventional technologies assessed. Post-treatment monitoring remains ongoing. CHC contaminants were mineralized to ethene within a two-year time period, based on the results of extensive pilot test monitoring prior to implementation of the full-scale remediation.

Active treatment duration 6 months; January thru June 2023 (Full-scale remediation).

- Plus 3 months; April thru June 2020 (Pilot-scale tests and resultant partial remediation)

Specific treatment costs, excluding consulting services and monitoring, of:

- 6,73 EUR / ton Soil
- 6,00 EUR / $m^3$ Groundwater
- 428 EUR / kg Pollutant

Specific energy consumption, excluding energy required for the production of active ingredients, of:

- 0,3 kWh / ton Soil
- 100 g $CO_2$ / ton Soil

**Efficient removal of per- and polyfluorinated alkyl substancesfrom potable- and waste water with selective Lewatit resins**

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In this presentation, we will discuss the efficacy of Lewatit ion exchange resins—specifically Lewatit TP 108, Lewatit TP 108 DW, and Lewatit TP 108 DW BF—in removing short- and ultrashort-chain per- and polyfluoroalkyl substances (PFAS). These resins have shown superior performance in a range of PFAS removal applications, including ground remediation, wastewater treatment, reverse osmosis (RO) concentrate management, and drinking water purification.

Our focus will be on the removal mechanisms of these ion exchange (IX) resins, examining how they target PFAS compounds to achieve high removal efficiencies. Additionally, we will cover essential design criteria for state-of-the-art IX systems, ensuring optimal resin performance across different applications. This presentation will provide insights into leveraging Lewatit's advanced ion exchange technology for effective, scalable, and reliable PFAS removal solutions in diverse water treatment settings.

# PFAS

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