Dépollution du sous-sol par traitement in-situ BAND des HET-NSO, HAP, Solvants chlorés, etc.

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Dépollution du sous-sol par traitement in-situ
BAND des HET-NSO, HAP, Solvants chlorés, etc.

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Micropolluants toxiques et les biotechnologies des traitements de dépollution in-situ microbiologiques et biochimiques applicables : Exemples des BAND (Bio-Atténuation Naturelle Dynamisée) / L'Approche au meilleur bilan Coût-avantages

Toxic Pollutants and Application of Bio-Technologies by microbiological & bio-chemical in-situ-Treatments: Examples DNBA (Dynamized Natural Bio-Attenuation) / The most Cost-effective Approach

Dr. (es. Sc.) Frank Karg / Scientific Director of HPC-Group (INOGEN JV) &
CEO-President of HPC INTERNATIONAL / France, Germany, Suisse, Hungary, Balkan, etc.
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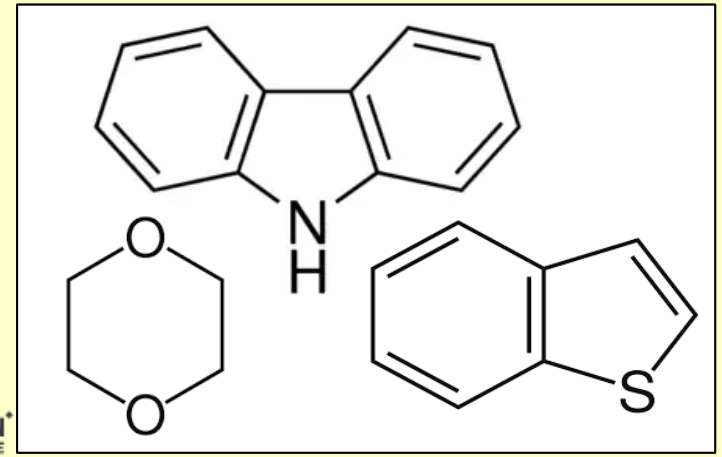

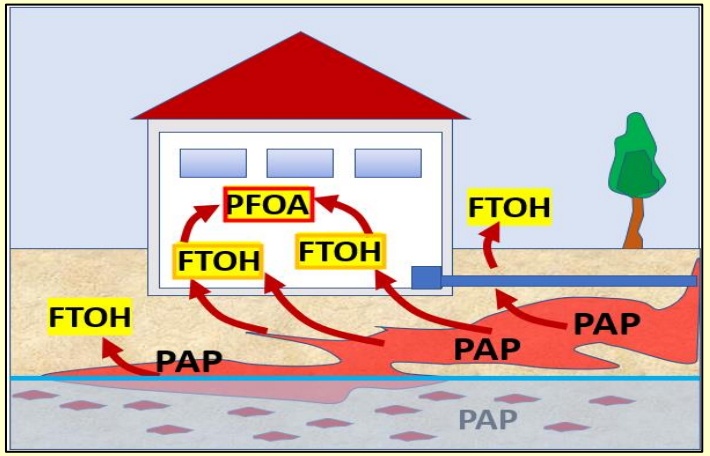

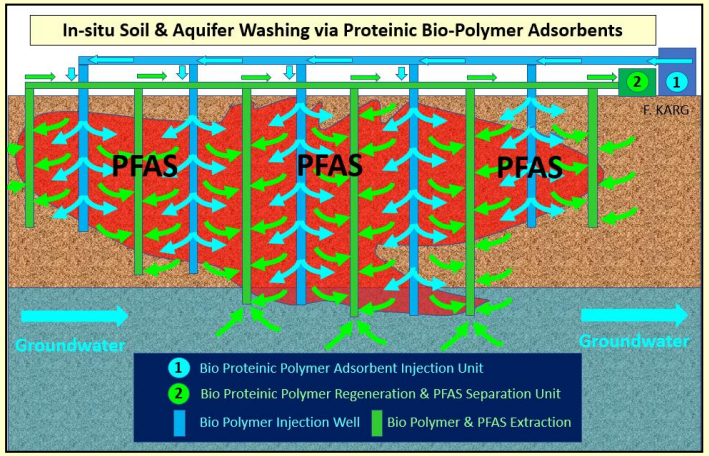

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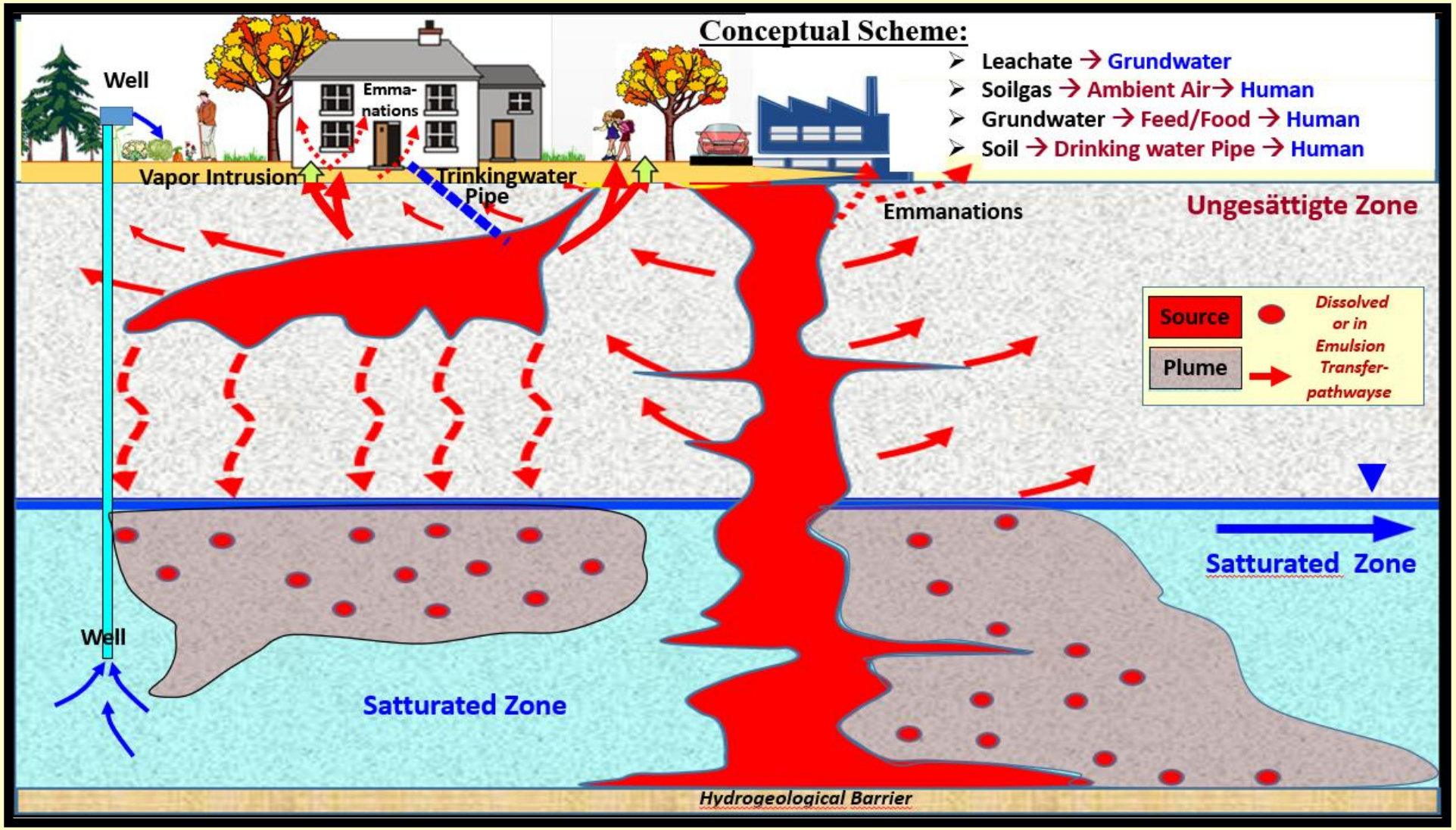
Polluants : Solvants chlorés, HET, HAP, etc.

HET: Héterocycliques & Amines aromatiques.

Solvants chlorés (PCE, TCE, DCE, CV, etc.).

HAP (Hydrocarbures Aromatiques, Poly-cycliques)

Pollutions sous forme de LNAPL, DNAPL (huiles de goudron et dissoutes.



Dépollution du sous-sol par traitement in-situ
BAND des HET-NSO, HAP, Solvants chlorés, etc.

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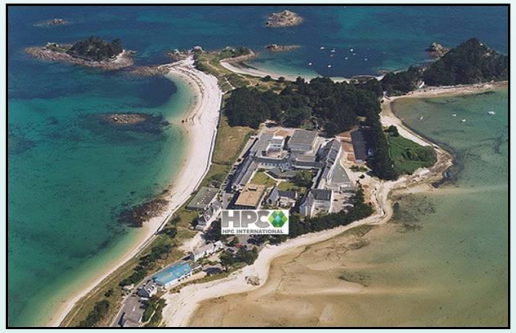
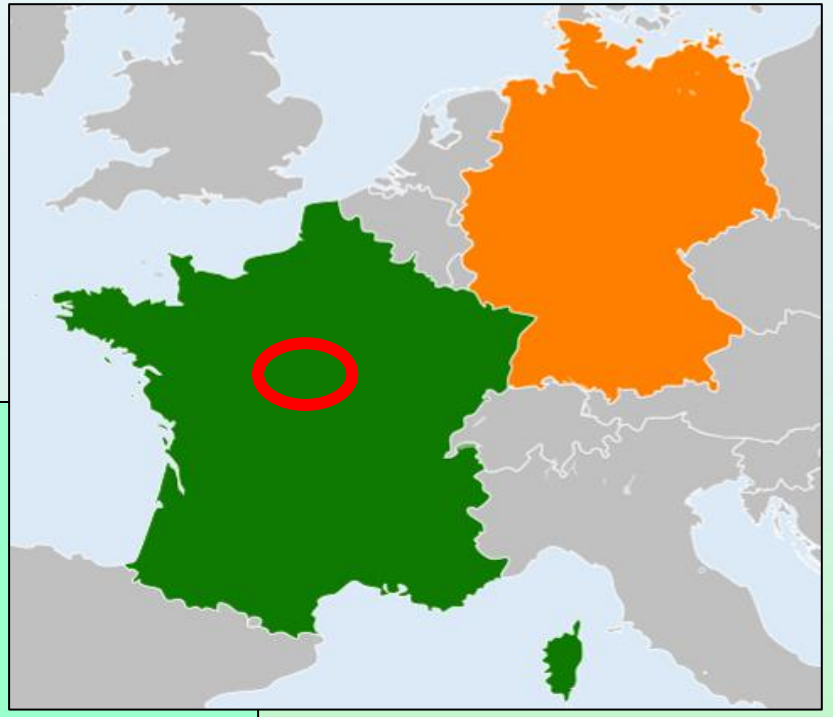


In-situ DNBA: Dynamized Natural Bio-Attenuation



Project Example: Aerospatiale/

Chlorinated Solvents + Cr6:

Microbiological In-situ-Treatment

Bio-Technologies & Genetic Bacteria Selection

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA (France)

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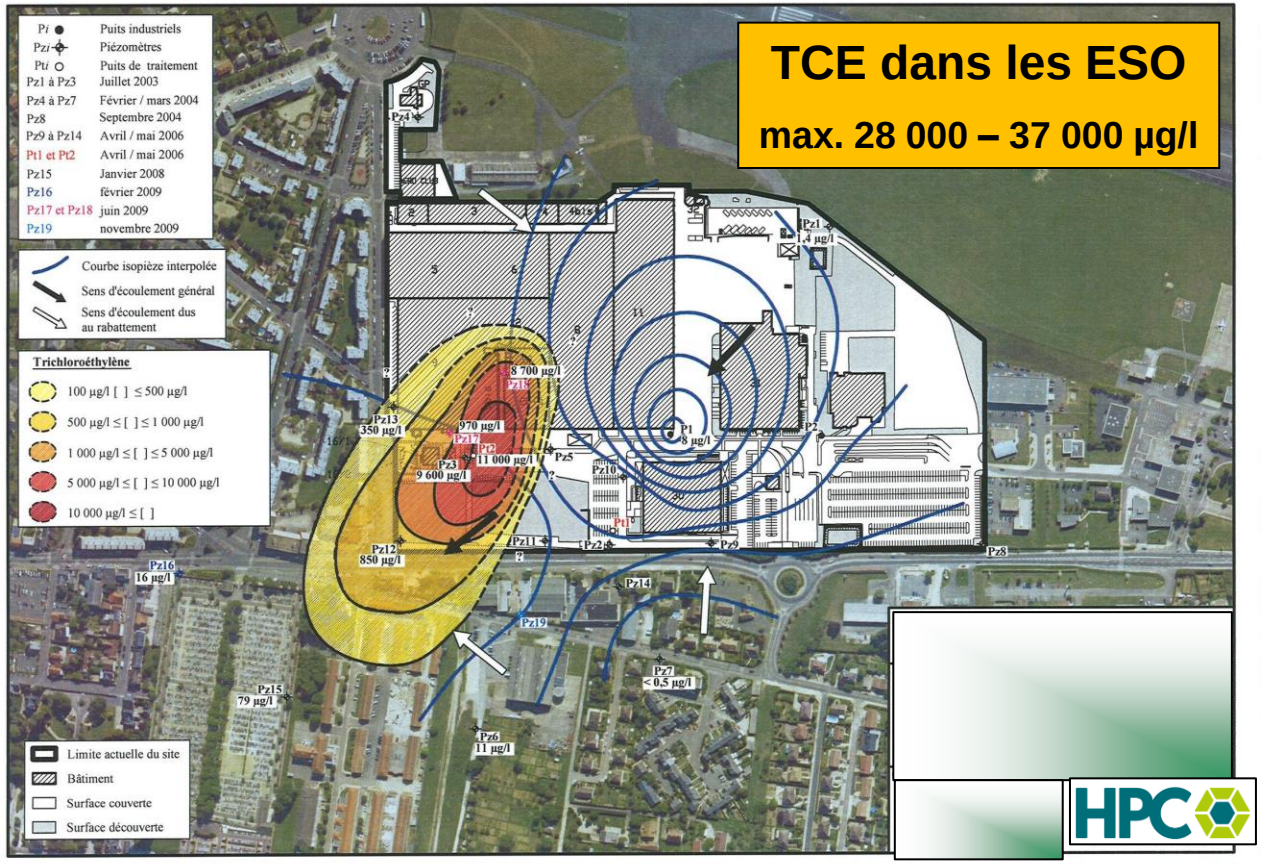

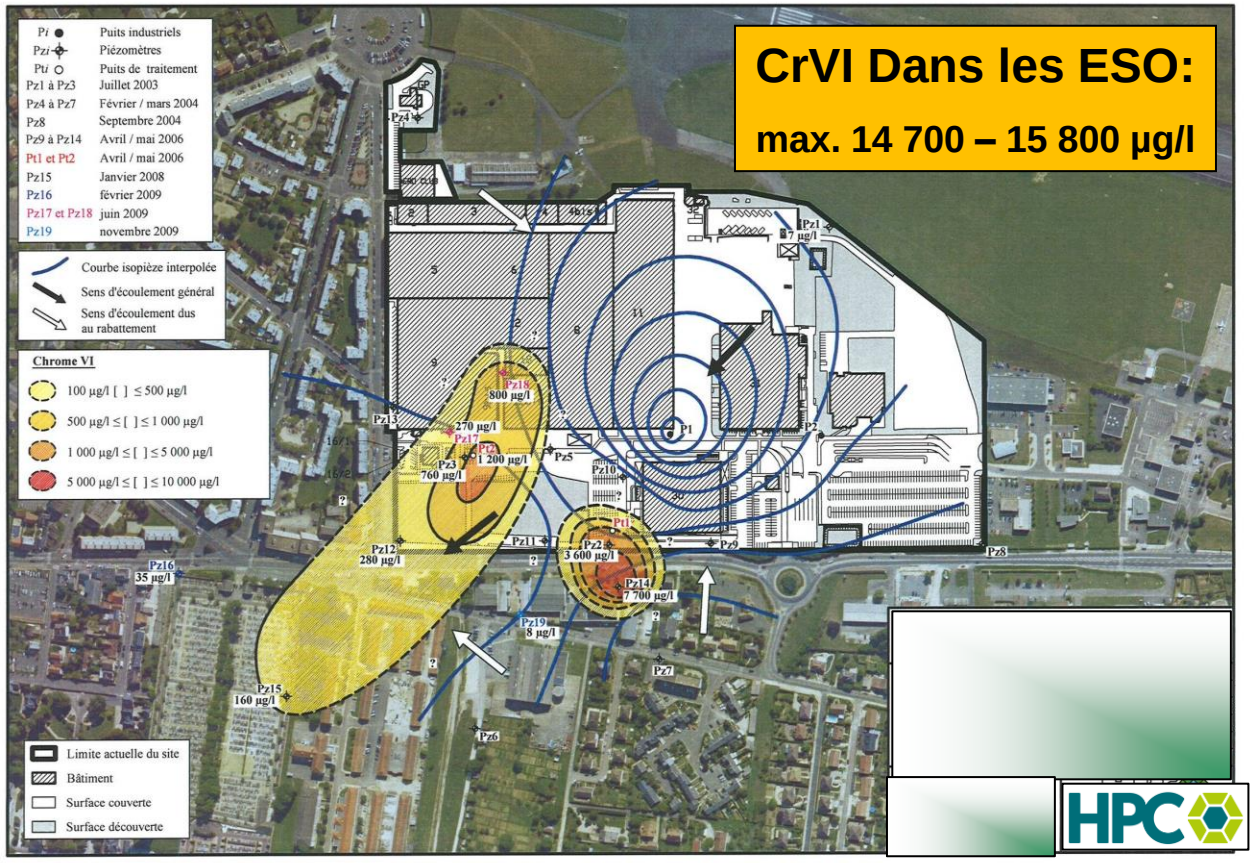

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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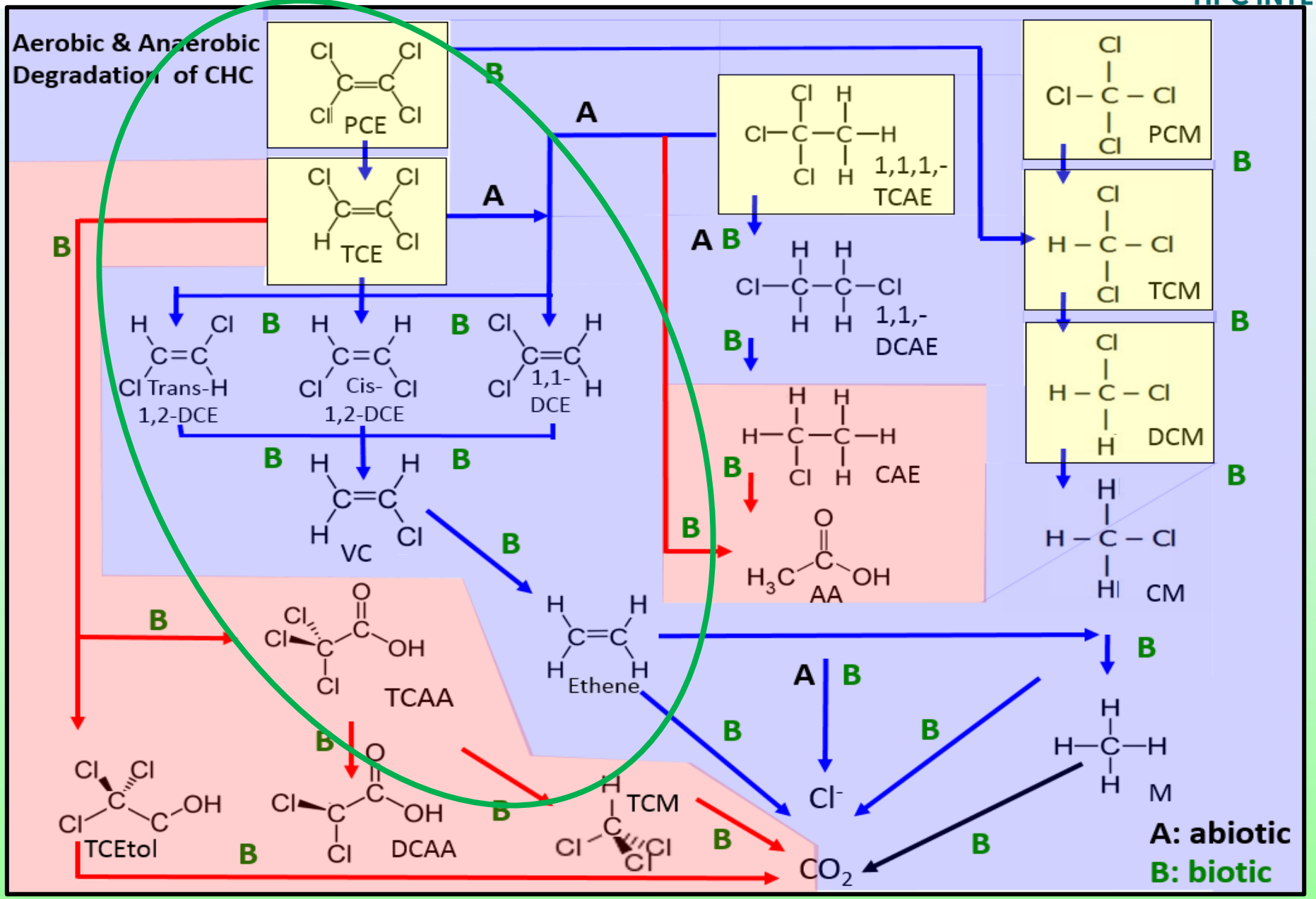

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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Aerobic and anaerobic Degradation Reactions of TCE Reduction of various electron acceptors. PCE Degradation only in anaerobic conditions.

Reaction equation of the TCE Degradation		Eh [mV]
Oxygen consumption	$C_2HCl_3 + O_2 \rightarrow C_2Cl_3O_2H \rightarrow$ $C_2Cl_3O_2H + O_2 + 2\,H^+ \rightarrow 2\,CO_2 + 3\,H^+ + 3\,Cl^-$	> 740
Nitrate reduction	$3\,C_2HCl_3 + 2\,NO_3^- \rightarrow 3\,C_2Cl_3O_2H + N_2 \rightarrow$ $3\,C_2Cl_3O_2H + 2\,NO_3^- + 6\,H^+ \rightarrow 6\,CO_2 + N_2 + 9\,H^+ + 9\,Cl^-$	500 → 740
Nitrate reduction	$3\,C_2HCl_3 + 2\,NO_3^- + 6\,H^+ \rightarrow 3\,C_2Cl_3O_2H + 2\,NH_3^+ \rightarrow$ $3\,C_2Cl_3O_2H + 2\,NO_3^- + 6\,H^+ \rightarrow 6\,CO_2 + 2\,NH_3^+ + 9\,H^+ + 9\,Cl^-$	
Manganese redaction	$3\,C_2HCl_3 + 3\,MnO_2 \rightarrow 3\,C_2Cl_3O_2H + 3\,Mn^{2+} \rightarrow$ $3\,C_2Cl_3O_2H + 3\,MnO_2 + 6\,H^+ \rightarrow 6\,CO_2 + 3\,Mn^{2+} + 9\,H^+ + 9\,Cl^-$	0 → 500
Iron reduction	$3\,C_2HCl_3 + 3\,Fe^3O(OH) \rightarrow 3\,C_2Cl_3O_2H + 3\,Fe^{2+} \rightarrow$ $3\,C_2Cl_3O_2H + 3\,Fe^3O(OH) + 6\,H^+ \rightarrow 6\,CO_2 + 3\,Fe^{2+} + 9\,H^+ + 9\,Cl^-$	-50 → 0
Sulfate reduction	$2\,C_2HCl_3 + SO_4^{2-} + 10\,H^+ \rightarrow C_2H_4 + 2\,CO_2 + H_2S + 6\,H^+ + 6\,Cl^-$	-240 → -50
Methanogese	$2\,C_2HCl_3 + 4\,H_2O + 4\,H^+ \rightarrow 2\,CH_4 + 2\,CO_2 + 6\,H^+ + 6\,Cl^-$	< -240

+ 0 -

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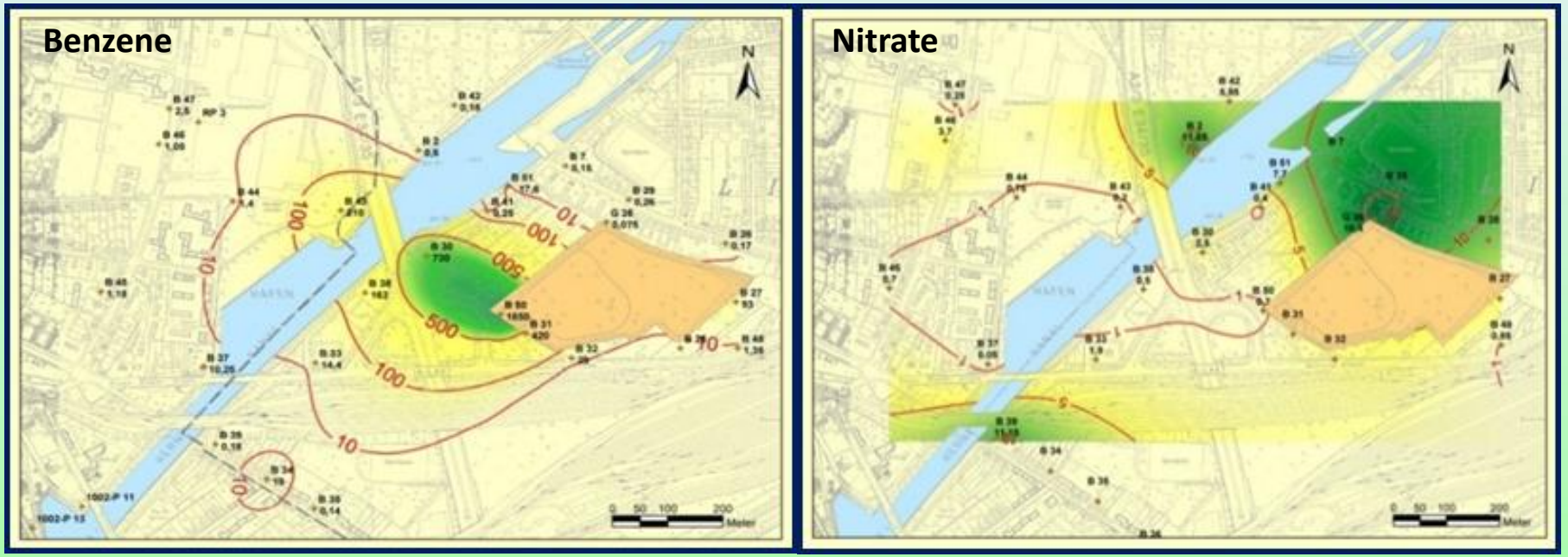
Microbiological Pollutant Degradation and Electron Acceptor use : Nitrate



Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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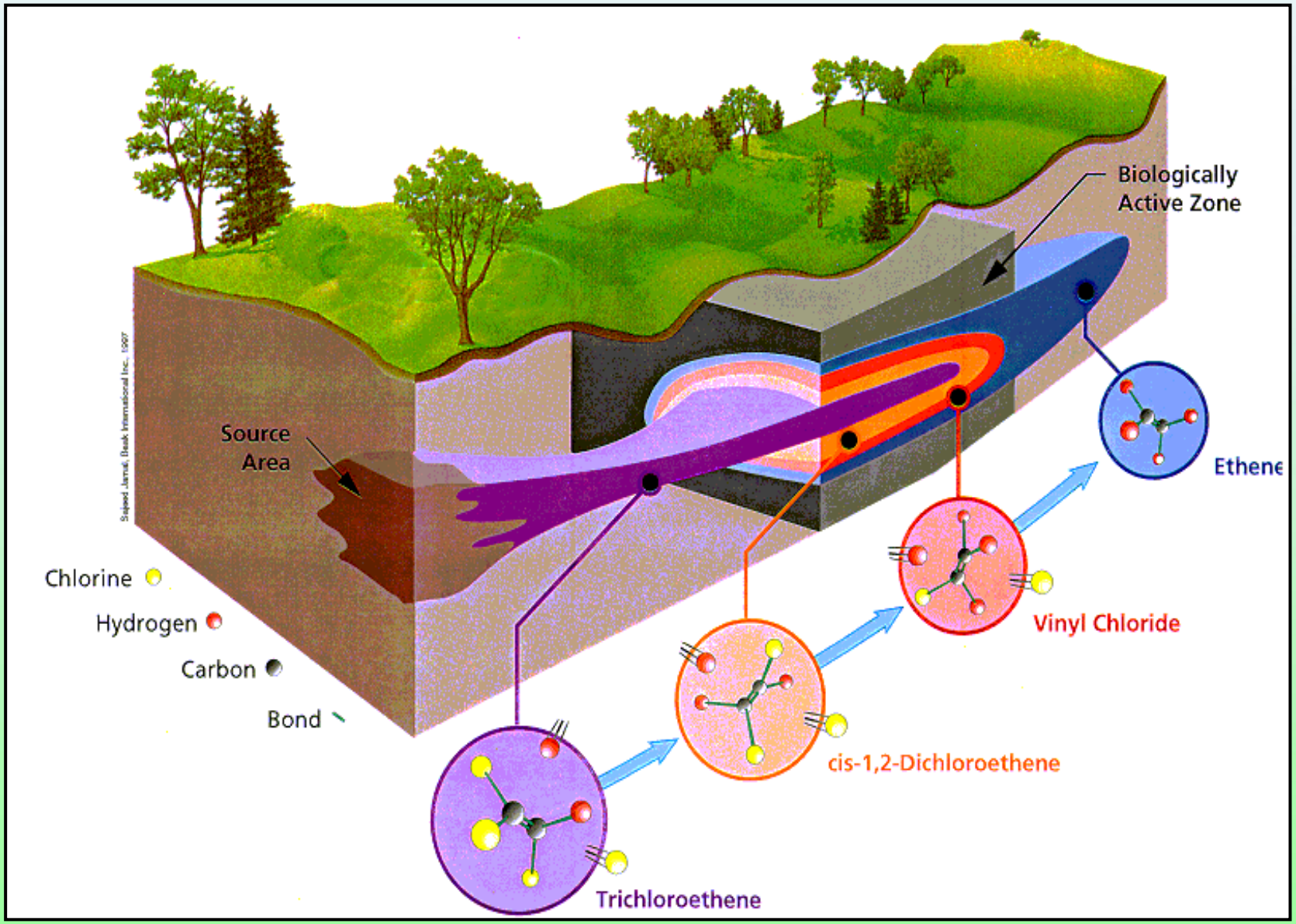

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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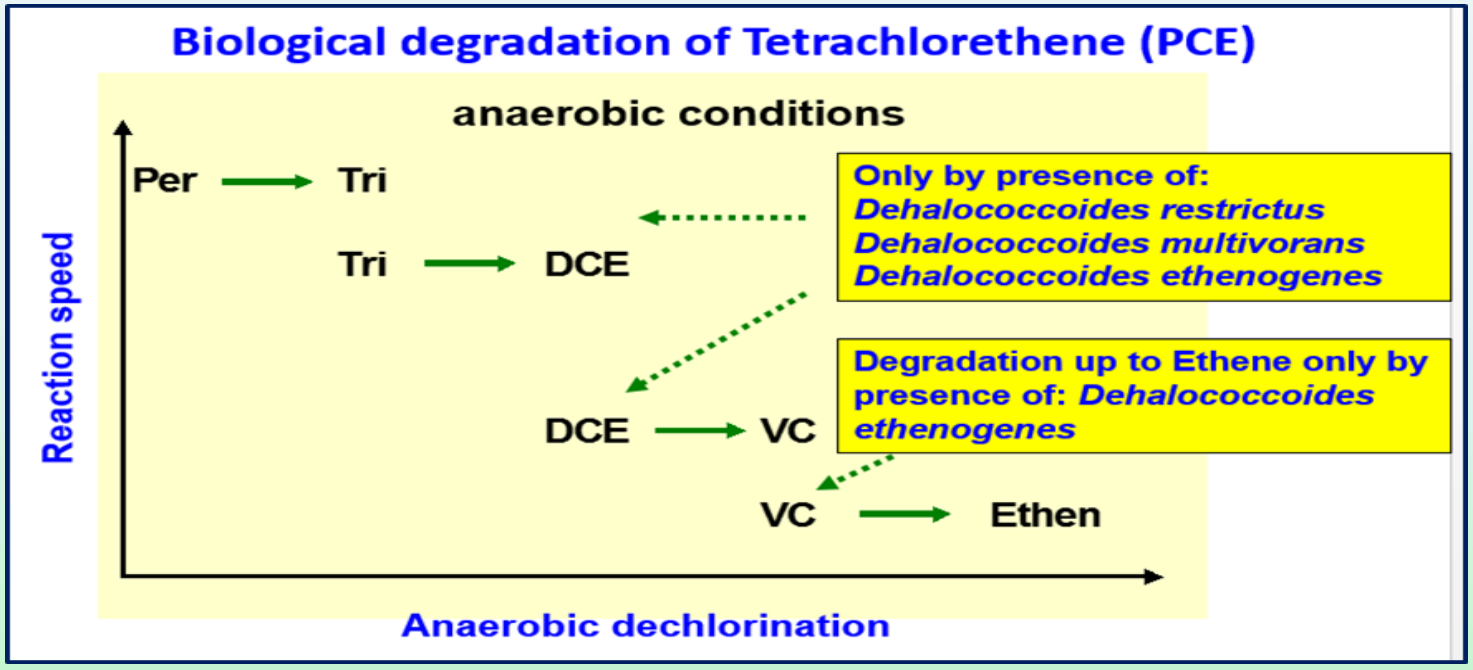
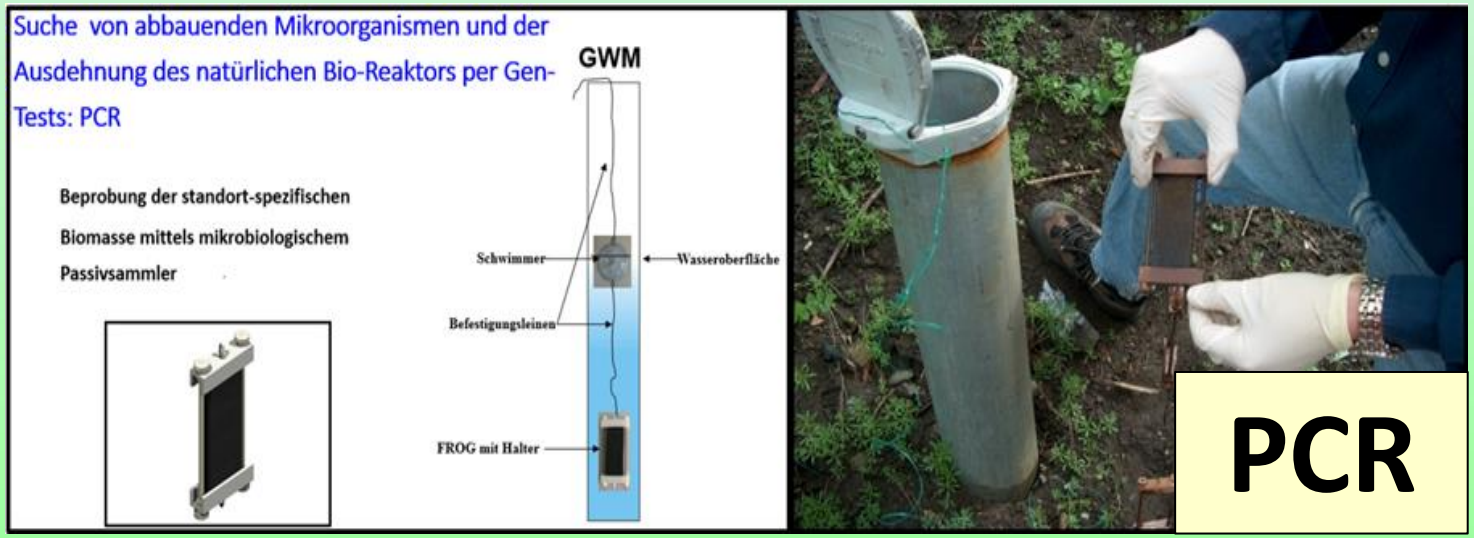
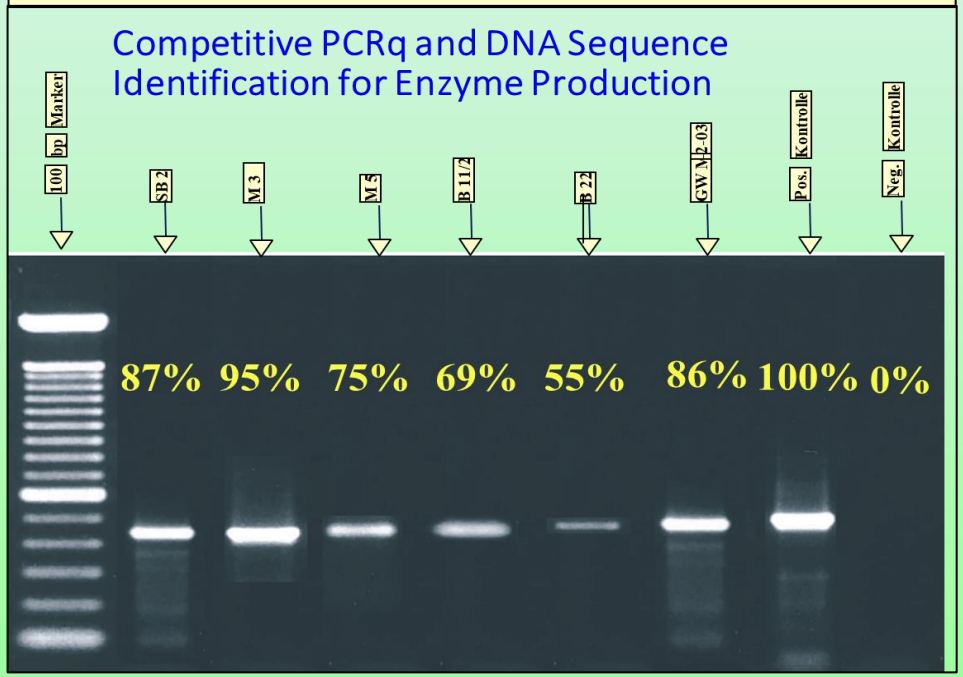


PCRq-based Bacteria Selection:

Sampling of Bacteria Consortia of groundwater with microbiological Passive Samplers (Frogs) by installing it in a Groundwater Monitoring Well (GWM) for PCRq testing.



PCR



Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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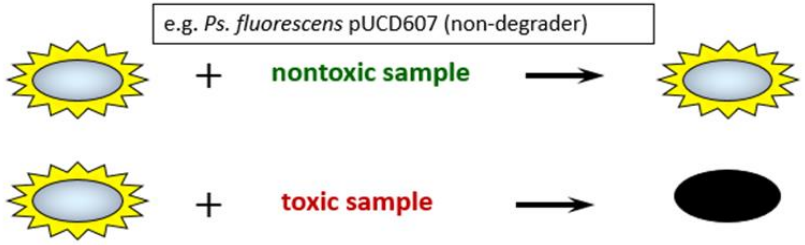
Microbiological ecotoxicity

Microbiological ecotoxicity tests (Investigation of disruptive factors of the pollution degradation), like:

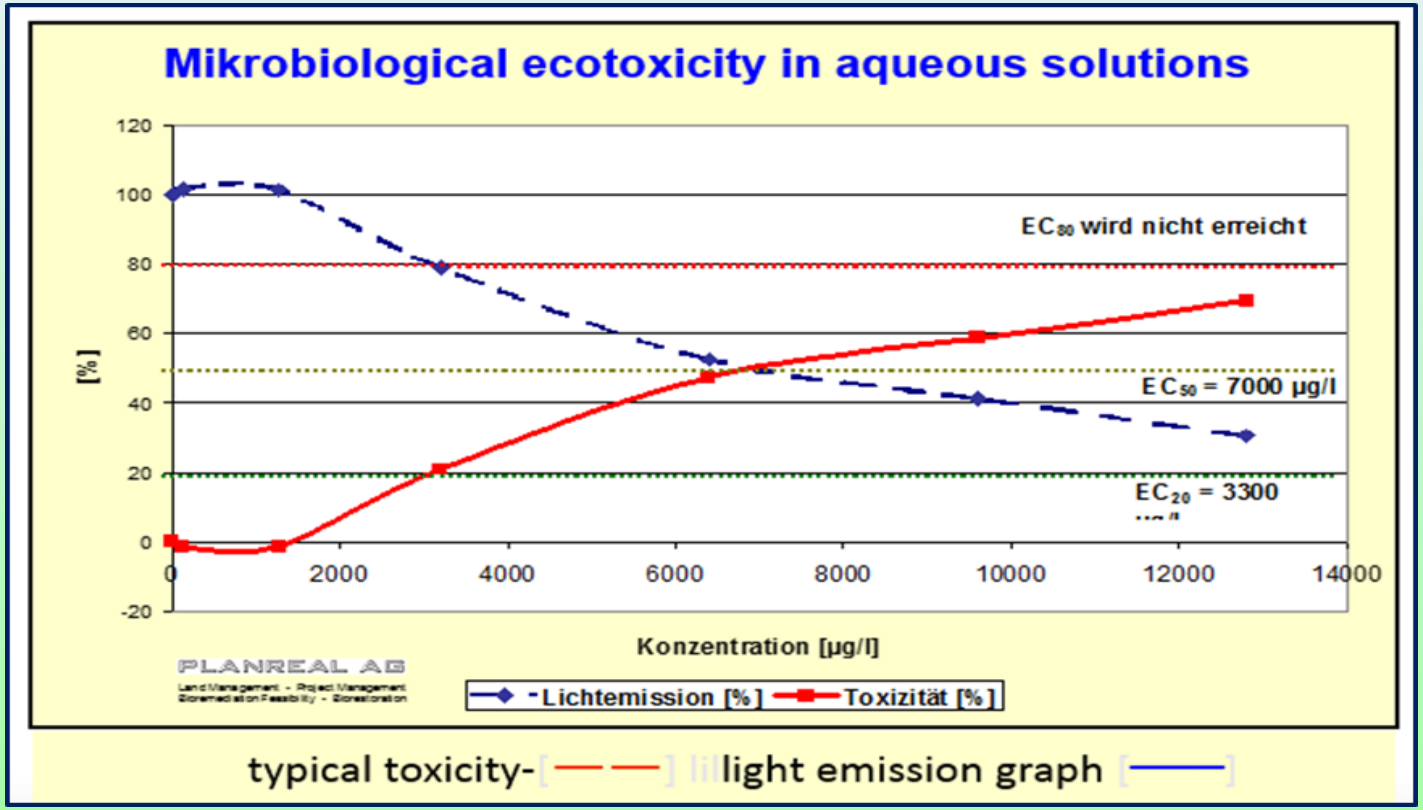
Toximeter tests (Measurement of the metabolic activity of selected soil bacteria strains by using luminous soil bacteria)

Determination of pollution toxicity for soil bacteria with gene-modified soil bacteria



Microbiological Excotoxicity:

Determination of Microbiological Eco-toxicities to identify disruptive factors to the current microbiological degradation and to identify zones with DNBA measures required.



Mapping of constraint zones of microbiological TCE & PCE degradation → *Treatment of Cr^{6+} first !*

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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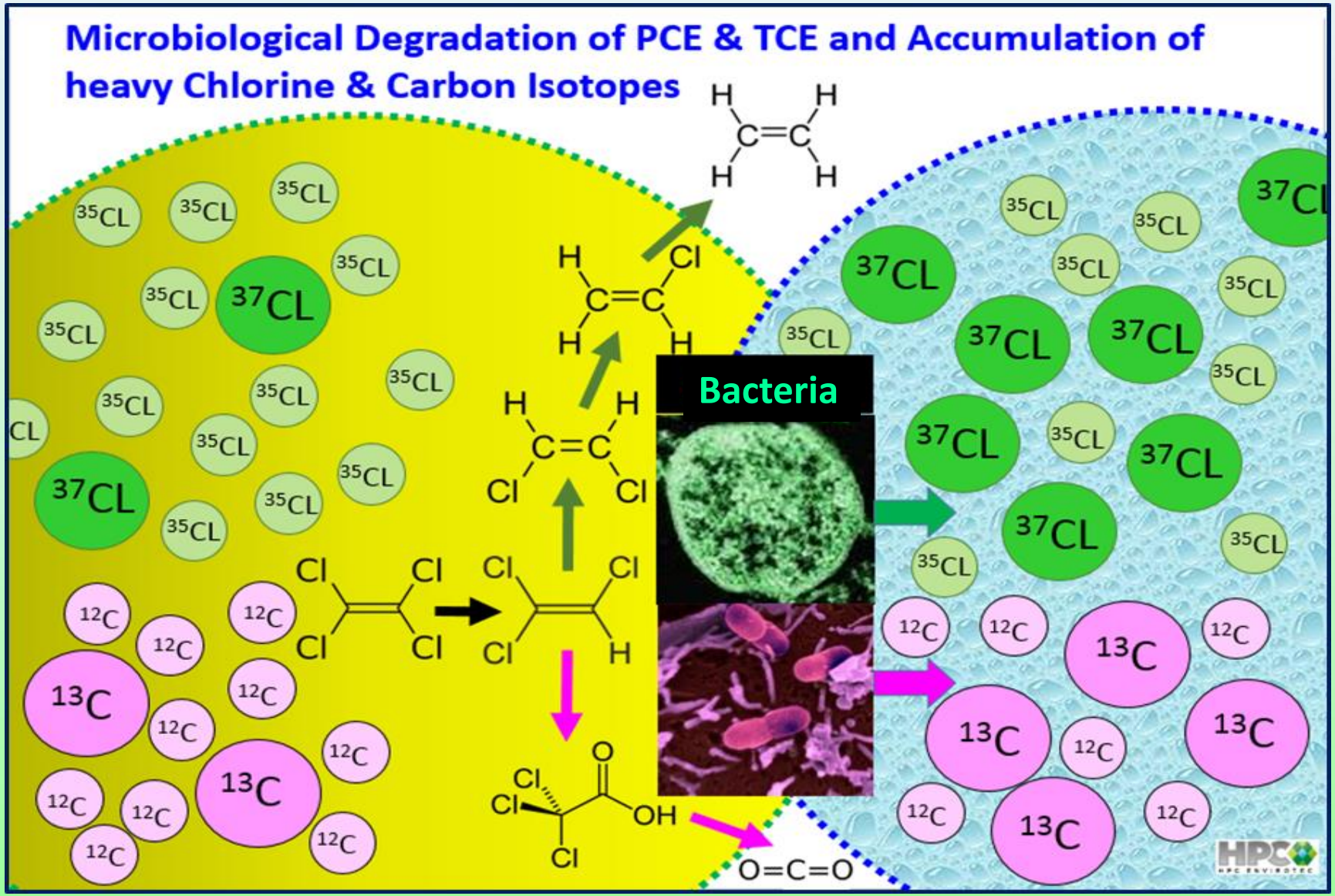
Isotopic Fractioning to Identify in-situ Microbial Biodegradation

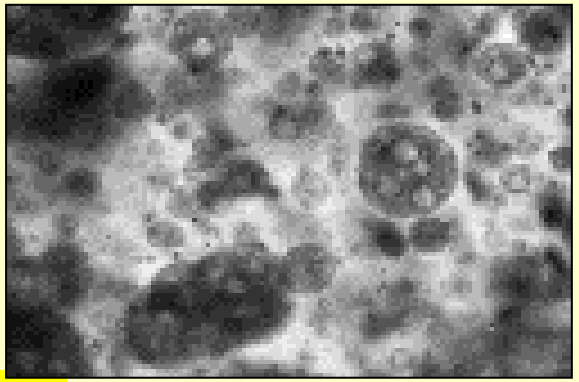


Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

DNBA-Treatment:

- **SENS: Substratum – Emulsifier – Nutriments - Stabilizator for anaerobic Aquifer Conditions:**

>Eh of about -200 mV: special Veget. Oil Emulsion of 2,5 – 7 µm,
>Special Lactates (site specific & Bacteria Consortium specific),
>Bio-available degradable Surfactants / Alginates from Brittany / Roscoff or Emulsion Stabilization,
>Special Nutriments & Oligo-elements, to dynamize the Bio-degradation (constituted Site specifically):



→ For reductive, anaerobic Dehalogenation of the HVOC and

→ For reductive Immobilization of CrVI to CrIII.

- **SSMC: Site Specific Microbiological Consortium:**

Dehalococcoides restrictus, Dehalococcoides multivorans, Dehalococcoides ethenogenes:

→ Anaerobic Degradation of PCE, TCE to cis-DCE (SENS + SSMC-KB1®),
→ Aerobic Degradation of cis-DCE to Ethene / CO_2 SSMC-162).

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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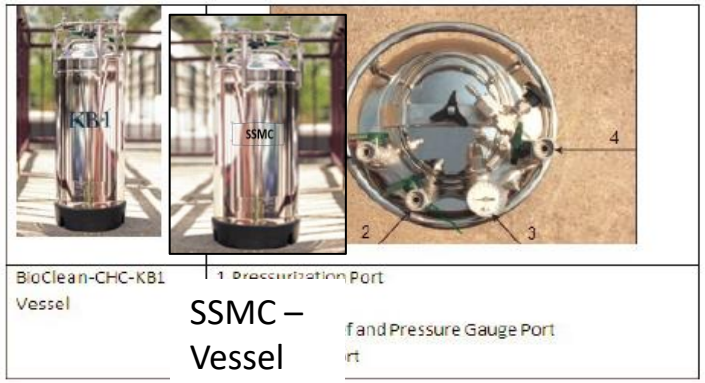
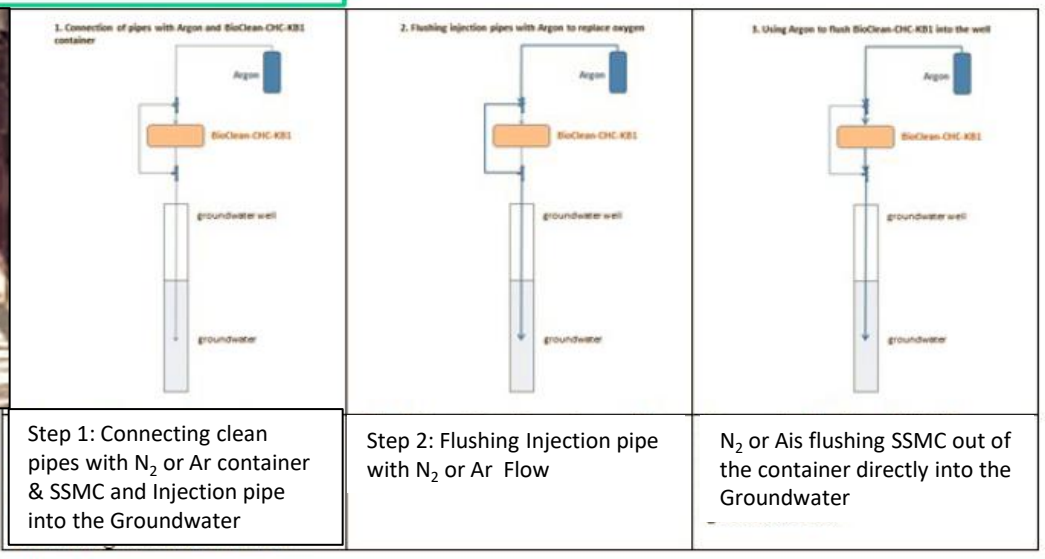
Injection Phase 2 → SSMC-CHC-KB-1

SSMC is delivered in stainless steel container for injection under Nitrogen or Argon



Production and injection of Bacteria Consortium

Injection of SSMC at the site "B"



Step 1: Connecting clean pipes with N_2 or Ar container & SSMC and Injection pipe into the Groundwater

Step 2: Flushing Injection pipe with N_2 or Ar Flow

N_2 or Ais flushing SSMC out of the container directly into the Groundwater

A Partner of Inogen Environmental Alliance

Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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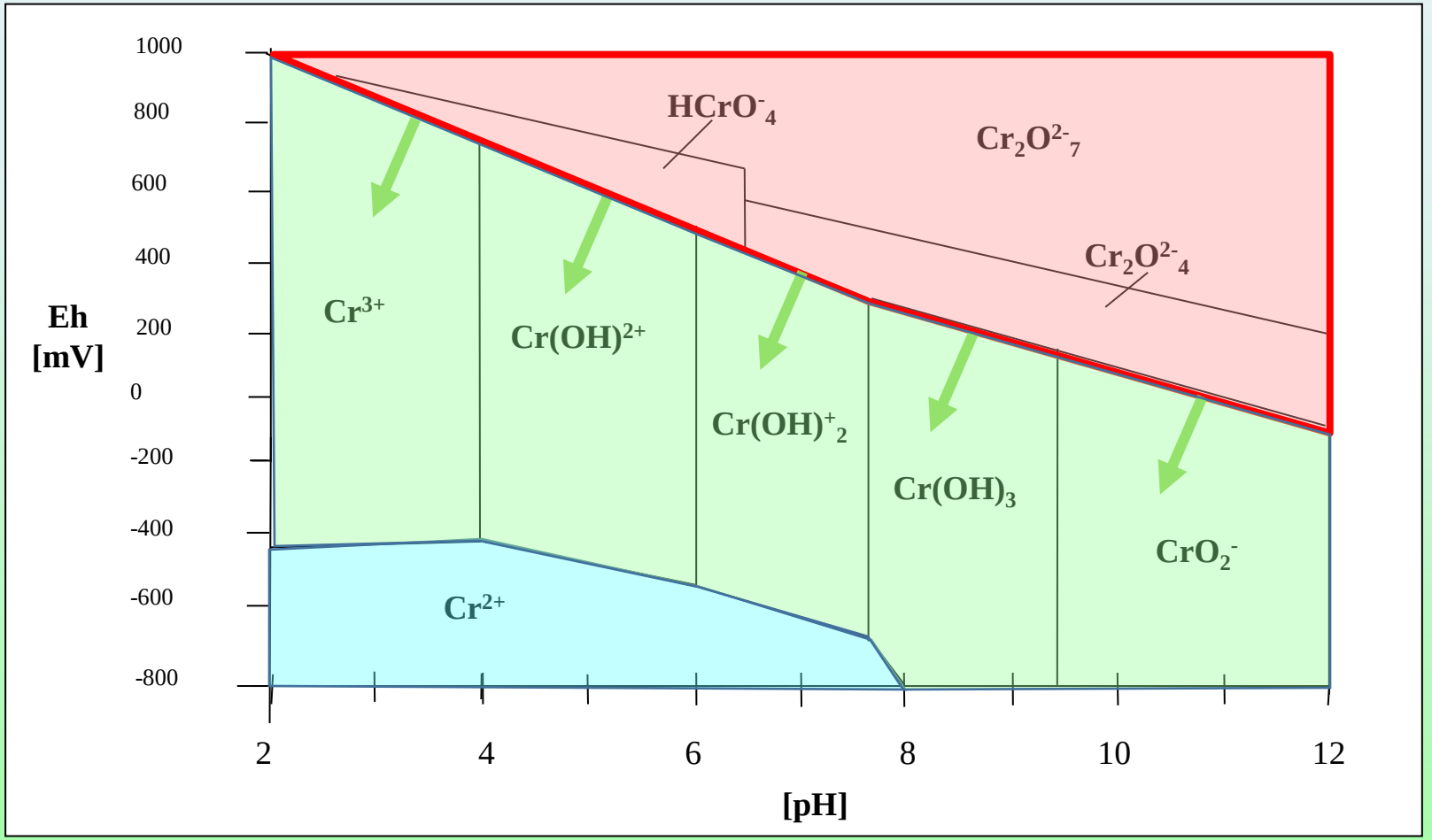
Goal: Reduction of CrVI to CrIII and Immobilisation



Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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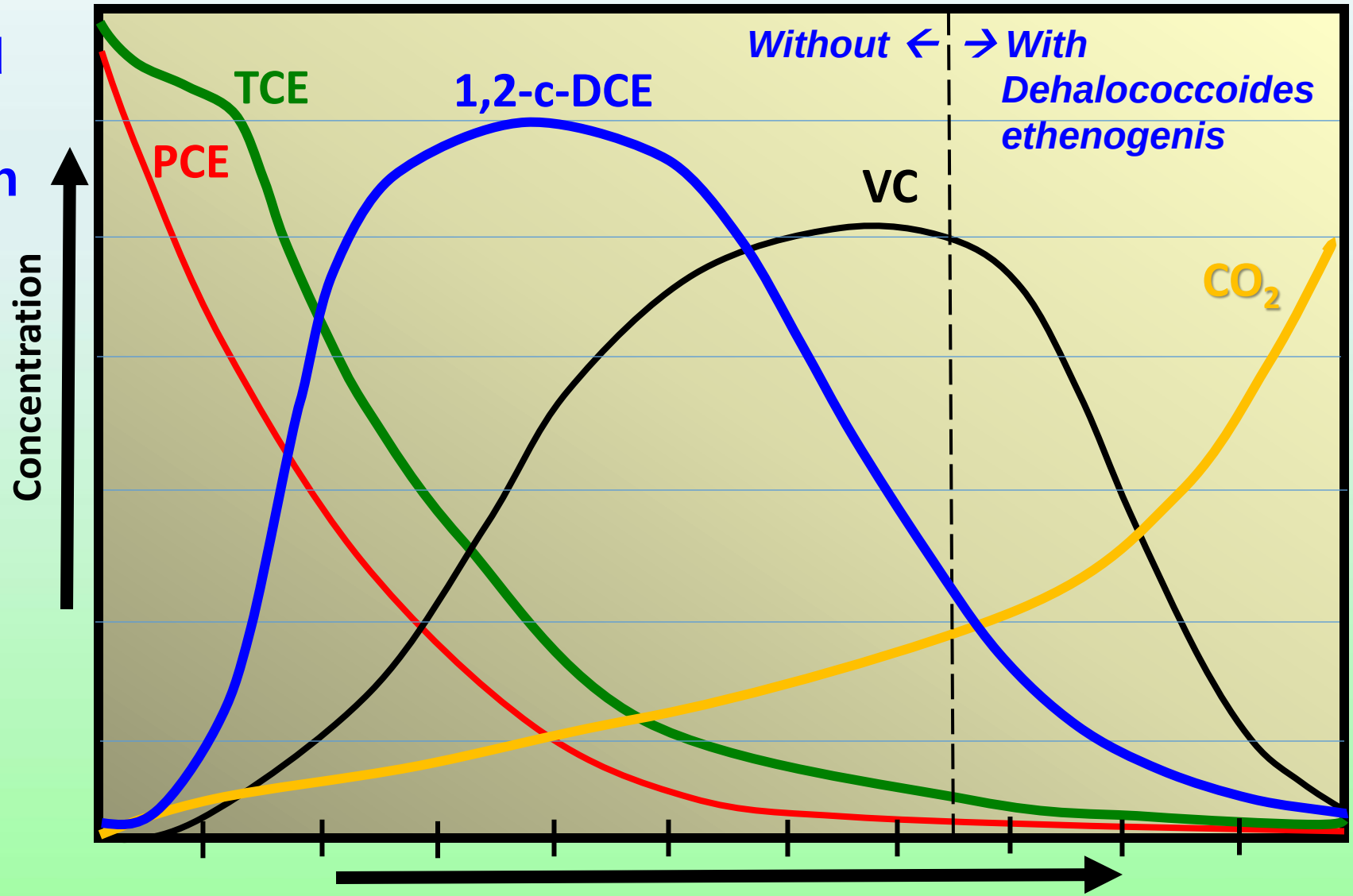
Chlorinated Solvent Degradation



Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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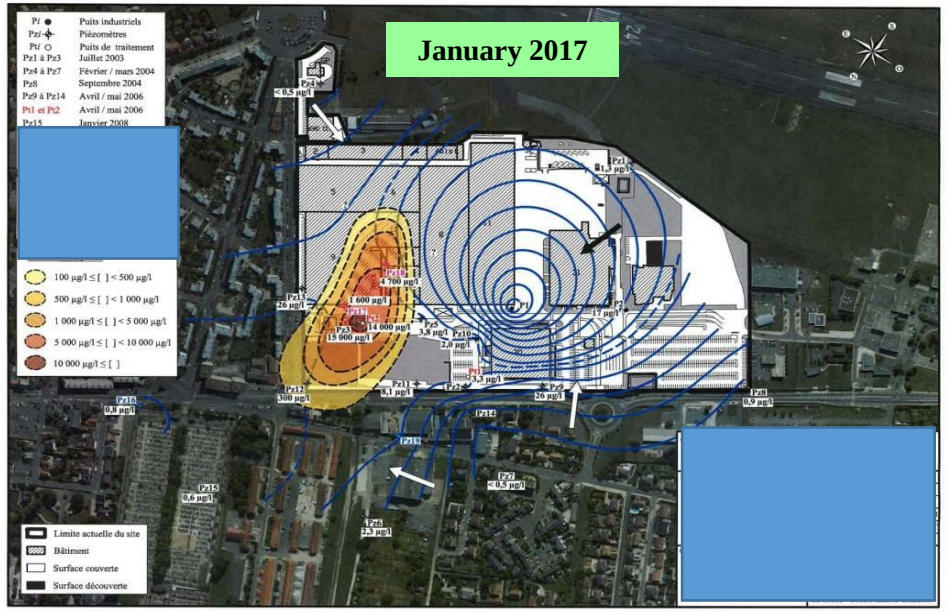
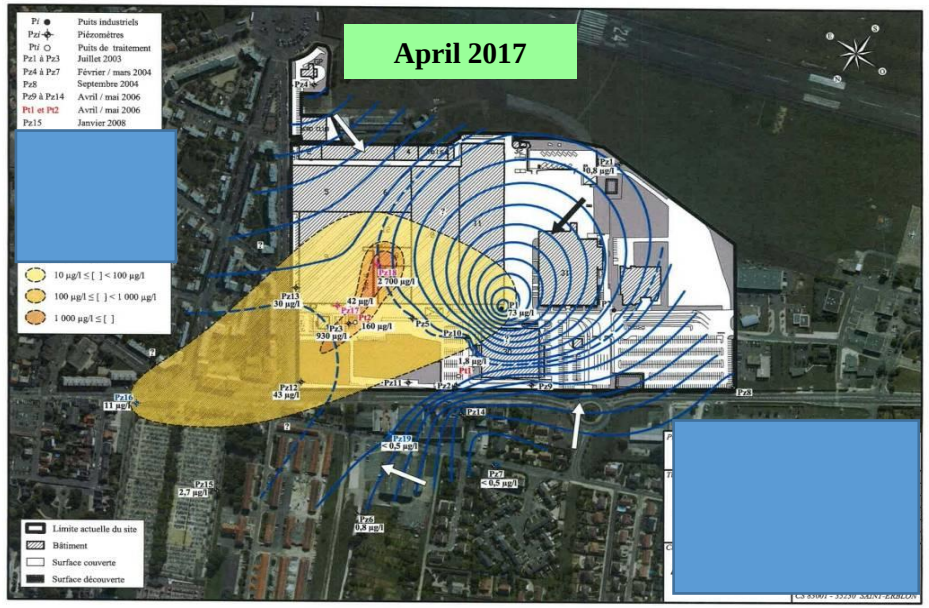
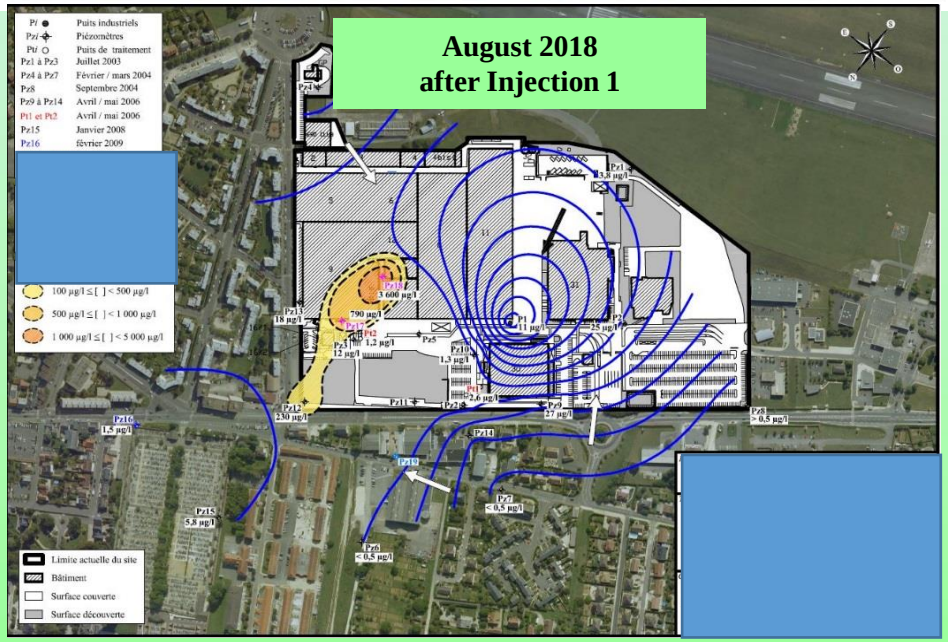
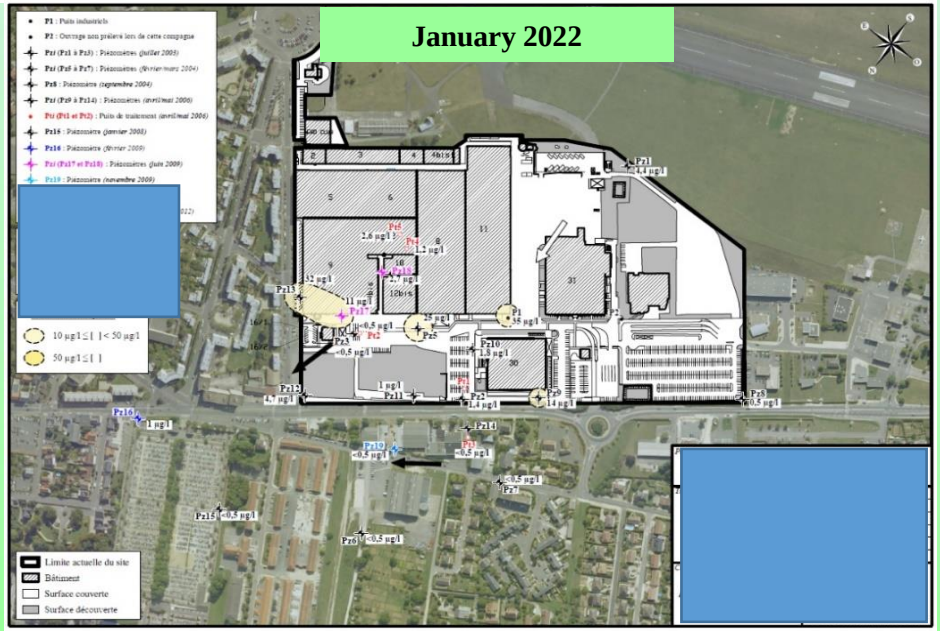
TCE









Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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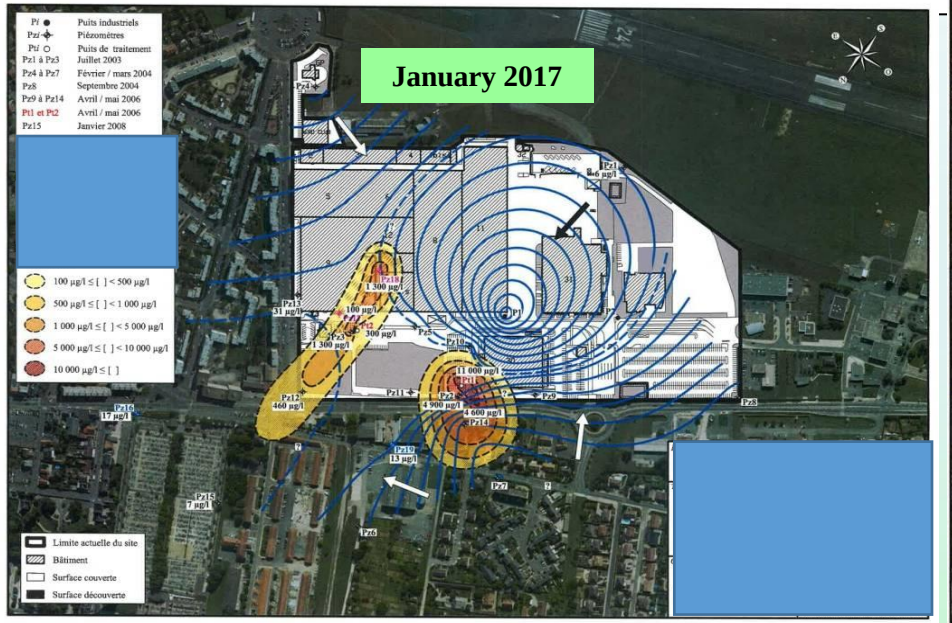
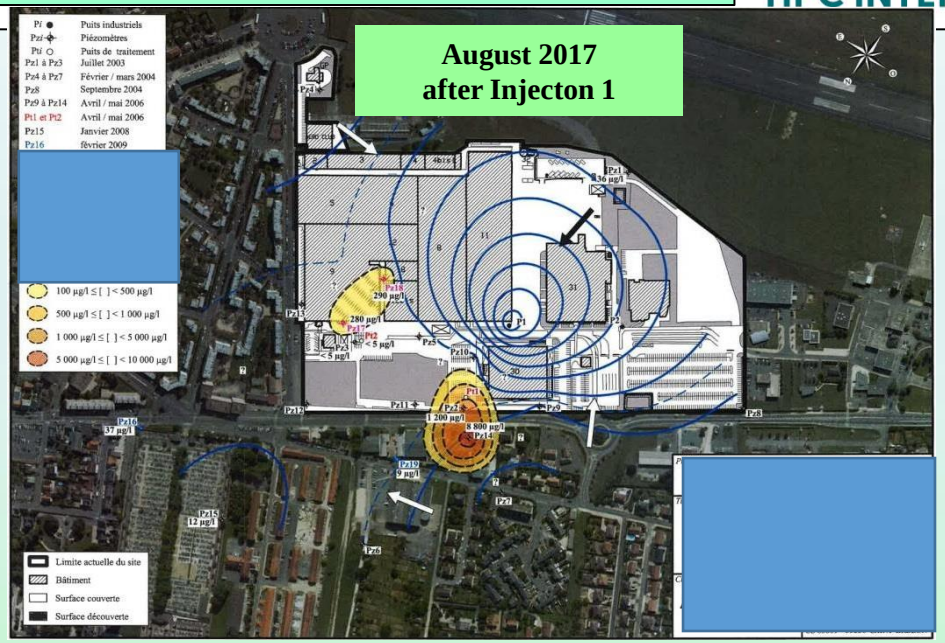
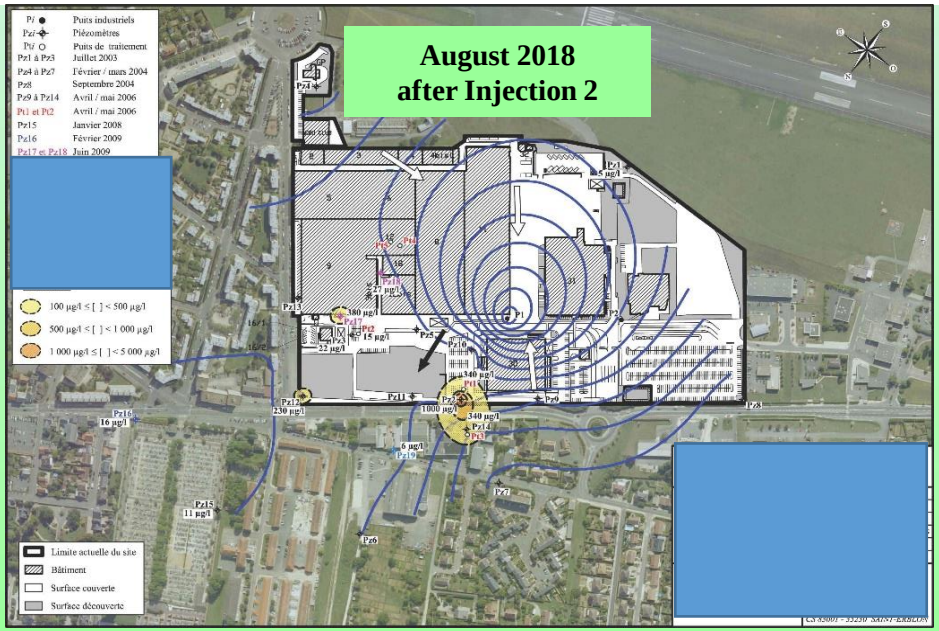
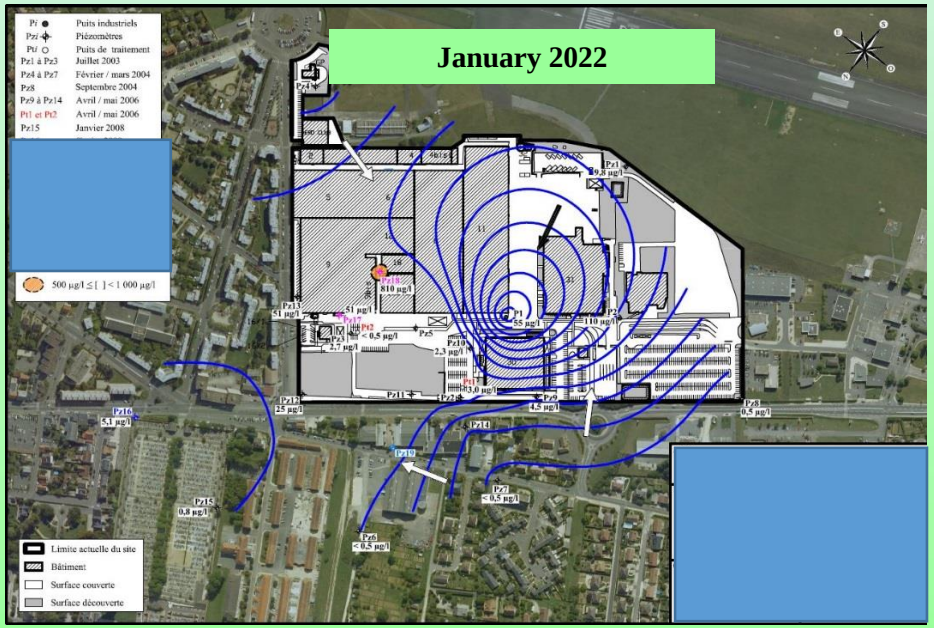
Cr6









Project Example: DNBA: Chlorinated Solvents + Cr6: Microbiological In-situ-Treatment via DNBA

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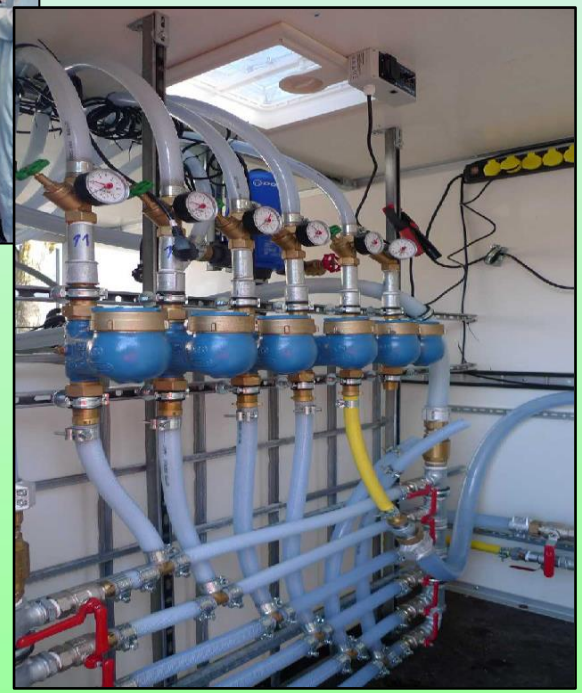
Full DNBA-Treatment



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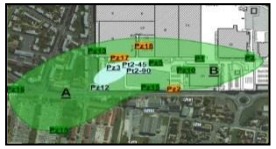
Conclusion: DNBA Aerospatiale Site





The technical-economic Feasibility Study and detailed DNBA Investigations was the Basement for the Successfully microbiological DNBA-Remediation by NBA Dynamization.

→ **Cost Savings**: in Comparison to P&T: Pump & Treat:
Minimum: 7,8 Million €uros

→ **Time Savings**: Remediation Time of 2 - 3 Years in
Comparison to P&T: 22 – 35 Years.

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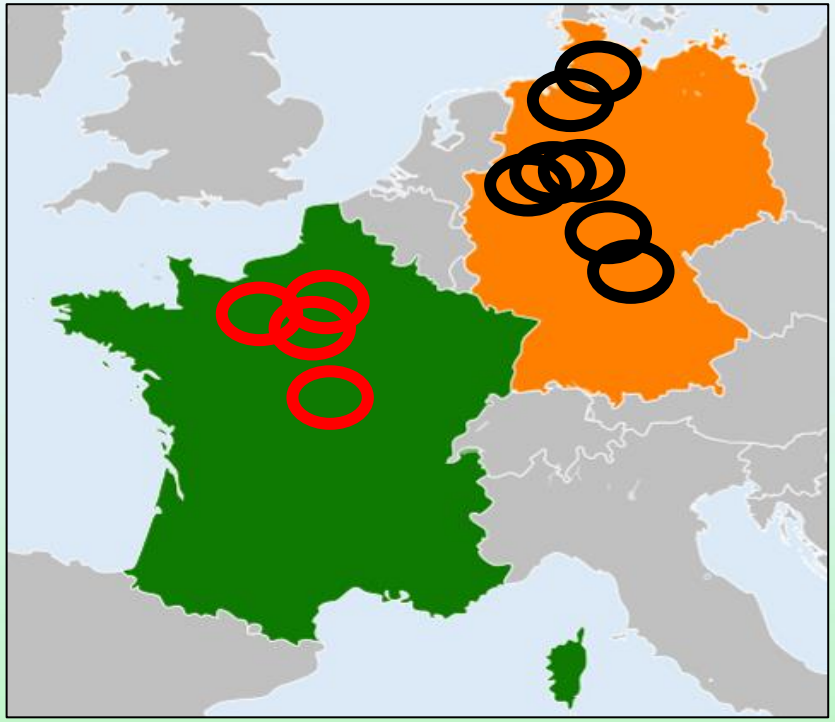
In-situ DNBA: Dynamized Natural Bio-Attenuation



Project Examples: Chemical & Electronic Industries:

Microbiological In-situ-Treatment

Bio-Technologies & Genetic Bacteria Selection

Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

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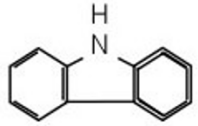
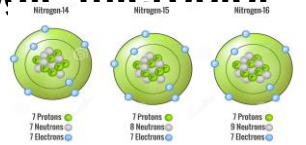
Traitements in-situ des HET-NSO & AA: BAND (DNBA) microbiologique aérobie

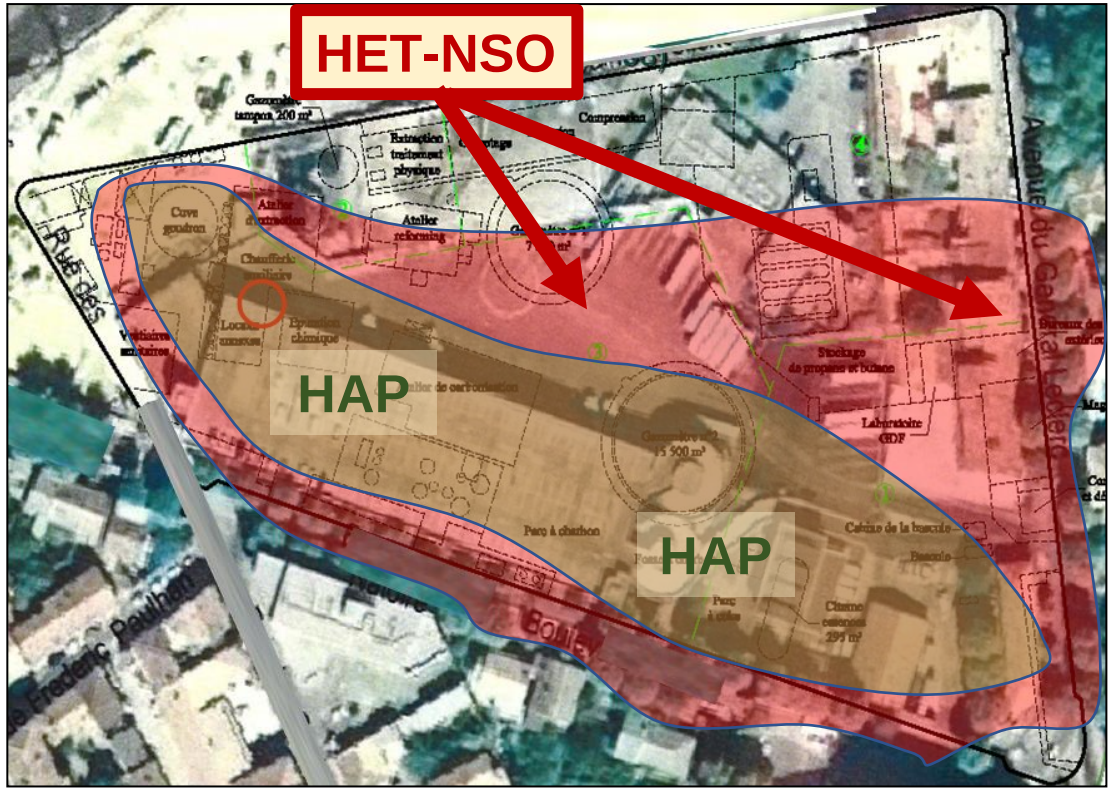
→ **Bio-Atténuation Naturelle Dynamisée : Example via *Percolation 25°C + Aération & B-Consortium* :**
Site de l'ancienne Usine à Gaz d'EON

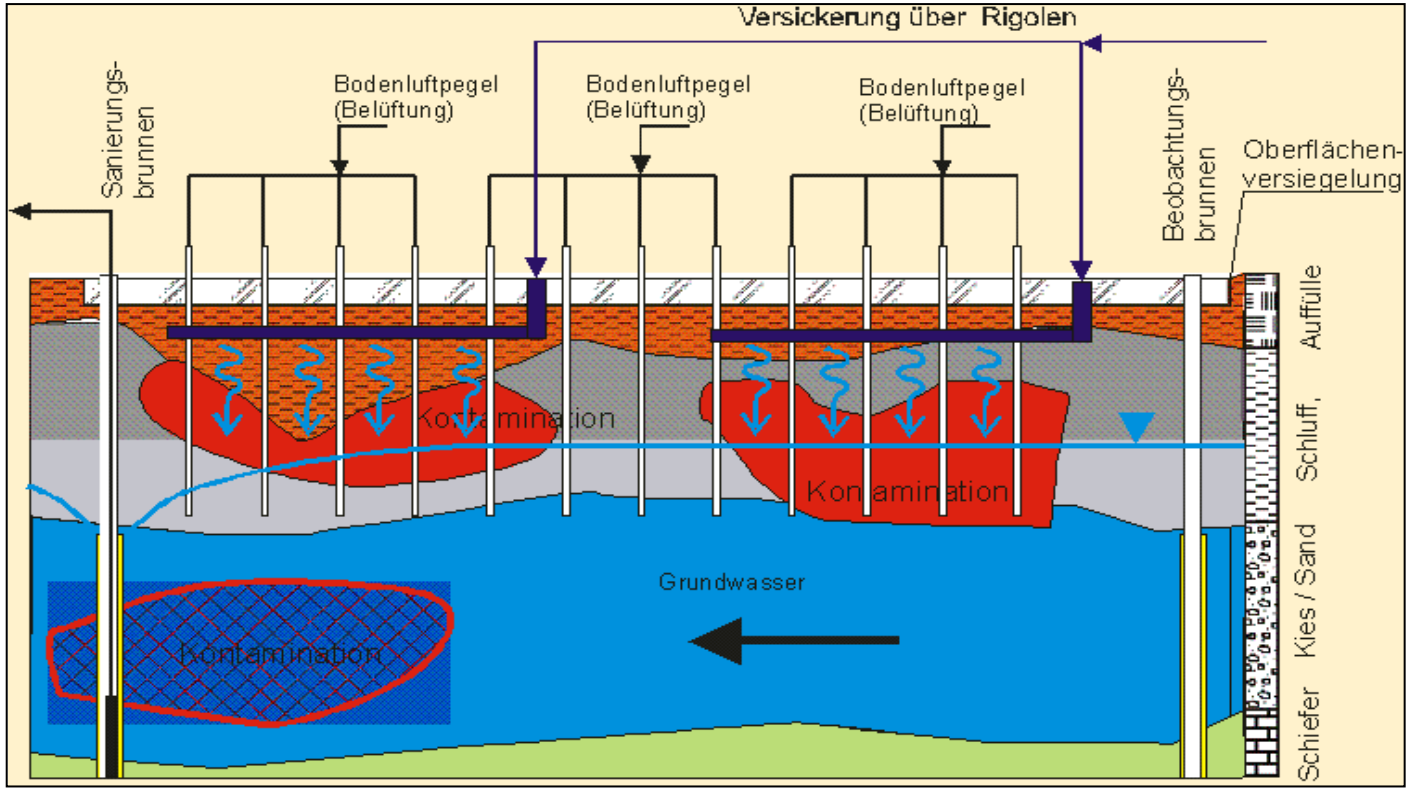
→ **A préalable: Etude de Faisabilité:** **>Sélection d'un Consortium Bactériologique par PCRq, Ecotoxicologie microbiol**
>Fractionnement d'isotopes $^{12}C/^{13}C$, $^{32}S/^{33}S$, $^{16}O/^{17}O$ & $^{14}N/^{15}N$,
>Tests de Challenge, de Respiration et de Minéralisation

Carbazole









Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

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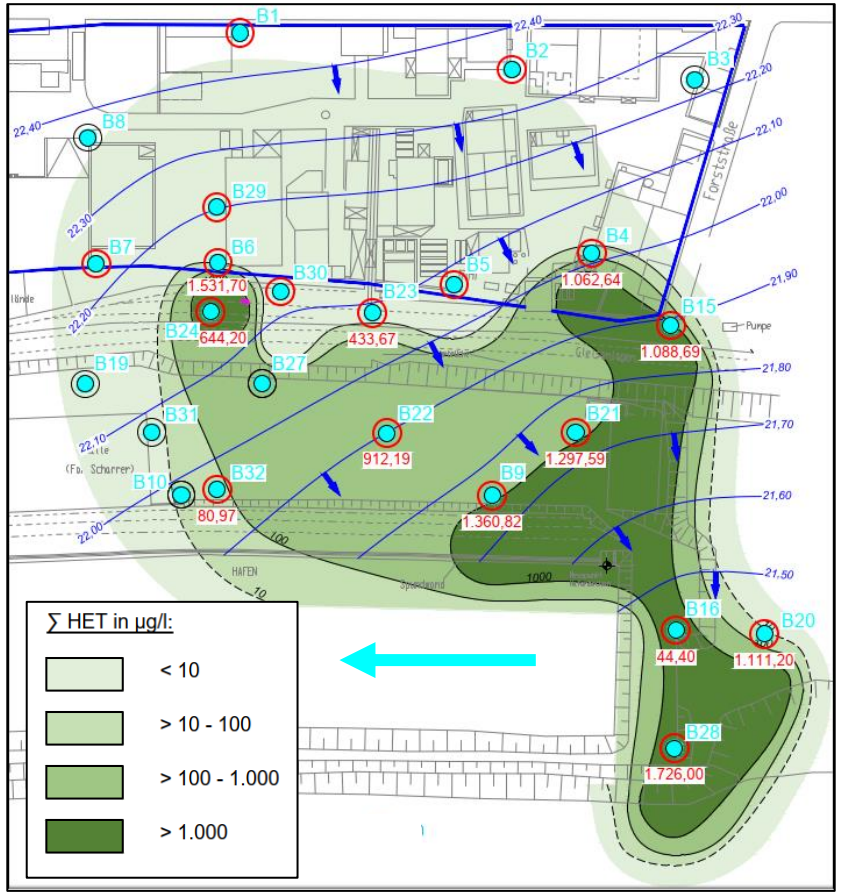
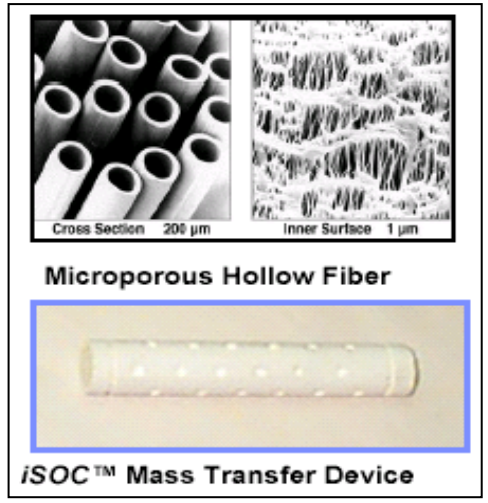
Traitements in-situ des HET-NSO & AA: BAND (DNBA) microbiologique aérobie

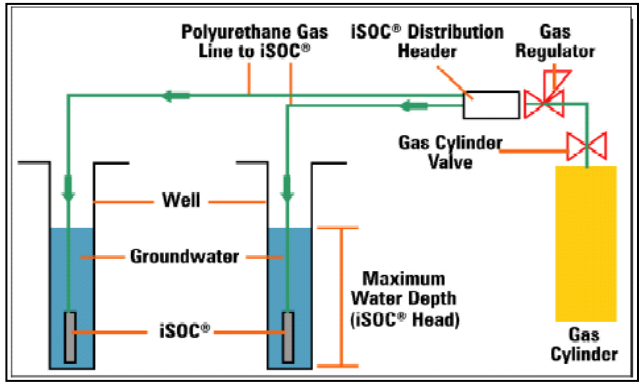
→ **Bio-Atténuation Naturelle Dynamisée : Example via *BAS & B-Consortium* : Site de l'ancienne Usine Carbochimique C**

→ **A préalable: Etude de Faisabilité:** **>Sélection d'un Consortium Bactériologique par PCRq, Ecotoxicologie microbiol.,**
>Fractionnement d'isotopes $^{12}C/^{13}C$ & $^{32}S/^{33}S$, & $^{16}O/^{17}O$ et $^{14}N/^{15}N$,
>Tests de Challenge, de Respiration et de Minéralisation, Tests BAS & ISOC.

Benzo-thiophene





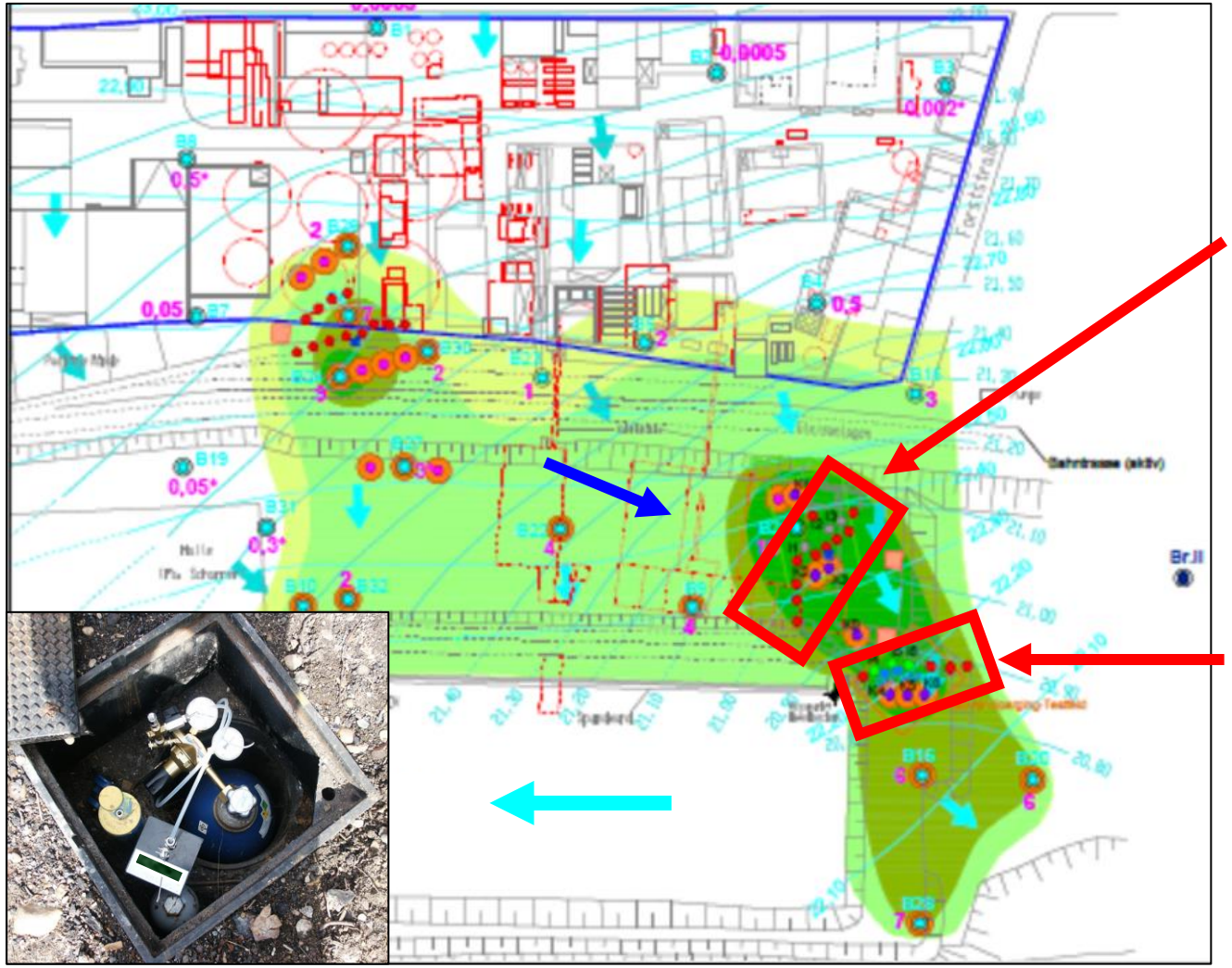


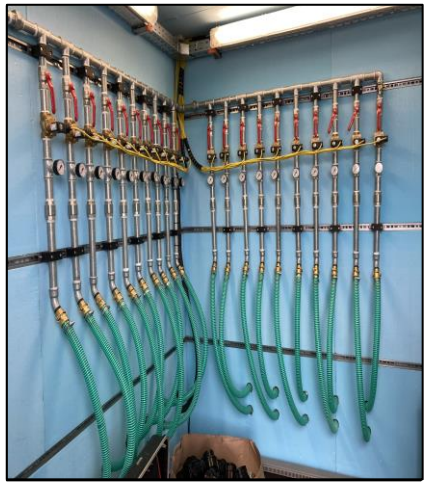
Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

Traitements in-situ des HET-NSO & HAP: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *BAS & B-Consortium* : Site de l'ancienne Usine Carbochimique C**



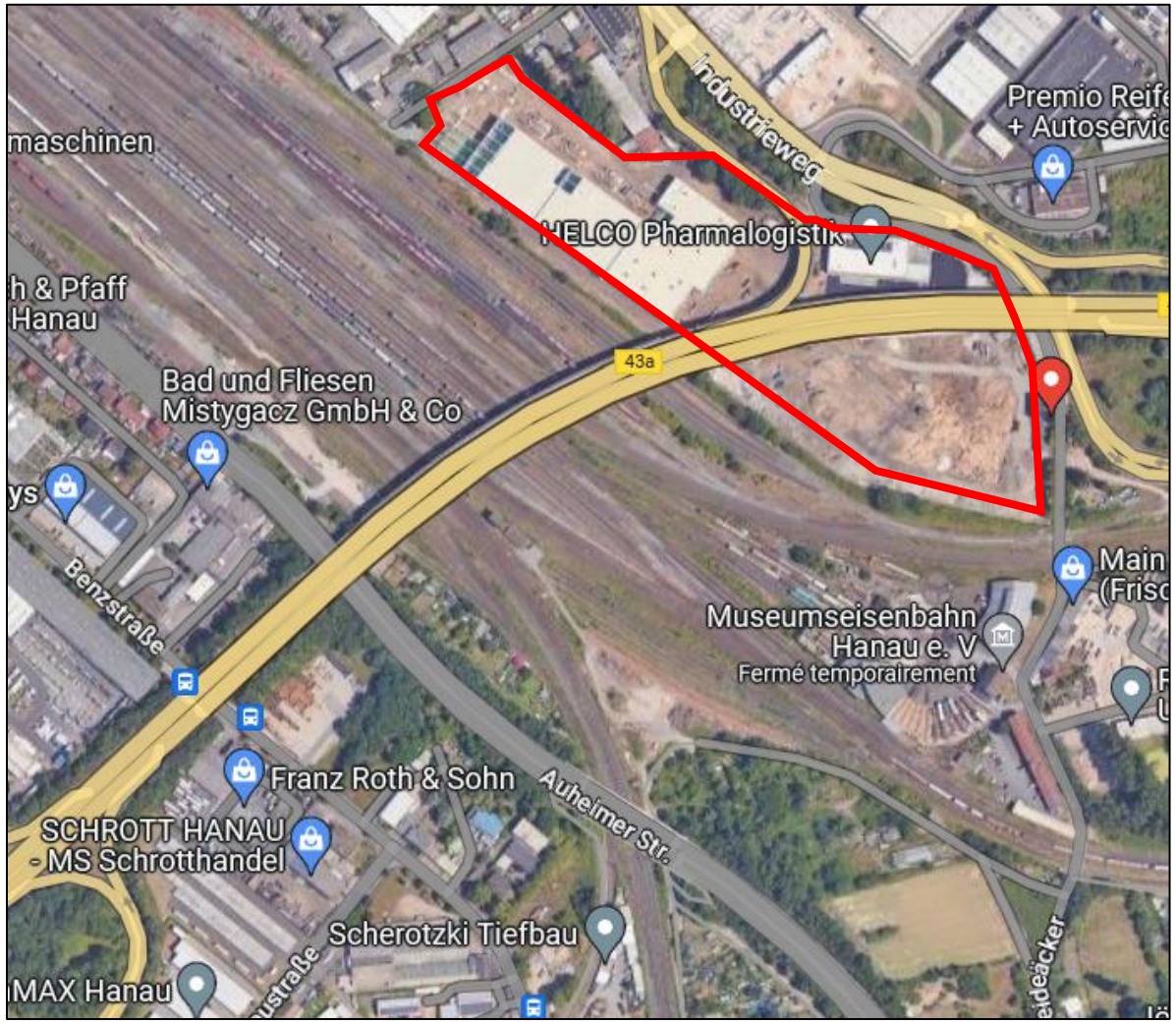


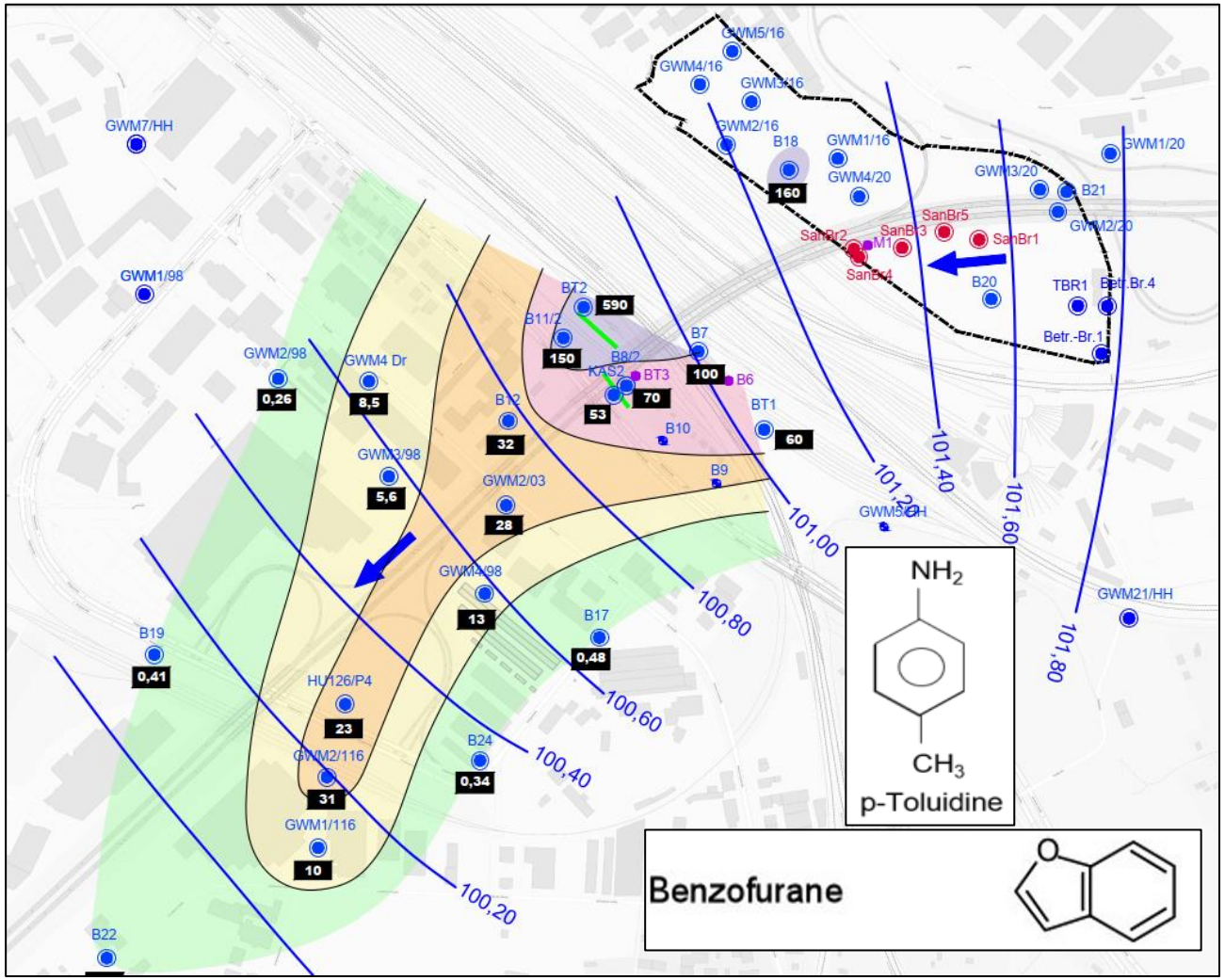
Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

Traitements in-situ des HET-NSO & AA: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *In-situ BAS*: Site de l'ancienne imprégnation de bois: Hanau**



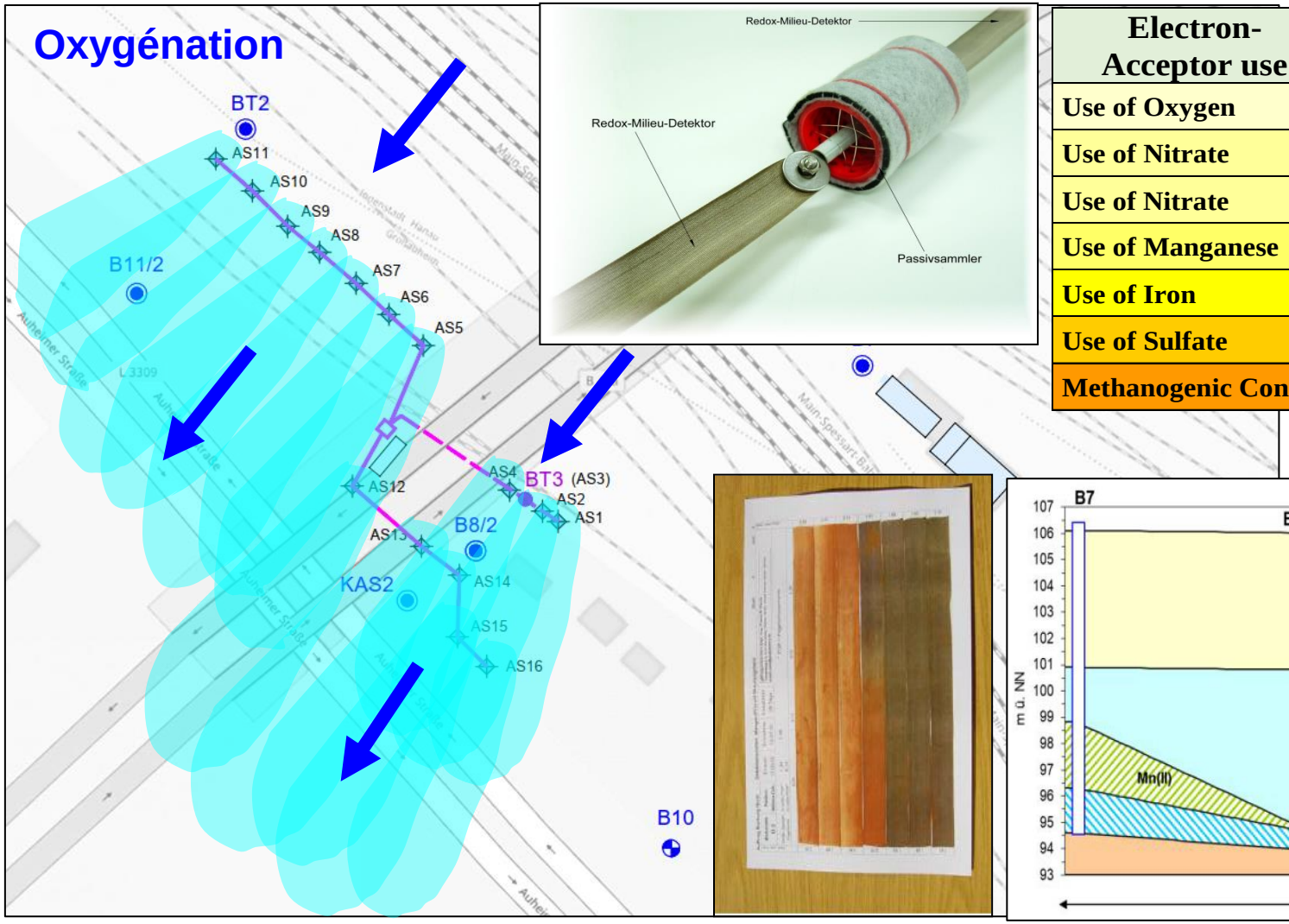


Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

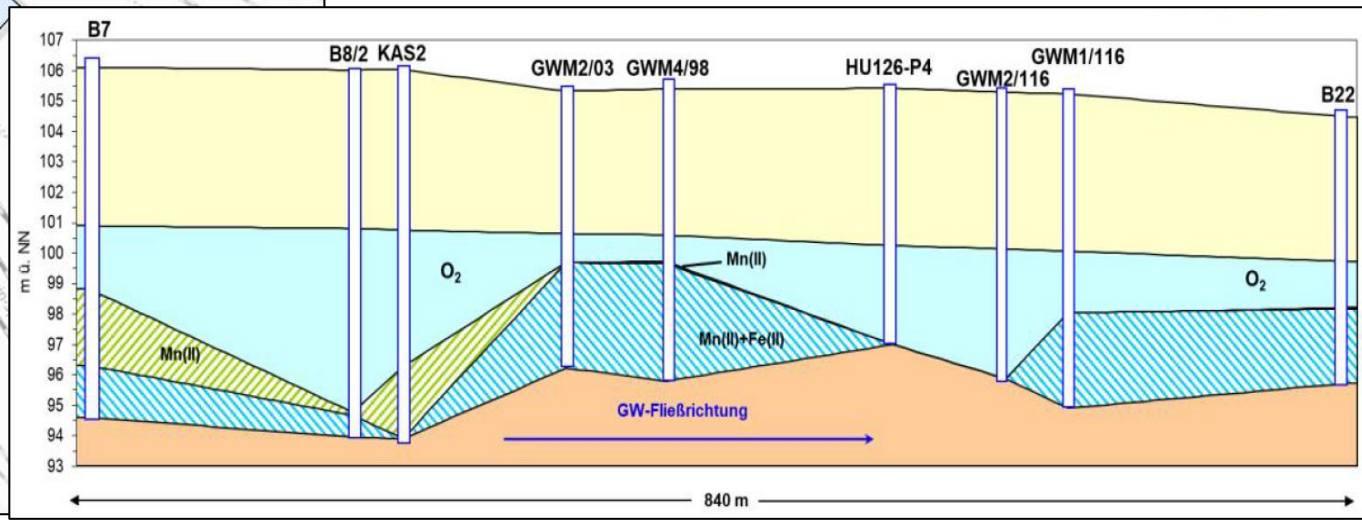
Traitements in-situ des AA & HET-NSO: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *In-situ BAS*: Site de l'ancienne imprégnation de bois: Site H.**



Electron-Acceptor use	Course of Reaction
Use of Oxygen	$C_{10}H_8 + 12\ O_2 \rightarrow 10\ CO_2 + 4\ H_2O$
Use of Nitrate	$C_{10}H_8 + 9{,}6\ NO_3^- + 9{,}6\ H^+ \rightarrow 10\ CO_2 + 4{,}8\ N_2 + 8{,}8\ H_2O$
Use of Nitrate	$C_{10}H_8 + 9{,}6\ NO_3^- + 38{,}4\ H^+ \rightarrow 10\ CO_2 + 9{,}6\ NH_3^+ + 8{,}8\ H_2O$
Use of Manganese	$C_{10}H_8 + 48\ H^+ + 24\ MnO_2 \rightarrow 24\ Mn^{2+} + 10\ CO_2 + 28\ H_2O$
Use of Iron	$C_{10}H_8 + 20\ H_2O + 48\ Fe^{3+} \rightarrow 48\ Fe^{2+} + 10\ CO_2 + 48\ H^+$
Use of Sulfate	$C_{10}H_8 + 9\ H^+ + 6\ SO_4^{2-} \rightarrow 3\ H_2S + 3\ HS^- + 10\ CO_2 + 4\ H_2O$
Methanogenic Cond.	$C_{10}H_8 + 8\ H_2O \rightarrow 6\ CH_4 + 4\ CO_2$

Redox Zones

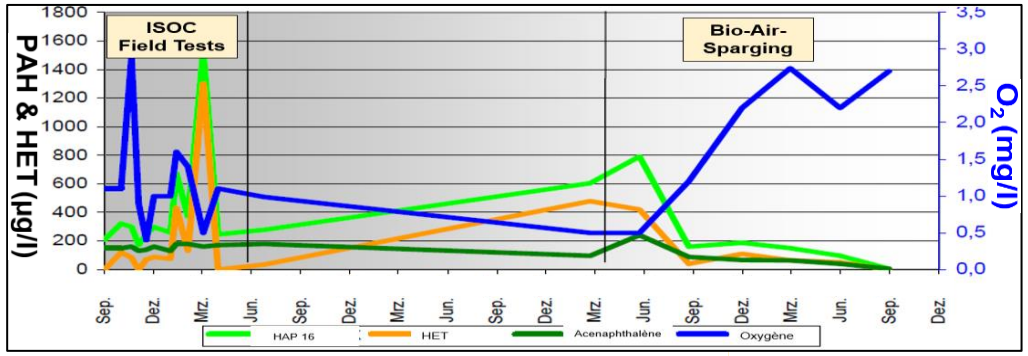


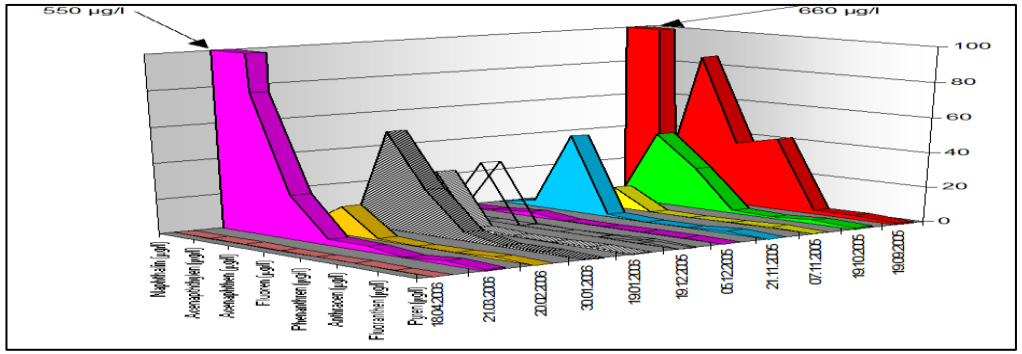
Project Exemples : Chemical & Electronic Industries/ PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

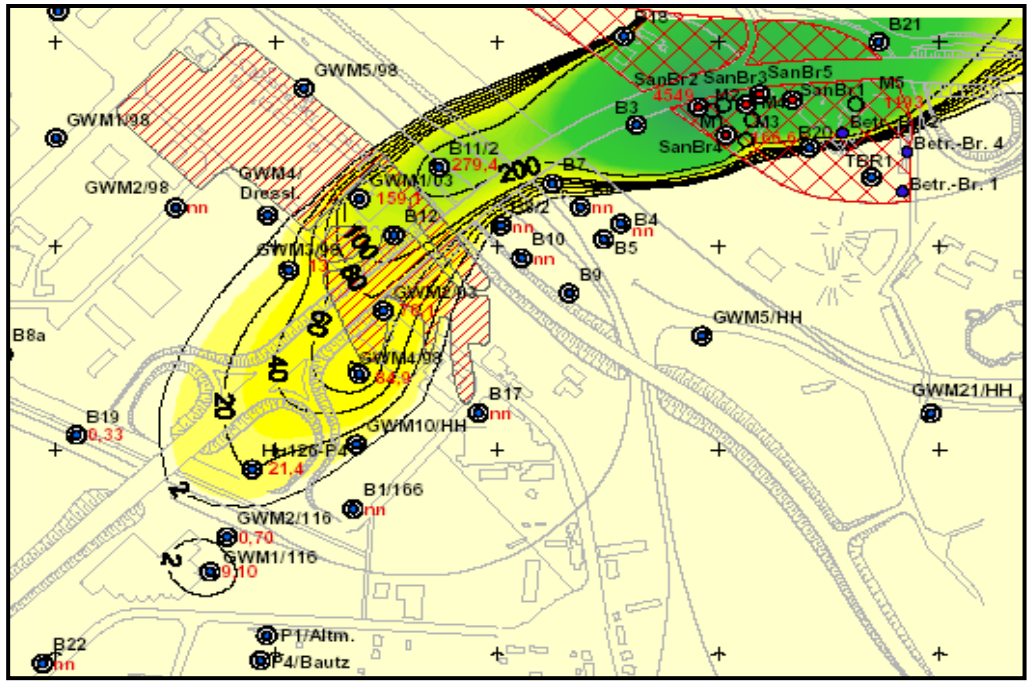
HPC INTERNATIONAL SAS

Traitements in-situ des AA, HET-NSO: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *In-situ BAS* : Site de l'ancienne imprégnation de bois: Site H.**

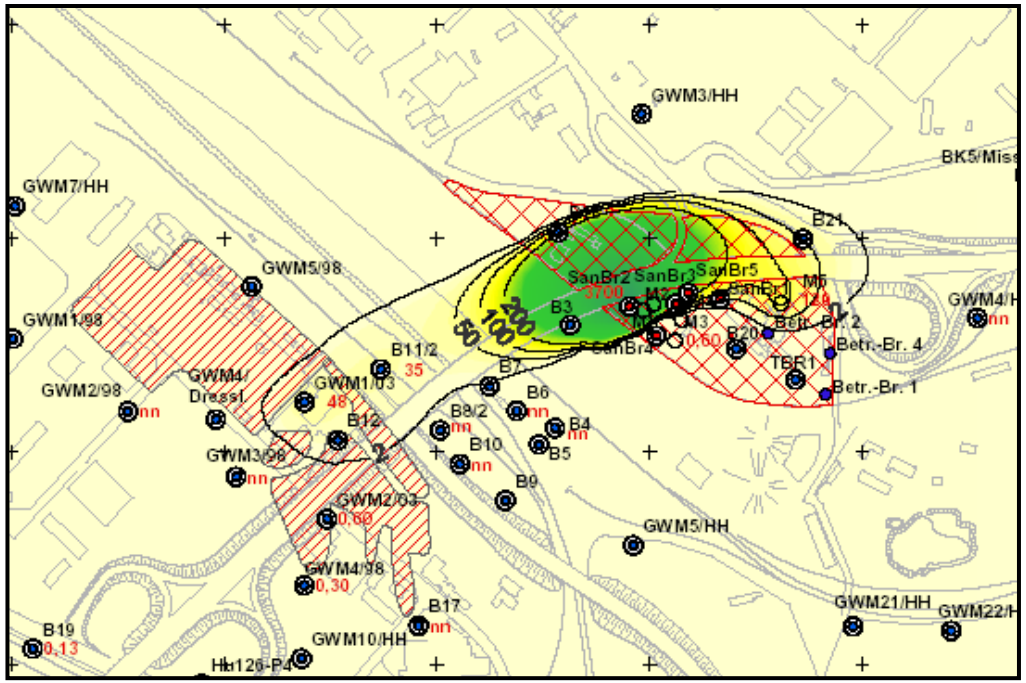






8 months

Carbazole (µg/l)



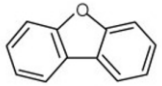
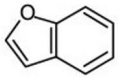
Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

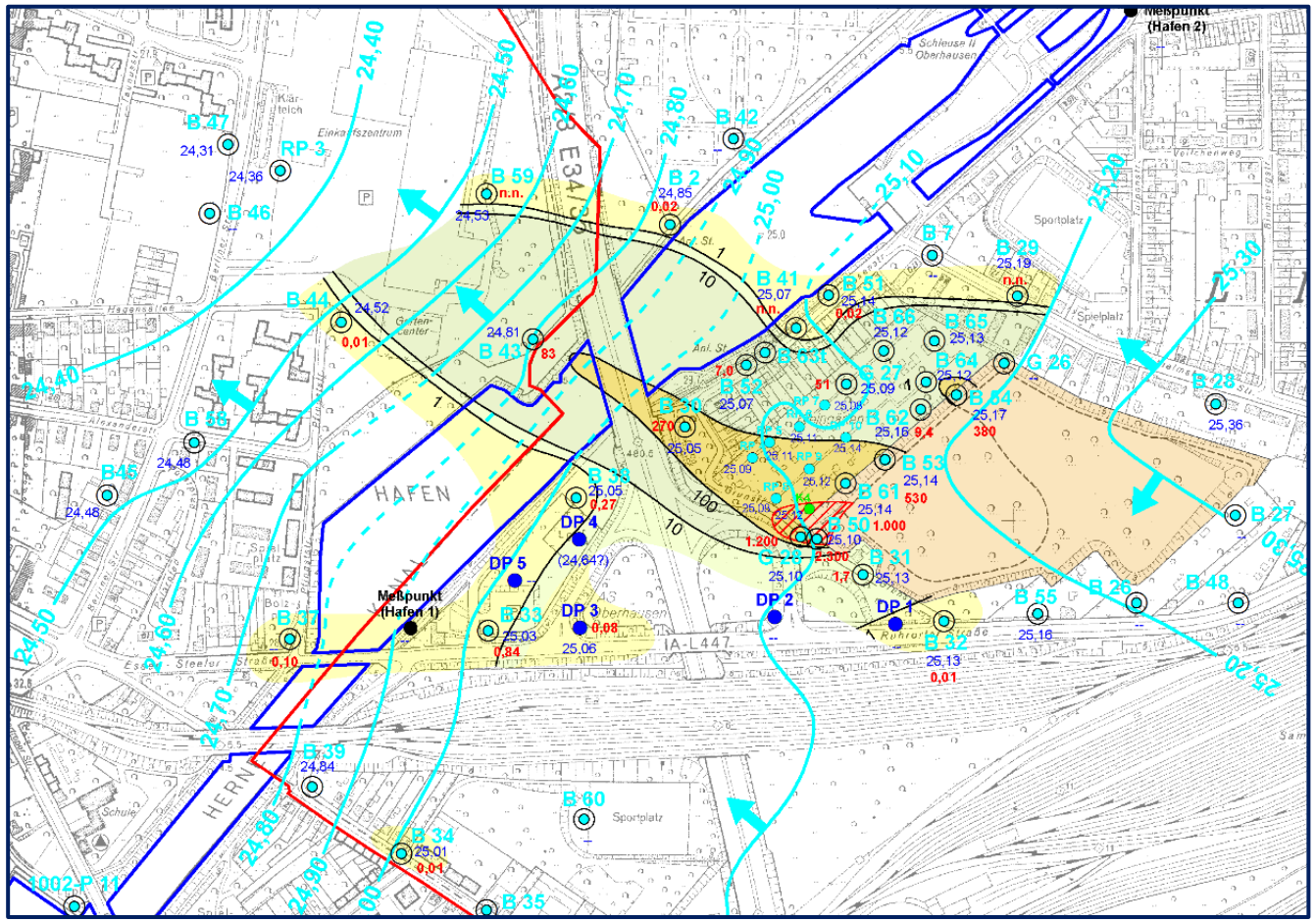
HPC INTERNATIONAL SAS

Traitements in-situ des BTEX & HET: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *In-situ Oxyactivator*: Site de l'ancienne décharge Oberhausen-L.**

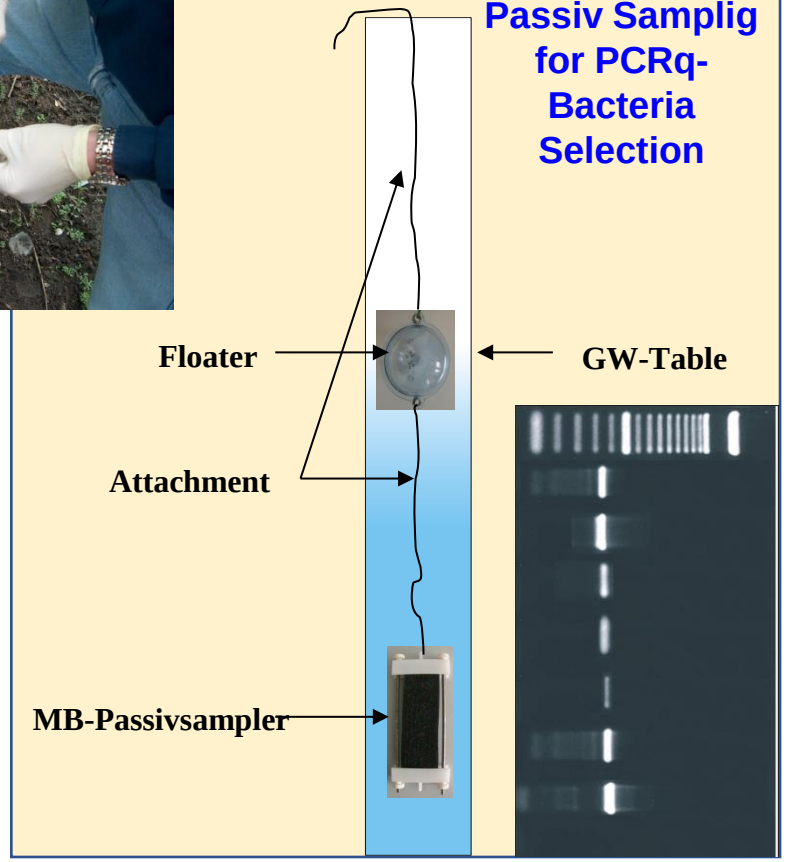
→ **A préalable: Etude de Faisabilité: >Sélection d'un Consortium Bactériologique par qPCR, Ecotoxicologie microbiol., >Fractionnement d'isotopes $^{12}C/^{13}C$, $^{32}S/^{33}S$,Tests de Challenge, Respiration.**

Dibenzofurane  Benzofurane 



Production of Site specific Bacteria Consortium

Microbiological Passiv Samplig for PCRq-Bacteria Selection

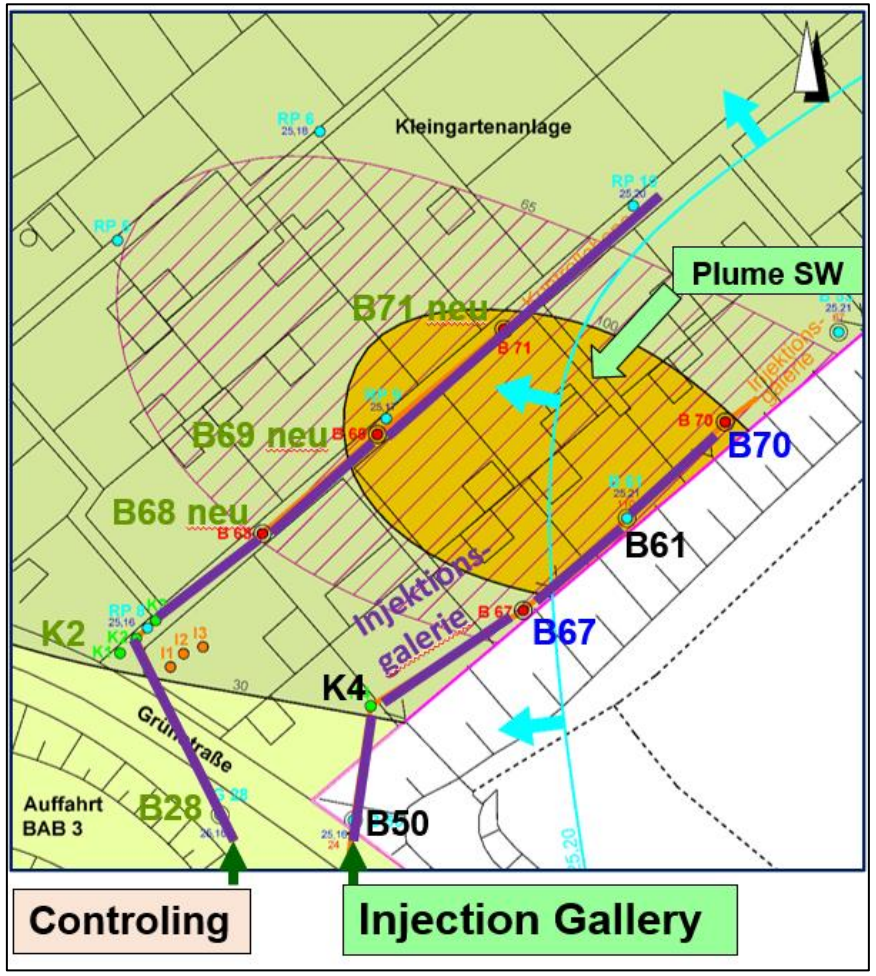


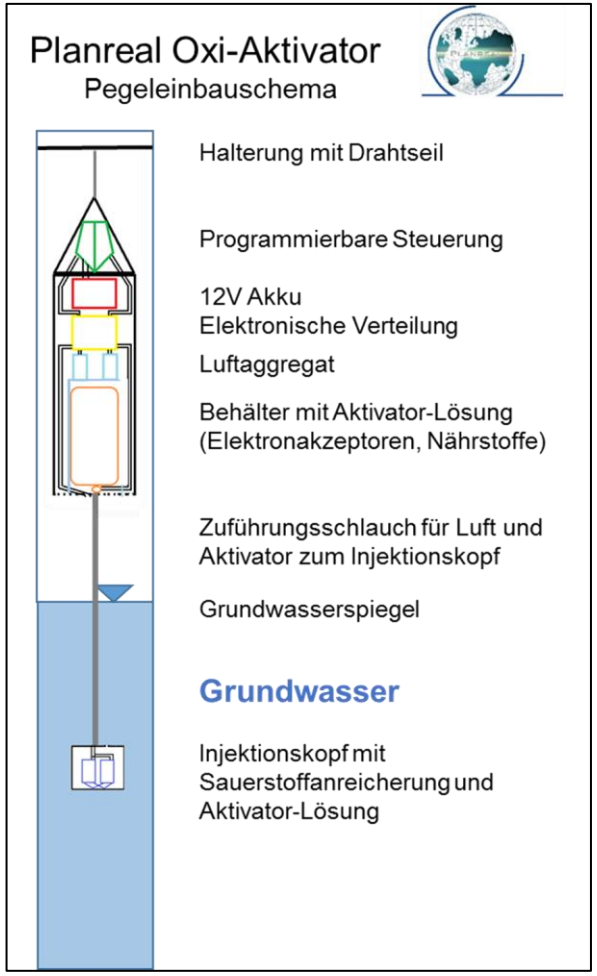
Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

Traitements in-situ des BTEX & HET: BAND (DNBA) microbiologique aérobie

→ **Bio-Atténuation Naturelle Dynamisée : Example via *In-situ Oxyactivator*: Site de l'ancienne décharge Oberhausen-L.**
Infiltration d'oxygène, de nitrate et des nutriments. Mesures in-situ Eh, pH, O_2





Oxy-activators (O_2 & NO_3^-)

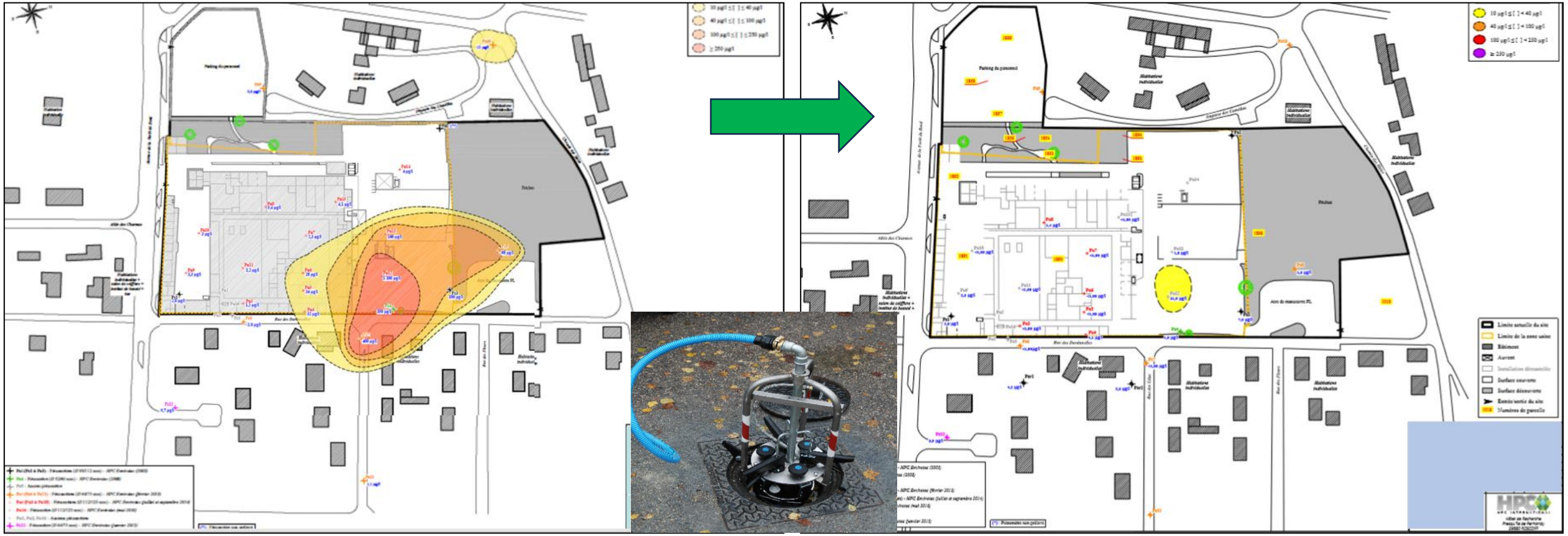
Project Exemples : Chemical & Electronic Industries/ Chlorinated Solvants b(PCE, TCE, DCE, CV) Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

Traitements in-situ des PCE, TCE, DCE, CV: BAND microbiologique anaérobie

→ **Bio-Atténuation Naturelle Dynamisée : Site en Normandie : Example via *Injections n-situ sous Eh de _75 à -250 mV***

Infiltration des Substrates - Nutriment et Consortium Bactériologique spécifique sous Azote Mesures in-situ Eh, pH, O_2



Après 8 mois : PCE: 6 800 µg/l → 26 µg/l max.

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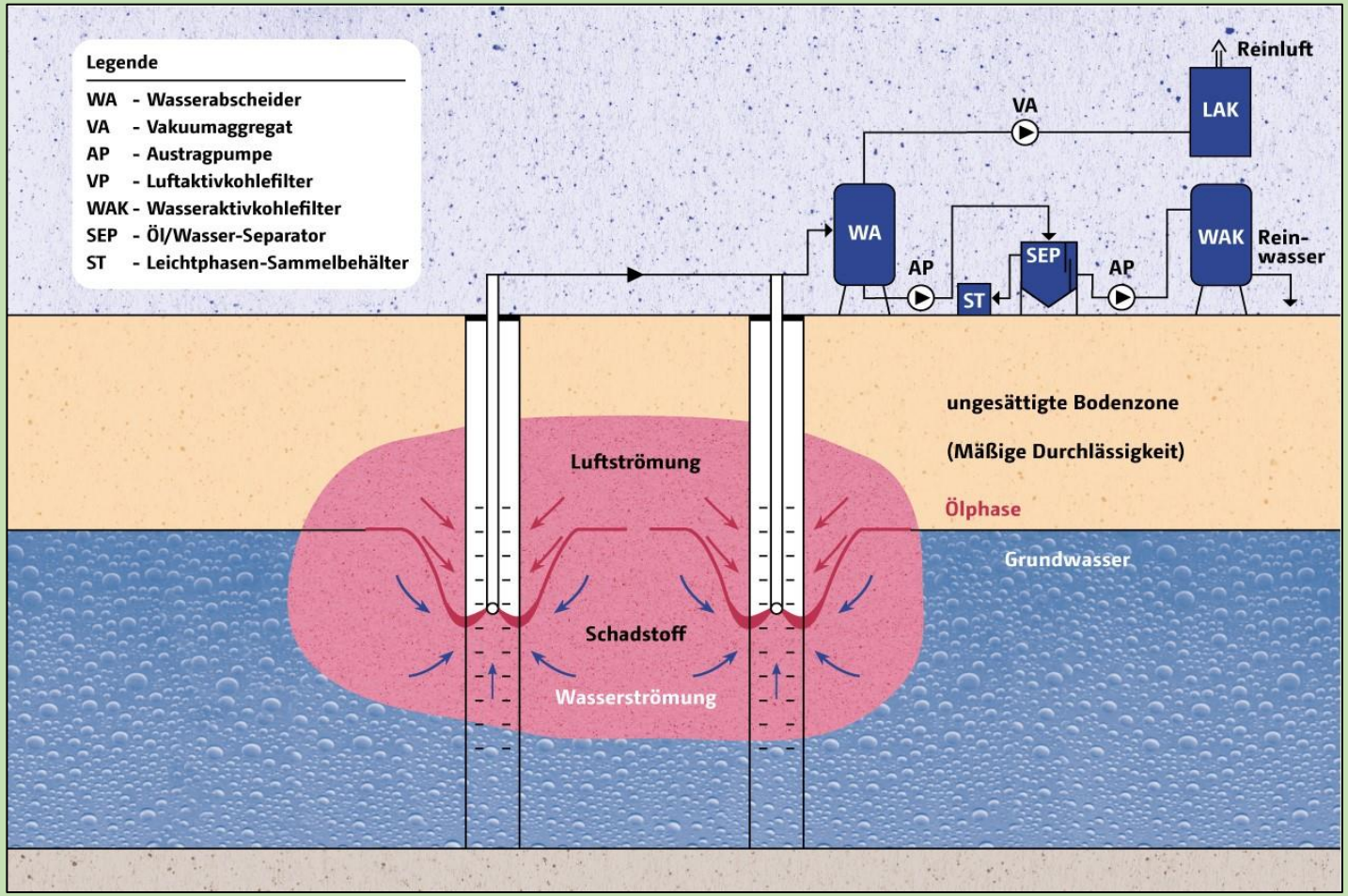
Traitements in-situ des HET-NSO, BTEX, HAP & AA: Alternatives couteuses: P&T !

→ **MPE: Multiphase Extraction (Cornelsen)**



Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

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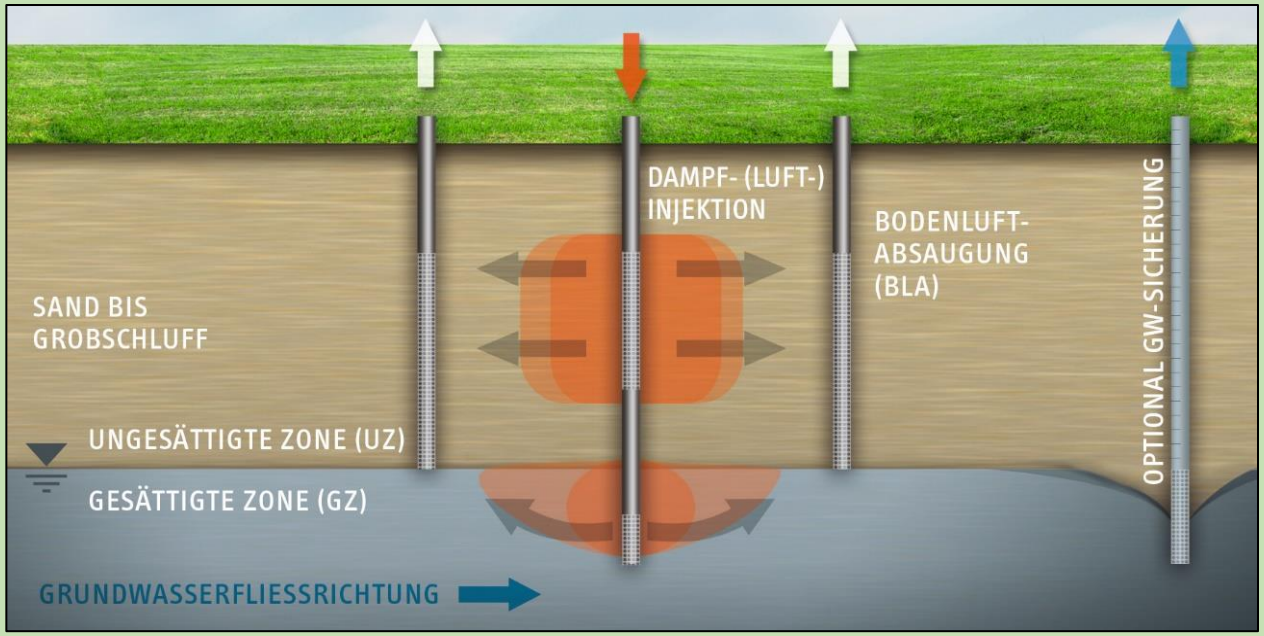
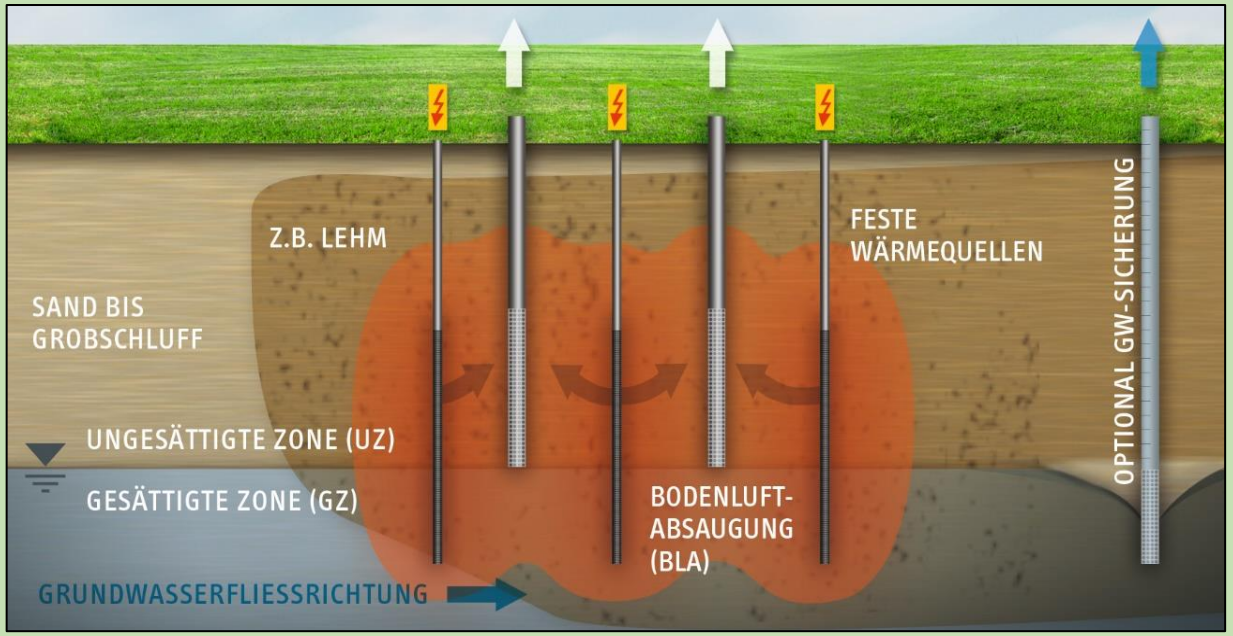
Traitements in-situ des HET-NSO & AA:

→ TUBA: Injection de Vapeur sous pression (Reconsite)
Volatilisation & remobilisation des polluants et MPE



Alternatives thermiques (220 °C !)

→ THERIS: Traitement thermique électrique (Reconsite)
Volatilisation & remobilisation des polluants et MPE



Project Exemples : Chemical & Electronic Industries/
PAH, HET, AA, BTEX, etc.: Microbiological In-situ-Treatment via DNBA

HPC INTERNATIONAL SAS

Traitements in-situ des PFAS: Immobilisation in-situ

→ **Application du Charbon Colloïdal ou des Adsorbants spécifiques**

PFOS, etc. dans les sols et eaux souterraines Site pétrolier HH

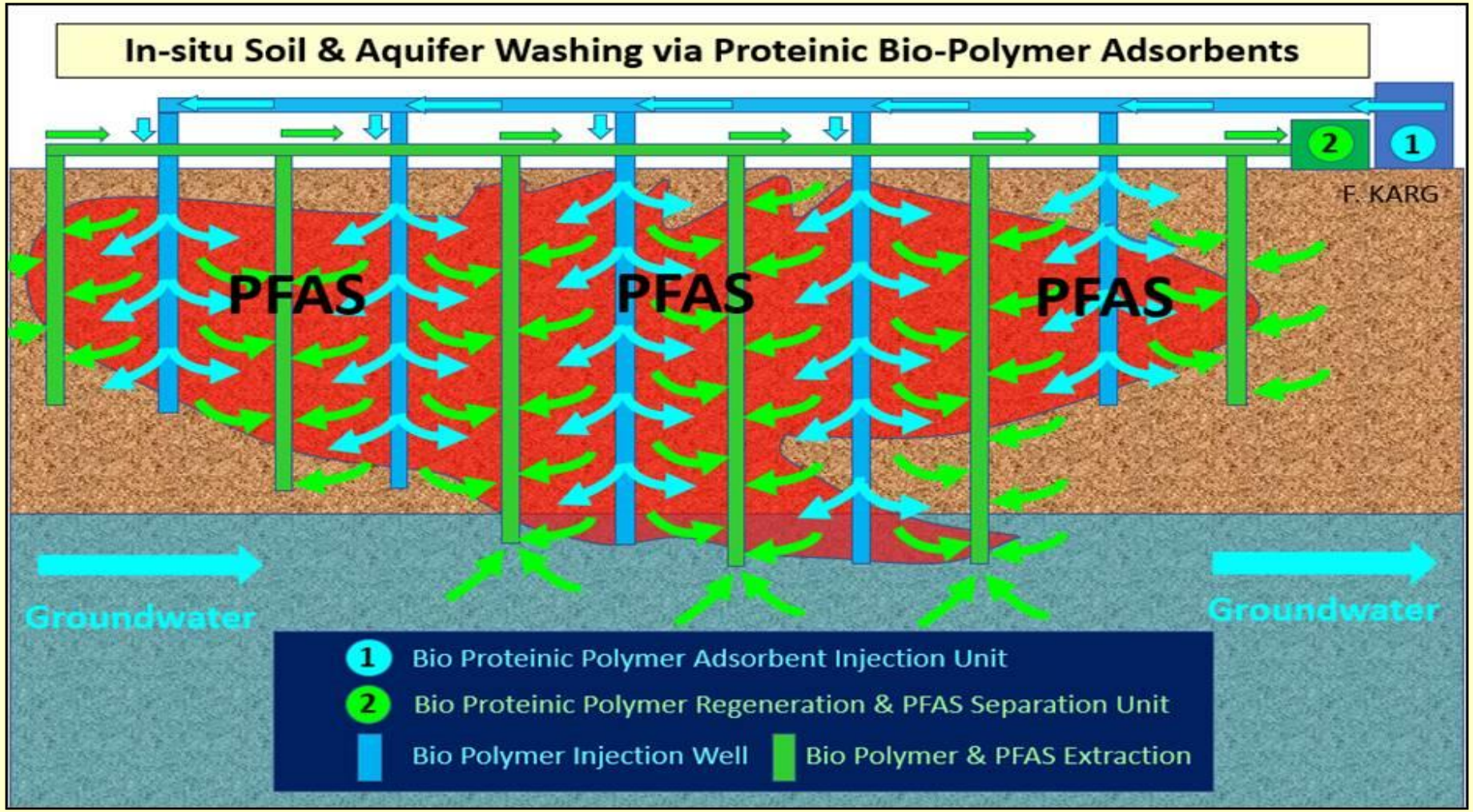
Increasing or Reduction of Solubility and Extractability of some PFAS-Fluorotelomers
Erhöhung bzw. Erniedrigung der Polarität & Löslichkeit einiger PFAS-Fluortelomere

Example: Sea water Impact to Groundwater (HH): Analyses by DIN 38407-42 (solid-liquid extraction) F. KARG

Acid pH 6,7	→ to →	pH 7,3 Basic
6:2-FT(S)AB = Capstone B (Fire Fighting Foam)		6:2-FT(S)AB = Capstone B (Fire Fighting Foam)
6:2 Flourotelomer sulfonamido propyl betaine		6:2 Flourotelomer sulfonamido propyl betaine inert salt
1-Propanaminium, N-(carboxymethyl)-N,N-dimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl]sulfonyl]amino] and inert salt		
N-(Carboxymethyl)-*N*,*N*-dimethyl-3-{[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoroctyl)sulfonyl]amino}-1-propanaminium and inert salt		
PFPeA & PFHxA ← Less polar & soluble at acid pH		PFPeA & PFHxA ← More polar & soluble at basic pH
Conc. In GW: 130 µg/l		Conc in GW: 1 500 µg/l
6:2-FTS = H4-PFOS		6:2-FTS = H4-PFOS
(6:2-FTSA) 6:2 Fluorotelomer sulfonic acid		6:2 Fluorotelomer sulfonic acid polar

Traitements in-situ des PFAS: in-situ Washing (Belgique: site confidentiel)

→ **Application des produits de lavage du type Bio-polymères protéiniques et régénération des réactifs**



Micropolluants toxiques et les biotechnologies des traitements de dépollution in-situ microbiologiques et biochimiques applicables : Exemples des BAND (Bio-Atténuation Naturelle Dynamisée) / L'Approche au meilleur bilan Coût-avantages

Merci !

Questions ? Remarques ?

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CEO-President of HPC INTERNATIONAL / France, Germany, Hungary, Balkan, etc.

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