Lesson learnt during bioremediation of over 150 sites contaminated with chlorinated aliphatic hydrocarbons in Japan

October 25, 2010

ECOCYCLE CORPORATION Japan

We do not inherit the earth from our forefathers, we borrow it from our children

Field Experience

- Contaminations: Ethenes –Cl (PCE, TCE, DCE) , Ethanes-Cl (TCA, EDC), Methanes -Cl (CT, DCM)
- High concentration: ~ few hundred mg/L
- Low K : $<10^{-4}$cm/sec (silty -clay)
- Largest site: 7 million m^3
- Japan, Thaiwan, Thailand, the US, India……..

Biostimulant injection at a CAHs contaminated site in Taiwan

Curtsy: Guan Cheng Enviro Tech Protection Co., Ltd

Remediation Process

Site investigation (Hydrogeology, contamination details etc.)

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Microcosm experiment (Optional)

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Pilot demonstration

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Remediation design

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Full scale injection

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Post injection monitoring

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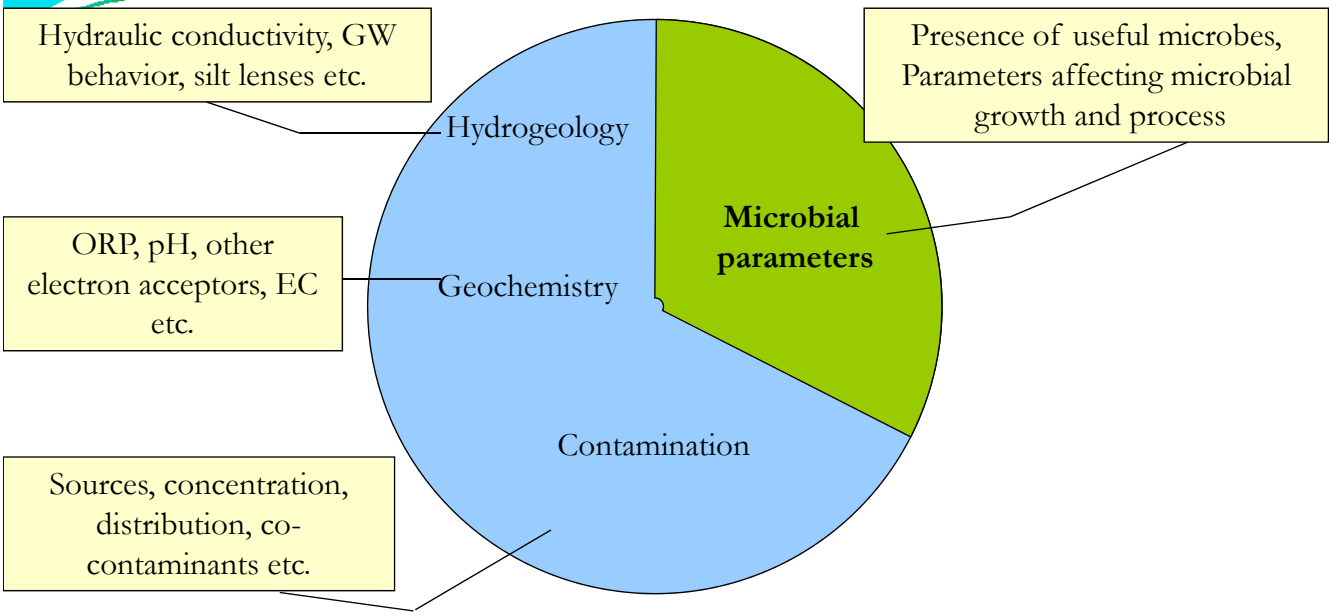
Site closure

Proper site assessment and investigation are keys for successful bioremediation



Obtaining data on site hydrogeology, geochemistry and contamination is more important than just concentrating on microbiology of the site.

Site Investigation

Hydrogeology:

- Bore logs, Soil cross sections, Hydraulic conductivity, seepage velocity, groundwater behavior, silt lenses, etc.

Contamination Data:

- Source (storage/usage/spillage points), pathways like drainage, type of contamination, concentration , phase partition, Contamination distribution, etc.

Geochemistry:

- ORP, alternative electron acceptors, pH, etc.

Microbiology

- Count of useful microbes
- Factors affecting microbial development and process

(The process is complex for sites that are large, old manufacturing facilities, near large rivers or sea)

Understand the contaminant !!

! Point

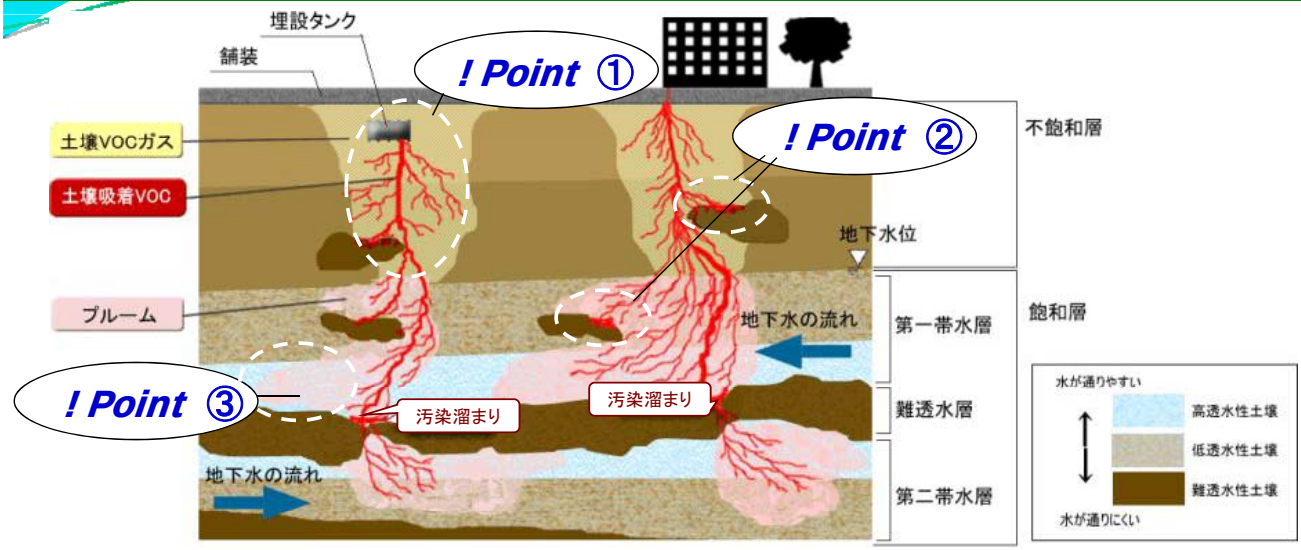
! Point

Name of Compound		Specific gravity	Water solubility	Soil/water distribution, K_{OC}	Vapor Pressure
		g/mL	mg/L	-	mmHg
Tetrachloroethylene	PCE	1.62	150	265	17.8
Trichloroethylene	TCE	1.46	1,100	94	57.9
Cis, 1,2-dichloroethylene	*cis*-DCE	1.28	3,500	36	208

Higher chlorinated compounds have less solubility. That means considerable mass remains as residual or free-phase DNAPL

Higher chlorinated compounds are easily adsorbed to organic matter of the soils. Therefore sorbed mass is much more than the concentrations seen in the groundwater

Understanding the extent of contamination



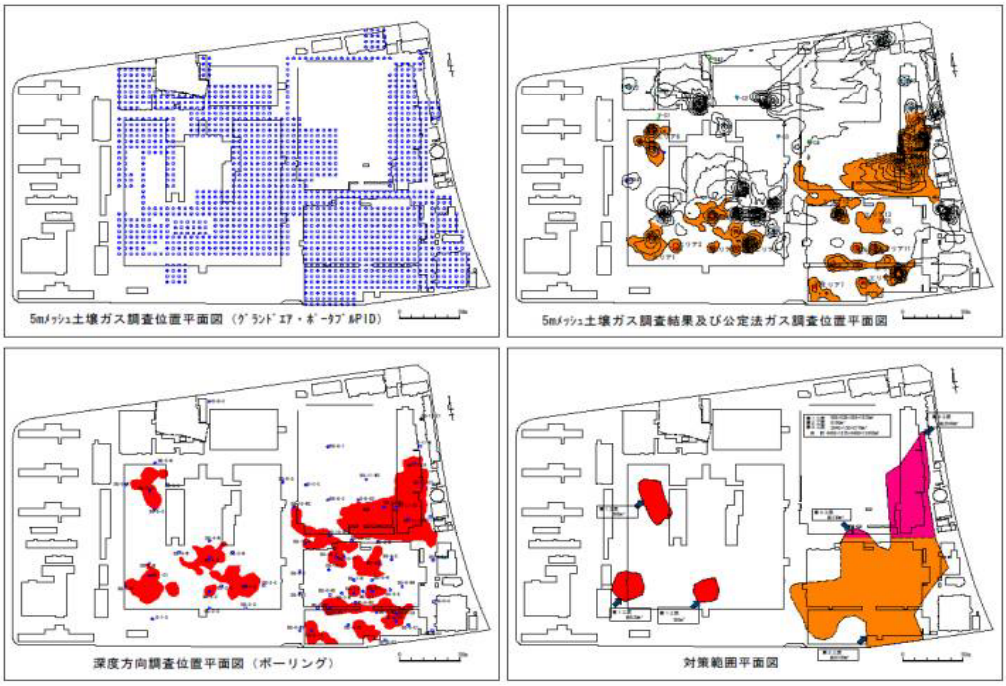
Point ① : Understanding of contamination in the vadose zone is essential to prevent post remedial rebound in concentrations
Point ②: Special attention to clay lenses and organic matters where considerable mass might be sorbed
Point ③: The extent of groundwater contamination

Obtain data on co-contaminant

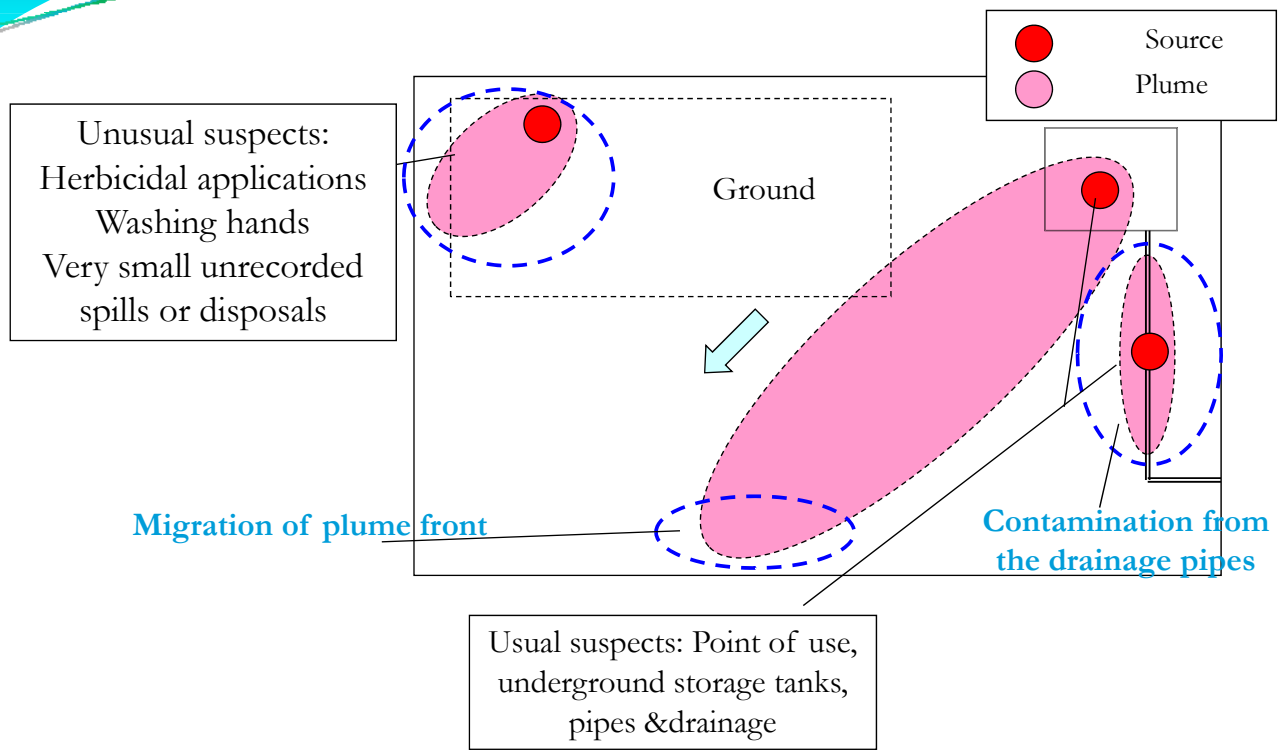
Components	Caution	Counter-measure
Petroleum hydrocarbons	・CAHs dissolve more easily (10～100 times) in oil than in water ・ Plus points: Natural anaerobic conditions, carbon source, higher microbial populations, advanced degradation of CAHs	• Obtain data on dissolved mass in the oil during site investigation • Treat LNAPL before treating CAHs
Mercury, Cyanide etc.	・Toxic to the microbial population ・Possibility of volatile or organic mercury formation ・Post injection production of Organic acids may lower GW pH resulting in Cyanide volatilization.	・Treat Hg/CN preferably ・Monitor pH carefully
Extreme pH	・Lime in dumping pits, cement used for containment, hot-soil (quick-lime) treatment of soil causes high pH ・Leakage of acidic compounds into the ground	・Removal before bioremediation ・Adjust pH
Other VOCs	Mixed contamination of Chloroethanes, Chloromethanes and Chloroethynes have inhibitory effect on microbial degradation process	・ Prior risk assessment for higher remedial cost and time
Coastal Areas	・High EC and sulfate contents ・Difficulty in reading groundwater behavior	・Special importance for full scale injection engineering

Case A: Cell-phone Parts Manufacturer

Near Tokyo, 40,000 m2 X 12 m Plume Size, Active facility, pump and treat on going

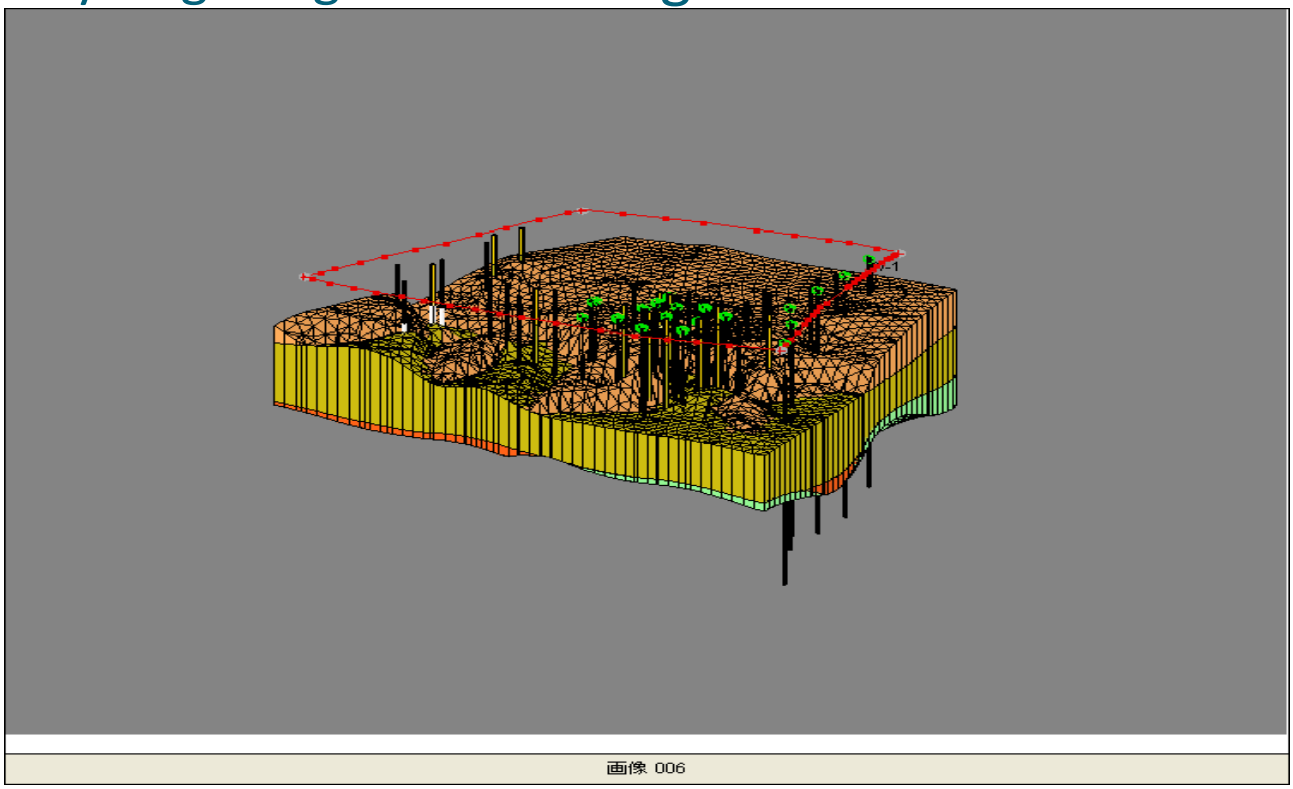


The usual and unusual suspects

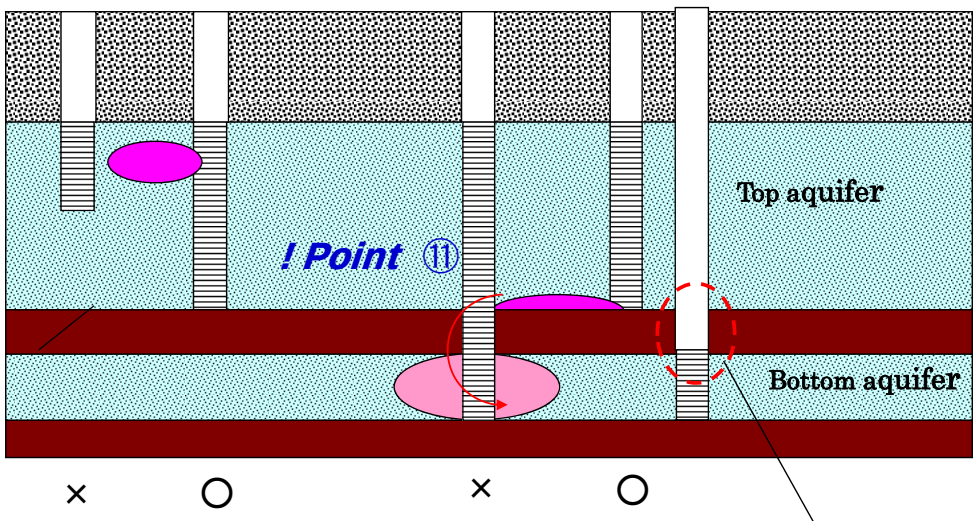


What looks on the record may not be accurate

Hydrogeological Modeling



Monitoring Well Installation

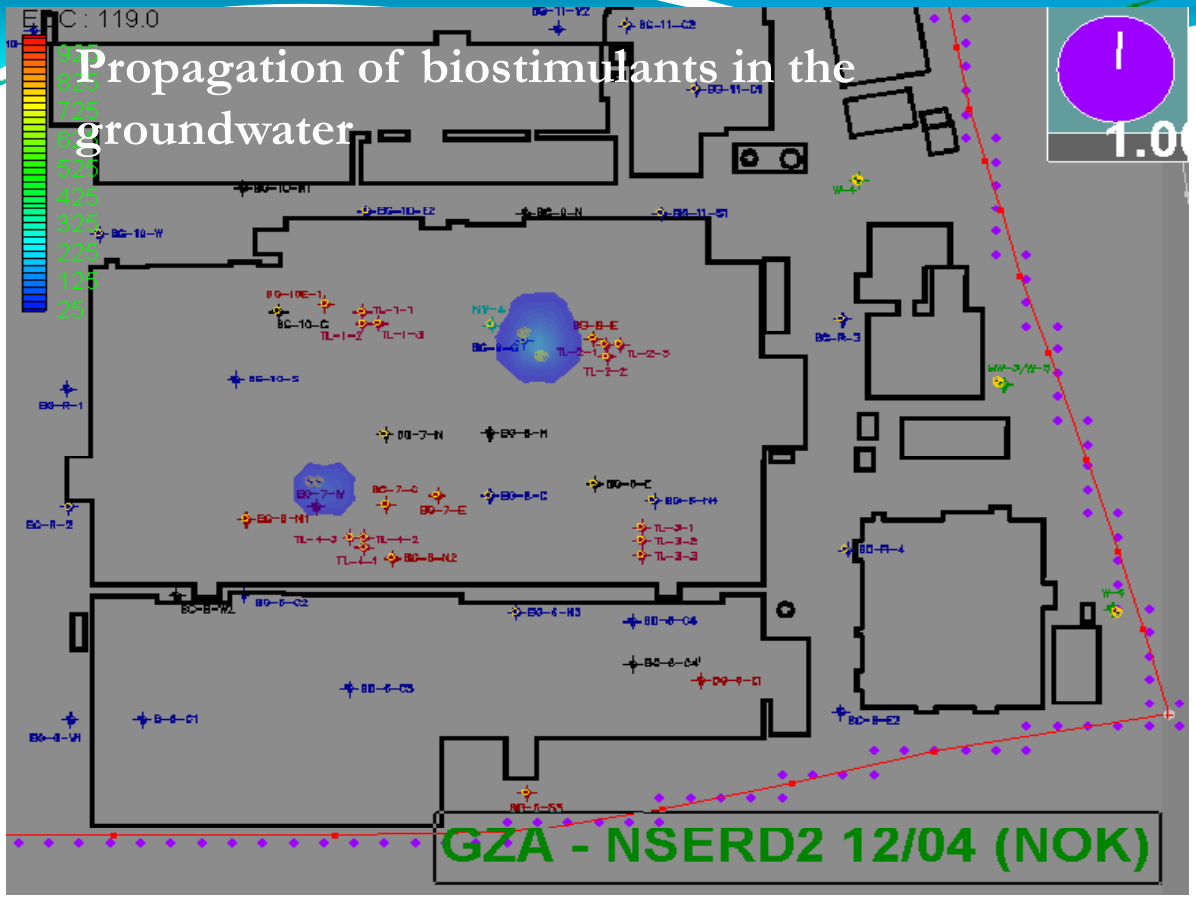


Depending on the hydrogeology carefully design the well

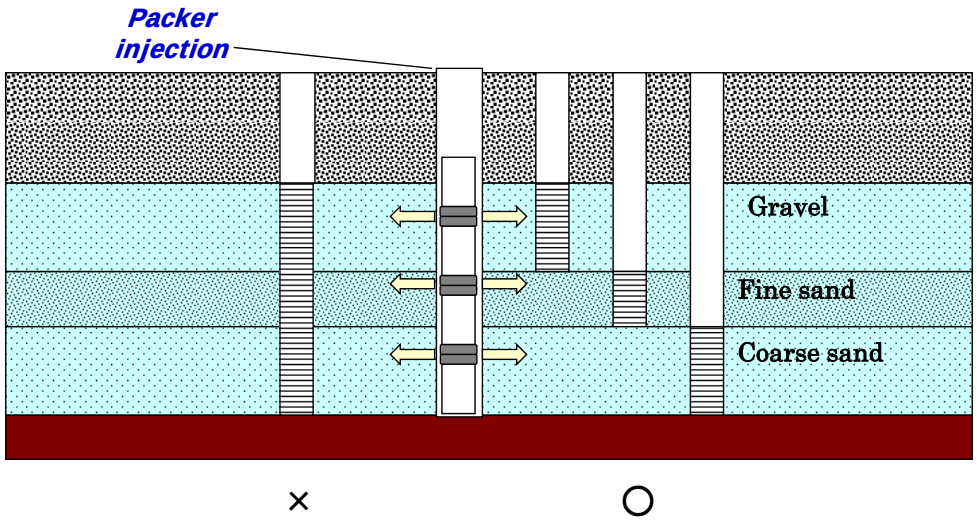
Telescope drilling and proper precautions to be taken to avoid spread Contaminants

Sorbed mass

Propagation of biostimulants in the groundwater



Injection well-nests



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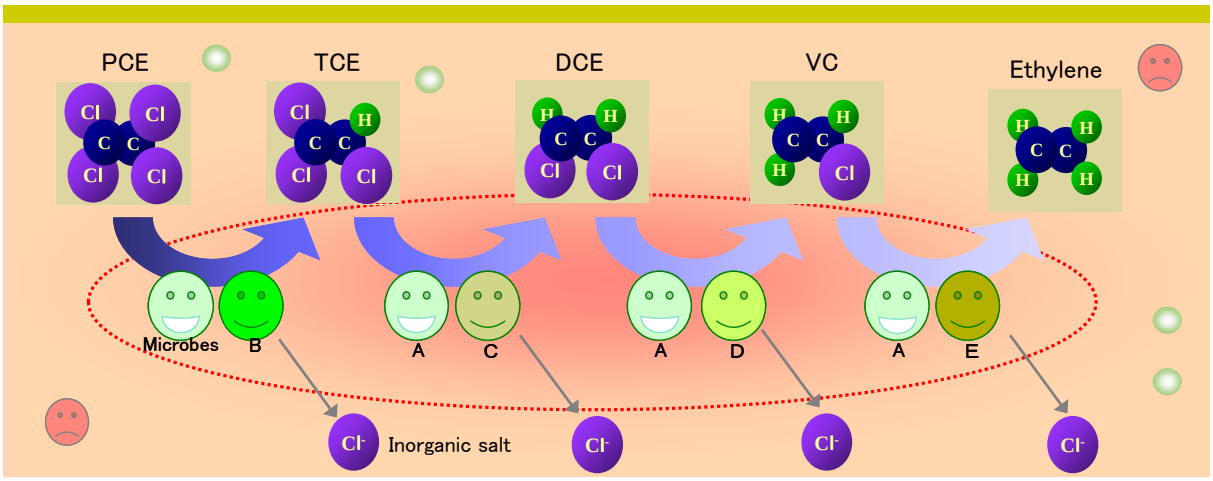
Injection well design based on site specific hydrogeology helps uniform propagation of biostimulants in the heterogenic aquifer

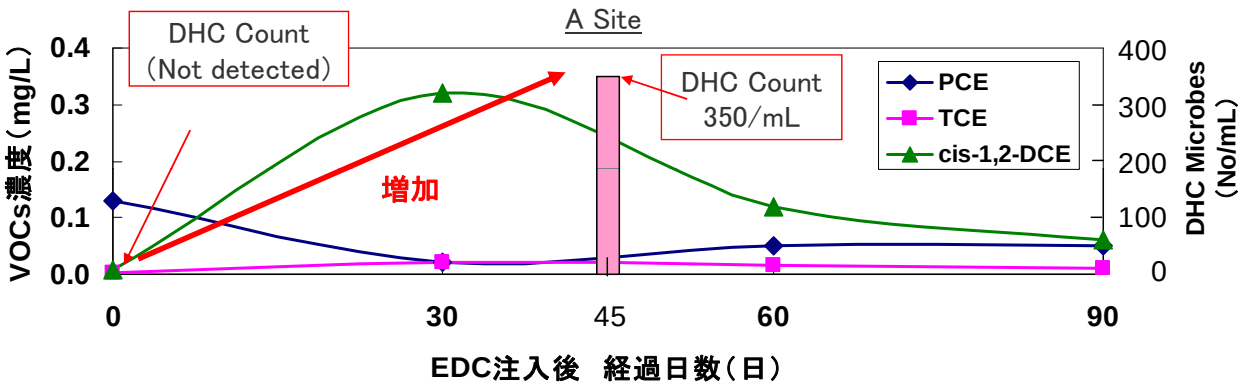
Injection Set-up

Dehalogenation Process



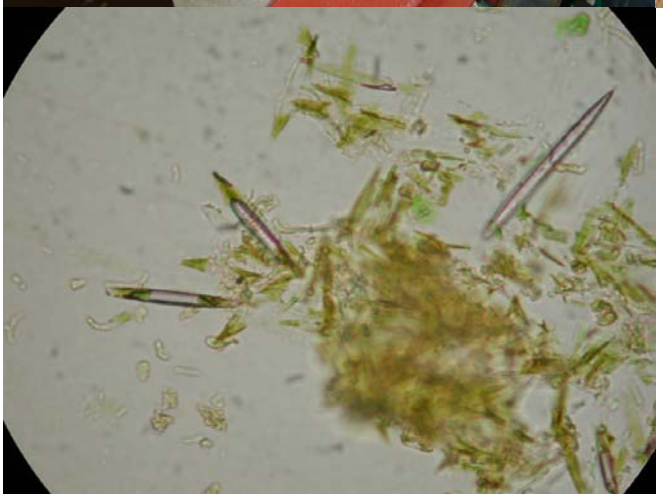
Stimulating microbial consortium is important than just concentrating on a single microbial community

Do not give-up on initial microbial counts



After the nutrients injection		0 day	45 days	60 days	90 days
B Site	*Dehalococcoides* count	<40/mL	200/mL	-	-
C Site	*Dehalococcoides* count	<70/mL	<70/mL	450/mL	<70/mL

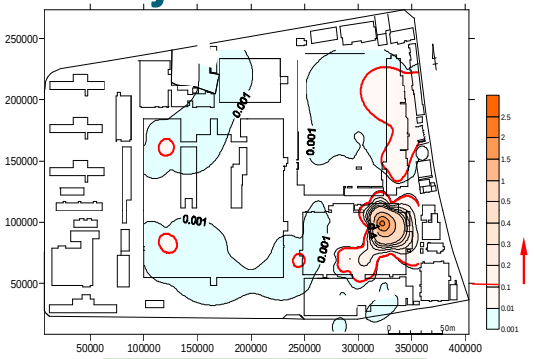
Lower soil organic carbon and contamination levels/ near sea areas: Initial microbial count might be below detection limit.



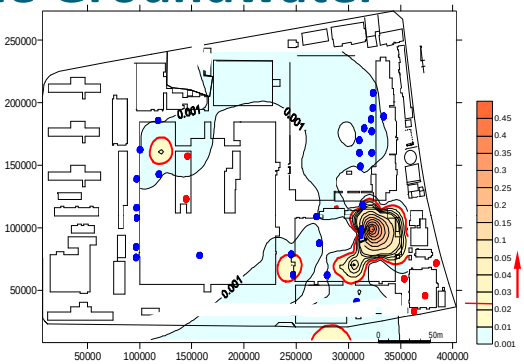
Trouble shooting: Befouling; well clogging, byproduct gas emission, fall in pH etc. are not uncommon.

How to overcome: Use of filters, clean injectio water and set-up, gas extraction, pH buffering etc.

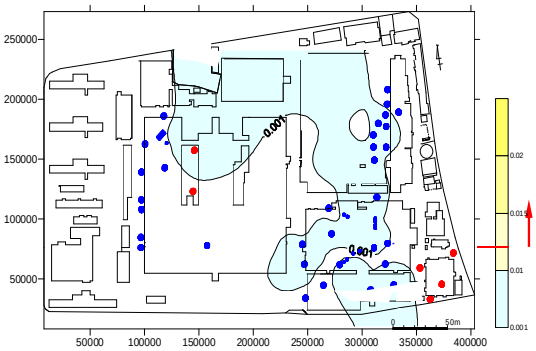
Post injection PCE in the Groundwater



2004.1.30 (Before injection)

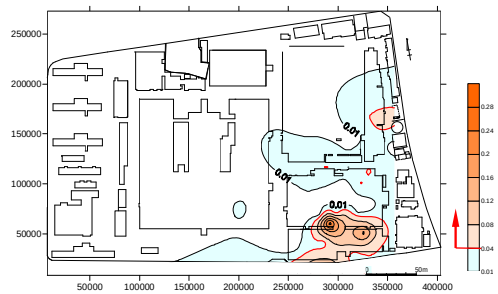


2004.12.17（Unit 3 remediation）

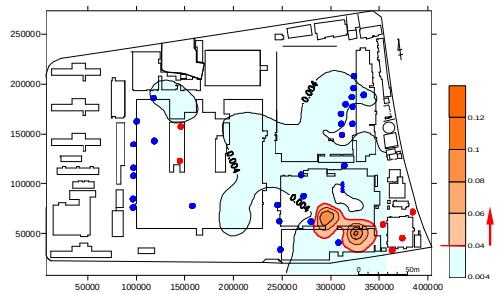


2005.10.3（Unit 1 remediation）

Post injection cis-DCE in the Groundwater



2004.1.30 (Before injection)



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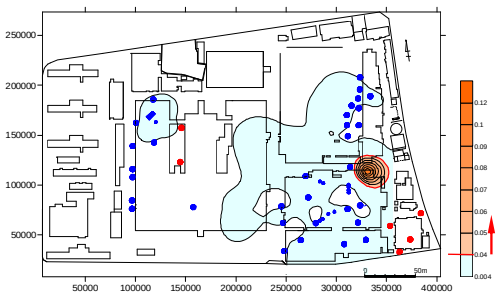

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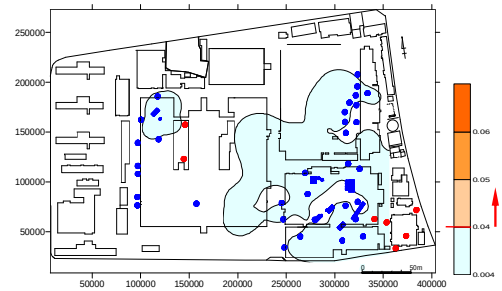
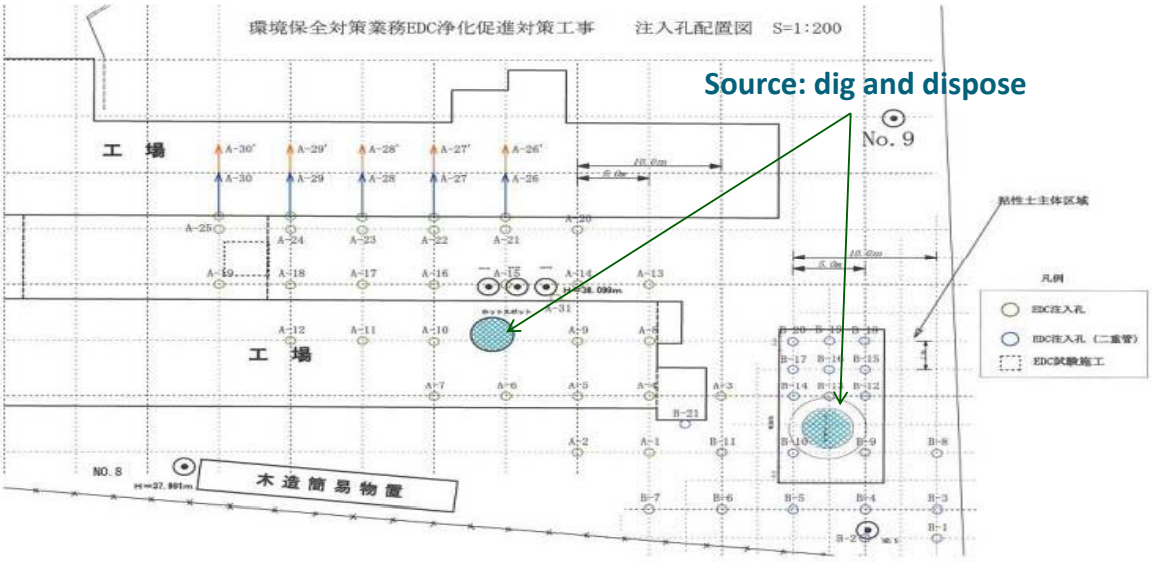


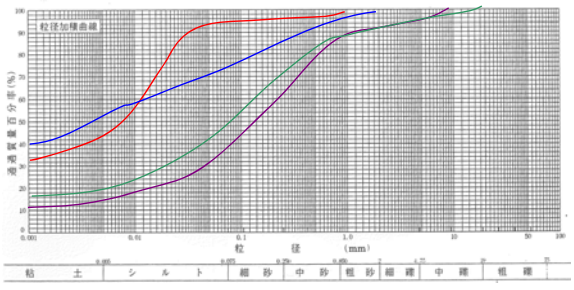
2005.10.3（Unit 2 remediation）

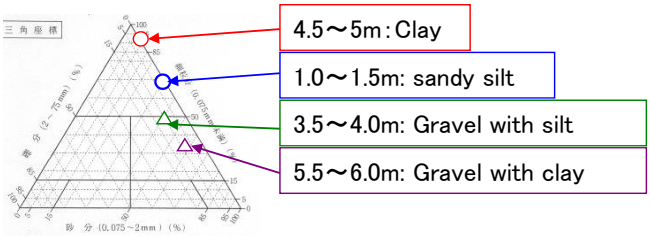
Electronic mgf., Kyushu



Partially active facility; Area: 3000 m2; Overburden thickness: 6m, Soil: Silty, sand-silty ; Contamination: TCE and daughters; Source area was dig and Disposed; GW : Pump and treat on going

Hydrogeology





Particle size analysis

Curtsy: New Japan Grout Corp.

Injection with Direct Push Technology

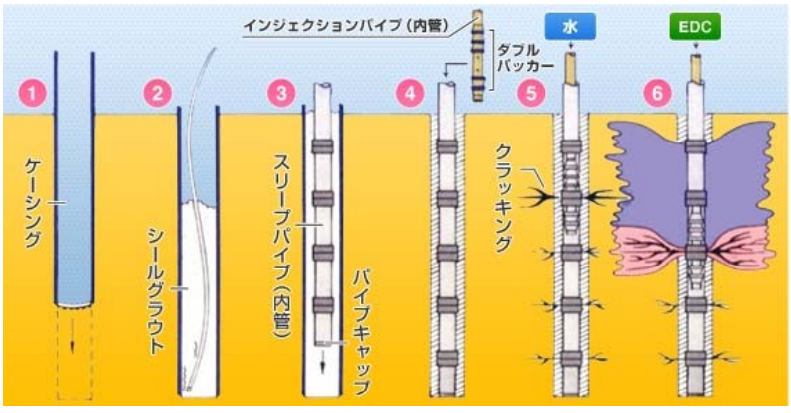
Sturm Ruger,
NH, USA

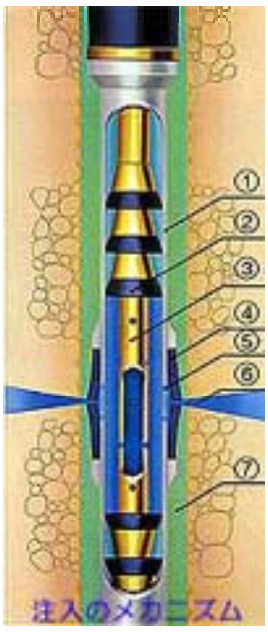
Wyman-Gordon
Grafton, Massachusetts, USA

GeoProbe 6610-DT track rig

- **2.3 GPM capacity pump, with pressures up to ~1,000 PSI**

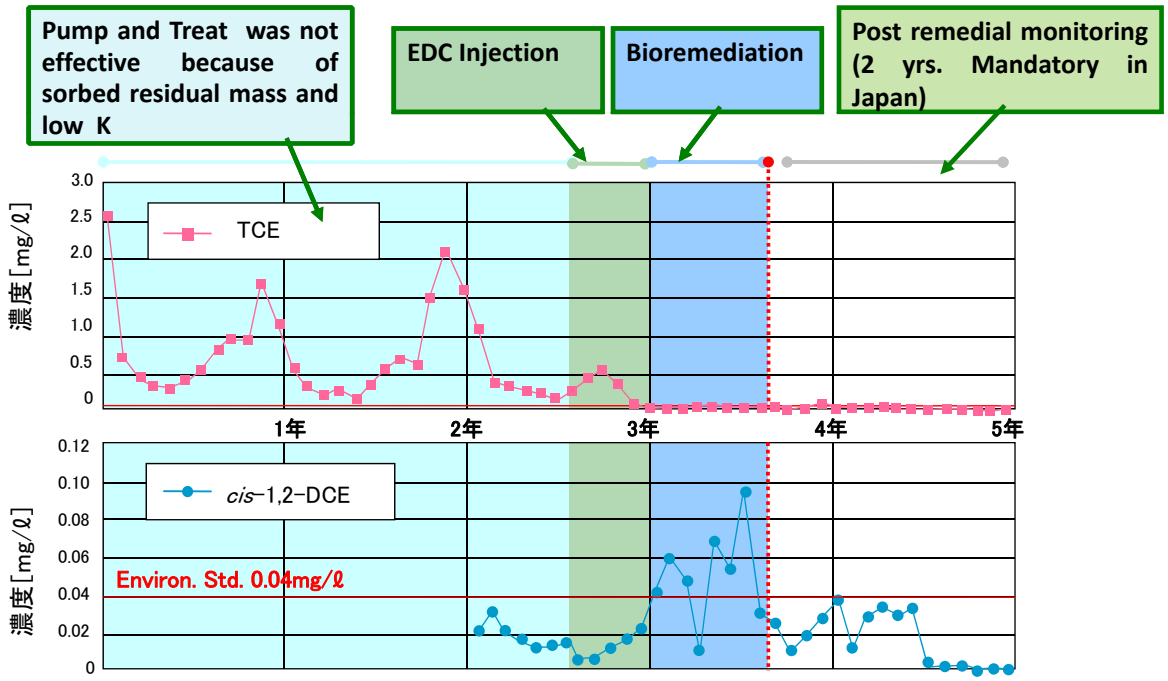
Double Packer Injection





- Injection points are designed based on distribution of contamination
- Injection pressure, dilution etc. depend on hydrogeology
- Precautions taken to avoid short-circuit

Bioremediation where pump and treat no longer works



Summary

- **Site assessment and investigation are vial parts**
- **Knowing hydrogeology and contamination is more important than obtaining data on site microbiology for developing bioremediation designs**
- **Remedial design varies depending on site hydrogeology, contamination data, geochemistry, site usage, budget, etc., and evolve over the coarse of remediation process**
- **Proper precautions can avoid common trouble shootings**
- **Bioremediation implementation based on scientific and site-specific facts can save huge $.**

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