SNOWMAN NETWORK
Knowledge for sustainable soils

State of the art concerning MNA in Europe – Denmark

SNOWMAN network conference on monitored natural attenuation
November 7th 2011
Salon du Relais, Paris

October 2011

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Natural Attenuation in Denmark – Experiences and Status

1. Summary of country status, existing documents & projects

A report from 1995 /1/ which summarizes experiences with in-situ remediation in Denmark describes enhanced aerobic biological processes and physical removal techniques for remediation or mitigation of LNAPL's. The report does not describe Monitored Natural Attenuation (MNA) as a possible approach for site remediation.

With respect to DNAPL contaminations there was a growing awareness about anaerobic natural attenuation as a process for remediation or mitigation of DNAPL contaminated soil and groundwater. Nonetheless, in the background paper from 1998 for the inclusion of NA in a national risk assessment model (Danish EPA model JAGG, /2/), the anaerobic degradation processes were still only briefly described as a remediation process /3/.

In the beginning of 2000 a few full scale (enhanced) NA remediation projects were implemented in close collaboration between the Danish EPA; different regional authorities; research institutes and different consultant companies, /4/, /5/. The overall objective was to verify the effect of NA processes ("proof of principles") under different Danish geological settings and to identify challenges and obstacles with this method. Besides verifying the NA processes; the challenges of adding carbon sources into the ground were also investigated and assessed.

In 2000 a project with the objective to investigate key conditions and parameters for NA and estimate degradation rates of DNAPL and LNAPL was conducted on a site in Copenhagen /3/. During the following years the trend was active removal and/or stimulation of biotic processes for LNAPL remediation. Only in a few investigation projects (#:3) with tar and gasoline/diesel the main approach was MNA /100/. Nonetheless MNA has been used by several private partners as the final remediation phase in a "treatment train" with the aim to achieve the final risk reduction in a cost-effective and sustainable way.

With the objective to assess the applicability of enhanced NA as a remediation technology on Danish sites (polluted with DNAPLs) a comprehensive study was conducted in 2005, /6/. The main project document summarizes and discusses technical aspects, risk considerations, remediation time frames, financial aspects, legal and monitoring issues, etc. Also topics to be further developed and investigated were identified and suitable contaminated sites for further tests are identified and listed in the report. The identified research issues were:

- Choice and consumption of donors;
- Remediation of low-permeable sites or remediation in the unsaturated zone;
- Remediation of free phases or on the contact surface between free phases;
- Remediation of the pollution plume;
- Handling and injection of bacteria;
- Assessment of need for bioaugmentation;
- Laboratory methods for the assessment of anaerobic dechlorination potential and rates of degradation;
- Authorities' approval of injection of donor and bioaugmentation.

Following the above recommendations, several separate research projects with specific objectives have been conducted e.g NA of TCA /7/; injection of carbon sources into low permeable formations /8/; treatability teats, design criteria's for a NA project and assessments of carbon sources / bioaugmentation needs /9/; characterization of the processes controlling contaminant transport and fate and assessment of treatment effect and time frame /10/; assessment of isotopic fractionation as a

method to be used for the documentation of NA /11/. The outcome of the above activities (together with international results) is used to asses if NA is a feasible remedial approach, the actual design of full scale enhancement of NA, a monitoring programme etc.

During the late 2000's MNA was discussed on several occasions. It was assessed from a technical and legislative viewpoint and a general good understanding of concentration reduction by e.g. dilution, volatilization, sorption, abiotic and biotic degradation was established. It was also clear that the actual mass reduction, only caused by degradation, should be verified by monitoring of parameters like redox potential, isotope fracturing, lab-degradation tests, and other geochemical components when using MNA. The common understanding is that using MNA as a remediation (also partial) technique requires a clearly defined line of evidence and comprehensive monitoring program.

Parallel to the still ongoing research and investigation activities several full scale projects at "commercial level" have been implemented using different carbon sources (as described in more detail below).

In general the use of NA as a remedial approach in Denmark has followed a typical development path starting with the common understanding and awareness of the process at laboratory scale, followed by bench scale and pilot tests and finally the present phase where full scale projects are implemented within a continues cycle of identifying and overcoming project challenges under different environmental settings. As it also has been the case during the "introduction" and use of other new remediation approaches and techniques there has been a technology transfer from other countries. Especially contributions from the United States, but also countries like e.g. the Netherlands have played a significant role. This has happened in close collaboration with foreign consultants and universities and Danish stakeholders during the initial implementation and adaptation of the different remediation techniques to Danish settings and requirements.

1.1. Actual status

Due to the focusing and demand of a sustainable green remediation approach there is a general interest to push forward the use of MNA and Enhanced NA where the method is feasible due to e.g. technical restrains, environmental settings, the time perspective. The NA as a remediation alternative is manifested in the "Remediation catalogue" /12/ elaborated by the Danish knowledge center for contaminated soil (www.avjinfo.dk) within the institutional framework of the Danish regional environmental authorities. This remediation decision making tool also provides different modules that facilitate a proper use of various remediation techniques and approaches, e.g. NA.

As already mentioned full scale in-situ enhanced NA projects have been and are still being implemented. A list including the main part of projects conducted in Denmark until now is found in Table 1 below. Within each project there has been an initial detailed investigation phase that also includes the collection of data to evaluate if NA is feasible and following for design purpose. Some projects also include a pilot test phase with the objective to achieve site specific information about e.g. treatability, risks, injection radius of influence using different injection techniques, formation, contaminant spreading and transports. The data from the pilot tests are used for in the design of subsequently full scale projects but also to elaborate a project tender material when selecting contractors (to e.g. inject a carbon source into the ground).

The commercial carbon source products used until now in Denmark for enhanced NA are mainly delivered by US providers e.g. Regenesis, Newman Zone, Adventus. In some cases the consultants have "produced" their own products based on molasses, ethanol and lactate mixtures. Depending on the pre-investigation results, bio-augmentation is sometimes part of the "enhancement" and in one case, nutrients are added to the mixture prepared by the consultant for injection.

1.2. Where is NA applied?

Due to the general advantages of in-situ methods the technique is typically applied where the contamination is detected at great depth, in large volumes and/or under installations/constructions. Also as a cost-effective and sustainable step for risk reduction in a remediation project. It is general accepted that MNA and ENA is a sustainable and cost-effective approach under the right conditions, a long remediation time span is acceptable and if no unacceptable potential risks using the NA approach are identified (e.g. the potential spreading of vinyl chloride).

The financing institutions are mostly public and in a fewer cases private landowners.

As an overall assessment for Denmark the main remedial objectives of the in-situ MNA and enhanced NA projects is to protect drinking water interests and in a few cases also to protect the indoor climate in residential areas. In a few cases the objective is a long term preparation of brown field areas for future (more sensitive) land use. A very few NA projects are implemented with the objective to protect a recipient, e.g. a sea or stream.

The enhanced NA method is often used as a part of a “treatment train” or as a parallel action with other remedial techniques, e.g. immediate physical removal of contaminated soil (excavation) or soil vapor extraction in the vadose zone under a building.

NA project descriptions are presented to the relevant municipal and regional environmental authorities before initiating a pilot or full scale project. The descriptions include information about the specific technical approach. Important is also the description of the monitoring programme to be followed, to document the effect of the remedial action and to detect unforeseen negative impacts in a timely way.

During the project, monitoring is conducted to verify the effect and follow the decrease of concentrations and possible rebounds. Monitoring reports are frequently submitted to relevant stakeholders, e.g. the environmental authorities. At the end of a project a more comprehensive monitoring is conducted to determine the level of contamination left behind. Based on that, a final risk assessment is carried out and final conclusions are draw.

The remediation goals and success criteria’s are typically defined on the basis of a site specific risk assessment in combination with the general national threshold values for an “acceptable” risk/impact (at this specific location). This approach is used to achieve the optimal value of the “invested” tax money, as earlier in-situ projects have demonstrated that removal of the last 10% of a contamination mass may consume 50% of the total budget.

2. Projects and case studies carried out

The Danish survey of NA projects was conducted by contacting a number of key stakeholders with experience with enhanced NA projects in Denmark: the Danish EPA, key regional environmental authorizes (in relation to NA projects), private consultant companies and entrepreneurs. In addition a search and review of key documents on the internet were conducted to identify further projects and collect basic data about these. Table 1 cannot be seen as a complete list of NA projects implemented in Denmark as some of the stakeholders requested to provide information did not reply and stakeholders not contacted in the survey may have conducted NA remediation projects. It is estimated that the list includes 50 – 75 % of all NA remediation projects implemented in Denmark.

Remarkable is the clear regional difference in the use of enhanced NA as a remedial method. Two regions (the Capitol Region and Region South Denmark) of the five Danish regions have been involved in NA projects since the “start” (approx. 2000) and the other regions have just recently been involved or are still not involved in any NA projects. There are several reasons for that, e.g. differences in remediation needs, type of prioritized projects, institutional capacity and finally the individual visions and experiences of the technical staff which can possibly also be an important factor.

As seen in Table 1 NA has been applied under different geological settings, e.g. clay till, silt, sand and limestone. The NA approach is used in the source area as well as in the plume area.

It is noted that enhanced NA have been used on sites with indications of free product DNAPL: the detected concentrations levels with a value higher than approx. 100.000 µg/L of DNAPL indicate the presence of free product phase.

MNA has been used by large land and ”problem” owners like the Danish Defense and the oil company association (managed under OM) for partial remediation of contaminated soil and groundwater. Public and private partners have also used MNA as a part of the treatment train.

3. Technical documents

Reports on projects within the “Technology project – programme” up until 2007, can be found on the Danish EPA web-page http://www.mst.dk/Virksomhed_og_myndighed/Jord/Hvis+du+vil+vide+mere/Teknologiprojekter/. Most reports are in Danish but have an English summary. All EPA projects / documents can be found on http://mim.schultzboghandel.dk/publikationsresultat/publikationsvisning.aspx?text=in-situ+erfaringer&type=alle.

The Danish Technical University (DTU) has a quite comprehensive web-page with links to Master and PhD thesis documents, most of them in English (http://www2.er.dtu.dk/phdthesis/). Another web-page provides an overview of “joint research activities” involving DTU within the field of risk assessment and soil & groundwater remediation: http://www.sara.env.dtu.dk/.

As mentioned earlier the Danish knowledge center for contaminated soil managed by the Danish regional environmental authorities have a web-page with technical reports and guidelines about technical, legal, chemical and decision making within the soil & groundwater “sector” in Denmark (http://www.avjinfo.dk/index.php?id=7). Within the same web-page there is also a well developed overview of good links in English categorized in the following topics: Investigation; Remediation; Chemicals and Risks, Geology, Publications and Various (http://www.avjinfo.dk/index.php?id=9). It is a recommendable starting point.
Also found within this web-page is a literature database (http://www.avjinfo.dk/lix.php). Two searches using respectively the key words “natural attenuation” and “enhanced reductive” in this database gave the results below (the Danish short summary after each link is presented to illustrate the “service” provided by the center for contaminated soil).

ENHANCED REDUCTIVE DECHLORINATION IN CLAYEY TILL: A MODELING TOOL AND APPLICATION AT DANISH SITES
Chambon, J.; Damgaard, I.; Lemming, G.; et al.; DTU Miljø;; (2009)
Vintermøde om jord- og grundvandsforurening, Bind II, marts 2009
Clayey tills contaminated with chlorinated solvents are a threat to groundwater and are difficult to remediate. A numerical model is developed for assessing leaching processes and for simulating remed...
MODELLING IN-SITU ENHANCED REDUCTIVE DECHLORINATION AT SORTEBROVEJ - WHAT CAN WE LEARN IN TERMS OF EFFICIENCY AND TIMEFRAME?
Chambon, J.; Manoli, G.; Broholm, M.M.; DTU Environment; et al.; (2010)
Naturlig og stimuleret biologisk nedbrydning – processer og mikrobiologi, april 2010
Clayey tills contaminated with chlorinated solvents are a threat to groundwater and are difficult to remediate. Full scale enhanced reductive dechlorination (ERD) is a promising remediation technology...
Recent advances in bioremediation of chlorinated solvents in groundwater
Cox, E.E.; Durant, N.D.; GeoSyntec; (2005)
Vintermøde om jord- og grundvandsforurening, marts 2005, 125-136
Artiklen beskriver processerne bag anvendelse af ERD (enhanced reductive dechlorination - stimuleret reduktiv dechlorering) som afværgeteknik. Valg af donor og brug af forskellige injektionmetoder omt...
Model assessment of reductive dechlorination as a remediation technology for contaminant sources in fractured clay. Case studies
Chambon, J.; Lemming, G.; Broholm, M.; et al. ; DTU Miljø; (2009)
Miljøprojekt, 1296, 2009 fra Miljøstyrelsen
Denne rapport følger Miljøprojekt 1295, 2009 "Model assessment of reductive dechlorination as a

remediation technology for contaminant sources in fractured clay. Modeling tool - Delrapport II" og besk...

Model assessment of reductive dechlorination as a remediation technology for contaminant sources in fractured clay. Modeling tool

Chambon, J.; Damgaard, I.; Christiansen, C.; et al. ; DTU Miljø; (2009)

Miljøprojekt, 1295, 2009 fra Miljøstyrelsen

Det overordnede formål med denne delrapport er at opnå en bedre forståelse af anaerob reduktiv deklorering. Denne delrapport omhandler opstilling af modeller. For bedre at kunne karakterisere de styre...

The use of stimulated anaerobic biodegradation of chlorinated solvents: European experiences

Bemmel. M.; Bioclear; (2005)

Vintermøde om jord- og grundvandsforurening, marts 2005,137-140

Der er tale om en kort artikle på en side som er gengivet her i sin fulde længde: From the early 1980's on, soil remediation techniques have been intensively researched in The Netherlands. From the ve...

A field study to monitor processes involved in natural attenuation of hydrocarbon plumes. Et feltstudie for monitering af processer involveret i naturlig oprensning af hydrocarbon forureninger.

Stauffer, T. ; Libelo, E. L. ; Macintyre, W. G. ; Boggs, J. M. ; Stapleton, R. (1997)

Forskningsprojekter vedrørende jord- og grundvandsforurening; oktober 1997, 1-8

Med det formål at skabe et bedre grundlag for vurdering af naturlig nedbrydning er der udført feltforsøg med hydrocarboner ved Columbus Air Force Base. I feltforsøget blev der injiceret en forurening ...

Guidelines for natural attenuation

Rittmann, B.; Evans, J.; (2001)

Vintermøde marts 2001, 7-20

Indledningsvis omtales anvendelse af naturlig nedbrydning i USA og de diskussioner der finder sted om metodens anvendelighed. Derefter følger en kort præsentation af det arbejder der siden 1997 er udf...

Intern Rensning af benzinforureninger i grundvand

Bjerg, P.L.; Arvin, A.; DTU, Institut for Miljøteknologi; (1998)

Teknik og Administration 1998 nr. 6

Notatet omhandler intern rensning af benzinkomponenter i grundvand. Der er særligt lagt vægt på følgende tre stofgrupper: BTEX, trimethylbenzener og MTBE. Formålet med notatet er at give et konkret gr...

Natural attenuation of chlorinated ethenes at Dover Air Force Base, USA

Morgan, P.; Holmes, M.W.; Barnes, D.J.; et al (1999)

Vintermøde om Grundvandsforurening; marts 1999, 35-48

Artiklen beskriver undersøgelser af naturlig nedbrydning i en forureningsfane ved Dover luftbase, USA. Fanen indeholdt forurening med chlorerede opløsningsmidler. Undersøgelserne viser at der sker en ...

Natural attenuation of MTBE

Weaver, J.W.; Wilson, J.T.; Cho, J.S.; (2000)

Vintermøde; marts 2000, 41-58

Tre cases hvor naturlig nedbrydning af MTBE er undersøgt gennemgås. På den første lokalitet var ilt den dominerende elektron acceptor. På de to andre lokaliteter var der anaerobiske forhold med jern r...

Natural attenuation of xenobiotic compounds at the Grinsted old landfill, Naturlig rensning af miljøfremmede stoffer i Grinsted gammel affaldsdepot

Rügge, K. ; Bjerg, P. L. ; Mosbæk, H. ; Christensen, T. H. (1997)

Grundvandsforskningen i Danmark 1992-96; april 1997, 57-66

Med det formål at undersøge den naturlige nedbrydning i forureningsfanen ved Grinsted gamle losseplads er der udført et stort felt injektions forsøg løbende over 923 dage. Der blev injiceret 18 miljøf...

Natural attenuation of xenobiotic compounds: Anaerobic field injection experiment

Rügge, K.; Bjerg, P. L.; Mosbæk, H.; Christensen, T. H.; DTU; (1995)

Forskningsprojekter vedrørende grundvandsforurening;oktober 1995, 39-46

De foreløbige resultater fra injektionforsøg ved Grindsted losseplads præsenteres. Der udføres forsøg med 6 måneders kontinuert injektion af 18 stoffer bla. BTEX, nitroaromatiske hydrocarboner, chlore...

Natural attenuation: A feasible approach to remediation of groundwater pollution at landfills?

Christensen, T. H. ; Kjeldsen, P. ; Bjerg, P. L. ; DTU; (1999)

Naturlig nedbrydning - En ny oprensningsteknik; oktober 1999, 11-26

På baggrund af mere en 10 års undersøgelser af to danske lossepladser, diskuteres muligheden for at anvende naturlig nedbrydning på denne type forurende grunde. Det vurderes at naturlig nedbrydning er...

Naturlig nedbrydning af phenoxysyrer i en forureningsfane fra en losseplads

Ejlskov, P.; Ejlskov Consult ApS; Bjerg, P.L.; DTU; Pedersen, J.K.; Sønderjyllands Amt; (2002)
Pesticider og punktkilder; januar 2002, 35-46

Der har været udført en meget detaljeret forureningsundersøgelse af en pesticidforurening ved Sjølund losseplads. Formålet har været at komme ud af et "dødvande" og nå frem til at få afsluttet foruren...

Protocols for evaluating the natural attenuation of fuel hydrocarbons and clorinated aliphatic hydrocarbons in grundwater; Procedure for evaluering af den naturlige oprensning af benzin hydrocarboner

Wiedemeier, T. H. (1997)
Vintermøde om grundvandsforurening; marts 1997, 349-358

Der gives et resume af de tekniske vejledninger som er udviklet for USA´s Air Force Center for Environmental Excellence i forbindelse med benyttelse af naturlig nedbrydning ved grundvandsforureninger...

Sustainability of Natural Attenuation (S-NA) of Chlorinated ethylenes

Henssen, M.; Bioclear BV of Netherlands; (2003)
AVJinfo 2003: (4), 4-5

Artiklens forfatter peger på at ingen af de eksisterende protokoler for naturlig nedbrydning stiler krav om vertificering af den påviste nedbrydnings robusthed i fremtiden. Artiklen beskriver en ny sy...

The Værløse emplaced source field experiment: Laboratory and field evidence of natural attenuation in the vadose zone

Kjeldsen, P.; Christophersen, M.; Broholm; M.; DTU; et al; (2004)
Umættet zone; april 2004, 63-74

På flyvestation Værløse er der udført fuld skala forsøg med nedbrydning af olie i den umættede zone i en sandet formation. Nedbrydningforløbet for de udvalgte 13 VOC'er kunne beskrives som første orde...

Udbredelse af fri fase DNAPL i moræneler og kalk

Dyreborg, S.; Krüger A/S; (2000)
Orientering 2000: (2), 2-3

Denne artikel udtrækker hovedkonklusionerne på et kursus om " DNAPL in Fractured Geologic Media: Monitoring, Remediation and Natural Attenuation" afholdt i USA. Erfaringerne viser nu at praktisk talt ...

4. References

/100/ Status – Teknologiudvikling indenfor afværgeforanstaltninger overfor jord og grundvandsforureninger i Danmark. Miljøstyrelsen 2009.

Table 1: In-situ enhanced natural attenuation soil & groundwater remediation, DNAPL, projects implemented in Denmark (A3 format)

Method	Phases conducted - Investigation (I), Pilot (P), Full scale (F)	Used additive(-s)	Contaminant (initial)	Treatment volume (app. m3)	Mitigation objective (Risk reduction) * note below	Max. Concentra. GW: µg/L Soilvapo.: µg/m^3 Soil: mg/kg	Free product phase (DNAPL)	Geology	Site location	Executer	Financier	Responsible authority	Project period -expected	Remediation goal	Ref. Documents (pdf or link)	Info from
ERD	P	Laktat (recirculation) Newman Zone (passive)	Chlorinated solvents TCE and DCE	800 m3	GW	20,000 µg/L	no	Sand layer	Rugårdsvej 234-238, odense	COWI	Fyns Amt/ Region Syddanmark	Fyns Amt/ Region Syddanmark	Started in 2006 with 200 days of recirculation then passive, still on going		Danish EPA Miljøprojekt 1148 fra 2007	Mette Christophersen, Region Syddanmark
ERD	F	EOS	Chlorinated solvents TCE	40*60*20 m3	GW	20,000 µg/L	no	Moraine clay	Sortebrovej 26, Tommerup	Orbicon	Fyns Amt/ Region Syddanmark	Fyns Amt/ Region Syddanmark	Started in may 2006, still on going		-	Mette Christophersen, Region Syddanmark
ERD	F	Newman Zone	Chlorinated solvents TCE and Cr6+	2,000 m3	GW		no		Contex, Svendborg	COWI	Private	Fyns Amt	2005-2006	500 µg/L total CAH	-	Mette Christophersen, Region Syddanmark
ERD	P	Ethanol and lactate	PCE	25*10*5 m3	GW	270,000 µg/L	Yes	Sand	Kærgård Plantage	COWI and Rambøll	Region Syddanmark	Region Syddanmark	2010-2011		-	Mette Christophersen, Region Syddanmark
MNA	I, P, F	None	Heating oil	4,000 m3	GW, IC	200 mg/L	Yes	Mixed	Nøkkentvedgård, West Zealand	Orbicon	OM	Region Zealand	2005-2012	Verify stagnating source, impact on GW < threshold	-	- Vad betyder streck I den här kolumnen?
Enhanced NA - SRD	I, P, F	Biological Molasses and culture containing Dehalococcoides from Bioclear	Chlorinated solvents (TCE → ethen)	1200 m3	GW	740,000 µg/L, 62 mg/kg tS	Yes	Clay till	Gl. Kongevej, Copenhagen	Orbicon/ Ejlskov	Copenhagen county*	Copenhagen county*	2006-	Reduce contaminant mass in the treatment zone and flux to the underlying aquifer	attached	Orbicon
Enhanced NA - SRD	I, P, F	Biological Molasses and culture containing Dehalococcoides from Bioclear	Chlorinated solvents (TCE → ethen)	500 m^3	GW	15,400 µg/L	No	Clay till	Vesterbrogade, Copenhagen	Orbicon/ Ejlskov	Copenhagen county*	Copenhagen county*	2006-	Reduce contaminant mass in the treatment zone and flux to the underlying aquifer	attached	Orbicon
Enhanced NA - SRD	I	Biological Molasses and KB-1	Chlorinated solvents (PCE → ethen)	2,400 m^3	GW	50-100 mg/kg 1000 µg/L	yes	Clay till	Vadsbyvej, Sjælland	Orbicon/ To be determined	Capital Region of Denmark	Capital Region of Denmark	To be determined	Reduce contaminant flux to the underlying aquifer	Not available	Orbicon
SRD	I, P, F	EOS 584 B42	TCE → VC	25,000 m^3	GW	20,000 µg/L	No	Fractured clay till	Sortebrovej, Tommerup	Arkil A/S Miljøteknik	Region Syddanmark	Region Syddanmark	2003-2006	GW: 100 µg/L of total CAH	Not available	Orbicon
SRD	I, F	Melasis, nutrients	Chlorimated solvents	640 m^3	GW, IC	15,000 µg/L	no	Sand - till	Aarhus	DGE /Ejlskov	Private	Aarhus County	2008-2011	Soilgas: 100 µg/m^3	Not available	DGE
SRD	I, P, F	Melasis, glucoses, Newman zone	Chlorinated solvents	6,000 m^3	IC	10,000,000 µg/m^3	Yes	limestone	Grenaa	DGE	Private	Norddjurs county	2004-2011	Soilgas: 1.000 µg/m^3	Not available	DGE
Enhanced NA - SRD	I, P	HRC Regenesis	PCE	Test area	GW	-	No		Jægersborg Allé 24	DTU, Orbicon			2001-2003		/5/	Literature
NA	I	No enhancement	PCE / oil	-	GW	BTEX 4,400 µg/L PCE: 3,900 µg/L	No		Drejøgade	NIRAS			2000		/4/	Literature
Enhanced NA - SRD	I,P, (F)	Newman Zone + Bio augmentation	PCE, TCE	3,750 m^3	GW	700 µg/L 170,000 µg/m^3	No	Sand-silt	Ahornvej 19 Hørsholm	COWI	Capital Region of Denmark	Capital Region of Denmark	2009-ongoing	Protect GW resources	-	-
Enhanced NA - SRD	I,P,(F)	Newman Zone + Bio augmentation	PCE→ VC	5,000 m^3	GW	1,400 µg/L PCE 310 µg/L VC 3,700 µg/m^3	No	Sand-silt	Rungstedv. Hørsholm	COWI	Capital Region of Denmark	Capital Region of Denmark	2009-ongoing	Protect GW resources	-	-

Table notes:
* Risks: GW = groundwater, IC = indoor climate, R = recipient, PC = physical contact/soil handling.