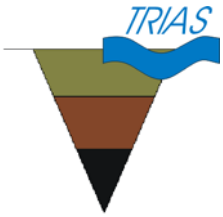


Eindrapportage-formulier TRIAS projecten
Final report format for TRIAS projects.

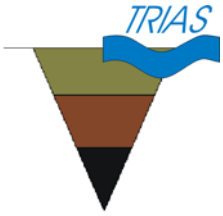
When a TRIAS project has finished, or is about to finish, a Final Report is required. This report serves several goals simultaneously:

- it enables the program commission to check whether the project has met its goals,
- it enables NWO-ALW to finalize the project administratively, e.g. pay the final part of the personnel costs of the project,
- it provides some of the information needed for evaluation purposes,
- it provides information which can be publicized, e.g. via a web site.

We have integrated the questionnaires from TRIAS and ALW into one, in order to prevent the need to fill in the same answers twice.

Please send in the filled out forms within a month after the project is completed to:

Netherlands Organisation for Scientific Research
Earth and Life Sciences
Carmen van Meerkerk and/or Theo Saat
P.O. Box 93510
2509 AM The Hague



Part I

General information, also intended for publication through the TRIAS website

01 Project Title

*CORONA: **C**onfidence in f**or**ecasting **o**f **n**atural **a**ttenuation*

02 TRIAS/ALW project number or file number

TRIAS 835.80.121

03 Research period, at what date did the project start, at what date did it end.

November 2002 – October 2004

04 Names of the researchers involved, the names and addresses of the institutes where the research work was carried out.

Dr. M. Luijten, Dr. J. Gerritse, Ir. N. Hoekstra, Ir. H. Slenders, and Dr. Ir. H.H.M. Rijnaarts

TNO-MEP, Postbus 342, 7300 AH Apeldoorn

05 Short scientific summary (500 words) in English of: main research objective, research methods, results and conclusion

Research objective

The most important mass-removal process for natural attenuation is biodegradation. The hypothesis of this project is that a common pattern of biodegradation activity exists in most groundwater pollution plumes. Better conditions for biodegradation occur in distinct zones within the plume. Such "Corona" zones are for example created by a heterogeneous distribution of organic matter or iron oxides in the inner core of the plume, or by oxidizing conditions at the plume fringe due to mixing with electron acceptors in the surrounding groundwater. More rapid pollutant degradation in these zones contributes significantly to the overall pollutant mass loss from the entire plume. The objective of this project was to investigate whether Corona zones exist in a chlorinated solvent plume at a car manufacturing site in Brabant and to determine their contribution to reductive and/or oxidative biodegradation of the pollutants. At this site metal cleaning solvents, trichloroethene and 1,1,1-trichloroethane, were spilled into the groundwater resulting in a pollution plume with a length of about 1 kilometer.

Research methods and results

Six multi level groundwater samplers (MLS) were constructed and installed to obtain high resolution data from the chlorinated solvent plume at the Brabant site. Each well typically contained 16 filters from which groundwater samples could be collected over vertical profiles of the plume from depths ranging from 30 up to 80 meters below surface. From the boreholes 48 soil samples were also obtained. The groundwater and soil samples were used to determine the distribution of contaminants and their isotope signatures,

physical parameters (temperature, redox potential, pH, conductivity), soil matrix, organic and anorganic geochemical parameters important for biodegradation (dissolved organic carbon, nitrate, iron, manganese, sulfate, methane and hydrogen) and pollutant degrading micro-organisms.

The plume area consisted of coarse sand with accidentally some wood and clay particles. The groundwater had a temperature of 10-15°C, a neutral pH of 6,5-7,5 and a redox potential of about -100 to -300 mV, indicating mildly reducing conditions. The main pollutants were cis-1,2-dichloroethene (cis-DCE), vinyl chloride (VC) and 1,1-dichloroethane (1,1-DCA). Their reductive (bio)transformation products ethene and ethane were also detected. The dissolved hydrogen concentrations (0.1-0.5 nM) and the organic carbon content of 3-10 mg/l were generally low, but sufficient to fuel bacteria capable of reductive dechlorination. The occurrence of reductive dechlorination of cis-DCE and VC was confirmed by the increase of dechlorination products and the enrichment of their ^{13}C isotopes along a flow-line in the plume. Biologically available ferric iron^{III} in soil samples from the boreholes was analyzed by Wilfred Röling (VU) and generally corresponded to concentrations from 0 to 3 mM. This is essentially sufficient to oxidize all contaminants in the plume. The range of dissolved H_2 concentrations and the presence of ferrous iron^{II} in the groundwater were indicative for the occurrence of iron reduction in the subsurface. In some wells peaks in H_2 concentration (>1 nM) and iron content were observed, indicative for the existence of more reduced and oxidized zones within the plume. Sulfate concentrations were positively correlated with the chlorinated solvent concentrations in the groundwater. This suggested a common origin. Other differences were not found in physical and geochemical parameters inside and outside the plume. Of the electron acceptors needed by bacteria to oxidize the pollutants, oxygen was not present and nitrate was only detected in some wells at very low concentrations of <0,5 µM. Thus oxidation of the contaminants due to mixing with electron acceptors at the fringes of the plume is not a main biodegradation process at the Brabant site.

Degradation of chlorinated ethenens and ethanes was studied in microcosms filled with contaminated groundwater and soil obtained from different depths of one MLS at the Brabant site. Various redox conditions were imposed by addition of different electron acceptors (oxygen, nitrate, manganese oxide, iron oxide or sulphate) or an electron donor (protamylasses). Analysis after one year of incubation indicated no reduction or oxidation of the chlorinated contaminants in anaerobic microcosms with manganese oxide, iron oxide, nitrate or sulphate. In the aerobic microcosms VC was readily and completely degraded, cis-DCE was partially removed (35±19%, n=8 batches) and 1,1-DCA was not degraded. Apparent degradation products were not detected, suggesting oxidation to CO_2. In all microcosms with protamylasses a complete reductive dechlorination of 1,1-DCA to chloroethane had occurred. Slow reductive

dechlorination of cis-DCE to VC was observed in 4 out of 7 of the batches with protamylasses. In 3 out of 8 blank microcosms (no electron donor or acceptor supplied) cis-DCE and VC had completely disappeared and ethene was formed. The variation of dechlorination potential in the microcosms from different depths suggests the existence of Corona zones within the plume core. Supply of a dechlorinating enrichment culture with Dehalococcoides resulted in rapid and complete dechlorination of cis-DCE and VC and the production of ethene. Real-time PCR was used in collaboration with Meta van Heusden (WUR) to quantify the number of dechlorinating Dehalococcoides cells in field samples. High numbers in the range from 10^2 to 10^4 Dehalococcoides cells per ml groundwater were detected in a bioscreen installed near the source of the contamination and in one well downstream of the bioscreen. No Dehalococcoides cells were observed in groundwater (detection limit about 5 cells per ml) or soil (detection limit about 500 cells per gram) from the MLS and other wells further downstream in the contaminant plume.

Conclusions

The microcosms and molecular studies indicate the potential for reductive dechlorination of chlorinated ethenes and ethanes at the site. Bacteria capable of aerobic oxidation of VC and cis-DCE are also present. No evidence was found of anaerobic chloroethene or –ethane oxidising bacteria, in spite of the availability if iron^{III} in the subsurface. The occurrence of slow reductive natural attenuation of cis-DCE and VC was confirmed by their changing isotope signatures along a flow-line. The peaks in H_2 concentration in some wells and apparent absence or presence of dechlorinating bacteria in samples from different places in the plume core are not in contradiction with the presence of Corona zones with enhanced potential for reductive dechlorination.

Recommendation

The aquifer studied here is low in organic carbon content, and has an intermediate anoxic redox condition, which is typical for sandy confined aquifers of North-Western Europe. In this nutrient-poor environment, Natural biodegradation processes were demonstrated to be active in the attenuation of this chlorinated solvent plume. However, it was difficult to quantify these processes in the timeframe of the project. For this, long term extensive monitoring and repeated reactive transport modeling is needed. The reduction of the spreading of the pollutants by NA could therefore not yet not be quantified. It is recommended to combine the findings of this project with the results from other projects in The Netherlands, Germany (i.e. Hannover-Süd project in KORA), Denmark and Belgium, and to develop a long term groundwater management approach for these types of pollutants in these types of aquifers using monitored natural attenuation as the basic principle. TNO–Wageningen University Research Centre is planning to initiate such a project.

06 Popular summary to inform the general public (1/2 to 2 pages of text)

in Dutch.

The funding organizations of TRIAS (SKB, NWO-ALW and Delft Cluster) want to inform a more general audience about the results of the TRIAS Research projects. That is why we ask you to give an executive summary of the project in a popularizing way and written in the Dutch language.

Nederlandse samenvatting

Natuurlijke afbraak/afname (NA) neemt in Nederland en Europa een steeds belangrijkere plaats in als saneringsstrategie voor verontreinigd grondwater. Algemeen wordt aangenomen dat afbraak door micro-organismen in de ondergrond het meest belangrijke proces is dat verspreiding van verontreiniging in het grondwater kan beperken en terugdringen. Het huidige beleid is gebaseerd op het bereiken en handhaven van een "stabiele eindsituatie" van een verontreinigingspluim. Een stabiele eindsituatie is in de praktijk echter zeer moeilijk vast te stellen en voorspellingen van het gedrag van verontreinigingen in het grondwater zijn nog aan grote marges van onzekerheid onderhevig. Daarom is er meer inzicht en vertrouwen nodig in de factoren en processen die de snelheid van NA in het veld bepalen en de duurzaamheid daarvan. Dit mede door TRIAS gefinancierde post-doc onderzoek bij TNO-MEP maakt onderdeel uit van het EU-project CORONA. Dit project heeft tot doel om een wetenschappelijke basis te vormen voor NA van veel voorkomende grondwater-verontreinigingen. In het Corona project werken onderzoekers uit 8 Europese landen samen om NA op 6 locaties met verschillende typen verontreinigingen en geohydrologie te doorgronden. De centrale hypothese is dat binnen verontreinigingspluimen in het grondwater er zones zijn waar de afbraak sneller verloopt dan elders. Deze "Corona zones" zijn bepalend voor het gedrag van de pluim, d.w.z. groei, stabiel of afname. In het project worden twee verschillende soorten zones onderscheiden:

1. *Een actieve, oxiderende pluimrand waar afbraak wordt bepaald door dispersie en menging van de verontreiniging met elektronen-acceptoren in het omliggende grondwater;*
2. *Anaërobe zones in de pluim waar afbraak wordt bepaald door de beschikbaarheid van elektronendonoren of –acceptoren, micro-organismen en verontreiniging. De anaërobe afbraak kan hierbij reductief of oxidatief zijn.*

Het eindresultaat van het Corona project is een eenvoudig te hanteren en robuust voorspellingsinstrument voor NA, gekoppeld aan rekenmodellen en een cursus.

Het doel van het onderzoek van de post-doc bij TNO-MEP (Maurice Luijten) was om de aanwezigheid van Corona zones en het optreden van reductieve en oxidatieve NA vast te stellen in een chloorkoolwaterstoffenpluim in het grondwater bij een verontreinigde locatie van een vrachtwagenproducent in Brabant. Op deze locatie is voor het ontvetten van metalen in het verleden trichlooretheen en 1,1,1-trichloorethaan gebruikt. Dit heeft in het

grondwater een verontreinigingspluim met een lengte van ongeveer een kilometer veroorzaakt.

Aanpak van het onderzoek

Zes "hoog resolutie peilbuizen" (HRP) zijn gemaakt en op de locatie in Brabant in de verontreinigingspluim geïnstalleerd. Iedere HRP had 16 filters waarmee grondwatermonsters konden worden genomen over een verticaal profiel van de pluim op dieptes variërend van 30 tot 80 meter onder maaiveld. Tijdens het installeren van de HRP zijn tevens 48 bodemmonsters genomen. De grondwater- en bodemmonsters zijn gebruikt om de ruimtelijke verdeling vast te stellen van de verontreinigingen, de geochemische condities, de structuur van de bodem en de micro-organismen verantwoordelijk voor afbraak.

Resultaten

De bodem bestond uit grof zand met hier en daar hout- en kleideeltjes. Het grondwater was anaëroob, had een temperatuur van 10-15°C en een neutrale pH. De belangrijkste verontreinigingen waren cis-1,2-dichlooretheen (cis-DCE), vinylchloride (VC) en 1,1-dichloorethaan (1,1-DCA). Hun reductieve (biologische) omzettingsproducten etheen en ethaan werden ook aangetroffen. De opgeloste waterstofconcentraties en het organisch stof gehalte waren relatief laag, maar wel voldoende om reductieve dechloreringsprocessen te kunnen laten verlopen. Het optreden van reductieve omzetting van cis-DCE en VC werd onderbouwd doordat werd gevonden dat er een toename was van dechloreringsproducten en een verrijking in ^{13}C isotopen in cis-DCE en VC langs een stroombaan in de verontreinigingspluim. Op enkele monsterpunten werden pieken aangetroffen in de waterstof- en ijzerconcentraties. Dit kan duiden op locale zones met meer gereduceerde of geoxideerde condities in de pluim. Er werden geen beduidende verschillen waargenomen in de geochemie van het grondwater binnen en buiten de pluim. Zuurstof en nitraat waren niet of in zeer geringe concentraties in het grondwater aanwezig en er was geen sprake van een oxiderende pluimrand met een verhoogde afbraaksnelheid van de verontreinigingen.

De afbraak van de gechloreerde ethenen en ethanen is ook onderzocht in batchcultures gevuld met verontreinigd grondwater en grond van verschillende dieptes uit een HRP op de Brabant locatie. Verschillende redox condities zijn aangebracht door het doseren van elektronenacceptoren (zuurstof, nitraat, mangaanoxide, ijzeroxide of sulfaat) of een electronendonor (protamylasse). Na een jaar incubatie was er geen reductie of oxidatie van de verontreinigingen opgetreden in de anaërobe batches met mangaanoxide, ijzeroxide, nitraat of sulfaat. In de aërobe batches werd VC snel en volledig afgebroken, werd cis-DCE gedeeltelijk verwijderd (35±19%, n=8 batches) en werd 1,1-DCA niet verwijderd. Afbraakproducten werden niet gedetecteerd, wat wijst op een oxidatie tot CO_2. In al de batches met protamylasse werd 1,1-DCA volledig omgezet tot

chloorethaan. Een langzame reductieve dechlorering van cis-DCE tot VC werd waargenomen in 4 van de 7 batches met protamylasse. In 3 van de 8 blanco batches (geen electrondonor of –acceptor toegevoegd) waren cis-DCE en VC na een jaar volledig verdwenen en werd etheen gevormd. De variatie van dechloreringscapaciteit in de batches van verschillende dieptes zou kunnen duiden op Corona zones binnen de pluim. Een snelle omzetting van cis-DCE en VC en vorming van etheen trad op nadat een dechlorerende verrijkingscultuur met Dehalococcoides in een niet-dechlorerende batch werd geënt. De aantallen Dehalococcoides cellen in veldmonsters zijn bepaald met de moleculaire methode "real-time PCR". Hoge celaantallen in de range van 10^2 tot 10^4 werden aangetroffen in een "bioscherm" dat vlak bij de bron van de verontreiniging is aangelegd. In dit bioscherm wordt reductieve dechlorering gestimuleerd door protamylasse in het grondwater te pompen. In een peilbuis stroomafwaarts van het bioscherm werden ook hoge etheenconcentraties en Dehalococcoides aangetroffen. In het grondwater en bodemmateriaal van HRP en peilbuizen verder stroomafwaarts in de verontreinigingspluim werd echter geen Dehalococcoides gevonden (detectiegrenzen ongeveer 5 cellen per ml grondwater en 500 cellen per gram grond).

Conclusies

In het onderzoek is aangetoond dat in de bodem en het grondwater op de Brabant locatie bacteriën aanwezig zijn die gechloreerde ethenen en ethanen reductief kunnen omzetten. Bacteriën die cis-DCE en VC aëroob kunnen afbreken zijn ook aanwezig. Voor de aanwezigheid van anaërobe bacteriesoorten die chloorethenen of –ethanen kunnen oxideren is geen bewijs gevonden. Dicht bij de bron van de verontreiniging, waar dechlorering in een bioscherm wordt gestimuleerd, zijn de celaantallen van de dechlorerende bacteriesoort Dehalococcoides veel hoger dan stroomafwaarts in de pluim waar de concentratie van het organisme zelfs te laag was voor PCR detectie. Toch duiden de batchexperimenten en isotopenanalyses op een geringe omzetting van cis-DCE en VC in de pluim. Er zijn enkele aanwijzingen gevonden voor Corona zones met verhoogde dechloreringsactiviteit in de pluim. De bijdrage van afbraak in deze zones aan de totale verwijdering van verontreinigingen in de pluim kon echter niet worden gekwantificeerd. De resultaten van dit project zullen worden gebruikt bij het opstellen van beslissings- en rekenmodellen en een cursus (vrij beschikbaar op het internet) voor het voorspellen van NA van chloorkoolwaterstofverontreiniging in anaëroob grondwater.

07 What impact and relevance has this project's outcome for practicing soil protection and/or soil remediation? Again, please motivate.

The project results in expertise, guidelines and training courses free available via the internet. These guidelines can be used by consultants, site owners and policy makers to determine the possible usefulness of natural attenuation for a particular polluted site and its plume area. Furthermore,

the project intends to reinforce our confidence in natural attenuation as a remediation strategy.

08 Please list the presentations held in connection to this project
1) Bodemdiep 2003 and 2004, oral and poster presentation
2) EU-CORONA project meetings, 3 times an oral presentation

09 Please list publications (published and submitted) in connection to this project. Please indicate publication took place in either a refereed journal, a non-refereed journal (incl. conference proceedings); whether it was published as a chapter of a book, as a monography or as a dissertation.
1) Luijten, Hoekstra, Gerritse and Slenders, The role of CORONA zones for the natural attenuation of contaminants in deep sub-surface groundwater. Bodemdiep 2nd national scientific soil symposium, 2003, Woudschoten, the Netherlands. p. 4-6.
2) Luijten, Ballerstedt, Slenders, Hoekstra and Gerritse, Expansion of dechlorinating activity from a bioscreen into a chlorinated solvent plume. Soil and water Netherlands Scientific symposium 'Bodemdiep', 2004,
3) Luijten, M., N. Hoekstra, H. Slenders, N. Tuxen, H-J. Albrechtsen, P. Bjerg and J. Gerritse. 2004. Microbial activity – geochemistry distribution patterns at the Brabant and Sjoelund site (EU-CORONA: D21). TNO-report: R2004/467.
4) Luijten, M. and J. Gerritse. 2003. Microbial toxicity protocol (EU-CORONA: D14). TNO-report: R2003/389.
5) Van Heusden, M., M. Luijten, J. Gerritse, H. Smidt and W. M. de Vos, In-situ molecular detection of the dehalogenating potaential and activity, poster presentation, ISME Cancun, Mexico, August 2004.

10 Please list Patent applications or other professional products (including contracts, articles in the popular media, contributions to documentaries or scientific television or radio programs, CD-ROMS, DVD or other (electronic) media).
None

TRIAS

Part II

Detailed information, primarily intended for administrative and statistical use by NWO-ALW

11a Under item 5 you have filled in the main research objectives. Please list all the original research objectives as indicated in the project's application and

both indicate as well as motivate, to what extent these goals were realized, and/or whether the original research objectives had to be adapted.

Within the TRIAS project 2 main research objectives were specified for the PostDoc at TNO. The first objective was to determine whether Corona zones with enhanced biodegradation activity could exist in the plume at the Brabant site. Via the installation of 3 multi level samplers 48 high resolution sampling points (soil and groundwater) were obtained on both meso (50 cm difference) and macro (meters difference) scale. The 48 samples were used to characterize the plume area with respect to geochemical and microbiological parameters. The geochemical data and the microbiological characterization via molecular techniques (DGGE) showed a low diversity between the different samples, indicating that the samples were rather homologues. The presence of the pollutants did apparently not change the geochemistry of the groundwater, or vice versa. Nevertheless, the occasional peaks in H_2 concentration and bio-available iron, and the variation in biodegradation potential in microcosms from different samples from the plume, did correspond to the possible presence of Corona zones in the plume core. Therefore, the initial hypothesis on the existence of patches with enhanced biodegradation activity could not definitely be rejected or verified. The second objective was to characterize the anaerobic reductive and oxidative transformation possibilities at the site. To do so microcosm experiments were started using soil and groundwater samples collected during the installation of the MLS. The microcosms confirmed the potential for aerobic oxidation of VC and cis-DCE and the potential for anaerobic reductive dechlorination of 1,1-DCA, cis-DCE and VC. The oxidative transformation of chlorinated pollutants under anaerobic conditions could not be demonstrated, suggesting that this is not a main natural attenuation process at the site.

Because pollutant degradation was relatively slow, with no clear evidence of Corona zones in the plume, the research focus was shifted to the source area at the site. Here a bioscreen is operated, where reductive dechlorination is stimulated through infiltration of protamylasses. It was found that enhanced reductive dechlorination in the bioscreen corresponded with increased numbers of <u>Dehalococcoides</u> bacteria, responsible for this process. Interestingly, the same bacteria and dechlorination products were also found in groundwater from a monitoring well downstream of the bioscreen, but not (yet) in the wells further down in the plume. This finding suggests that the bioscreen is expanding, resulting in enhanced biodegradation in the plume area.

11b Did the project also include objectives which were not scientific? For instance, did the project also intend to apply research results, or strengthen the economic position of certain businesses?

The overall goal of the project was to get a better understanding of plume development and the occurrence of natural attenuation. Since the results will in the end be free available as web-based courses and guidelines, this

information may help to strengthen the position of natural attenuation as a tool to control plumes. The results of the project are used by the site owner and supervisors to define actions to remediate and/or monitor the pollutants in the plume area.

11c Did the project's aims include the expanding the (international) network of contacts (at what level), providing education, improve communication, serve as input for policy drafting or policy decisions, etc.? Please motivate.
The end product of the EU-CORONA project, to which this TRIAS project is directly linked, will be guidelines and predictive models for site owners and policy makers. Also free available web-based courses and workshops will be produced. These educational aspects will be finished at the end of the EU project mid 2005.

12 Do the results obtained match the original objectives?
Please provide a short motivation why they do or don't.
The results do match the initial objectives in the sense that much of the work originally planned was done. However, pollutant degradation was not fast, with not clear evidence of Corona zones in the plume. Therefore the research focus was shifted to the source area at the site.

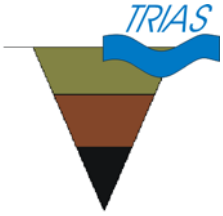
13 Will the results of this project serve as input for an initiative integrating/and or generalizing input from several projects, for instance into a (numerical) model, or into more understanding at the higher/system level? If so, was this intended and optimized from the beginning or did it occur by chance/ spontaneous? Please elaborate.
Yes, the results of this TRIAS project are used in the framework of the EU-CORONA project for the development of guidelines and simple models to forecast the role of natural attenuation in plume development. This was intended from the beginning.

14 To what extent has this research project pointed the way in which further research has to be undertaken? Please motivate the guiding role perceived.
This research project indicated that the process of natural attenuation appears to occur slowly at the studied site. To be able to forecast plume behavior (expanding, stable or shrinking plume?) it is important to assess actual degradation rates in the field. This may be possible by combining more detailed isotope analyses with mathematical modeling. To this end, collaboration has been started with Boris van Breukelen (VU). To further confirm natural attenuation and the existence of Corona zones additional molecular characterization of the involved micro-organisms and their functional genes (e.g. dehalogenases) in the subsurface has to be undertaken.

15 In what way, and to what extent, are the results reached of importance to research done by others? Please motivate or elaborate.

In this TRIAS project different methods have been developed and verified which can be used by others to study polluted plumes in general. Especially the use of MLS to collect detailed pollutant profiles and geochemical and microbiological parameters, the quantitative molecular methods and the stabile isotope fractionation can be used to define natural attenuation processes occurring at various other sites. The integration of the methods used is rather new and can also be of interest for other researchers, consultants and site owners to learn more on their own sites.

16 Are you aware of any essential gaps or obstacles standing in the way of applying the results from your research project? Please elaborate.
Still it is not exactly known why natural attenuation does not occur at high rates in the studied plume. Our results point to very low numbers of responsible micro-organisms. However, the reason(s) why a highly active dechlorinating population has not emerged is (are) not clear. Are the conditions for their activity not at hand or do they first have to be introduced from another location? It is important to find an answer on such fundamental questions to further apply the results from this project.



Part II - continued

Detailed information, primarily intended for administrative and statistical use by NWO-ALW

17 Which new research questions were generated through this project? Were these new questions addressed within this research project itself? Or will these new questions, or the results from your research project lead to new research projects (to be) funded by either 1st, 2nd, or 3rd category funding or funding through international funding agencies? Please elaborate.
Why is only slow natural attenuation ongoing at the selected site? This new question was addressed, but not solved within this TRIAS project.
Under methanogenic conditions 1,1-DCA was converted into CA. Unknown was why no further reduction occurred. In a TNO project with funding from the ministry of economic affairs this question was further addressed.
The new question whether dechlorinating activity can spread from a bioscreen into a plume area was addressed within this research project. A new project with funding from the ministry of economic affairs focusing on this question is now in preparation.

18 In what way did you link this project to other projects within the TRIAS-program or link it to projects outside TRIAS? Did you cooperate within the TRIAS-program and did this cooperation lead to integrated results?
The project was linked to TRIAS project 835.080.007 through combined progress report meetings. Furthermore, actual integration with the subproject of Hauke Smidt and Meta van Heusden within 835.080.007 on research level was achieved. This resulted in cooperation within the research and will lead to joint scientific output.

19 Can you elaborate on the impact on society as a whole of your results (e.g. societal organizations, NGO's, businesses, schools, municipal authorities, etc.)
The results obtained within the TRIAS subproject of the EU-CORONA project will be integrated in workshops, web-based trainings and guidelines that will be freely available. These can be used by different groups/societies that are related to specific polluted areas.

20 What actions were taken to disseminate the results in the direction of the general public, besides the usual scientific channels?
The EU-CORONA project (scheduled to finish in May 2005) will deliver workshops and training courses that will be freely available via e.g. the internet.

21 Have the researchers involved obtained a new position or employment after the project came to an end? Please specify and elaborate!
Dr. Gerritse, Ir. Hoekstra, Ir. Slenders and Dr. Rijnaarts will continue their work with TNO. Dr. Luijten is looking for a new position.

Apeldoorn/Wageningen, December 2004.