COOP-CT-2004-508442

ECOSOIL

INNOVATIVE PROCESS FOR THE ON-SITE DECONTAMINATION OF SOILS

CO-OPERATIVE RESEARCH PROJECT

REPORT

FINAL ACTIVITY REPORT

Period covered from 1st June 2004 to 31st May 2006 Date of preparation: 4th July 2006

Start date of the project: 1st June 2004 Duration: 24 months

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Revision: 1

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1. Publishable executive summary

This test site is situated in the centre of the city of Linköping, Sweden, a town with 135.000 inhabitants 190 km south-west of Stockholm. On the test site is a dry-cleaning facility that has been in operation since the middle of the fiftieth, and is still in use. The property is privately owned by the company Startvätten AB. As dry-cleaning agent, PCE (Tetrachloroethene, also called Perchloroethylene), which is a chlorinated organic compound has been used and still is in use. Due to improper use and inadequate disposal, PCE and its degradation products contaminated soil and groundwater on the site.

The degradation of PCE, a compound with double bond between two carbon atoms ($Cl_2C=CCl_2$), results in several different degradation products: Trichloroethene (TCE), cis-1,2-Dichloroethene (c-DCE), trans-1,2-Dichloroethene (t-DCE), 1,1-Dichloroethene (1,1-DCE) and Vinyl Chloride (VC). All these degradation products are unsaturated aliphatic hydrocarbons with a double bond between the carbon atoms. The degradation products including PCE belong to a group of compounds generally called DNAPL (*dense non-aqueous phase liquids*). The characteristics of DNAPLs are that they have a low solubility in water and are heavier than water. These properties makes the compounds sink through water and through the soil until it reaches impermeable parts of the soil. As a consequence of the low solubility, the compounds can stay in the soil for long periods of time, up to decades, slowly leaking contaminants to the surrounding area.

In a period between 1955-1964, also TCE was used in a smaller amount.

Halogenated hydrocarbons are used for surface cleaning processes in metal industry and chemical laundries as well as for production of paint, glue etc. One can estimate that two thirds of the produced halogenated hydrocarbons are emitted into environment by waste air while one third is emitted by (solid) waste and only 1…3% are emitted by (waste) water. While halogenated hydrocarbons can be found in small concentrations on large area caused by rainwater immission the reason for punctual contaminations can be seen in mistakes during handling and accidents. Increased concentrations were found today only after accidents or in the neighbourhood of landfill sites.

When emitted into soil volatile halogenated hydrocarbons spread out initially in liquid phase, but evaporate into the gas phase very soon. The transport in the two phases depends on the type of soil as well as on the water saturation of the soil. Due to the fact that most of the halogenated hydrocarbons have a higher density than water the vertical transport into the groundwater region is promoted.

Mineral oil has also been found within the area, but the original source of this contamination has not been localised yet. It is assumed, that the oil's source of origin is the car repair shop next to Startvätten. An additional hint may be the fact that Dichloromethane (DCM) was found in the soil as well. DCM is not used in dry-cleaning facilities but is common in metal processing to clean parts and surfaces. In contrast to the chlorinated hydrocarbons described above, oil has a lower density than water and tends to accumulate on the water surface. However, the water solubility is low.

When mineral oil hydrocarbons are detected in soil near or under infrastructure they emanate normally from human activity, either from regular use or from accidents. In these cases they must be considered as non-natural soil compound and need to be removed when a limiting value is exceeded. While the German legislation sets a test value of 200 µg/l for the soil-groundwater correlation respectively for the groundwater, the Polish legislation sets values for the soil itself.

This situation was found right at the beginning of the project, thus it started with an analysis of the site investigating the geological conditions as well as the actual contamination situation.

The geological examination identified a soil composition which is rather difficult to remediate. The top soil layer consists of gravely sand crossed by humus and mixed with brown sand respectively clay down to 0,75 m. The next layer is brown silty sand and silt down to (maximum) 2,0 m, partially crossed by dry clay crust. In 3,0 m depth a very dense silt layer have been found, obviously dividing the groundwater into 2 regions above and below this layer. Below this very dense layer fine sand and silt can be found as well as, partially, dry zones.

The conductivities in the soil layers vary by 3 (!) orders of magnitude, with a maximum of $3*10^{-7}$ around 1,0 m and 6,0 m and a minimum of $2*10^{-10}$ around 3,0 m respectively $1*10^{-9}$ around 1,8 m. One can assume there is an additional dense layer at 1,8 m with the power to divide the groundwater flow into 2 regions, but there was not groundwater found above 2,0…2,5 m. The very small conductivity leads to a very small speed of the groundwater flow and the contamination will move only very slow with the groundwater.

However, the diameter of most of the particles in the relevant areas are in the interval between 10 and 30 µm providing a very great surface where the contaminants stuck on. Thus the decontamination system must provide sufficient power for cracking the binding forces between the contaminants and the particles. In the project an option for providing this power is foreseen.

The contamination analysis delivered an extreme contamination with PCE. Taking into account a limiting value (Poland) of 0,1 mg PCE/kg soil — the maximum concentration found is ~10.000 mg/kg !!! — one can say, the total layer thickness on Startvätten's site is contaminated respectively is exceeding the limiting value. For groundwater the situation is very similar. The limiting value is 10 µg/litre (Germany) respectively 40 µg/litre (Dutch level limits) while the concentrations on-site are far above with a maximum of 13.250 mg/litre (!!!). The high concentrations for PCE and TCE refer to only 4 sampling points[1]: 402, 403, 405 and 407 (soil sample) respectively 409 (water sample).

The other highly volatile halogenated hydrocarbons found in soil and groundwater are the above mentioned degradation products. Beside these compounds DCM was found with increased concentrations in the soil layers close above the very dense layer at 3 m.

The analysis of the different groundwater samples regarding mineral oil hydrocarbons shows that 1 of the groundwater samples exceeds the German test value by the factor ~2 while 1 sample exceeds it by the factor ~58.000 (!!!). In the remaining samples no mineral oil could be found (detection limit: 0,2 mg/l).

The analysis of the soil samples on the other hand identified at least 4 "hot spots" referred to the limiting values in Poland with concentrations above 1.000 mg/kg respectively 6 "hot spots" with a concentration above 200 mg/kg. Emphasis must be placed on the fact that 3 of

[1] Location of sampling points: See Annex

these 4 samples needed to be diluted by the factor 10 (2 samples) respectively by the factor 100 (1 sample).

However, almost 85% of the site has mineral oil pollution below 200 mg/kg. The other 15% of the samples refer to 4 sampling points, i.e. point 402 (2x), 405 (2x), 407 and 409. The highest concentration was found at point 402 in a depth between 2,8 and 2,9 m.

The heavy metal concentrations found in the soil can be neglected due to the very small amount.

Based on the chemical analysis biodegradation test were carried out. In case of chlorinated unsaturated hydrocarbons like TCE and PCE it seems that the only way of biodegradation is co-metabolism – the metabolic pathway with co-substrate. For TCE usually used co-substrates are phenol and its derivatives (e.g. toluene, propane and methane). In some groundwater, PCE undergoes reductive dechlorination (first to TCE) catalysed by anaerobic bacteria that yields VC, a potent human carcinogen. The biodegradation process of TCE can take place both in aerobic and anaerobic conditions, although anaerobic pathways are less well-understood. Only the first enzyme in this pathway has been isolated.

Results of research revealed weak biodegradability of the PCE in the test-site soil. It was about 21%, 47% and 27% after 7, 14 and 21 days after the beginning of experiment, respectively. The bacteria enumeration confirmed the weak biodegradability of PCE. The highest bacterial content was observed on 7th day of experiment (1,3*10^{6} CFU/g of dry soil), but in the next week this number drastically decreased – to about 4*10^{4} CFU/g of dry soil and was at the same level till 21st day.

Finally, biodegradation as a remediation procedure is not any longer one of the priorities within the project, but is kept as one further (additional) treatment step.

The remediation of the site will be done by use of adsorption mechanism. Horizontal drillings will be placed in the soil and filled with so called oil booms, which include sockets filled with sorbents. Thus, an analysis searching for the optimum sorbent was carried out.

Various sorbent materials can be used for the removal of different contaminants from soils. Nowadays the most commonly used are activated carbon, peat and synthetic polymers. In the last years the research efforts have been intensified for the development of alternative materials to replace the use of activated carbon. Available alternatives which were considered to be used were bark, fly ash, limekiln dust, clay materials, sawdust or alumina. During the work "E-clay®" was set to the list of sorbents to be analysed due to its very promising features, so it was decided to test E-clay®, modified pine bark, lignite, fly ash, peat and activated carbon as reference. The standards used as chemical compounds to be adsorbed have been set to: hexane (as the example of aliphatic hydrocarbons), benzene (aromatic hydrocarbons) and TCE (chlorinated hydrocarbons).

Adsorption isotherms were drawn for the three tested sorbents (except fly ash, where results have relatively big errors because of the nature of this sorbent – in water it creates hardly sediment suspension which in headspace method overestimates results). None of examined sorbents appears to be applicable to remove this type of contaminants from groundwater with efficiency comparable to activated carbon. However, lignite seems to be the best among so far examined sorbents. On the other hand fly ash occurred completely useless for the reason of a very low adsorbness. Moreover when it is added to water it makes hardly sediment suspension (due to very small particles). This impedes its application into groundwater.

After finishing this first project phase (analysis and basic results) the project participants **Sytrud** (Sweden), responsible for horizontal drilling, **Lännen** (Finland) as consultant for drilling, **Argus** (Germany) and **Hydrogeotechnika** (Poland) as experts for remediation, **Globe Water** (Sweden) as provider of the ECOSOIL idea, **Envirotreat** (United Kingdom) as provider of E-clay®, **Stadspartner** (Sweden) as the responsible organisation for the test site in Sweden and the RTD performer **TTZ Bremerhaven** (Germany), coordinator and responsible for chemical analysis and hydraulic modelling, **Linköping University** (Sweden) as responsible for geotechnical issues and **Warsaw University of Technology** (Poland) as responsible for biological issues, identified the hot spots on-site and defined the basic drilling procedure. While Styrud, Globe Water and Stadspartner are very active in preparation of the test site (assisted by Linköping University), Lännen, Argus and Hydrogeotechnika provided additional useful information about their own activities (drilling respectively remediation) and helped in particular the RTD performer executing their tasks.

The partner expect to have at the end of the project a remediation system which can easily be adopted to other geological and chemical conditions. The rather weak biological decontamination potential of the soil refers to the contaminations found at Startvätten (mainly highly volatile halogenated hydrocarbons) and will be much better, e.g., on sites with pure mineral oil contamination. Therefore the biological aspect is still kept in the project work as an opportunity.

2. Project objectives and major achievements during the months 6 to 24

The months 6 to 12 were characterised by the lab analyses of the samples taken at Startvätten's site and the characterisation of the sorbents to be included into the ECOSOIL system. These analyses, in particular the determination of the chemical contamination at Startvätten, provide the basis for decision where to drill on the site, and together with older information about the site an estimation about the contamination dispersion is possible.

The chemical analysis was finished during this period and shows, that the main pollutant under the buildings is an highly volatile halogenated hydrocarbon (HVHCs), here Tetrachloroethene (synonyms: Perchloroethylene, Per). It is the typical compound found under laundries. The other HVHCs found are representing the natural degradation of Per except Dichloromethane (DCM), which is a solvent used in metal processing industry.

Beside the HVHCs a serious mineral oil contamination was found in the soil. One can estimate, that the source of DCM's origin is the same as the source of the mineral oil, i.e. a car repair shop formerly on this site, now in the neighbourhood.

The heavy metal concentration in the soil does not exceed "natural" background values and can be neglected here.

Based on the chemical analysis biodegradation tests were executed to check the option of biological decontamination of the soil. This option was taken into consideration before the test site finally was selected. The results show an extreme dependency of the viability of the microorganisms from the concentration. However, after finishing these tests a biological decontamination is not recommended to have first priority, but should be tested after the first treatment step(s).

Sorbents to be included into the ECOSOIL system were tested according to their adsorption capacity. During a technical meeting in Warsaw some sorbents have been selected: E-clay®, a modified clay with special properties, lignite, (modified) pine bark, peat, fly ash and activated carbon as a well known reference material. Due to some problems with the delivery of some sorbents only lignite, peat, fly ash and activated carbon have been tested up to now; the test with modified pine bark and E-clay® will be executed during the following period, i.e. month 13 to 18.

Detailed information about chemical analysis can be found in Deliverable D03 (with 3 annexes). The sorbent material specification is included in Deliverable D05, which need to be completed by a chapter about geometrical data (e.g. specific surface, pore diameter etc.). Deliverable D04 provides information about microbial degradation in the soil.

After the Ecosoil system has been successfully installed at the test site, which was as mentioned situated in the centre of the city of Linköping, Sweden, a town with 135.000 inhabitants 190 km south-west of Stockholm, the system was in used for almost one year. However, the sorbents have been changed over after about 6 month in order to get information on the handling of the system as well as to get the contaminated sorbents analysed in the laboratories of WUT and the TTZ. The following sorbents have been tested and analysed: Modified pine bark, Peat, E-clay and standard active carbon. Active carbon was only used to have a comparable material since active carbon is very well known in market of sorbents.

With respect to the installed equipment as well as the operation and handling of the single components of the Ecosoil system all information can be found in deliverable D13 and D14. All results about the laboratory tests are listed in detail in deliverable D15.

Further more the issue of the reutilisation was investigated. Since the modified pine bark has proven as the best performing sorbent these investigations where only done for pine bark. The results were that for mineral oil hydrocarbons pollution the sorbents could be easily reused after biodegradation under controlled conditions, however, for chlorinated hydrocarbons it wasn't an efficient procedure since they are highly volatile and must be also degraded as a co metabolite by adding other pollutants to the sorbent. All other proposals only show that the poison can only be shifted from one location to another where they will stay. However, if environmental problems with volatile chlorinated hydrocarbons were not taken into consideration and/or a different soil in a different place was not contaminated with those, the sorbents could always be reused with no restrictions.

Since it was realistic that volatile chlorinated hydrocarbons must be taken into consideration at least sometimes further investigations have shown that the only realistic way of getting rid of the contaminated sorbents will be a special waste combustion plant, which has permission for burning such a waste. The estimated cost for burning 1000 kg of contaminated modified pine bark is about 500 euros.

All analytical results about the reutilisation and the waste specification note are shown in deliverable D17 and D18.

3. Work package progress of the period

3.1. Work package 1: Specifications of requirements

3.1.1 Objectives and starting point of work at the beginning of the period

The aim of this work package is to define the technical specifications of the process technology in accordance with the end-users' needs in terms of soil, type and degree of contamination, legal requirements for the final quality of the soil and economical and administrative circumstance.

3.1.2 Progress towards objectives

The first data acquisition could be finished completely by providing background information about the site's history and former contamination analysis. It is now well known which contaminations can be expected in the site's soil.

The geo-technical characterisation of the Swedish test site was done as well, providing information about the site's particle size distribution, water permeability, grain density and plasticity, organic matter content and so on.

The study of soil and groundwater contamination as well as the analysis of microbial degradation in the soil were finished delivering important information for layout of the ECOSOIL system.

The specification of sorbent material was started and meanwhile 4 sorbents were characterised; this analysis is going on and will be finished by month 16.

3.1.3 Deviations from the work programme and corrective actions

During this period the delay in executing work package 1 could be recovered by 95% as it was foreseen in the last Progress Report (Deliverable D19). The remaining 5% refer to the finalisation of the sorbent material specification, which will be done latest by month 16.

No corrective action in work package 1 is necessary to reach the set goals.

3.1.4 List of deliverables

No.	Title	Scheduled month	Status	Date
D01	End user's requirements sheet	2	Delivered	22.11.04
D02	Geo-technical characterisation sheet	4	Delivered	20.12.04
D03	Contamination characterisation sheet	4	Delivered	27.05.05
D04	Degradation specification	7	Delivered	30.06.05
D05	Sorbent materials specifications	7	Delivered	30.06.05

3.1.5 List of milestones

No.	Title	Scheduled month	Status	Date
M01	ECOSOIL system specification	7	Reached	01.06.05

M02	Drilling specification	4	Reached	01.06.05

3.2. Work package 2: System development

3.2.1 Objectives and starting point of work at the beginning of the period

The aim of this work package is to design and manufacture the ECOSOIL system and to choose and set up a drilling method, which creates the adequate infrastructure for its installation on-site.

3.2.2 Progress towards objectives

Most important point is the selection of the appropriate drilling location. Based on the results gathered in work package 1, i.e. chemical analysis of the contamination, soil structure and groundwater flow, the drilling location was fixed to the south-south-west corner of the building and the direction of the drilling towards north-north-east. Should the concrete reinforcement disturb the communication between the steering equipment and drilling head an alternative drilling will be done. For details see Deliverable D07.

The drilling will be carried out by first drilling a pilot hole, where a protection boom will be included. The protection boom carries the later decontamination boom, which including sockets containing the sorbents. In the decontamination boom slits allow the groundwater flow into the boom transporting the contamination towards the sorbents. The slits are covered by a plastic mesh protecting the sorbents inside the boom against particles.

The development of the hydraulic model started with the analysis of the geotechnical characterisation regarding important boundary conditions of the soil, e.g. thickness of soil layers, conductivity inside the layer etc. Based on these analysis a model for Computational Fluid Dynamics (CFD) was set up to simulate the plume dispersion under the building. Up to now the model delivered not suitable results, thus it was decided during the Mid-term meeting to reject this simulation and try to find a solution by using the programme “Mudflow” instead of “CFX”. The simulation with “CFX” goes on to simulate the sorption process near the boom.

3.2.3 Deviations from the work programme and corrective actions

The work on the lab model to verify the results provided by CFD was not started yet. Due to the deviations in executing the simulation it is assumed to finish the work on the hydraulic model by month 16 to 17. This will give enough time for field tests to be carried out in work package 3 and the system evaluation to be carried in work package 4.

However, the lab model will be finished by the same time to guarantee the validity of the assumptions done for setting up the hydraulic model.

3.2.4 List of deliverables

No.	Title	Scheduled month	Status	Date
D06	Drilling drawings	6	Delivered	30.06.05

D07	Drilling protocol	8	Pending
D08	Hydraulic model	7	Pending
D09	Computer simulation report	8	Pending
D10	Lab test report	12	Pending
D11	CAD layout of the system	10	Not started yet
D12	Users' manual	12	Not started yet

3.2.5 List of milestones

No.	Title	Scheduled month	Status	Date
M03	Manufactured system	12	Not reached yet	

3.3. Work package 3: System installation and demonstration

3.3.1 Objectives and starting point of work at the beginning of the period

The aim of the WP 3 is to get the system installed on the test site and to demonstrate its performance under real conditions.

3.3.2 Progress towards objectives

The Ecosoil systems was installed at the test site in the centre of the city of Linköping, Sweden, a town with 135.000 inhabitants 190 km south-west of Stockholm. On the test site is a dry-cleaning facility that has been in operation since the middle of the fiftieth, and is still in use. The property is privately owned by the company Startvätten AB. As dry-cleaning agent, PCE (Tetrachloroethene, also called Perchloroethylene), which is a chlorinated organic compound has been used and still is in use. Due to improper use and inadequate disposal, PCE and its degradation products contaminated soil and groundwater on the site.

The equipment that was required for the installation procedure and the components used for the Ecosoil systems consists of the drill, which is mounted to some kind of carrier system and the lubricant, which has the function of cooling the drill, fixing the walls of the drilled hole and to build up the slurry (lubricant plus soil), which then can be pumped out of the holes.

Further more there are the components of the Ecosoil system. Inside the hole first off all a filter was placed to allow any ground water to drain through on the one hand and on the other hand to secure sufficient space for the sockets filled with the different sorbents. Inside the filters the sockets were used to carry the different types of sorbents. For the tests a socket of 25 meter length was used, which could be pulled in and out of the filters by means of a rope. The sockets are produced from the material Polyproylene. The sockets were filled with the different types of sorbents. Each sorbent took about 5 meter length of the socket.

All detail information about the drill, the lubricant, the filter, the sockets and the main important sorbents used can be found in deliverable D13. Additionally deliverable D06 illustrates the actual drilling work by means of some pictures.

After the Ecosoil system has been successfully installed at the test site the system was in use for almost one year. However, the sorbents have been changed over after about 6 month in order to get information on the handling of the system as well as to get the contaminated sorbents analysed in the laboratories of WUT and the TTZ. The following sorbents have been tested and analysed: Modified pine bark, Peat, E-clay and standard active carbon. Active carbon was only used to have a comparable material since active carbon is very well known in market of sorbents. All results about the laboratory tests are listed in detail in deliverable D15.

3.3.3 Deviations from the work programme and corrective actions

There have been none deviations from the work programme during work package 2. The drilling procedure took longer than expected due to unknown obstacles in the ground. Therefore the final position of the Ecosoil system was not as where anticipated. However, there was no negative influence estimated with respect to the results of the operation.

3.3.4 List of deliverables

No.	Title	Scheduled month	Status	Date
D13	System installation	15	Delivered	???
D14	System operation	15	Delivered	24

3.3.5 List of milestones

No.	Title	Scheduled month	Status	Date
M04	Decontamination of the soil	16-23	Completed	

3.4. <u>Work package 3: System evaluation and validation</u>

3.4.1 Objectives and starting point of work at the beginning of the period

The aim of this work package is to assess the efficiency of the Ecosoil system in removing or decreasing the contamination of the ground, by means of new analysis of the decontaminated soil and groundwater. The results of this evaluation will help to identify necessary modifications in order to optimize the systems performance. Finally, if the technical, environmental and safety objectives are reached, the system will be validated.

3.4.2 Progress towards objectives

The progress towards task 4.1 was the analytical part of the project. On a regular basis samples were taken from the sorbents, the soil and the groundwater. These samples were sent to WUT and the TTZ for analyzing their content of mineral oil and chlorinated hydrocarbons, as well as performing microbiological investigations of micro-organisms inhabiting the sorbents used for decontamination with the Ecosoil system.

The results of all analysis can be found in deliverable D15.

Further more the issue of the reutilisation was investigated. Since the modified pine bark has proven as the best performing sorbent these investigations where only done for pine bark. The results were that for mineral oil hydrocarbons pollution the sorbents could be easily reused after biodegradation under controlled conditions, however, for chlorinated hydrocarbons it wasn't an efficient procedure since they are highly volatile and must be also degraded as a co metabolite by adding other pollutants to the sorbent. All other proposals only show that the poison can only be shifted from one location to another where they will stay. However, if environmental problems with volatile chlorinated hydrocarbons were not taken into consideration and/or a different soil in a different place was not contaminated with those, the sorbents could always be reused with no restrictions.

All information about soil reconditioning, reutilisation of the sorbents as well as the disposal of contaminants/contaminated sorbents can be found in the deliverables D16 – D18.

3.4.3 Deviations from the work programme and corrective actions

Concerning the soil reconditioning it was originally planned to refill the drilled hole after use with the Ecosoil system again with soil. However, during discussions within the consortium a more logical approach was discussed and finally agreed on. This was to cap both ends of the hole off. This would stop any rain water to carry unwanted soil into the boring, which, by time, would than be blocked and therefore not functional for any further use in the future. It also would stop any rats getting into the boring. This method also presents from a financial point of view the highest efficiency, even more since a hole left behind empty does not implement any dangerous situation concerning the stability of the ground itself. "Soil reconditioning" by capping both ends off was the best alternative, if any further actions are expected to happen as e.g. testing other sorbents, using new sorbent for further decontamination, and well possible controls through official organisations.

Other than that there have been no further deviations from the work programme.

3.4.4 List of deliverables

No.	Title	Scheduled month	Status	Date
D15	Real tests report	24	Delivered	31.06.06
D16	Soil reconditioning	24	Delivered	31.06.06
D17	Study of reutilisation of the sorbents	24	Delivered	31.06.06
D18	Study of reutilisation/disposal of the contaminants	24	Delivered	31.06.06

3.4.5 List of milestones

No.	Title	Scheduled month	Status	Date
M05	Validated system	24	Reached	31.05.06

SCHEDULING OF TASKS (ORIGINAL PLAN) – MONTH 12 TO 24

Calendar year and month	2005							2006				
	6	7	8	9	10	11	12	1	2	3	4	5
Project month	13	14	15	16	17	18	19	20	21	22	23	24
System installation & demonstration												
Task 3.1: System installation												
Task 3.2: System operation												
System evaluation & validation												
Task 4.1: Performance evaluation												
Task 4.2: Reconditioning of soil & reutilisation of materials												

SCHEDULING OF TASKS (UPDATE) – MONTH 12 TO 24

Calendar year and month	2005							2006				
	6	7	8	9	10	11	12	1	2	3	4	5
Project month	13	14	15	16	17	18	19	20	21	22	23	24
System installation & demonstration												
Task 3.1: System installation												
Task 3.2: System operation												
System evaluation & validation												
Task 4.1: Performance evaluation												
Task 4.2: Reconditioning of soil & reutilisation of materials												

4. Consortium management

The project coordination was performed by Umweltinstitut on a daily basis. The friendly and productive atmosphere led to a successful work in the project's different tasks, in particular the close cooperation between the partners from the same geographic area was impressive. However, the information flow in between the partners was ensured by use of usual media systems.

To strengthen the personal contact and to guarantee the transfer of project data and knowledge, several meetings were held at the sites of the partners. With this partner visits at the site of the SME and RTD performers, the projects' progress and the potentials of every single partner was reviewed on a regular basis.

A technical meeting was held in Warsaw in the beginning of February 2005, where actual results were discussed and further orientation of the project work fixed, e.g. type of sorbents to be analysed. Delays and a new work plan was discussed to be as close as possible to the originally scheduled work.

The Mid-term meeting, done in Berlin in the beginning of June 2005, does not fall into the reporting period but will be mentioned here as well. During the meeting the partners presented their work and could be seen very clearly that most of the delays could be recovered up to the end of the first year.

The second technical meeting was held in Linköping, Sweden on the 14th of February 2006. During the meeting the last remaining tasked of the project were planned. It also was agreed on another tests series with fresh sorbents in order to get comparable results toward the end of the project.

The final meeting took place in Berlin on the 23rd of May 2006. All results from the second year of the project were presented. Further management aspect as e.g. use of knowledge, dissemination and cost statements were also presented and discussed.

5. Other issues

5.1. Contribution of the RTD performer to assist the SME in solving their problems

The first project year was characterised by data acquisition regarding the contaminants in the soil and the options to remove them. Therefore the main work carried out in this first phase was done by the RTD performer. The SME assisted them by providing infrastructure and equipment for carrying out the work.

The table below will give a summarised overview about the work of the RTD performer done for the SME. Detailed information can be found in the deliverables.

	TTZ Bremerhaven	Linköping University	Warsaw University of Technology
Group 1 — Drilling			
• Styrud • Lännen		- Providing information about geological conditions (soil layers, conductivity particle size distribution etc.) to improve drilling technique	
Group 2 — Execution of remediation			
• Argus • Hydro-geotech-nika	- Characterisation of contamination in the soil, allowing optimum selection of remediation strategy - Providing information about potential sorbents (geometry)		- Providing information about potential sorbents (physical properties) - Providing information about application of biological remediation methods
Group 3 — Provider of adapted remediation tools			
• Globe • Enviro-treat	- Characterisation of contamination in the soil, allowing optimum selection of remediation strategy - Characterisation of contamination in the soil, allowing optimisation of E-clay® - Providing information about sorbents (geometry)	- Providing information about geological conditions (soil layers, conductivity particle size distribution etc.) allowing selection of suitable tools for selected remediation strategy	- Providing information about sorbents (physical properties)

Group 4 — Owner of abandoned land			
• Stads-partner	- Characterisation of contamination in the soil, allowing optimum selection of remediation strategy	- Providing information about geological conditions (soil layers, conductivity particle size distribution etc.)	- Providing information about potential for biological remediation

While the collection of information and data acquisition took place in the first year of the project, the second year was rather characterised by onsite work, sample collection/preparation and laboratory analysis. While all the system installation and operation work was performed by the SME partner, did the RTD partner focus on the analytical part of the work.

The table below will give a summarised overview about the work of the RTD performer done for the SME. Detailed information can be found in the deliverables.

	TTZ Bremerhaven	Linköping University	Warsaw University of Technology
Group 1 — Sample provider			
• Styrud • Lännen • Stads-partner	- Provider of groundwater samples and sobent samples for analysis (see Group 3) - Support during system evaluation	- Installation of the Ecosoil system by means of drilling the hole fit the filters, sockets and sorbents, including the choice of best lubricant .	- Provider of groundwater samples and sobent samples for analysis (see Group 3) - Support during system evaluation
Group 2 — Execution of remediation			
• Argus • Hydro-geotech-nika	- Support during analysis of the LHCW and MKW of the ground water and soil samples	- Support during analysis concerning any interferences of the used lubricant to the sockets	- Supply of sorbents (modified pine bark, E-clay, active carbon) and filling of sockets - Substitution of sorbents during system operation
Group 3 — Provider of adapted remediation tools			
• Globe • Enviro-treat	- Supply of sorbents (modified pine bark, E-clay, active carbon) and filling of sockets - Substitution of sorbents during system operation		- Supply of sorbents (modified pine bark, E-clay, active carbon) and filling of sockets - Substitution of sorbents during system operation

5.2. Balance of work/resources

The following tables will give a summarised overview about the balance of work and resources done by each partner.

	Work carried out	Resources made available
Styrud	Execution of drilling procedure Installation of Ecosoil system Execution of system operation Support during sample preparation	*Personnel*: Engineer, technicians *Material*: Ware of drill, protectors for pipe, lubricant, filters *Equipment*: Drilling rig

Argus	Assistance in chemical and biological analysis Selection of suitable sorbents	*Personnel*: Scientific staff *Material*: Consumables for lab tests
Globe Water	Development of sockets for sorbents Development of E-clay® Definition of basic capabilities of the ECOSOIL system	*Personnel*: Scientific staff
Hydrogeotechnika	Definition of basic capabilities of the ECOSOIL system Selection of suitable sorbents	*Personnel*: Engineers, technicians *Material*: Consumables for lab tests *Equipment*: Lab equipment (GC)
Stadspartner	Assistance in sampling Development of sockets for sorbents Preparation of test site	*Personnel*: Engineer, technicians *Material*: Sockets, material for site preparation
Lännen	Assistance in geo-technical characterisation of the soil Definition of basic capabilities of the ECOSOIL system	*Personnel*: Engineer
Envirotreat	Development and analysis of E-clay® Preparation of granular E-clay® for on-site application	*Personnel*: Scientific staff, lab staff *Material*: E-clay®, consumables for E-clay® preparation and modification *Equipment*: Machines for production of granular E-clay®
TTZ Bremerhaven	Chemical analysis of soil and water samples Analysis of sorbents by application of REM Preparation of hydraulic model for simulation	*Personnel*: Scientific staff, technicians *Material*: Consumables for chemical and REM analysis, *Equipment*: CFX, lab equipment (GC/ECD and GC/FID, AAS, REM, dryer, particle size analyser)
DWES	Assistance in getting soil and water samples Analysis of geological conditions	*Personnel*: Scientific staff, assistants *Material*: Consumables for PLFA and particle analysis, tubes for ground water sampling, consumables for sampling, hydraulic map *Equipment*: Particle size analyser, Darcy apparatus
WUT	Analysis of biological degradation of contaminants Characterisation of sorbent properties (e.g. isotherms)	*Personnel*: Scientific staff, assistants *Material*: Consumables for biological analysis and determination of adsorption isotherms *Equipment*: Lab equipment (OxiTop, GC/FID, shaker)

Annex I: Startvätten pictures

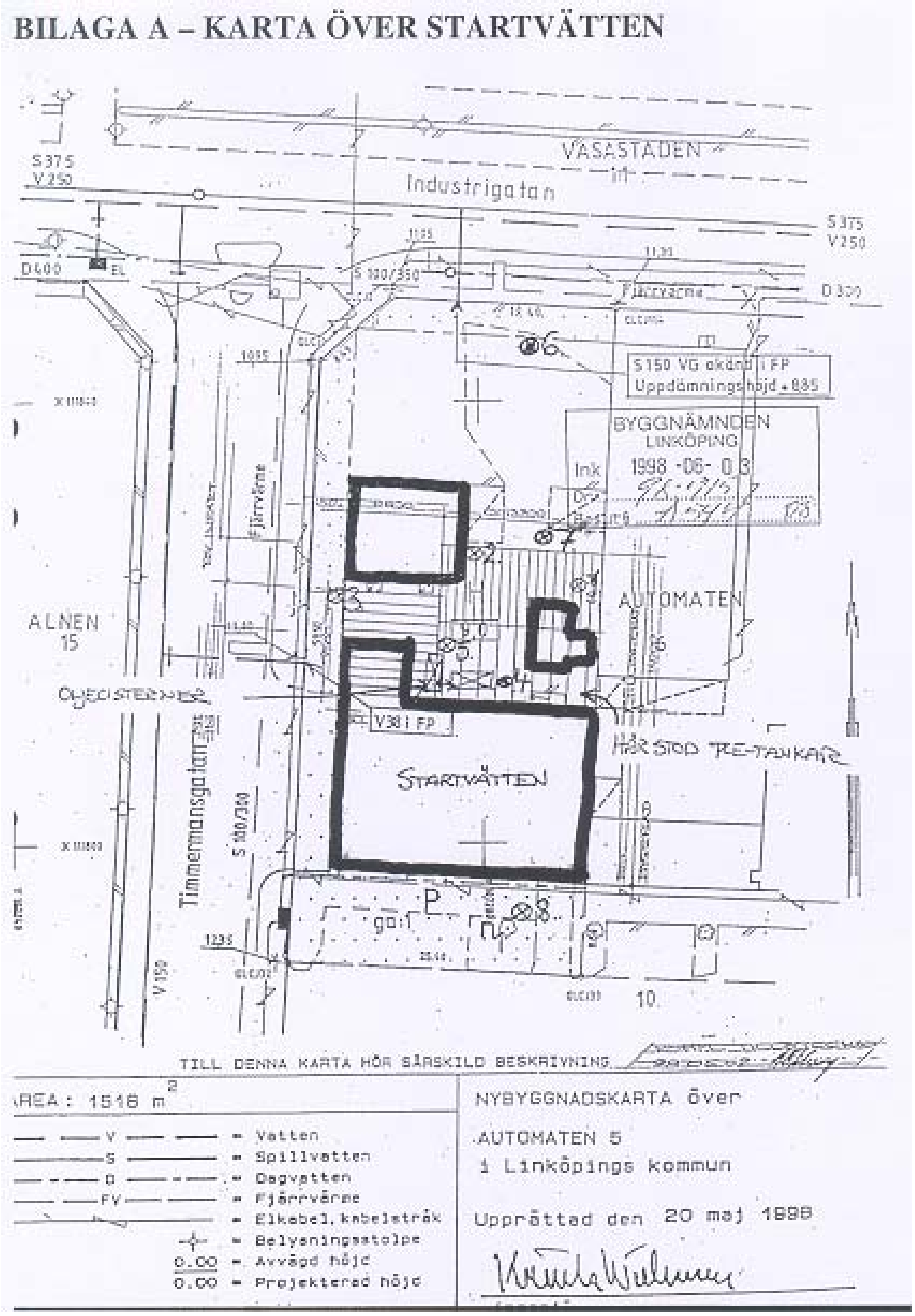

Figure 1: Startvätten overview (old layout of the factory)

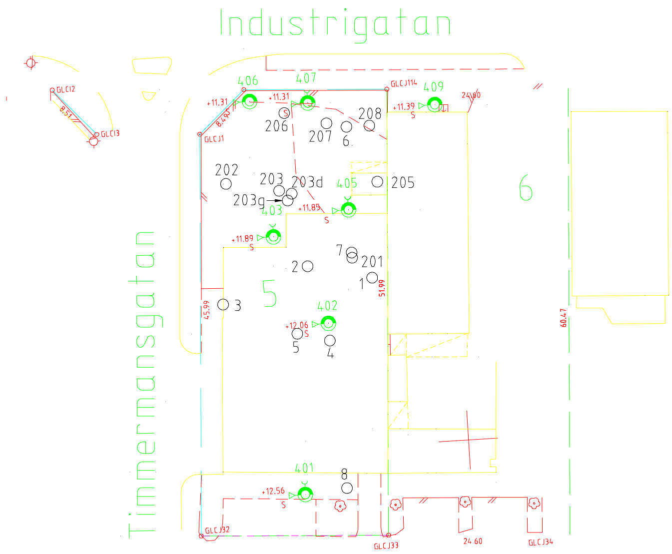

Figure 2: Startvätten – new layout

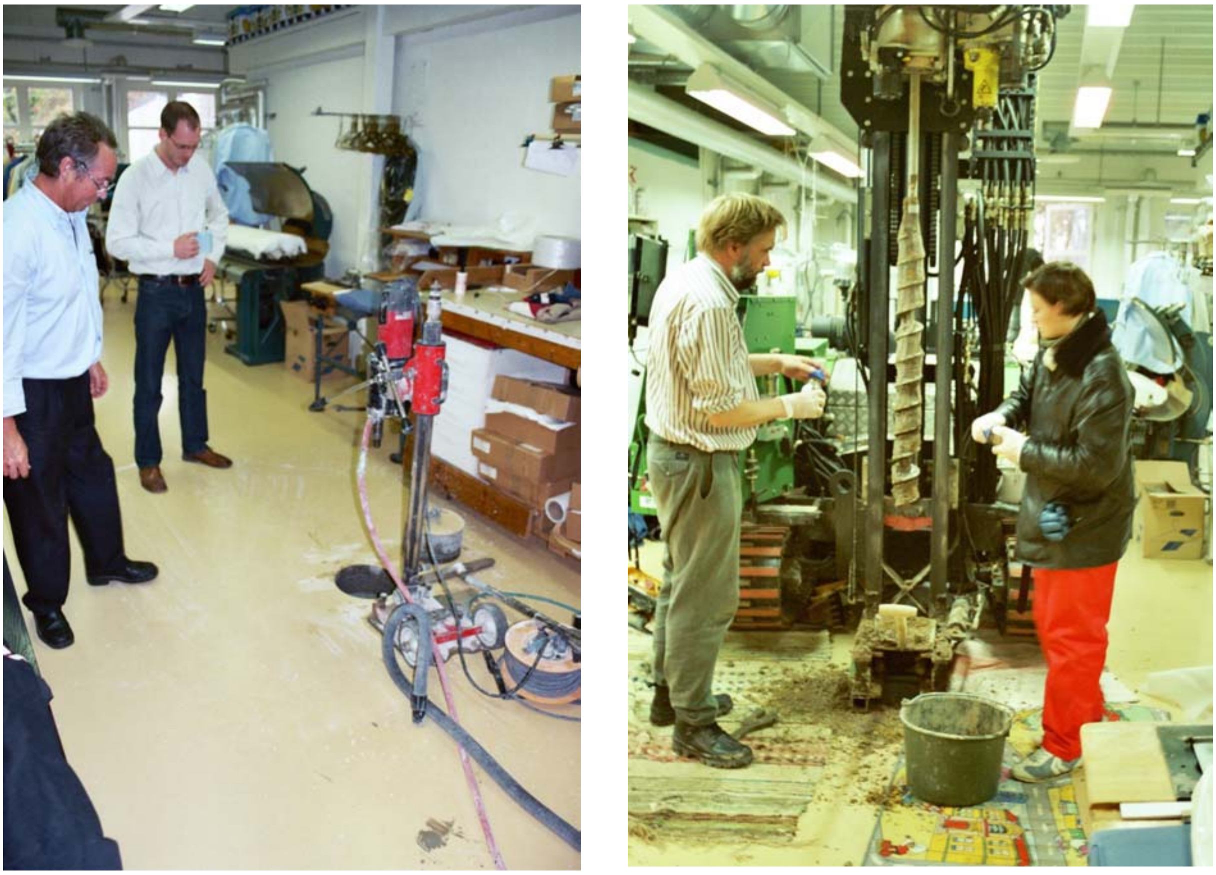

Figure 3: Drilling and sampling inside the factory (location 402)

Figure 4: Groundwater with oil layer

Figure 5: Modified pine bark after three month use in Ecosoil system

Annex II: Plan for Using and Dissemination of Knowledge

Section 1 – Exploitable Knowledge and its Use

This section is presenting exploitable results, defined as knowledge having a potential for industrial or commercial application in research activities for developing, creating or marketing a product or process or for creating or providing a service.

No.	Exploitable knowledge	Exploitable products or measures	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
1	New sorbent	Granular E-clay	Process engineering, chemical engineering, soil remediation	2006…2007	A material patent is pending	Envirotreat
2		Process for E-clay granulation		2006…2007	A patent is planned as soon as technical requirements completely known and fixed	
3		Modified pine bark		2006…2007	No IPR action planned	
4	System for sorbent containment	Socket for sorbents	Soil remediation	2007…2008	A trademark right is planned for 2006	Stadspartner, Globe Water
5	System for soil remediation	ECOSOIL process	Soil remediation	2006…2007	A trademark sight exists	Globe Water, Styrud, (Envirotreat)

1) and 2):

Granular E-clay is a modified clay mineral in granular form with capabilities for adsorbing ions in liquid media. It was developed by company Envirotreat Technologies Ltd.. The application in granular form is quite new and was never tested on other sites or in other applications.

The field tests in the ECOSOIL project will provide more detailed information about the behaviour of granular E-clay in soil remediation processes. It may result in an adaptation of the granulation process or in modification of the E-clay itself – this can not be foreseen now.

Envirotreat will produce and distribute granular E-clay by them selves.

3):

The field tests in the Ecosoil project have shown that modified pine bark has the biggest potential with respect to absorption of volatile organic compounds. Also on the cost side it seems to be one of the most competitive products on the market. The product itself as well as the required treatment to produce this sorbent are well known and controlled, a growth in used should therefore be of no problem.

4):

The socket developed is a containment e.g. for granular E-clay and other potential sorbents. It is similar to a hose but can be flown through by water respectively liquids. Sockets are connect to each other by Velcro mechanism, so lengths up to 800m can be reached. The socket is introduced in the pipe placed in the bore hole. Then the socket can be drawn into the pipe via a rape. The socket was developed by Stadspartner and Globe Water and these two companies will be responsible for the further distribution.

Up to now it is not possible to make any statement about further development – within the upcoming field tests the sockets must demonstrate their capabilities.

5):

The overall ECOSOIL process consists of the technique for horizontal drilling, the introduction of porous pipes in the soil and the placement of the sockets filled with sorbent (e.g. granular E-caly). Styrud as expert for horizontal drilling and Globe Water as the owner of the IPR of the ECOSOIL method will be responsible for the distribution.

The remediation of Startvätten site in Linköping is a demonstrator where interested parties may see how the ECOSOIL system will work. A first commercial contact was made (new headquarter of IKEA in Helsingborg) for application of the ECOSOIL system to an other site, but it was agreed to wait until the tests in Linköping are finished.

Section 2 – Dissemination of Knowledge

Planned / actual dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
June 2005	Project web-page	General public, Research, Industry, Authorities	Industrial countries		Globe Water, Stadspartner
17th November 2004	Oral presentation	Research, Authorities	Sweden	40	DWES
17th June 2005	Oral presentation	Umweltamt	Potsdam, Germany	2	ARGUS
14th-16th September 2005	Lois symposium	Community interactions	Uppsala, Sweden		DWES
27th September 2005	Oral presentation	Admenistrative senate	Berlin, Germany	15	ARGUS
3rd – 7th October 2005	Conference	Scientists, local authorities, SMEs	International		WUT
9th December 2005	Oral presentation	Bodengesellschaft	Wünsdorf, Germany	2	ARGUS
27th-29th April 2006	International conference	Industry	Poznan-Puck, Poland		Hydrotechnika
6th-7th June 2006	International exhibition	Geological, Industrial	Warszawa, Poland		Hydrotechnika
End of project	Dissemination Flyer	Potential industrial user	Countries of consortium members		TTZ
End of 2006	International conference	Science and technology	Houston, Texas, USA		DWES
After end of project	Ecosoil part on ttz web-page	General public, Research, Industry, Authorities	Industrial countries		TTZ

The project web page is actually designed for information of the public and will give later on more detailed information about the project itself and the applied technique. It is not foreseen to have a restricted user area (mainly for the Consortium), but addresses will be given where interested parties, either public, authorities, industry or research, can ask for more information.

A 5 min presentation of the project will be given at the *Geotechnical Research Day* (“Geoteoknisk forskardag”). This is conference arranged by the Statens Geotekniska Institut (SGI) will be done in November this year in Linköping.

Dr. Niebelschütz from ARGUS visited the “Umweltamt” (Ministry of Environment) in Potsdam, Germany. In the audience were the two main responsible persons in the ministry. They were informed tasks of the ECOSOIL project.

A poster was presented by DWES at "Chlorinated solvents and microbial community interactions in soils" that was based on the preliminary results of the concentrations of the contaminants and microbial populations present within the same soils. The poster was presented at the Focus on Soils symposium, 14-16 September 2005 in Uppsala.

Dr. Niebelschütz from ARGUS gave a presentation in front of 15 people about soil decontamination at the “Senatsverwaltung für Stadtentwicklung und Umweltschutz“, Berlin, Germany. The presentation included topics from the ECOSOIL system as it was operating in Sweden.

A dissemination activity WUT participated in was the ConSoil Conference in 2005 9th International FZK/TNO Conference on Soil/Water-Systems ConSoil 2005 - looking for partners, available sorbents, potential users of the technology.

Dr. Niebelschütz from ARGUS gave a presentation about the tasks of the Ecosoil project at the „Brandenburgische Bodengesellschaft für Grundstücksverwaltung und –verwertung“ in Wünsdorf, Germany. First results from the project as well as entire technology were explained to the experts of the ministry.

Dissemination via posters and leaflets took was performed by Hydrogeotechnika on the 20th - 29th of April 2006 - XII International Conference Reclamation and revitalisation of demoted areas, Poznan-Puck, Poland,

Another dissemination activity of Hydrogeotechnika took place on the 6th – 7th Juni 2006 - IV-th International Geological Fair, Warszawa, Poland.

The consortium of the project agreed on having a dissemination flyer. This flyer is not a normal project type of flyer but will show the components of the functional Ecosoil systems as well as some of the results gained during the project. This flyer is meant to be used as an advertising brochure to convince potential customer to use the Ecosoil system.

An abstract "Chlorinated solvents and microbial community interactions in soils" was accepted for an oral presentation at the International conference on environmental science and technology 2006 in Houston, Texas.

Section 3 – Publishable Results

During elaboration of task 1.1.2 and 1.1.3 analysis of phospholipid fatty acids (PFLA) were executed. Results obtained from these PLFA-analyses are being statistically processed and will constitute the basis for an article to be published in a scientific journal later this year. The PLFA data will be compared to the results that already have been obtained and reported in Deliverables No. D02 and D03 (Geotechnical characterisation and Contamination characterisation). This compilation will be done by Linköping University (DWES).

Since the absorption results gained form the pine bark tests were quite promising Sturyd is planning to design an “Ecosoil – Advert – Flyer” which then can be used with their standard advertisement brochures to sell the Ecosloil system.

Annex III: Deliverable and Milestone List

No.	Name	Work package No.	Date due	Actual/ forecast delivery date	Lead contractor
D 01	End-users' requirements sheet	1	31.07.2004	22.11.2004	Stadspartner
D 02	Geotechnical characterisation sheet		30.09.2004	20.12.2004	DWES
D 03	Contamination characterisation sheet		30.09.2004	27.05.2005	UWI
D 04	Degradation specification		31.12.2004	01.06.2005	DWES
D 05	Sorbent materials specifications		31.12.2004	01.06.2005	WUT
D 06	Drilling drawings	2	30.11.2004	30.06.2005	Styrud
D 07	Drilling protocol		31.01.2005	30.06.2005	Styrud
D 08	Hydraulic model		31.12.2004	31.10.2005	UWI
D 09	Computer simulation report		31.01.2005	31.10.2005	UWI
D 10	Lab tests report		31.05.2005	31.10.2005	UWI
D 11	CAD layout of the system		31.03.2005	31.08.2005	Globe
D 12	Users' manual		31.05.2005	31.08.2005	Globe
D 13	System installation	3	31.08.2005	10.06.2005	Styrud
D 14	System operation		31.08.2005	31.08.2005	Globe
D 15	Real tests report	4	31.05.2006	31.05.2006	UWI
D 16	Soil reconditioning		31.05.2006	31.05.2006	Argus
D 17	Study of reutilisation of the sorbents		31.05.2006	31.05.2006	WUT
D 18	Study of reutilisation/disposal of the contaminants		31.05.2006	31.05.2006	UWI
D 19	Progress report 1	5	31.12.2004	20.12.2004	UWI
D 20	Progress report 2		30.06.2005	30.06.2005	UWI
D 21	Progress report 3		31.12.2005	31.12.2005	UWI
D 22	Progress report 4		31.05.2006	31.05.2006	UWI
D 23	Plan for using and disseminating knowledge – DRAFT		30.06.2005	30.06.2005	UWI
D 24	Plan for using and disseminating knowledge – FINAL		31.05.2006	31.05.2006	UWI
D 25	Mid term review report		31.07.2005	31.07.2005	UWI
D 26	Final report		31.05.2006	31.05.2006	UWI

No.	Name	Work package No.	Date due	Actual/ forecast delivery date	Lead contractor
M 01	ECO-SOIL system specifications	1	31.12.2004	01.06.2005	Globe
M 02	Drilling specifications		30.09.2004	01.06.2005	Sytrud
M 03	Manufactured system	2	31.12.2004	31.07.2005	Globe
M 04	Decontamination of the soil	3	30.09.2005 - 30.04.2006	30.09.2005 - 30.04.2007	Argus
M 05	Validated system	4	31.05.2006	31.05.2006	*consortium*
M 06	Mid term assessment report	5	31.07.2005	31.07.2005	UWI
M 07	Final review		31.05.2006	31.05.2006	UWI