

## Research & Development managed & originated by Drs. Ben Keet

Subject ( <b>most recent first</b> )	Aim	Status / Interim Results
1. Research leachate reduction of boron salt by adding clays to top soil	- Even minor addition of clays with a high CEC could reduce penetration of boron to groundwater	Soil columns made to test leachate throughput using different clays, clay and boron concentrations
2. IHRIS system for substrate dozing in groundwater	- Develop automatic dozing system with reduced chance on well-impairment	Pilot-testing of manual operated system succesfull: programming of IHRIS control system planned
3. Improved horizontal drain placement system	- Place near horizontal drains and filters without soil permeability reduction	Pneumatic sonic system tested and modifications planned before next full scale project
4. Increase CO <sub>2</sub> binding capacity of soil during in-situ remediation projects	- Reduce CO <sub>2</sub> emission during biodegradation projects	Several CO <sub>2</sub> binding processes identified; stimulation in pilot-study ongoing
5. QC-software for anaerobic degradation	- Develop software - hardware to improve quality and steering capacity of anaerobic VOCl biodegradation	Preliminary sensorarrays functional and with software implemented in substrate injection project
6. AP04 fast leaching test	- Reduce processing-time of leaching test, past of AP04 protocol	Ultrasonic leaching columns made; analysis show close comparison with standard tests
7. Steamstrip simulator	- Realistic in-situ steamstrip simulation on lab-scale for more reliable steamstripping experiments	Lab set-up designed, in cooperation with Technical University Twente (The Netherlands)
8. Heterogeneity profiler to determine micro-flow zones (<5 cm) continuous over 100 m deep profiles	- Dual CPT mounted probe can rapidly scan for high migration zones around municipal landfills, contaminated sites etc.	Prototype with tracer test tested. Discussions with development partners started
9. GHCD membranes can be used to remove Nitrate from drinking water BEFORE it is pumped from the aquifer.	- Reversing the groundwater remediation principles of anaerobic remediation nitrate can be removed from groundwater by dosing minor amounts of food-grade hydrocarbons. To avoid overdosing this can be done with a diffusion system.	The Geo & Hydro Controlled Delivery membranes are very well suited to this purpose.  Several drinking water supply companies like to participate in the project.
10. Remediate domestic heating oil -tanks for € 5.000,- all-in?	- Using smart sensors and simple remediation systems which utilise natural forces as wind and rain, reliable miniature remediation systems can be applied to remediate serious heating oil contamination in gardens etc. for the current cost for garden reinstatement.	System operational. Cost depends on scale of application

11. ZERO energy remediation	-	Introducing ZENS systems (Zero ENergy Sanering) to the Dutch remediation market is one of the new SKB proposals of Geo & Hydro.	More then 10 techniques are available: difficulty is that actually no-one has a benefit from these techniques except the (un-knowing) customers
12. Smart Sensors can feed dataloggers information not normally measurable with chemical sensors	-	Smart sensors are in fact automated mini laboratories. BOD or anaerobic nitrate consumption-rate are two of the many remediation variables which can be measured with smart sensors.	Using intelligent dataloggers these data can used as input to control complex aerobic / anaerobic groundwater remediation systems.
13. In-situ Steam destilation pilot project to remove migration-sensitive components from deep DNAPL layers	-	In-situ steam destilation of DNAPL layers situated below the groundwater table on impermeable clay layers has the potential for significantly reducing the leachable components. Light mono aromatics and naphtalene can thus be removed leaving only a heavy tar residue.	Feasibility study completed
14. Verification protocol in-situ remediation projects	-	Risk-based, toxicological, or value-based clean-up targets need well defined, statistically sound verification protocols. A consortium of experts chaired by Geo & Hydro will undertake the production of a 'cook-book' protocol which result in a program distributed on CD-ROM	Workshop in preparation of this study has been held. A pilot project is launched by the Prov. of Utrecht. First draft of guidelines written. 1 year contract for writing 2 <sup>nd</sup> opinion reports of SP's
15. Multi Point Porewater Sampler (under water)	-	Development of rapid porewater sampler for ecotoxicological research of underwater soils for the evaluation of the need for dredging canals and lakes.	Design and make (support for further development obtained from several waterboards, awaiting add. funding)
16. Application of interfacial and partitioning tracers to determine mass of DNAPL contamination	-	The application of 2 - 4 different tracers simultaneously allows mass determination of free DNAPL in the saturated zone. Intermediate or terminal 'sink-layers' can thus be quantified and remedial projects better evaluated.	The study (for 40% a lab parameter characterisation and 60% a field trial in 3 sedimentological settings) is being discussed with parties at present.

17. Nutrient flux in the smearzone	- Micro-porous cup sampling at 5 cm interval reveals nutrient and electronacceptor transport in the smearzone, which allows quantification of biological activity in the capillary fringe zone.	Method using rhiosphere samplers succesfully applied
18. Unsaturated zone gas-flux determination to quantify natural attenuation in 'smear-zone' and influence of meteorologic variations.	- Fully computerised set-up linked to sample ports in a 6 meter deep measurement 'well' of 1.2 m diameter. Numerous sondes are hydraulically pushed horizontally up to 3 meter from the observation well. For low voltage sensors (such as the x, y, z soil-air velocity sensors) amplifiers are placed at the different floors in the well.	Study complete, soilgas-probes, as well as x,y,z soil air velocity sensors successfully developed and integrated in study of natural attenuation in the 'smear-zone'.
19. Development of groundwater flow velocity and directional sensor.	- CPT mounted probe. Through use of microwave heating very quick response time resulting in continuous log of grw flow speed and direction.	Prototype with simpler heat source tested. Discussions with development partners started
20. CDT distillationssystem (patent applied for in 48 countries): 2 x 20 ltr. pilot operational	- Low energy, low temperature distillation for solvent rec., pharma-use and water prod.	As solvent recovery, perfume production, wastewater minimalisation and low cost water prod. system
21. Optimalisation of fully automated SVE / Bioventing test instrument which allows soil air pressure built-up and transient analysis to be made	- Detect inhomogeneties in soil, boundary conditions for soil vapour modelling and optimise full scale installation in respect to X, Y and Z directional soil air flow down to mm/min.	Using microbar-sensitive pressure transducers and 32 channel PC dataloggers with 10 msec recording speed several sites have been tested (sensitivity sufficient to record passing trucks!)
22. Development of in-situ Fe (III)-Fe(II) and NO <sub>3</sub> reduction tracking system	- Serves as feedback system for the remediation of less permeable sediments and layers within aerobic settings	Trial system in place to test efficiency of Fe(III)NO <sub>3</sub> injection in silts and peat to optimise anaerobic degr. below a zone of aerobic (sparging) degradation.  Improvements currently being made on 2 <sup>nd</sup> & 3 <sup>rd</sup> site
23. Development of 16 channel automated soil vapour sampler and GC-TCD mol-sieve analyser	- Assess vapour and gas (O <sub>2</sub> /CO <sub>2</sub> /N <sub>2</sub> O/H <sub>2</sub> S/CH <sub>4</sub> ) movements through unsat. zone to predict nat. att. in saturated zone	Application operational jan 1998. In use in MoD research project coupled to meteo station with 3D wind turbulence meter.
24. Development Innovative Solvents (for extraction to allow analysis of soils and water) and PHCs Recovery Systems	- Reduce influence of Humic Compounds  - Recycling of Solvents and PHCs	Research funded partly by Department of Defence; further funds being sought  Patent applied for while application and Improvements ongoing

25.	Improve radius of influence GHCD membrane biofence system	- Field trial to influence width of in-situ flow-cell.	Pilot-trial with auxiliary sandfilled side-holes currently underway in Smilde, Drente NL.
26.	Improve In-Situ O <sub>2</sub> - diffusion tracking device	- Surveys as feedback sensor for aerobic in-situ remediation projects.	Status: operational. Trials running at two sites: Deventer: passive aerobic remediation using (MgO <sub>2</sub> ) Capellen: active aerobic remediation in clay using HP bioventing and Fe-lignosulphanate to open clay bonds
27.	Development of Software to Assess the Duration In-situ Remediation Techniques	- Assess the Costs and Design of an In-situ Remediation System	Application and Improvements ongoing
28.	Development of Remote Control Systems for In-situ Remediation Systems	- Cost Reduction towards Maintenance and Trouble shooting; - Fast Optimisation of the Systems, prototype IHRIS	Application at a site in Luxembourg (Capellen) and at a site in Holland (Ter Apel) ongoing
29.	Development of On-site Treatment of Contaminated Groundwater and Soil	- <u>Cost Reduction towards:</u> Treatment of Contaminated Groundwater and Soil; - Reduction of Energy Consumption; - Reduction of the Emission of PAHs and Noise; - Reduction of the Transport of Soil	Application of a Ground-water Treatment System at a site in Luxembourg (Schengen) ongoing; Evaluation of the Environmental Impact of a New Soil Treatment System completed (mercury, oils, /PAHs)
30.	Development of an Innovative Technique to Determine the BOD of a Water or a Soil Sample	- The BOD (Biological Oxygen Demand) of a Water or a Soil Sample is an important Indicator of the Activity of the Biodegrading Micro-organisms	Application now standard and has been auto-mated with PC data acquisition software, however improvement of the measuring system ongoing
31.	Determination of the Diffusion Rate of Oxygen dissolved in the Saturated Zone (Technique developed by Geo & Hydro)	- Determination of the Feasibility of Sparging in low permeability layers to stimulate biodegradation of PHCs in the Saturated Zone	Application with respect to sites in Holland (Ter Apel, Diemen) completed; results comparable with calculated Diffusion Rates, used as feedback system with full-scale sparging projects
32.	Determination of the ration between <u>primary</u> and <u>secondary</u> Hydraulic Conductivity of a Layer of Clay (Technique developed by Geo & Hydro)	- Determination of the Risk of Migration of BTEX and PHCs through a layer of Clay - Application at Luxembourg Airport and a depot on-going	Application with respect to a depot site in Luxembourg (Bertrange) completed; results comparable with results obtained by a classical elaborate technique

33.	Study of the Migration of Floating Layers in the Smear Zone	<ul style="list-style-type: none"> <li>- Selection and Design of a Suitable Technique for the Removal of a Floating Layer</li> <li>- Study of effects of pre-saturation (full-scale = 150 m) of migration path completed</li> </ul>	Application and Research of the use of tensiometers pre-saturated with hydrocarbons at a site in Belgium (near Brussels Airport) ongoing
34.	Determination of the Influence of Humic Substances upon the Analysis of PHCs in Soil	<ul style="list-style-type: none"> <li>- Make a better Distinction between PHCs and Humic Substances in Soil</li> </ul>	Research ongoing (based on White Rot Fungy project for Shell Australia in 1992)
35.	Stimulation of the Conversion of BTEX, PAHs and PHCs into Humic Substances	<ul style="list-style-type: none"> <li>- <u>Reduction of the Risk of Migration</u> of BTEX, PAHs and PHCs in the Unsaturated and Saturated Zone</li> </ul>	Research ongoing (Department of Defence finances part of this research)
36.	Development of Soil Separation Techniques	<ul style="list-style-type: none"> <li>- <u>Cost Reduction towards:</u></li> <li>- Treatment of Contaminated Soil</li> </ul>	Research on Hydro-dynamic Separation of Contaminated Fractions of Soil and laser analysis of fractions ongoing
37.	Treatment of mercury contaminated soil	<ul style="list-style-type: none"> <li>- Evaluation of suitable techniques and liaison for acceptability for use in Luxembourg</li> </ul>	Positive evaluation from third party laboratory has led to 'in principle' acceptance.
38.	Development of Portable Measuring Systems	<ul style="list-style-type: none"> <li>- <u>Cost Reduction towards:</u> Treatment of Contaminated Soil and Groundwater; Analysis of Soil, Soil Air and Groundwater Samples; Determination of the Standard Deviation of Analysis Results;</li> <li>- Rapid Optimisation of On-site Treatment Systems for Contaminated Soil and Groundwater</li> </ul>	<p>Classifying of Soil and Groundwater ongoing;</p> <p>Application of Organic Vapour Analysers ongoing</p> <p>Statistical Analysis ongoing;</p> <p>Application at a site in Luxembourg (Schengen) ongoing; a site in Belgium (Verlaine) ongoing; sites in Holland (Woudenberg / Soest/Maarn) ongoing</p>
39.	Quantifying Natural Attenuation and biodegradation bottlenecks	<ul style="list-style-type: none"> <li>- Determination of the Degree of Biodegradation, Diffusion and Dilution of PHCs resulting in a Natural Decrease of Concentration of PHCs</li> </ul>	Several studies ongoing: examples: an AFB site in Holland (Soesterberg) is being the least confidential, 4 for an international paint manufacturer and 3 for an oil multinational
40.	Geo & Hydro Controlled Delivery (GHCD) System consisting of a flat membrane incorporated in a drainage system	<ul style="list-style-type: none"> <li>- Stimulation of the Bio Degradation of PHCs by Controlled Dosage of Nutrients (N/P)</li> </ul>	Research ongoing in conjunction with large manufacturer of non-woven synthetics

41. Geo & Hydro Controlled Delivery (GHCD) System consisting of cylindrical membranes, with or without an in-well groundwater circulation pump.	<ul style="list-style-type: none"> <li>- Optimisation of aerobic Bio Degradation of Petroleum Hydrocarbons (PHCs) by Controlled Dosage of Nutrients</li> <li>- Stimulation of anaerobic Bio Degradation of Petroleum Hydrocarbons (PHCs) by Controlled Dosage of electron-acceptors</li> <li>- Through fluid-fluid extraction removal of DNAPL layers on deep impervious layers</li> </ul>	<p>Applied as a remedial technique at sites in Holland: BP Eindhoven, Air Force Base Soesterberg, Transport depot Ter Apel;</p> <p>To be applied as a controlling technique to prevent migration (Biofence) at a site in Holland: old steel melter in Hengelo(O)</p>
42. MPRS recovery system	<ul style="list-style-type: none"> <li>- Automated intrinsically safe fuel recovery system. Patented Us Aus etc. Applied Sydney, Luxembourg, many sites in The Netherlands</li> </ul>	Operational
43. Vacuum controlled double wall fuel tanks using flexible liner over permeable layer	<ul style="list-style-type: none"> <li>- 1989 developed leak detection system for underground fuel storage tanks based on flexible coating on permeable liner.</li> </ul>	Commenced patent but dropped due to economics. Product later appeared on market as the Perma-Tank