Remediation Technologies

- Reactant infiltration and -injection
- Pump-and-treat, reactant circulation
- AirSparging, methane-biostimulation
- BIOXWAND-technology, direct gas injection
- Carrier-gas-based reactant injection
- Mesothermal and high-temperature treatment
- Surfactant mobilization
- Aerobic and anaerobic biostimulation methods
- ISCO / ISCR
- Immobilization techniques for heavy metals

Environmental Biotechnology: Reactants, Microbial Compounds

- Permanganate, persulfate, peroxide
- Molasses, lactate, glycerol, emulsified vegetable oil
- Dehalococcoides spec.
- Contaminant degrading cultures

PERFORMANCE-KNOWHOW/ EXPERIENCE

Laboratory Analysis / Process Analysis

- Bio degradation analysis
- Process identification and -quantification
- Reactant selection
- Migration analysis
- Bioaugmentation
- MNA-analysis

Sensor Technology

- Aquifer-integrated (AISK), measuring-point-integrated (MISK)
- Remote access
- Redox potential, conductivity, temperature, dissolved O2, pH
- Ion selective electrode
- Pressure, hydraulic gradient
- Gas saturation sensor technology

Drilling Technology

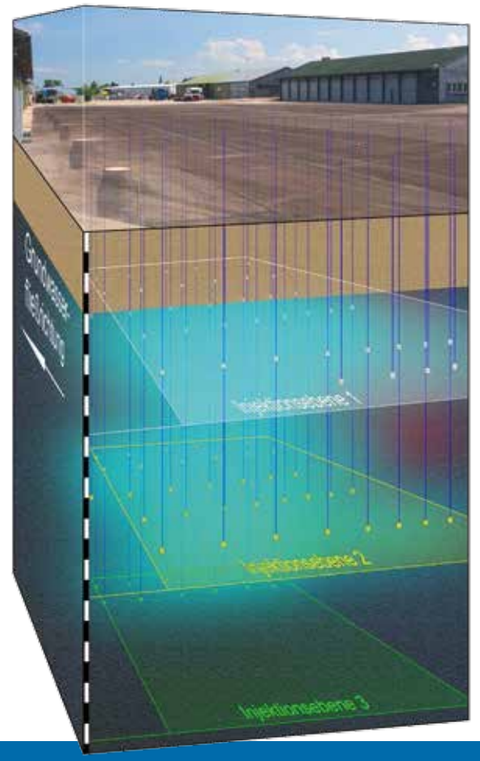
- Percussion drilling, hollow stem auger drilling, direct-push-sampling, sonic drill
- Groundwater sampling
- Soil vapor sampling
- Monitoring gauge
- Injection gauge
- Infiltration gauge
- Gas lance
- Multilevel systems
- Multifunctional gauge

Sensatec Ltd. provides sophisticated technologies for contaminated site analysis and remediation. Furthermore, it offers intelligent sensor-based environmental monitoring systems. With more than 300 successful reference projects, Sensatec belongs to Germany's market leaders in in-situ groundwater remediation services.

We are highly dedicated to providing products and services of very good quality. This includes being highly committed and providing reliable service as well as closely collaborating with our clients and customers. It is our corporate management's and all of our staff's obligation to understand and satisfy our customers' needs.
Our collaboration with our clients is based on mutual respect, trust, close cooperation and open discourse. We commonly strive to create healthy and safe working conditions and successful project outcomes.
Continuous service and procedure improvement and development ensures that our products and services remain highly competitive on the global market. Our working procedures are constantly analyzed and optimized, minimizing process malfunction and avoiding hazardous working situations and injuries.

RESPECT COOPERATION TRUST

The interdisciplinary **Sensatec** team is comprised of process technicians, engineers, biotechnologists, hydrogeologists, soil scientists and geologists as well as electrical and environmental protection engineers, among others. Our outstanding performance in both implementing technical environmental remediation measures and successfully managing contaminated sites results from interlinking both technical and scientific know-how with interdisciplinary thinking. Currently, we are working on app. 150 remediation projects, several research projects and numerous feasibility studies.
Together with our partners from distinguished research institutes, we are working on creating innovative and powerful new environmental remediation technologies.



The only economical remediation technique for large-scale subsurface soil and groundwater contamination is making use of natural self purification capacities.

Sensatec possesses the necessary comprehensive expertise for analyzing, optimizing and making technical use of natural pollutant degrading microorganisms.

Successfully utilizing methods to trigger natural self-purification mechanisms can only be achieved in an interdisciplinary team of biotechnologists, geologists, hydrogeologists, process technicians and geochemists.

Exactly this is Sensatec´s strength.

Underground drinking water reservoirs plays an important role in meeting future needs for freshwater supplies. Due to pollution these drinking water resources have partially been rendered useless. Sensatec has developed efficient methods, such as the patented BIOXWAND technology, for restoring these resources and effectively protecting them from new contamination. This lasting method aims at shielding drinking water protection areas from inflowing contamination by removing contaminants in bioreactive, underground zones. This remediation technology is designed to suit the needs of long-term protection goals, with its high efficiency and its minimal requirements for reactants and energy.

Contact person:
Frank I. Engelmann, Fehrbellin

phone *++49 (0) 33932 60 912*
mail *f.engelmann@sensatec.de*

In-Situ REMEDIATION INVISIBLE TECHNOLOGY

DRINKING WATER BioxWand O_2

In-situ methods can only fully develop their high potential, if the contamination site is properly managed and specific site characteristics are taken into account. These are evaluated using

- Biotechnical monitoring (bioactivity, bacterial counts, biomass analysis, biomolecular evidence, biotoxicity screenings, among others)
- Automated, sensor-based in-situ monitoring (e.g. spatially monitoring reagent fronts in aquifers, the intensity of biological uptake processes, reaction speeds)
- Geohydraulic and geochemical analyses (e.g. detection and temporal analyses of aquifer gas storage, geohydraulic process analysis, considering concomitant geochemical processes)

Gas storage technology BIOXWAND, Pat. DE102004001802 – Clean gases or gas mixtures are stored in the pore space of the soil matrix, forming permeable gaseous reactor curtains.

Upon contact with inflowing, contaminated groundwater, the reactants change phase and are chemically and microbially degraded passing through a multi-level in-situ flow-through reactor.

Specially designed gas injection lances, aquifer-integrated sensors as well as spatially integrated monitoring elements are used for gas injection and for detecting, monitoring, and balancing the injected reactive gas concentrations. For purposeful gaseous wall management, reactants are injected based on their consumption, which is derived from a geological structure model, including site-specific pressure and volume flow rate regimes.

Feasibility Studies Process Analysis LABORATORY

Our **process analysis laboratory** in Kiel is focussed on implementing feasibility studies of environmental remediation projects. These studies aim at significantly increasing remediation projects' prospect of success by acquiring site-specific data on microbial and chemical degradation processes as well as crucial project data on accompanying reactions.

Common questions:

- Are microbial degradation processes present at the particular site and could microbial degradation potentially be accelerated?
- Which local limiting factors restrict biological degradation?
- Could chemical oxidation (ISCO) degrade the measured contamination and how large is the expected reactant consumption?

Contact person:
Eike Sophie Winkler
phone *++49 (0) 431 389 00 912*
mail *e.winkler@sensatec.de*

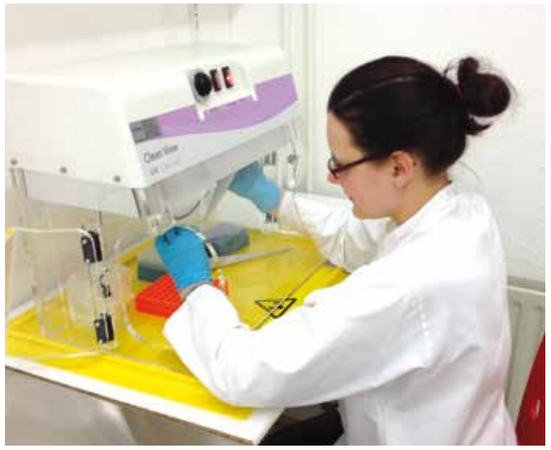
We offer the following analytical methods:

- Complete biotechnological feasibility studies on contaminant degradation in groundwater, soil and waste water
- Microbiological analyses (specific bacterial counts, cell counts, microbial metabolic capacities, physiological analyses)
- Microorganism cultures with specific contaminant degradation abilities
- Implementation of ISCO feasibility studies, Soil Oxidant Demand (SOD), solid phase buffer response, reactant consumption computations
- Reactant migration analyses / contaminant dispersion scenarios in column and channel systems

Molecular Biology vcrA Augmentation

Biomolecular Laboratory

Today, biomolecular analyses allow for delivering reliable answers for recurrent questions on how to successfully treat chlorinated hydrocarbons contamination. These comparably inexpensive biomolecular analyses cost many times less than the high expenses associated with an unsuccessful in-situ remediation project.
Using qPCR on environmental (soil and groundwater) samples, the key genes necessary for completely dechlorinating chlorinated hydrocarbons (CHC) vcrA and bvcA are quantified.



Contact person:
Mark Zittwitz, Berlin
phone *++49 (0) 30 8094 1576*
mail *berlin@sensatec.de*

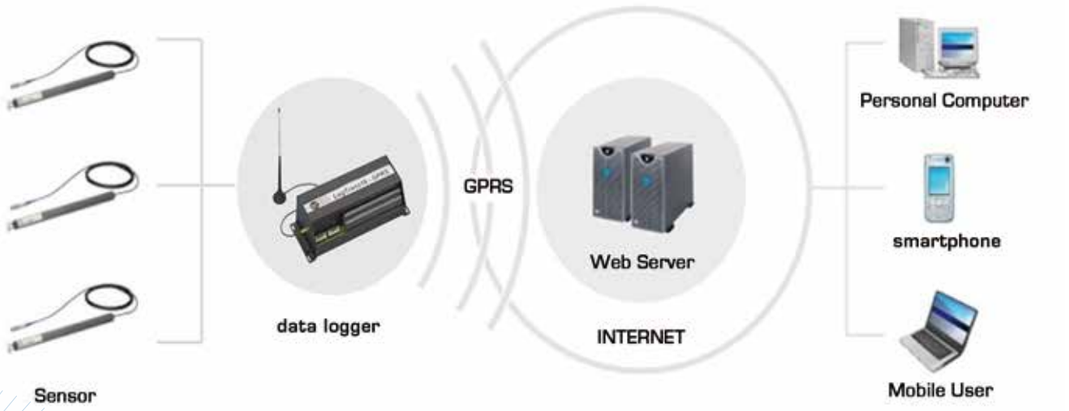
Sensabac – Bioaugmentation of CHC Impacts on Groundwater

Sensatec has systematically analyzed the self-purification potential of hundreds of contaminated sites. In this study, the most effective microorganisms capable of degrading contaminants were isolated and cultivated for further future events of damage. The new product is called **Sensabac**:
Laboratory microorganism cultures with high chlorinated hydrocarbon (CHC) degradation potential. Depending on local contamination characteristics, a contamination-specific laboratory culture can be amplified and injected as a highly concentrated solution. Microorganism culture quality is controlled using biomolecular analyses of enriched gene copies, encoding the enzyme systems responsible for degradation. Laboratory and field studies have shown that bioaugmentation can significantly contribute to complete dechlorination. Detailed knowledge on the applied microorganisms' degradation capacities guarantees an efficient, less time-consuming and highly economical remediation process.

The efficient control of environmental impacts requires thorough knowledge of relevant underground process dynamics. Added reactant degradation and dispersal processes, microbial processes and migration dynamics need to be recorded precisely, in order to physically control and properly manage all procedures applied. Very often, it is only possible to precisely capture processes using online-sensor techniques. For this reason, **Sensatec** has been using in-situ sensor techniques right from the start and has acquired comprehensive knowledge in this field, assisting in highly efficient and economical environmental impact remediation procedures.

IN-SITU-SENSORS	DETECTION
Redox potential **(Eh)**	Aerobe or anaerobe conditions, reactant dispersal detection, ISCO processes
Temperature **(T)**	ISCO reaction temperature or biological specific heat generation
Oxygen content **(O_2)**	Oxygen content (O2) Free oxygen in groundwater, oxidation fronts, oxygen transport during gaseous wall technology application
pH value **(pH)**	For instance, biological acidification during anaerobe treatments, pH decrease during Fenton's reaction, pyrite oxidation in oxidation processes
Conductivity **(EC)**	Increase in dissolved salts, e.g. during pyrite oxidation
Pressure **(p)**	Pressure increase with chemical gas formation during groundwater ISCO reactions, temporal ground water gas injections dynamics
Selective ion sensor	E.g. for tracer tests: chloride (Cl), bromide (Br), nitrate (NO_3)

Groundwater Remediation Sensor Technology Redox Infiltration Circulation PDI



Making Maximum Use of Chemical Processes For Contaminant Removal

Natural purification processes are not always able to remove contaminants from soil or water. In such cases, chemico-physical processes can be used for support or in replacement.
Chemical oxidation processes enable removing highly toxic underground pollution, allowing natural (biological) purification processes to take on the remaining pollution at low costs.
Chemical reduction processes are also able to eliminate certain organic contaminants from groundwater flow. Given specific conditions, these processes are even able to efficiently immobilize and remove mobile heavy metals from water.

In-Situ Biological Reduction (ISBR) and In-Situ Chemical Oxidation (ISCO) Using Actively-Controlled Circulation Cells

During in-situ chemical oxidation dissolved contaminants are degraded via chemical-oxidative pathways. Peroxide, persulphate or permanganate are the oxidants applied. A prerequisite for effective contamination degradation is direct contaminant exposure to infiltrated reactants. Actively controlled horizontal and vertical circulation cells are necessary for extensively dispersing reactants. Circulation cell installation requires conveyor, infiltration and monitoring elements as well as the respective industrial equipment for groundwater purification, substrate dosage, distribution and infiltration. Equipment operation follows a cyclic routine, containing pulse infiltration, dispersal and incubation cycles that are controlled by an in-situ conductivity sensor (measuring oxygen dispersal).

Microbial Compounds
Fermentation Laboratory

Contaminant-Degrading Microorganism Isolation, Enrichment, Optimization and Maintenance From Environmental Samples

Our **microbiological laboratory** in Cologne, Germany, is specialized on contaminant-degrading microorganism isolation, enrichment, fermentation and commercial propagation. Microorganisms that are naturally abundant in soil samples and that are able to degrade certain contaminants are cultivated in controlled laboratory environments. These degradation specialists are selectively grown and enriched under optimal growth conditions for further use in our biotechnological remediation procedures. Subsequently, mixed culture bulk stocks are produced in bioreactors.
This enables us to preserve the respective specialist culture for different contaminant groups and to strategically implement them if necessary.

Near-surface soil contamination of up to 2 m depth can be efficiently removed using extensively-applied soil treatment procedures. Land farming or soil bio piling are examples for suitable procedures. Sensatec possesses a wide array of technical skills and deep knowledge on widespread soil contamination treatments in both temperate and extreme climate conditions.

Our company holds a comprehensive microbial culture collection, containing species with specific degradation abilities from all over the world, e.g. oil-degrading microorganisms from desert soils (Kuwait) and extremely salt-tolerant PAH-degraders from Libya and South America.

Drilling Technologies
Probing MLP

We are in command of tested and proven sophisticated **drilling and injection technology**. Especially in the case of in-situ remediation, it is crucial that the injection system is customized according to the aquifer's complexity. We offer the following system component for meeting these demands:

- Multi-level injection systems
- Pressure-resistant, oxidant-resistant fluid injection systems
- Profiler probe
- Delivery and installation of in-situ sensor technology
- Gas lance construction
- Implementation of injection wells

Sensatec is equipped with comprehensive knowledge on both the application of displacement drilling, hollow stem auger drilling and sonic drill technology.

Contact person:
Dirk Meyer, Köln

phone *++49 (0) 2204 97 26 12*
mail *d.meyer@sensatec.de*

Railroad Ballast Remediation

In the course of running railroad operations railroad ballast is contaminated by oil spills at engine stops. Specially-designed and adapted microorganism cultures remove organic inputs, such as motor oil, diesel or hydraulic fluid from railroad ballast and foundation.

Your advantages:

- Undisturbed railroad operation
- Neither railroad nor track bed deconstruction nor new constructions necessary
- Economic method, disposal costs do not apply
- High degree of flexibility, i.e. no need stationary extensions

Contact person:
Stephan Hüttmann, Kiel

phone *++49 (0) 431 389 00 90*
mail *info@sensatec.de*

Perfluorinated carbon compounds (PFC) are environmentally-hazardous substances that are particularly abundant in fire-fighting foam, textiles, household goods and many industrial products. Since they bioaccumulate in the human body, they pose a particulary high threat to humans. To date, there's no practical in-situ means of removing PFC's from groundwater. The only applicable method of treating PFC-contaminated groundwater, as it may be necessary after major fire extinguishments, is its extraction and subsequent purification using adsorption techniques (pump-and-treat strategy). Sensatec offers innovative sorption materials for PFC decontamination, reducing costs by more than 50 % in comparison to conventional techniques that traditionally apply activated coal. Potential cost saving can be identified and quantified by means of analyzing site-specific, geochemical precipitation processes. The treatment as such consists of coupling industrially-proven water purification steps, i.e. coagulation, flocculation and contaminant sorption among others. Sensatec offers laboratory analyses as well as innovation sorption material.

Environmental Remediation in Extreme Climate Conditions

Contaminant elimination in soils in extreme climate conditions presents challenges to both materials and process technology. Sensatec and its international partners have specifically developed technologies to deal with such tasks. Their particularly resource-friendly methods focus on

- Low water demands due to circulation systems
- Coupling with wind and solar energy requiring only minimum energy demands
- Minimal reactant use
- Deployment of site-friendly biotechnology
- Maximum utilization of local resources

PFSA Sorption Energy Contaminants

Drilling Cutting Crude Oil

Besides PFC's, other environmentally-hazardous compounds have just started gaining attention and are thus coined emerging contaminants.

These include stabilizers for chorinated solvents, e.g. trichloropropane and dioxane among others. These substances can potentially be highly toxic, creating discussions on introducing thresholds in the nanogram range. Even so, microbial processes can most often brake down these substances co-metabolically. Sensatec has both the expertise to identify adequate degradation conditions in the laboratory as well as the capability and experience necessary for technically implementing large-scale treatment measures for purifying affected aquifers.

A precondition for successful contaminant elimination strategies is deep knowledge of the local site conditions, contaminant situation and implementation of site-specific feasibility studies. A good data basis and successful test series allows us to offer performance-based fees for remediation services. This practice offers maximum prospects of project success at high cost certainty, allowing successful large-scale soil contamination reduction and elimination worldwide.

SENSAGUARD

SensaGuard is an innovative, modular monitoring system for detecting contaminants in water cycles. The system's heart is a SensaGuard biomonitor, equipped with software for online data evolution retrieved from 8 biosensors.
Gammari (Gammarus Pulex) are used as indicator organisms in specially-designed sensor chambers. SensaGuard's modular system allows for adapting to highly variable, sensitive water systems even in decentralized supply networks. Unexpected water

contaminations can be detected using nonspecific measuring methods. This SensaGuard system offers a high degree of certainty and practicability.

Permanent Biosensing

www.sensaguard.de

Fields of Application

Water works: raw water and drinking water, supply network. **Wastewater treatment plants:** bacterial culture protection. **Water protection:** water quality measurement stations. **Dams, swimming holes:** water quality monitoring for blue algae toxins. **Industry:** raw water for industrial production or rather industrial waste water.
Science/laboratories: additional expansions to reference water companies

System Characteristics:

- Modular monitoring concept – adaptable to different applications
- Non-optical measuring principles – not disturbed by turbid water/ biofilms
- High sensitivity and non-specific monitoring – continuous biological water safety monitoring
- Indicator species Gammarus Pulex (invertebrate water organisms) - high toxicological sensitivity, robust und easy to culture, trained personal not necessary
- Adaptive alarm threshold – automatic adaptation, reducing false alarm frequency
- Fully-automated, economical operation – low maintenance requirements and energy demand
- Comprehensive IT package, data storage and transmission
- Low spatial requirements and easily operated with touchscreen and/or keyboard

Contact person:
Rolf Mainz, Kiel

phone *++49 (0) 431 389 00 90*
mail *r.mainz@sensatec.de*

PARTNERS

Automotive industry & transport sector	DB AG, VW AG, Daimler AG
Mining, land reclamation	LMBV, Brandenb. Bergbauamt
Chemical industry and distribution	Brenntag, Biesterfeld, Dow Chemical, Lehmann + Voss
Industrial production	Carl Zeiss AG, OTIS, Airbus, Siemens
Military real estate	GMSH (STOV), US Army, BBG
Petroleum industry	Shell, Mobil Oil, Oiltanking, Tanquid, Total, BP
Public entities	Dresden, Duisburg, Bremen, Hamburg, Kiel, Berlin, Potsdam
Project development, real estate developers	DIAG, DIBAG, KiWi, EGNO, S-Immo, Deutsche Annington, Gesa, Kaufland
Public transport	DB Netz AG, BWG Reimer
Insurance agencies	Axa, Gerling, Gothaer, Provinzial
Water companies	Berliner Wasserbetriebe, div. Stadtwerke
Energy suppliers	Vattenfall, RWE
Research	BTU Cottbus, TU Dresden, CAU Kiel, EMAU Greifswald, FH Osnabrück, GFI Dresden, TZW Karlsruhe, TU Berlin, UFZ Helmholtz-Zentrum