



# Innovative In Situ Treatment Technologies for Soil and Groundwater

## IEG Groundwater Circulation Wells™ for In Situ Remediation

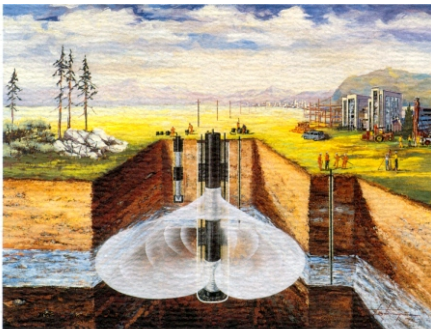
### Pump and Treat v Innovative In Situ Methods

The conventional approach for remediating contaminated groundwater has been to extract the contaminated water, treat it above ground, and reinject or discharge the clean water ("pump-and-treat"). It has become increasingly apparent that pump-and-treat methods require considerable investment over extended periods of time, and that they have been proven inadequate in many cases. In many cases, they do not actually clean up the source of groundwater contamination.

In situ treatment technologies for contaminated groundwater are now considered to be fundamentally more efficient, cost effective and are significantly more sustainable alternatives to pump-and-treat.

### Groundwater Circulation Well™ Technology

Groundwater Circulation Well™ technology (GCW™) is applied to treat halogenated solvents, semi-VOCs (SVOCs), pesticides, and petroleum products and their constituents such as benzene, toluene, ethylbenzene, and xylene (BTEX). It has been applied to a wide range of soil types from fine silty clay to coarse sandy gravel.



Rendering by Leslie R. von Pomeroy

### Artist's 3-D Impression of a Groundwater Circulation Well™ in Operation

This low energy technology is designed to run continuously with only routine monitoring and maintenance, and usually has no moving parts below ground and no complicated components. The process can remove contaminants continuously from groundwater without abstraction, avoiding the need for an abstraction licence or handling contaminated water above ground. The technology does not require reinjection wells, discharge consents or costly disposal fees. The contaminated vapours generated in the process are more easily removed and treated above ground than in contaminated water.

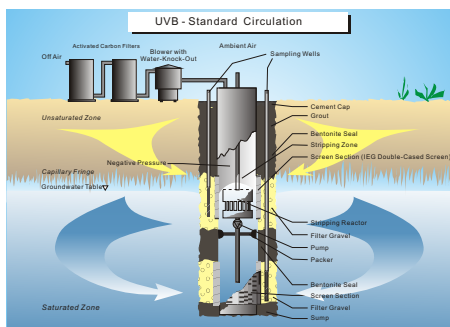
Groundwater Circulation Wells™ can be used in conjunction with other in-situ process methods such as bioaugmentation, enhanced natural attenuation, bioventing, soil vapour extraction, reactive nanoparticle dehalogenation, in situ denitrification and chemical oxidation.

Engineering decisions regarding the application of GCWs™ must take into account that this technology is site-specific. If the system is not properly designed or constructed, the contaminant plume may spread beyond the radius of influence or the wells may become clogged.

GCWs™ with at least two screened sections are universally applicable remediation tools. They are employed in several techniques, e.g. GZB™, UVB™, SZB™. These different techniques can be combined with an appropriate in-well or on-site method. Their hydraulic flow regime can be used to support biological degradation in the aquifer. Moreover, the controlled addition of nutrients and/or electron acceptors for stimulating bioremediation processes is possible when the groundwater passes through the well. The vertical circulation flow and transport regime around UVBs™ and GZBs™ has been the subject of continuing numerical and field investigations at the University of Karlsruhe in Germany.

### The UVB™ Technology

UVB™ technology provides for accelerated and aggressive in situ groundwater and soil remediation. The UVB™ offers several variations for the treatment of adsorbed, dissolved volatile organic hydrocarbons (VOC) and semi-volatile organic hydrocarbons (SVOC), as well as chlorinated solvents via a combination of both physical and biological processes.



### Schematic of a UVB™ System

During operation, the groundwater level rises in the upper section of the well due to reduced atmospheric pressure and a support pump, slightly increasing the total hydraulic head in the well. A significant hydraulic pressure is produced, forcing groundwater horizontally into the aquifer. Atmospheric air enters the well through a fresh air inlet connected to patented in-well labyrinth stripping reactor and creates a pressure equilibrium. The incoming fresh air forms bubbles as it jets through the pin hole plate of the stripper and mixes with the influent groundwater. Contaminant mass is transferred from the water phase to the air phase and rises adiabatically as expanding bubbles, which burst and release the volatilised contaminants. The contamination is then transported

by the dry air flow to a patented high efficiency IEG Granular Activated Carbon Stripper™ (IEG GACS™) unit or other appropriate off-gas treatment system such as a conventional package catalytic oxidation system.

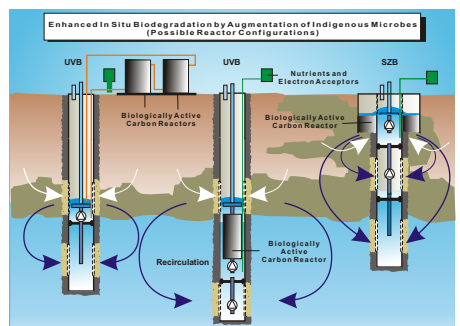
The pressure gradient between the two screen sections induces a circulation flow in the aquifer. The groundwater moves through the treatment zone both horizontally and vertically before entering the influent screen. Groundwater flows into the lower screen to compensate for the water removal from the upper section (UVB Standard Circulation™). The direction of flow can be reversed by reversing the direction of the pump (UVB Reverse Circulation™).

Thus, a three-dimensional groundwater flow field pattern develops. These flow dynamics and the dimensions of the capture zone, circulation cell, and release zone can be calculated using design aids based on numerical simulations of the groundwater hydraulics.

### UVB™-Enhanced Bioremediation

Another advantage of the UVB™ system is that groundwater is oxygenated to saturation point as it passes through the stripper in the well, which enhances the population growth of the indigenous microorganisms in the aquifer, thus accelerating the biodegradation process. Consequently, UVB™ technology is especially suitable for eliminating biologically degradable contaminants from groundwater without having to pump the groundwater to the surface.

The UVB™ produces a vertical groundwater circulation cell in the aquifer around the remediation well. The circulating groundwater constantly transports both contaminants and naturally-existing contaminant-degrading bacteria to the well. When flowing through an in-well bioreactor, contaminants are adsorbed onto the matrix material inside the bioreactor, at the same time as bacteria settle in the same area. If necessary, the accumulated microorganisms can be supplied with additional nutrients to enhance the process.



### IEG Systems for Enhanced Natural Bioremediation



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System variations include discontinuous circulation flow, reversing the circulation direction, and installing different bioreactor configurations. These variations enable the technology to be easily adapted to the requirements of different groundwater contamination scenarios.

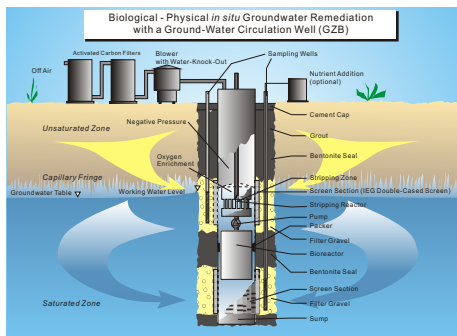
### GZB™ Technology - Partial Extraction and Infiltration

The vertical Groundwater Circulation Well™ can also be used as a pump or infiltration well for standard on-site remediation. In such cases, partial withdrawal or infiltration is taken from or added to the total volume of groundwater flowing through the well. It is possible to extract or to infiltrate water without changing the groundwater head at the well top for a specific ratio of the extracted or infiltrated flow to the vertical circulation flow around the well.

This has been numerically investigated for unconfined aquifer conditions by Herring and Stamm (1992). At a distance from the well, the groundwater head at the aquifer surface only slightly deviates from its normal resting level. In low yield aquifers, continuous pumping can be achieved at a much higher rate and re-infiltration can be realised for a much greater quantity.

GZB™ technology provides for the on-site treatment of partially-withdrawn groundwater and re-infiltration via the same well following treatment. The unit is similar to the standard UVB™, but without the in-well stripping reactor. The system remains "closed-looped" avoiding abstraction licence and discharge consent issues. Withdrawn groundwater is treated for non-volatile, semi-volatile organic or inorganic contaminants using appropriate technology such as ion exchange or carbon adsorption.

Unlike conventional pump-and-treat approaches this system maintains the standard UVB™ principles of being a self-contained, hydrologically self-balancing system resulting in no aquifer drawdown or re-injection mounding.



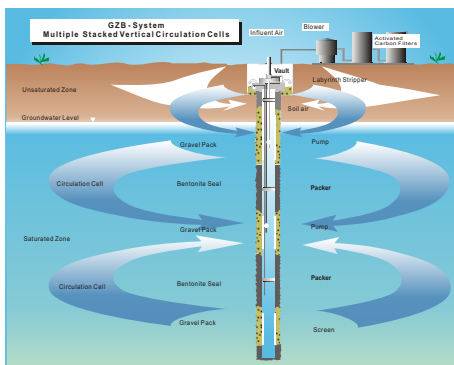
Schematic of IEG GZB™ System

### Multiple Circulation Cells in one Aquifer

The sphere of influence of a Groundwater Circulation Well™ depends on the distance of the

two screened sections or, in case of a fully penetrating well, on the aquifer thickness. The larger the circulation cell is, the larger the travel time for the circulation. For thick aquifers, it may be beneficial to install several circulation cells, one upon another. This produces smaller circulation cells and shortens circulation flow time.

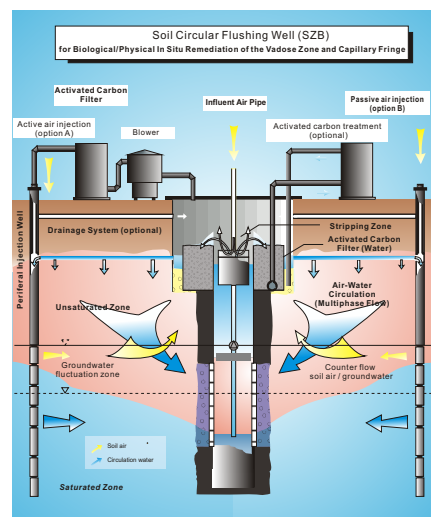
The hydraulic flow system can be combined with in-situ stripping, an in-well treatment reactor, or any appropriate on-site technology. The use of multiple circulation cells in one deep aquifer may be also advantageous when the hydro-chemical properties of the soil and groundwater are drastically dependent on the aquifer depth.



Schematic of IEG Multiple GZB™ System

### SZB™ Technology

In the unsaturated zone, bioremediation is critically affected by the soil moisture content. For most in-ground natural biological degradation processes, the optimal water content is in the range between 50% to 80%. When the unsaturated zone is contaminated with light non-aqueous phase liquids (LNAPLs, e.g. diesel, BTEX, mineral oil), the SZB™ will establish an adjustable, vertical, unsaturated multi-phase flow in the contaminated area.



Schematic of IEG SZB™ System

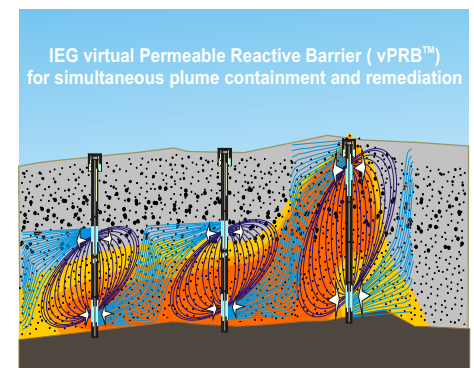
The flushing groundwater is pumped from the upper groundwater zone to a stripping reactor situated at the top of the well casing. Nutrients can be added for bioremediation processes or surfactants for an enhanced flushing process. In the unsaturated zone a vertical, circular multiphase flow occurs with a continuous supply of nutrients and oxygen within the sphere of influence. The SZB™ can also be combined with a GZB™ system.

### In-situ Virtual Permeable Reactive Barrier with Overlapped Circulation Cells

When a UVB™ or a GZB™ is situated within the body of a groundwater contamination plume, the polluted upstream groundwater is captured by the well and treated. Due to mass conservation, the same quantity is released by the well down-gradient. If the width of a plume is larger than the capture zone of a single well, several vertical circulation wells are arranged in one line perpendicular to the natural groundwater flow.

The distance between each system is determined in order to ensure that no groundwater can pass the virtual treatment wall without being caught and treated. The natural groundwater flow field is only locally influenced because no groundwater is extracted.

Thus, a line of several wells represents a Virtual Permeable Reactive Barrier™, and no contamination coming from upstream can pass the line of wells without first being treated.



Schematic of IEG vPRB™ System

IEG Technologies UK Ltd works with consultants and contractors alike, or direct for property owners, to provide comprehensive and effective in-situ solutions to simple and complex soil and groundwater contamination problems alike.

To learn more about our services and innovative and sustainable technologies, for a **free** remediation concept consultation and quotation, or to discuss in detail how IEG can eliminate risk and add value on your site, please contact us.