

SOIL AIR CIRCULATION FLOW AND COAXIAL GROUNDWATER VENTILATION (Contribution by E.J. Alesi)

Soil Air Circulation Flow

Directed soil air circular flow systems (SACF) are employed for the remediation of soils polluted with volatile contaminants (see Figure 17). In addition, it can be used to inject gas into the soil for the stimulation of biological or chemical degradation. SACF is a process patented by IEG mbH, Reutlingen, Germany.

The filter casing built into the bore-hole is separated into an upper and a lower section, each of which is connected to the above-ground ventilator. This allows for the withdrawal of air from either segment individually or from both simultaneously. The air extracted, after passing through a suitable remediation unit (i.e. activated carbon filter), is reinfiltrated into the soil. Horizontal and vertical flow circulation are generated in the soil surrounding the extraction well. The circulation direction is reversible and can be adjusted according to the distribution in the soil.

The SACF, in contrast to conventional venting methods, is capable of generating a directed circulation through the center of the contamination. No fresh air is added to the circulation system. Air passing through the ventilator is heated, thereby enhancing desorption of contaminants adsorbed onto soil particles. This leads to a more effective remediation of the site.

For stimulating the biological degradation of contaminants, nutrients, in liquid or gas form, can be introduced into the circulation. Chemical conversion of toxic substances into harmless and/or immobile material can be achieved in situ by introducing, for example, strongly reactive gases into the soil.

If only biodegradable substances are to be removed from the subsoil a SACF system (without an above ground extraction unit) consisting of an axial ventilator in the screened well can be implemented.

Should the capillary fringe be remediated along with the unsaturated (vadose) zone, it is possible to rinse the capillary fringe by creating a circulation directly around the well casing. This is achieved by a combination of SACF and coaxial groundwater ventilation (see next section).

Coaxial Groundwater Ventilation

Coaxial groundwater ventilation (CGV) is used in the remediation of groundwater and of stratum water contaminated with volatile pollutants, but can also be employed to inject gas into the groundwater for the enhancement of microbiological degradation (see Figure 18). CGV is a method patented by IEG mbH, Reutlingen, Germany.

CGV consists of a combination of soil air venting with in situ groundwater stripping ("push and pull technique"). Clean compressed air is pumped into a pressurized air distributor located between the capillary fringe and the aquifer base according to the vertical distribution of the pollutants. The air bubbles rise within the well, causing the water inside the well casing to flow upward (air-lift effect).

The design of the pressurized air distributor regulates the air flow so that the air can only flow upward. Consequently a continuous circulation of groundwater is generated in the area surrounding the remediation well, delivering new contaminants to the

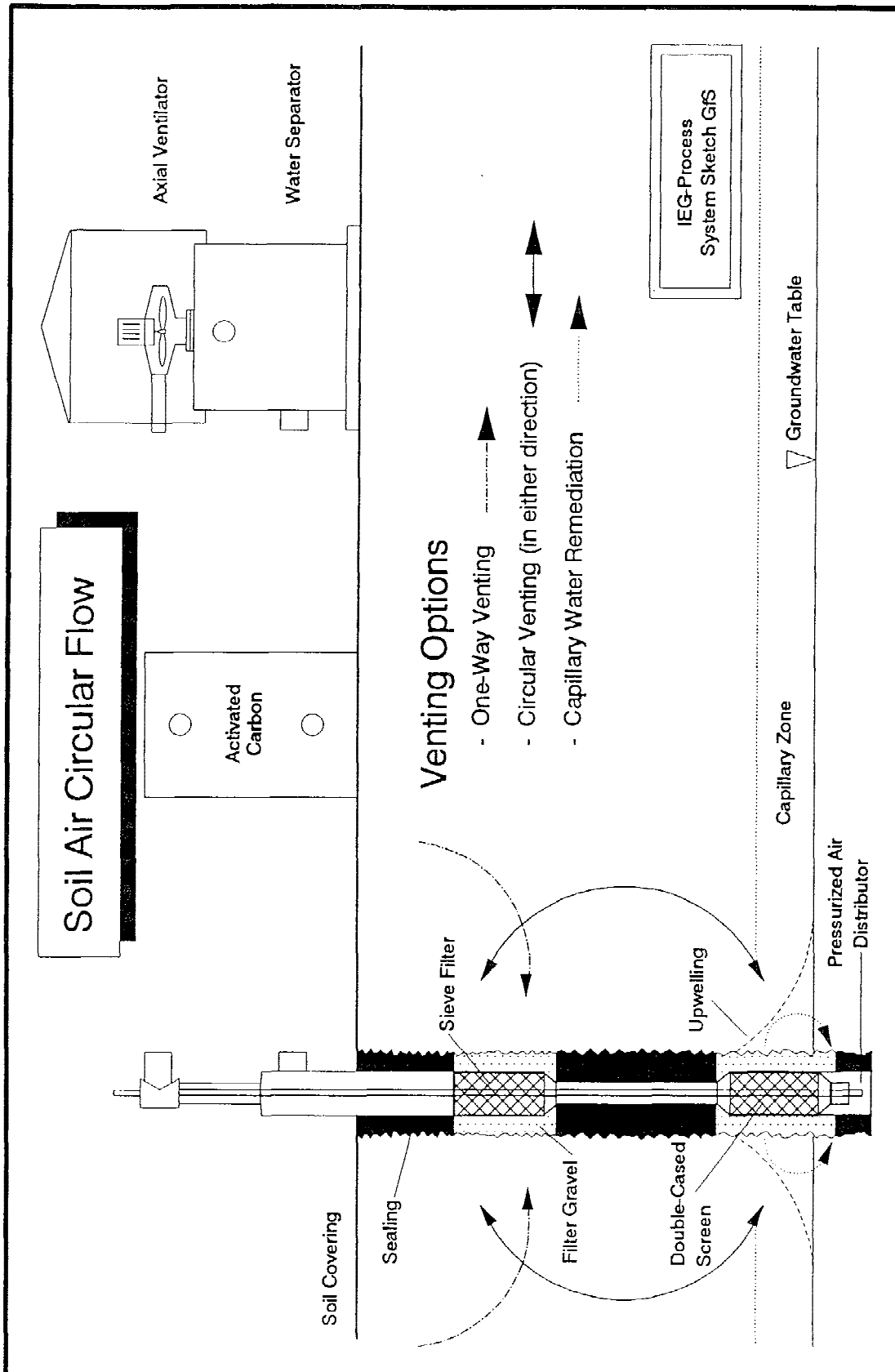


Figure 17. Principle sketch of the soil air circulation flow.

Soil Air Venting with a Double-Cased Screen Coaxial Groundwater Aeration

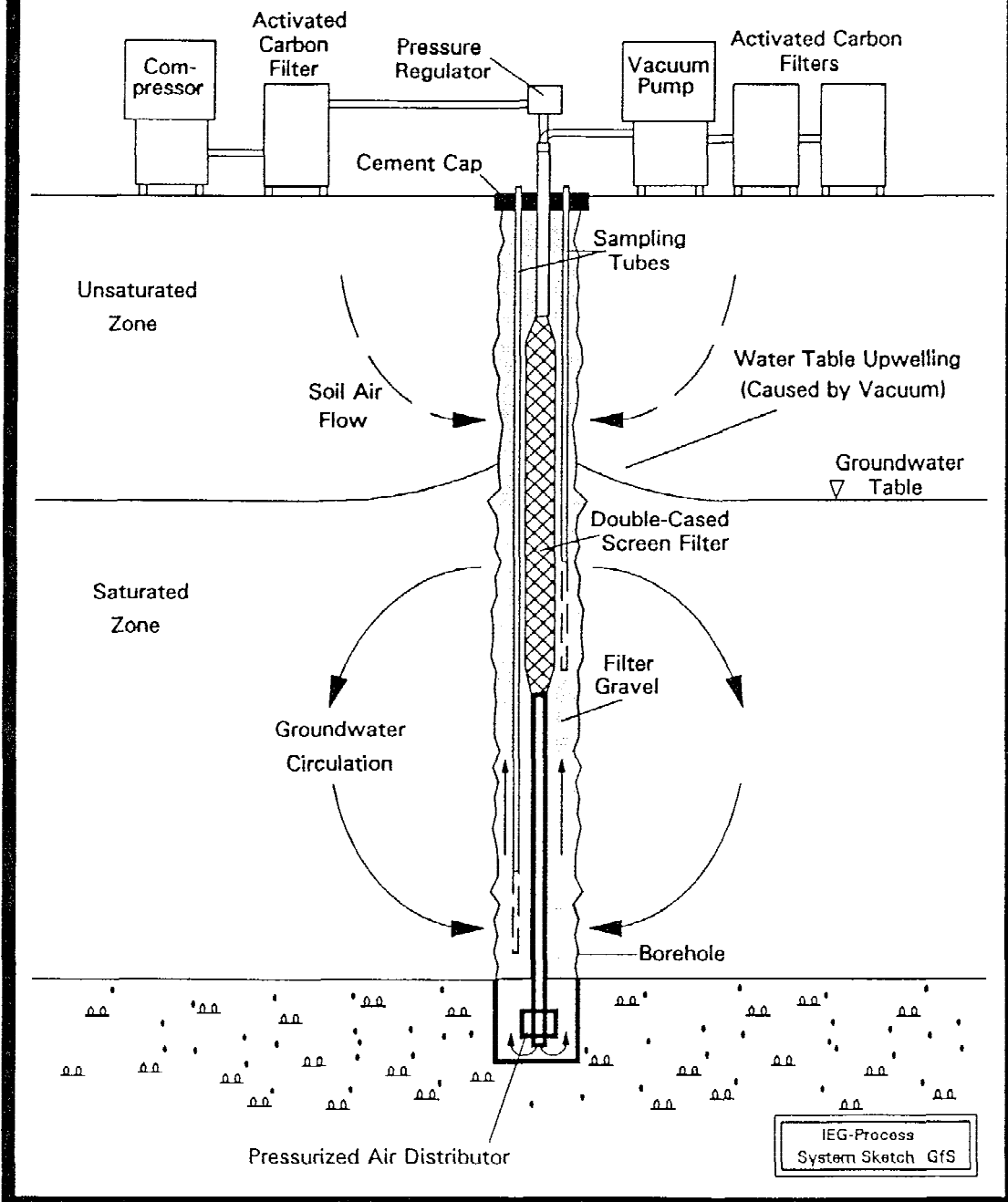


Figure 18. Principle sketch of the coaxial groundwater ventilation.

stripping site.

In contrast to other in situ stripping methods, the clean water leaving the upper screen section of the well has no air bubbles, therefore no air-water phases can impede the flow.

Volatile contaminants dissolved in the groundwater are transferred from the liquid to the gas phase in an amount relative to their gas-liquid distribution coefficient and are extracted from the groundwater surface via the double-cased screen. Soil air from the unsaturated zone is also extracted and remediated. By monitoring the volume of exhaust air the amount of air extracted from the unsaturated zone can be calculated (exhaust air - air injected into well). Small monitoring tubes located in the annular space of the remediation well allow the concentration of the contaminants in the groundwater to be measured before and after passing through the well.

Vertical water and air flows differentiates the CGV from other in situ stripping methods. Of special note is that groundwater need not be removed to prevent contaminant propagation when using the method. Best results can be achieved if fresh air is continuously sucked into the pressurized air distributor. Heating the groundwater and consequently increasing the off-air moisture is thus avoided.

A special advantage of the CGV is its ability to effectively remediate the often highly contaminated capillary fringe.

The difficulties that arise during conventional remediation procedures due to contaminated stratum water, which collects in the remediation well do not occur with the CGV. Stratum water can be stripped directly in the ground without having to pump it up to an above-ground treatment system.

CONCLUSION

The UVB technique can be used for in situ stripping of volatile contaminants from the groundwater zone and to clean the unsaturated zone at the same time by soil vapor extraction. For the saturated groundwater zone, the hydraulic circulation system of the UVB offers many advantages, particularly when compared with a typical hydraulic remediation system of pumping, off-site treatment, and reinfiltration of the groundwater. Such advantages include:

- No lowering of the groundwater level
- No groundwater extraction
- No waste water
- Less permeable, horizontal layers are penetrated vertically
- Remediation of the groundwater takes place down to the bottom of the aquifer
- Even at low well capacity, remediation operation is continuous
- Soil air extraction is possible at the same time
- Low space requirement
- Investment and operating costs will be considerably lower.

When the water discharge through the well casing is directed downward, the hydraulic head is lowered at the well top ($-\Delta h/2$, Fig. 9b; neglecting the increasing groundwater level in consequences of the vacuum), but this amount is much smaller than that caused by a normal withdrawal well.

The total aquifer is caught by the circulation flow of a UVB. When using different wells for extraction and infiltration, only those areas of an aquifer which are more permeable are penetrated. The other areas are reached mainly by diffusion. The groundwater flow system will only locally be influenced, there is no need for large extended groundwater flow investigations. Further, a plume can directly be treated without pumping lots of clean water as in case of using pump and treat methods.

A layered aquifer enlarges the sphere of influence or the distance between the well and the stagnation point. This has been found by numerical simulations and by comparison with field measurements of a tracer test. On the other hand, the positive effect of a layered aquifer is limited when an aquitard is present. Here, several remediation systems must be installed, one for each aquifer.

Different techniques of soil vapor extraction are compared by measured field data at a remediation site. It has been clarified by this investigation that a combination of slotted screen and side channel blower can cause water accumulation in the well casing which may contaminate the groundwater lying underneath the air well. The latter is avoided using a double-cased screen and a radial blower (ventilator).

For the vapor zone, circulation systems can be used as well, e.g. to realize special treatment technologies. A special remediation system allows for cleaning the capillary fringe.

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REFERENCES

Herrling, B.; Buermann, W. "A New Method for In-Situ Remediation of Volatile Contaminants in Groundwater - Numerical Simulation of the Flow Regime." In Computational Methods in Subsurface Hydrology; Gambolati, G.; Rinaldo, A.; Brebbia, C. A.; Gray, W. G.; and Pinder, G. F.; Eds.; Springer: Berlin, 1990; pp 299-304.

Herrling, B.; Buermann, W.; Stamm, J. "In-Situ Remediation of Volatile Contaminants in Groundwater by a New System of 'Vacuum-Vaporizer-Wells'." In Subsurface Contamination by Immiscible Fluids; Weyer, K.U., Ed.; A.A. Balkema: Rotterdam, 1991a; [in press].

Pedersen, T.A.; Curtis, J.T. "Soil Vapor Extraction Technology, Reference Handbook". Report: EPA/540/2-91/003; Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. EPA, Cincinnati, Ohio 45268; 316 pages, 1991.