COAXIAL GROUNDWATER AERATION FOR IN SITU REMEDIATION OF VOLATILE CONTAMINANTS IN SOIL AND GROUNDWATER

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INTRODUCTION

A new air sparging method "KGB" is implemented to restore the subsurface from volatile organic compounds. "KGB" is an acronym for the German words Koaxiale Grundwasser-Belüftung which translates into Coaxial Groundwater Aeration.

MODE OF KGB OPERATION

The KGB process differs from normal air sparging [1,2] in two main aspects:

- stripping occurs not in the aquifer but in the remediation well, filled with gravel
- air injection and air extraction are arranged along one vertical axis.

Clean compressed air is injected at the bottom of the remediation well through a air distribution system in an upward direction. The injection pressure must be higher than the hydrostatic and capillary pressure combined less the applied vacuum. The air bubbles rise in the remediation well, due to their buoyancy, and pick up the volatiles dissolved in the groundwater. The phase boundary layer between air and water remains constant because of the gravel fill. A steady-state movement of the air/water mixture takes place inside the well. The higher conductivity in the gravel fill, in comparison to the aquifer, prevents the air bubbles from escaping into the aquifer. In the vicinity of the capillary fringe, the air bubbles are removed through a double cased screen filled with hydrophobic material. A laminar flow results and simultaneous a phase separation of the air - water mixture is achieved. Treated groundwater leaving the well is degased due to the vacuum applied to the well. The KGB process is patented by IEG mbH Reutlingen, Germany [3].

GROUNDWATER CIRCULATION DUE TO KGB

The KGB process is based on inducing a groundwater circulation [4,5]. This requires a pressure gradient between the well and the adjacent aquifer which is unaffected by the gas flow. The hydrostatic pressure increases in the aquifer linear with depth ($p = \rho \cdot g \cdot h$). A gas flow of a variable rise velocity (v) reduces the hydrostatic pressure of a fluid with the density (ρ) by the dynamic pressure component ($\Delta p = 0.5 \cdot \rho \cdot v^2$). The total pressure is at a minimum near the air distribution system. Thus, groundwater flows towards the lower section of the well, is transported upwards by the airlift effect, passes to the upper region of the aquifer, and reenters the circulation. This provides a continuous supply of contaminants from the soil matrix to the well, thus preventing an off-site migration of the mobilized contaminants.

Air sparging in comparison to KGB uses a lance for injecting air directly into the aquifer. In case of low permeable layers which exhibit a high capillary pressure, a rather high air pressure has to be supplied. In this case, the dynamic component of the airlift effect is not utilized, thus no groundwater circulation is established.

SITE OF INVESTIGATION

At the site of investigation, alluvial deposits form a heterogeneous aquifer of 11 m thickness. The groundwater table is at 7.5 m below ground surface. The hydraulic conductivity is $K = 1.5 \cdot 10^{-3}$ m/s. The storage coefficient $S = 1.0 \cdot 10^{-2}$ indicates semi-confined conditions. The average groundwater flow velocity is $v_a = 2$ m/d. The contaminants are concentrated in the saturated zone (approx. 9 mg/l CHCs).

a) Optimization of Air Flow Rate

In order to optimize the contaminant extraction rate from the groundwater, the volume of the injected air was varied in a four week experiment [4].

- The soil vapor extraction rate (without the use of KGB) equals 0.06 g/h throughout the experiment. The total extraction rate increases by 0.41 g/h using the KGB process at a minimal air injection rate of 1 m^3/h (40 kPa).
- There is no linear increase in groundwater extraction rate with an increase in the volume of injected air. Instead, a maximum critical value of 0.72 g/h is achieved at 3 m^3/h (53 kPa).
- At the end of the experiment a total of 37.5 g CHCs was extracted from the soil vapor and additional 314 g CHCs were removed from the groundwater.

b) Tracer Experiment

A tracer experiment was conducted at the same well site to determine the radius affected by the groundwater circulation [4]. The volume of injected air was optimized at 3 m^3/h. The radius of influence in an upward direction to the natural groundwater flow direction is at least five times the thickness of the saturated zone. An intensive percolation of the pore space (v_{max} = 20 m/d) was achieved at a distance equal to double the thickness of the saturated zone.

CONCLUSIONS FOR THE IMPLEMENTATION OF THE KGB PROCESS

The KGB process presents an economical alternative when compared to other commonly used remediation processes. Its efficiency and controllable remediation progress has been proven at numerous sites [4,6]. The amount of injected air has to be chosen such that the pressure at the base of the remediation well is slightly higher than the hydrostatic pressure. Preference should be given to the KGB process over "pump and treat" in case of heterogeneous geological conditions. Remediation will proceed in an optimal manner if each of the KGB remediation wells is placed at a spacing equal about four times the thickness of the saturated zone.

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