APPLICATION OF A PILOT-SCALE FLUIDIZED-BED REACTOR FOR THE DECONTAMINATION OF GROUNDWATER

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Abstract

Groundwater, contaminated predominantly with aromatic compounds and chlorinated ethylene, could be biologically treated in a fluidized-bed reactor with immobilized cells. The decomposition efficiency for the aromatics was over 90% at the retention time of 2.5 h. The chlorinated ethylenes, especially trichloroethylene (TCE) and cis-dichloroethylene (DCE), could be decomposed only insufficiently. No anaerobic methane formation was observed for this groundwater even at a very low dissolved oxygen (DO) concentration of 0.75 mg/L. The variation of DO concentration resulted in an optimal value of 1.5 mg/L. The recycle of air waste could increase the utilization of oxygen. The amount of low boiling pollutants stripped out remained constant with the recycle, while for the higher boiling pollutants the stripping slightly increased. Using air instead of oxygen increases the flow rate of air waste, which is connected to a higher stripping of pollutants. In this investigation, the pollutant concentration in the air waste remained constant. The stripping of main pollutants did not exceed 0.3 %.

Introduction

Treating effectively a contaminated groundwater showed a successful scale up of a lab scale fluidized-bed reactor in a previous application. This pilot-scale reactor was supposed to proof its treatment feasibility for another contaminated groundwater. From previous application of pilot-scale reactor new questions in terms of economical operation arose. The crucial one is related to the aeration. To minimize the stripping out of pollutants from contaminated groundwater the air waste has to be minimized. Therefore technical oxygen was used for previous application. A pollutant balance showed that the stripping out part is very small compared to the biological degraded part. Moreover only a little part of the introduced oxygen was used. The aeration was optimized by comparing the use of oxygen and air, and recycling the air waste. Another goal of this experiment was to find out how far a simultaneous aerobic and anaerobic process was occurring in the biofilm of the polyurethane foam cube as carrier.

Materials and Methods

Main contaminants in groundwater

The main contaminants of the site in Berlin Steglitz are typical for contaminated ground waters. The main contaminants can be divided into two groups: substituted aromatics and chlorinated ethylenes. Among the aromatics the main compounds are xylene (up to 1920 µg/l), toluene (up to 1200 µg/l), ethylbenzene (up to 650 µg/l), trimethylbenzene (up to 280 µg/l). Among chlorinated ethylenes the main compounds are TCE (up to 500 µg/l), cis-DCE (up to 1800 µg/l) and vinylchloride (VC, up to 900 µg/l).

Pilot-scale reactor system

The pilot plant as a fluidized-bed reactor was developed by Linde AG and was sold under the brand name Linpor®-Versuchsanlage. It used polyurethane foam cubes as biofilm carrier. The source for biofilm was the groundwater itself. Before starting with continuous operation the biofilm was adapted to toluene and xylene by their addition into the reactor. The reactor was in parallel operation to a commercial groundwater decontamination stripper.

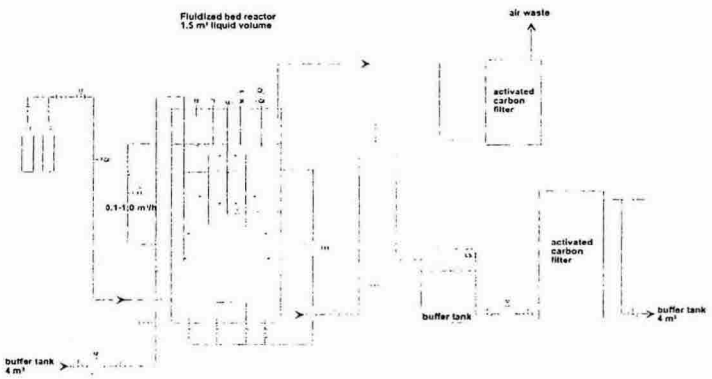

Fig. 1. Fluidized-bed reactor in pilot scale using polyurethane foam cubes, Linpor®-Versuchsanlage

Results

Efficiency of pollutant decomposition

The decomposition efficiency of the bio pilot-scale reactor, Linpor®-Versuchsanlage, for the chlorinated ethylenes was smaller than 30 %, except for VC which was eliminated up to 95 %. The reactor had no problems dealing with aromatics, which were eliminated up to almost 100 % at a retention time of 12 hours.

Table 1. Elimination ratio and Influent concentrations of main contaminants at a retention time of 12.0, 3.0 and 1.5 h

Pollutant	12 h		3 h		1.5 h	
	Inf. conc./ (mg/L)	Eliminat.	Inf. conc./ (mg/L)	Eliminiat.	Inf. conc./ (mg/L)	Eliminat.
m/p-Xylene	1750	98 %	1080	95 %	1050	90 %
Toluene	1200	98 %	580	91 %	750	80 %
Ethylbenzene	650	98 %	280	92 %	280	89 %
1,2,4-Tri-methyl-benzene	220	99 %	215	95 %	220	90 %
o-Xylene	170	98 %	85	90 %	80	75 %
1,3,5-Tri-methyl-benzene	65	99 %	55	91 %	55	75 %
cis-DCE	1800	30 %	1100	22 %	1000	20 %
VC	900	95 %	350	82 %	300	70 %
TCE	360	0 %	400	5 %	500	15 %
trans-DCE	35	0 %	40	5 %	35	5 %
PCE	15	20 %	16	5 %	15	13 %
1,1-DCE	6	25 %	8	10 %	9	15 %

Investigation of simultaneous aerobic and anaerobic decomposition in biofilm

The DO was controlled between 6.0, 3.0, 1.5, and 0.75 mg/L to change the ratio of aerobic and anaerobic decomposition applying a retention time of 2.5 h. The methane concentration was for all conditions smaller

than 0.1 %. For all DO levels the decomposition efficiency for most aromatics was more than 90 %. At the DO of 0.75 mg/L the decomposition efficiency for chlorinated ethylenes decreased. An optimal DO for the process is given at 1.5 mg/L by taking all decomposition efficiencies in account.

Optimization of aeration

Optimizing the aeration can lower the operation costs. Since the pollutants stripped out have to be removed from air waste it is important to consider them.

Recycling the air waste resulted in a 3-fold increase of volume flow compared to that of oxygen volume flow. The oxygen consumption decreased from 9.3 L per m^3 treated groundwater to 6.8 L, which means a saving of 26 %. Hereby the oxygen concentration decreased in air waste from 60 % to 40 %. The pollutant concentrations in air waste for recycle operation were higher than in normal operation. The concentration for high volatile compounds in recycled air was similar but for low volatile compounds the concentration increased disproportionate.

For all main contaminants the part stripped out in air waste is lower than 0.3 % according to mass flow in influent. By taking into account the costs for additional energy for recycling than a total cost savings for aeration of 18 % is given.

The mass flow of pollutants stripped out by using air from surrounding area was increased, but the part of the main contaminants was still below 0.3 %. The pollutant concentration in the air waste for oxygen and air operation is similar. Because the volume flow rose then from 3.64 L/h to 10.8 L/h the stripping was higher.

Acknowledgement

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