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Evaluation of Natural Attenuation of Petroleum Hydrocarbons in a Shallow Sand Aquifer: a Modeling Study (자연저감 모델링 연구)

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요 약 문

We evaluated natural attenuation of petroleum hydrocarbons in a shallow aquifer using a modeling study. The studied shallow aquifer was severely contaminated with petroleum hydrocarbons, especially toluene, ethylbenzene and xylenes (i.e., TEX). The exact spill history was not known. Therefore we used a contaminant level in May 1999 (the first sampling date of our integrated study) as an initial contaminant concentration. We calibrated required transport parameters using the contamination levels obtained from groundwater analyses in September of 1999. For fate and transport of the petroleum contaminants, five cases were studied: i.e., case 1 without sorption and degradation (dispersion only), case 2 with sorption and degradation, case 3 with sorption and degradation (half decay constant compared with case 2), case 4 with degradation but no sorption, and case 5 with sorption but no degradation. For sorption and degradation, a linear sorption isotherm and first order irreversible decay was assumed, respectively and no additional contamination source to groundwater is also assumed.

Key word: natural attenuation, degradation, sorption

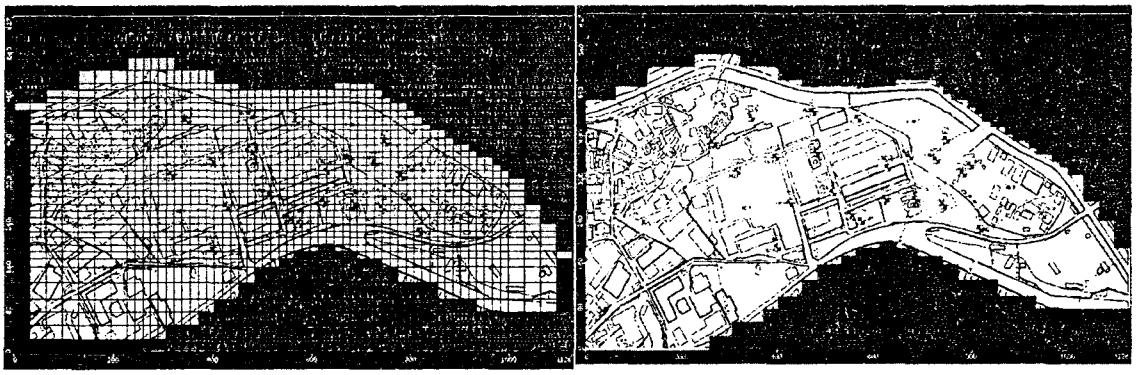
1. Introduction

Natural attenuation has been an acceptable alternative for contaminated aquifer remediation (Lu et al., 1999; Lee et al., 2001a). But this remediation approach does not mean do nothing. In some cases, natural attenuation will be a possible alternative but not the most desirable one in spite of its inherent appeal as a passive approach (Davee and Sanders, 2000). Natural attenuation must be supported by unequivocal evidence that natural attenuation will occur at the site of interest and will meet public and regulatory

levels within a reasonable time frame (Davee and Sanders, 2000). It is generally adopted as a viable remediation alternative in combination with other more active remedial options. A thorough and excellent discussion and/or studies of natural attenuation may be found in Wiedemeier et al. (1995), ASTM (1998), Chapelle (1999), USEPA (1999), and Davee and Sanders (2000). As commented in these materials, various lines of evidence should be guaranteed by field and numerical studies to adopt natural attenuation as a remediation option. This study is part of a integrated study of evaluating natural attenuation for remediating a petroleum hydrocarbon contaminated aquifer in Korea (Lee et al., 2001a,b,c,d). In this study, the fate and transport of the petroleum hydrocarbon was evaluated under various conditions by using a professional groundwater model program (Visual MODFLOW, v.8.2.2, Waterloo Hydrogeologic, Inc.).

2. Methods and Materials

The study site is located about 45 km southeast of Seoul, Korea. Subsurface contamination by petroleum hydrocarbons was first detected at this site when water from a shallow ground water well, installed in the center of the site, became undrinkable in March 1983 (Lee et al., 2001a,b). Chemical analyses revealed that the main components of the dissolved plume were toluene, ethylbenzene and xylene (TEX),



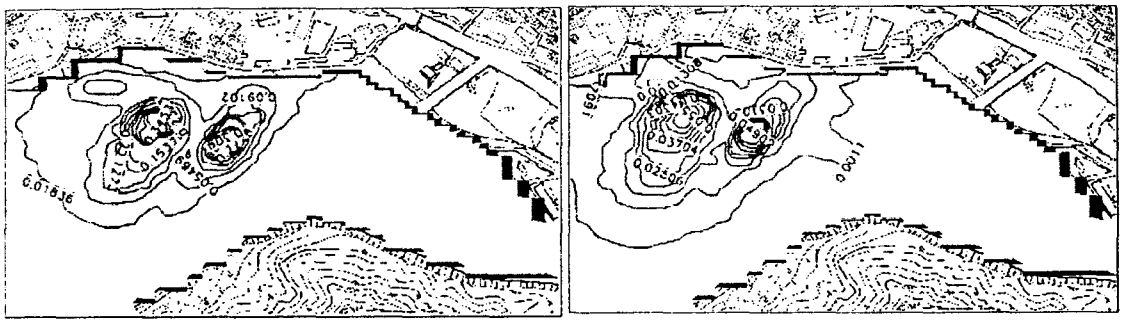
which are organic solvents used for industrial paint production. The model domain, grid system and vertical section are presented in Figure 1. The area, 1126 m 627 m was subdivided into 59 columns and 38 lows (Fig. 1).

Fig. 1 Model domain and result of flow simulation.

3. Results

The second case is related with active sorption and degradation. As commented previously, this case is best calibrated one for this site. But the short period of the calibration time may invalidate the calibration. Nevertheless, the calibration parameters of sorption and degradation is well supported a field study (Lee et al., 2001a). Fig. 2 shows

TEX concentrations at time of 15 and 20 years. As shown in the figure, the concentrations are decreased to a few ppb (μg/L) levels within 20 years. Surely



enough, the prediction is based on no additional contamination source in this area. But this is not real. Rather some additional sources from smeared zones and NAPL existing in this area (Lee et al., 2001a; Lee et al., 2001b). So this calculation is most optimistic.

Fig. 2. TEX distribution at elapsed times of 15 (left) and 20 (right) years.

4. Conclusion

From the modeling results, we obtained some valuable insights about the natural attenuation of this site. In case 2, which is considered most appropriate for this site, the TEX concentrations in the model domain will reach a ppb level only after 20 years. In case of neither sorption nor degradation, most of contaminants with high concentrations will overpass the model domain boundary in 20 years. As expected, sorption only delays migration of the plume and degradation plays dominant role in reducing contaminant concentration. In the all cases, at least 20 years or even more should elapse to obtain some reasonable natural attenuation. For more reliable model calibration and prediction of natural attenuation of petroleum hydrocarbons in this area, a longer monitoring data of contamination levels are essentially required.

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