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An Optimization Method for Remediation of "LNAPLs" from Contaminated Groundwater

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Abstract

Dual pump recovery has been optimized using UTCHEM 9.3, which is a comprehensive three-dimensional model simulator, along with a home made optimization package. An isothermal system is considered in which adsorption, biodegradation, chemical reaction, and surface-active agents are negligible and transport by diffusion, advection, and dispersion are the dominated transport mechanisms. Furthermore, the classic form of the binary genetic algorithm (BGA) is utilized for minimization of the objective function. By implementation of BGA algorithm the total costs of remediation is minimized by finding the most cost effective place and flow rate for remediation wells. The data related to the aquifer adjacent to Isfahan Refinery Company has been used as a case study for optimizing the remediation process using our developed code (LROPTIMIZER). The results are quite reasonably acceptable within the optimization constraints and the applied simplifying assumptions.

Keywords: Groundwater, LNAPLs, Remediation, Optimization, Genetic Algorithm.

1. INTRODUCTION

Water resources in many parts of the world have been exceedingly polluted by LNAPLs (Light Non-Aqueous Phase Liquids), because of irresponsible industrial practices in the last century. LNAPLs are serious threats to global water supplies. To prevent health risks for humans and damage to the environment the contaminated water supplies should be remediate. In long run, LNAPLs move toward the underground waterbeds mainly due to gravitational and capillary forces and their behavior depends on these forces. When these pollutants reach underground waterbeds, they will accumulate on the water surface and move as a thin layer. In case of water level fluctuations, the mobile LNAPLs can convert to residual LNAPLs. Residual LNAPLs are liquid droplets that are entrapped in soil by capillary forces. Regarding the considerable strength of capillary forces, particularly in fine soils, the remediation of residual LNAPLs is extremely difficult. Most techniques developed to clean up LNAPLs are based on pumping of contaminated waters. The technology that is presently in use is called dual pump recovery, which is an advanced method for remediation of oil-polluted waters in deep and permeable aquifers. This method utilizes two dynamic pumps simultaneously (one for water and the other for oil).

To analyze the above described situations, multi-phase flow models are necessary. Numerous petroleum reservoir codes to simulate the simultaneous flow of water, oil and gas in porous media have been developed since 30 years ago. These codes can be used to treat environmental problems as well. Multiphase flow of water and oil has been also investigated thoroughly. In the unsaturated zone, however, the gas phase (air) should be taken into account, and this additional phase makes the flow processes in porous media much more complex. Abriola and Pinder [1] developed such a multiphase flow model, where hysteresis was ignored. Kaluarachchi and Parker [2] showed that disregarding hysteresis results in significant errors in predicted fluid distributions. Subsequently Lenhard and Parker [3], [4] and Parker and Lenhard [5], [6] incorporated hysteretic constitutive relations.

Although we model a three phase system including water, oil and air, we assume that air is so mobile that the air pressure is approximately constant. The flow equations for two phases (water and oil) suffice to describe the flow phenomena, since the main interest in this situation is the flow behavior of oil. Therefore, the air entrapment and its effect on the relative water and oil permeability are neglected. This assumption is