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Development of Simultaneous Installation Model to Optimize Monitoring Network for Identification of Contaminant Plume Distribution

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ABSTRACT

A new framework of determining the optimal monitoring network which as possible as reduces the uncertainty of contaminant plume distribution is developed. Monte Carlo approach is applied to generate contaminant release scenarios considering uncertainty of field parameters. In this study, the factor making uncertainty is considered to hydraulic conductivity. Successive Random Addition (SRA) method is used to generate hydraulic conductivity random field.

The expected value of data information of each monitoring network is evaluated by how much uncertainty of plume distribution reduces. The array of monitoring wells having the maximum data information is selected as the optimal monitoring network. In order to quantify uncertainty of the plume distribution, the probability map of contaminant existence is made on all generated plume realizations on the domain field and the uncertainty is defined as the area that probability range is neither 0 nor 1. Using this quantified uncertainty, the expected value of sampling information (EVSI) is evaluated based on Bayesian theory.

The function of accident of contaminant existence at a location is defined as

$$e(\mathbf{x}_k,1)=\mathbf{x}_k, \quad e(\mathbf{x}_k,0)=\mathbf{x}_k^{C}$$

where k is node number; $\mathbf{x}_k$ is location at each node number k and accident that contaminant exist at the location, $\mathbf{x}_k$.

EVSI is defined as

$$\text{If } \forall i \neq \forall j,\ \mathbf{x}_i \neq \mathbf{x}_j\ (i,j=1,n)$$

$$\mathrm{EVSI}(\mathbf{x}_1,\mathbf{x}_2,\mathbf{x}_3,\cdots,\mathbf{x}_n)=\phi-\mathrm{E}(\phi')$$

$$=\phi-\sum_{l_1,l_2,l_3,\cdots,l_n=0}^{1}\left[\mathrm{P}\left(e(\mathbf{x}_1,l_1)\cap e(\mathbf{x}_2,l_2)\cap\cdots\cap e(\mathbf{x}_n,l_n)\right)\cdot\phi'\left(i(\mathbf{x}_1)=l_1\wedge i(\mathbf{x}_2)=l_2\wedge\cdots\wedge i(\mathbf{x}_n)=l_n\right)\right]$$

where n is the number of monitoring wells ($n \geq 2$); ϕ' is the quantified uncertainty after monitoring network installation; $\mathbf{P(x)}$ is the probability that monitoring wells installed at location $\mathbf{x}$; $i(\mathbf{x}_k)=1$ is contaminant is exist at the location, $\mathbf{x}_k$; $i(\mathbf{x}_k)=0$ is contaminant is not exist at the location, $\mathbf{x}_k$; ϕ is the quantified uncertainty before monitoring network installation. The optimal locations of monitoring wells are the locations where maximize EVSI. The Genetic Algorithms (GAs) is used to find the optimal combination of locations of monitoring wells by maximizing EVSI.

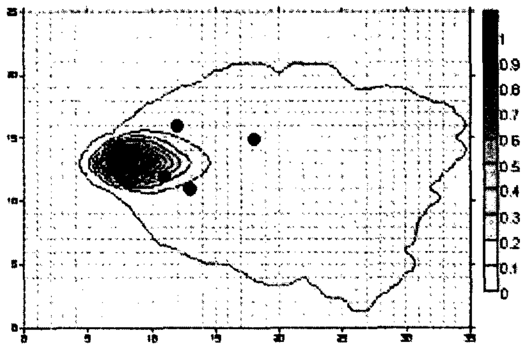

Figure 1 the probability map of contaminant existence. Dark area is high probability area, and bright area is low probability area. This map is generated using 2500 SRA random fields. A cross is contaminant source location and circles are the optimal locations for monitoring wells.

Figure 1 represents the optimal monitoring network. This monitoring network is optimized for four monitoring wells by 2500 SRA random fields. Locations of monitoring wells are distributed near contaminant existence probability 5~40%.

Efficiency of the developed model is evaluated by comparison with other monitoring networks. Results present that the developed model determine the optimal monitoring network effectively and linear array of monitoring wells along a certain direction is ineffective.

Key words: monitoring network, identification, genetic algorithms, simultaneous

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