含氯有機化合物污染場址被動式復育系統研析(I)

Studies on passive remedial systems for sites polluted by chlorinate organic chemicals

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中文摘要

關鍵詞：斗牆與阻門、零價鐵、零價鋅

本文利用一個三維污染物含生物性分解的傳輸模式結合地下水流模式 3DFATMIC **程式，配合斗牆與阻門系統（**funnel and gate system**），以桃園** RCA **場址為對象，模擬分析** PCE、TCE **污染物分佈情形，並在阻門內加入零價鐵與零價鋅作為還原劑，以分解** PCE、TCE **污染物。模擬結果顯示，經過兩年處理後，**RCA **場址下游監測井**(TM-601, TM-602, and TM-603)**最終濃度降為原抽取處理法的** 0.02**%，且遠低於** 40 ppb。**顯示斗牆與阻門系統能較有效地處理地下水中** PCE、TCE **等污染物。**

ABSTRACT

In this thesis, the 3DFATMIC model was employed to simulate the concentration distribution of PCE and TCE. A funnel and gate system, which adopts granular zero-valent iron and zero-valent zinc in the gate, is chosen to replace the pump and treat method for remediationg the RCA Taoyuan site. The simulation results from 3DFATMIC indicate that the final concentrations of PCE and TCE in downstream monitoring wells reduce to about 0.02 % of those when using pump and treat method after two years. Accordingly, the funnel and gate system may be a better choice over the pump and treat method to remove the dissolved chlorinated organic chemicals, such as PCE and TCE, at RCA Taoyuan site.

Field Simulation

The study site, its hydrogeological conditions are essentially adopted form RCA report (1998). Figure 1 shows the boundary of RCA site, the concentration of the initial contaminant plume, the monitoring wells, and the 2D finite element mesh for numerical simulations. In order to fit the size of the funnel and gate system, the mesh is designed to have non-uniform and 49 ×16 grids. The bulk density of the first zone is 1000 kg/m^3, the effective porosity is 0.25, and hydraulic gradient is 0.005. The aquifer hydraulic conductivity is 0.243m/day and groundwater flow direction is generally to the north beneath the site. The longitudinal dispersivity of the first zone is 3.0 m, and the transverse dispersivity is 0.9 m. Table 1 shows the simulation time which essentially follows the history of RCA event. Assume the contaminants were released into groundwater in the period of 1990 to 1992. The aquifer was being remediated for six months (180 days) under the pump and treat method. The location for each well is indicated in Figure 2.

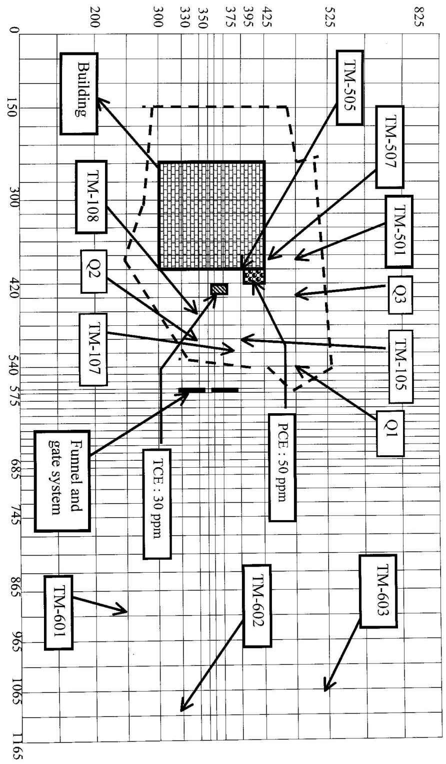


Figure 1. The simulation diagrammatic sketch of RCA Taoyuan Site

Table 1 Simulation time for the simulation of PCE and TCE

Period	Date
Total simulated phase	1990/03 ~ 1999/06
Plumes releasable phase	1990/03 ~ 1991/12
The pumping phase	1997/03 ~ 1997/09
Groundwater quality examinable phase of the site and vicinity	1997/03 ~ 1997/12
Groundwater quality examinable phase (the down gradient of the size)	1997/04 ~ 1999/06

Starr and Cherry (1994) used two-dimensional computer simulations to illustrate the effects of the funnel and gate configuration on capture zone size and on the residence time for reaction of contaminants in gates. They demonstrated that the funnel and gate system with a 180-degree angle, oriented perpendicular to the regional hydraulic gradient, has the largest capture zone and the optimum hydraulic conductivity of the gate is 10 times that of the aquifer. Thus, a funnel and gate system with a 180 degrees angle to produce a large composite capture zone is designed to explore the feasibility of implementing such as a system at RCA site and the gate conductivity, 2.43 m/day for the first zone, is chosen as one order of magnitude larger than the aquifer. The funnel is composed of an impervious material. Therefore, a very small value for the funnel conductivity, say 8.64E-16 m/day, is used. The funnel and gate system configuration is designed with the funnel length being 30m and both the gate length and the gate width being 5m (Gupta and Fox, 1999). The relevant degradation parameters of PCE and TCE by using funnel and gate system are given in Table 2 and Table 3 for the aquifer remediation.

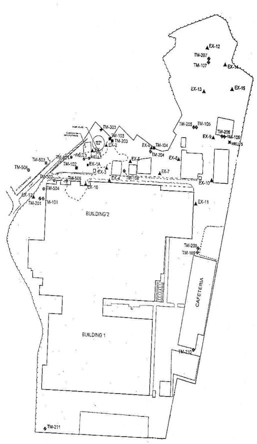


Figure 2. Site layout and well locations. (Source : Groundwater Remediation Technical Practicability Evaluation Report, 1998)

The target contaminants in this study

are chlorinated organic chemicals and assumed to be totally dissolved in groundwater. Therefore, the biodegradation likely occurred under the facultative condition (aerobic and anaerobic) and the oxygen, nitrate, nutrient and the contaminants are the principal substrates. Accordingly, a microbe with a mass of 1.77×10^{-4} kg/m^3 (Widdowson et al., 1998) which uses facultative respiration is considered in the biodegradation simulation. On the other hand, zero-valent metal, such as iron and zinc, are chosen in the reactor to remove the VOCs concentrations. Cheng (2000) reported the results of batch tests from which the rate of the first order decay of granular zero-valent iron for TCE is 0.0552 day^{-1}. The batch tests were also performed by using three different masses and source. The estimated rate of the first order decay when using those three different zero-valent zinc, Zn(a), Zn(b), and Zn(c), are respectively 0.3192, 0.4632, and 0.672 day^{-1} under operative conditions. The rates of the first order decay derived from the batch tests are assumed suitable for Taoyuan RCA site and used in this simulation.

Table 2 Biodegradation parameters of PCE when using funnel and gate system

Variable	Value/Unit
$\mu_{3,o}$	4.50 day^{-1}
$\mu_{3,n}$	3.00 day^{-1}
$Y_{3,o}$	0.05 kg/kg
$Y_{3,n}$	0.02 kg/kg
$\lambda_{3,o}$	0.01 1/day
$\lambda_{3,n}$	0.01 1/day
$K_{3,so}$	1.6E-2 kg/m^3
$K_{3,sn}$	1.8E-2 kg/m^3
$K_{3,o}$	1.0E-2 kg/m^3
$K_{3,n}$	2.0E-2 kg/m^3
$K_{3,po}$	0.0003 kg/m^3
$K_{3,pn}$	0.0003 kg/m^3
K_c	1.5E-3 kg/m^3

Table 3 Biodegradation parameters of TCE when using funnel and gate system

Variable	Value/Unit
$\mu_{3,o}$	3.50 day^{-1}
$\mu_{3,n}$	2.50 day^{-1}
$Y_{3,o}$	0.08 kg/kg
$Y_{3,n}$	0.05 kg/kg
$\lambda_{3,o}$	0.01 1/day
$\lambda_{3,n}$	0.01 1/day
$K_{3,so}$	1.5E-2 kg/m^3
$K_{3,sn}$	1.2E-2 kg/m^3
$K_{3,o}$	2.0E-2 kg/m^3
$K_{3,n}$	2.5E-2 kg/m^3
$K_{3,po}$	0.0003 kg/m^3
$K_{3,pn}$	0.0003 kg/m^3
K_c	1.5E-3 kg/m^3

SIMULATION RESULTS

The simulation data form monitoring wells, TM-108 and TM-507, are used to verify the modeling results match with RCA Taoyuan site sampling data or not. Figure 3 and 4 show that the sampling data of contaminant concentration at RCA Tayouan site when using the pump and treat method for remediation for six months confirm the simulation results; the maximum relative error for the simulated concentration compared to the sampling data is only 8.5% at time of June 1999.

It is important to determine whether the contaminants concentrations at the monitoring well are lower than the cleanup standard or goal and endanger the resident health that live in the down gradient of the RCA Taoyuan site after remediation. Thus, three off-site wells (TM-6012, TM-602, and TM-603) are chosen to monitor the concentrations distribution of CVOCs (PCE and TCE) and to evaluate the remediation performance of the pump and treat method and the funnel and gate system. The results after a simulation time period of two years (Figure 5) show that the concentrations of

PCE decrease to 2.42, 0.42, and 0.4 ppb at TM-6012, TM-602, and TM-603, respectively, when using the pump and treat method; on the other hand, the concentrations drop to 0.79, 0.28, and 0.19 ppb when using the funnel and gate system. Note that the maximum value of PCE concentrations drop below 1 ppb, which is lower than WHO drinking water standard (40 ppb), at the time of June 1999.

Figure 6 illustrates the sampling TCE concentrations and simulated TCE concentrations when using those two remediation techniques after two years. Results demonstrate that if the funnel and gate system is employed to remediate aquifer, the concentrations are significantly lower than those of pump and treat method during the time from April 1997 to June 1999. It is evident that the funnel and gate system produces lower contaminant concentrations then does the pump and treat method. If the time factor to cleanup the aquifer is not crucial, the funnel and gate system would serve as an efficient way to remediate the RCA Taoyuan site.

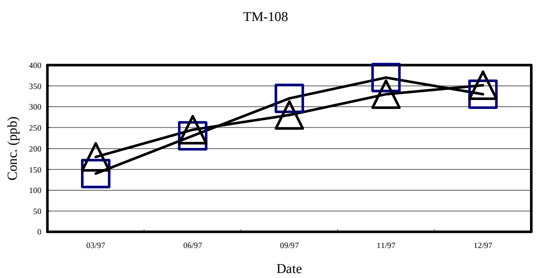
When employing the funnel and gate system with the biodegradation occurring in the gate, the concentration distributions of TCE is shown in figure 7. The maximum concentrations of TCE after being release at simulation time 750, 780, 810, and 840 days are respectively 32.12, 26.65, 21.18, and 15.71 ppb. The contaminant removal efficiency for the funnel and gate system with zero-valent iron is shown in Figure 8. When the zero-valent iron is used in the reactor, the downstream maximum concentrations of TCE is 28.63 ppb after 750 days and drop to 15.42 ppb after 840 days. Figure 8 and 9 indicate that when the same source and different mass of the zero-valent zinc, Zn(a) and Zn(b), are used in the reactor, the downstream maximum concentrations of TCE become 21.63 and 20.12 ppb, respectively, after 750 days. The concentrations of TCE decrease with simulation time and drop below 10 ppb after 840 days. When employing the funnel and gate system with powdered zero-valent zinc, Zn(c), in the reactor, the concentration distributions of TCE are presented in Figure 10. It shows that the maximum concentrations of TCE is 15.63 ppb after 750 days and drop to 5.2 ppb which is the lowest among these cases after 840 days.

The simulation results demonstrate that the funnel and gate system with zero-valent iron and zero-valent zinc as reducing agent in the reactor may effectively remove the dissolved chlorinated organic chemicals at the RCA Taoyuan site. Furthermore, it seem that the higher values of the first order kinetics of the zero-valent zinc use, the better the removal efficient will be.

CONCLUDING REMARKS

The 3DFATMIC model was employed to simulate the concentration distribution of PCE and TCE at RCA Taoyuan site. The simulation results for PCE and TCE, when using the pump and treat method as the cleanup measure, are very close to the well sampling data. when compared to the sampling data, the maximum relative error for the simulation results of PCE and TCE is only about 8.5%at the time of June 1999.

The simulation results of remediating RCA Taoyuan site illustrate that the funnel and gate system may be a better method in dealing with PCE and TCE than the pump and treat method when the latter operates for six months. The contaminant concentrations after a period of treatment are lower than WHO drinking water standard (40 ppb). Also, it is found that the funnel and gate system with zero-valent iron and zero-valent zinc as reducing agent in the reactor may play a major role to remediate the dissolved chlorinated organic chemicals.



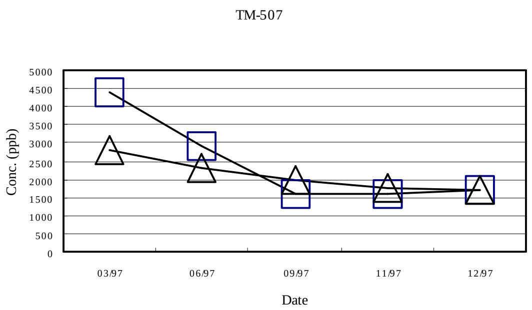
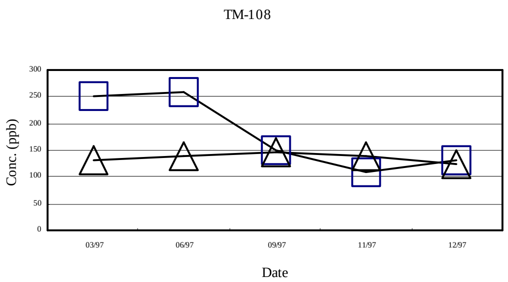


Figure 3 Tetrachloroethylene concentrations versus time near the monitoring wells TM-108 and TM-507. (- : sampling data, simulation results)



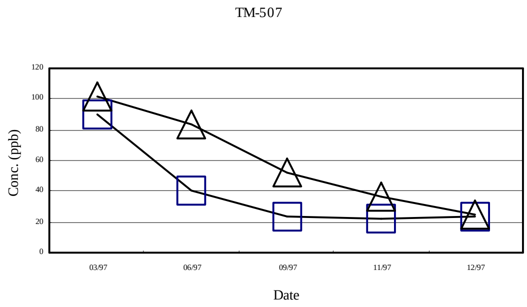
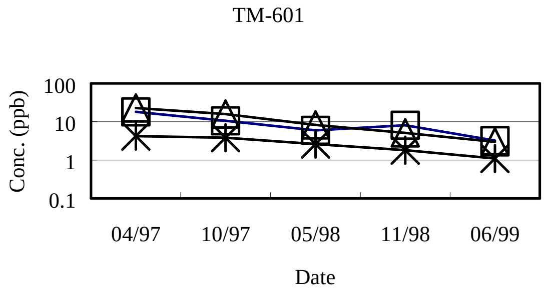
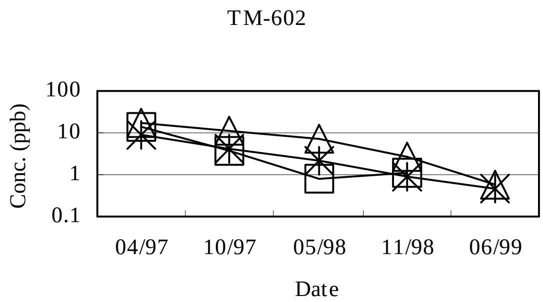


Figure 4 Trichloroethylene concentrations versus time near the monitoring wells TM-108 and TM-507. (- : sampling data, simulation results)





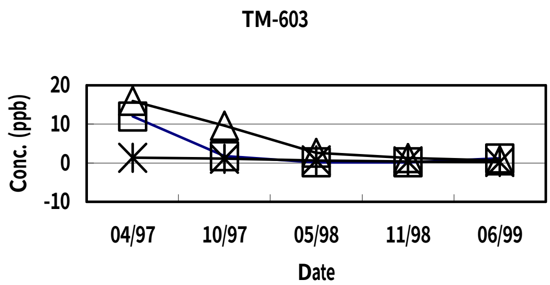


Figure 5 Tetrachloroethylene concentrations versus time near the three off-site wells, TM-601, TM-602, and TM-603. (- : sampling data; pump and treat method; * : funnel and gate system)

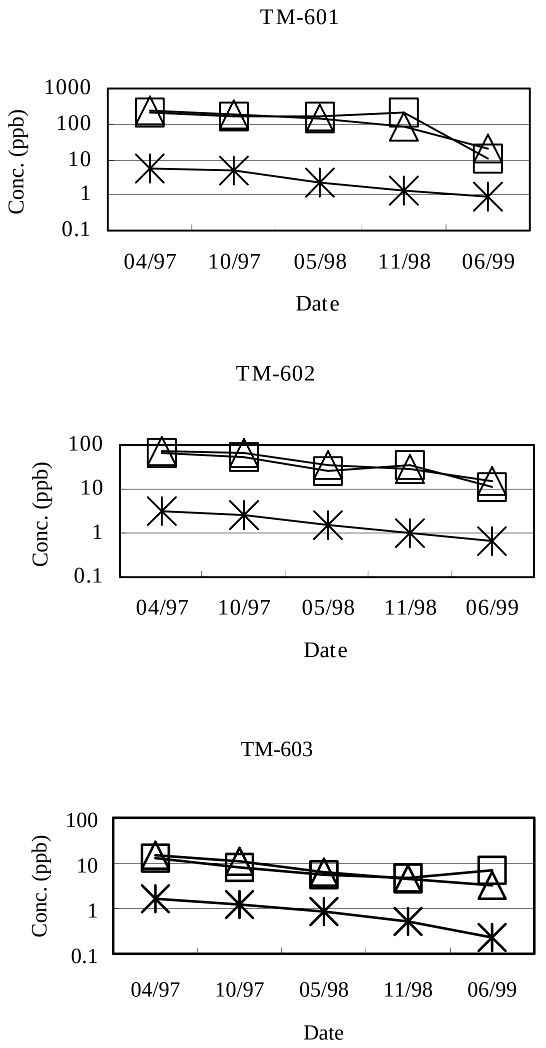


Figure 6 Trichloroethylene concentrations versus time near the three off-site wells, TM-601, TM-602, and TM-603. (- : sampling data; pump and treat method; * : funnel and gate system)

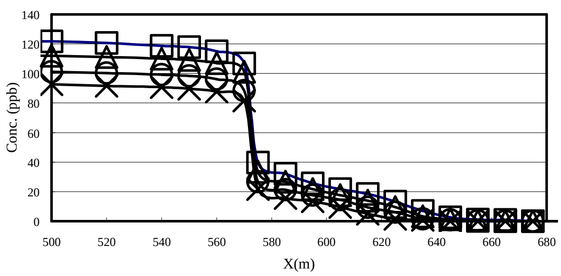


Figure 7 TCE concentration distributions when employing the funnel and gate system with biodegradation in the gate. (- : 750 780 days; days; ß : 810 days; * : 840 days)

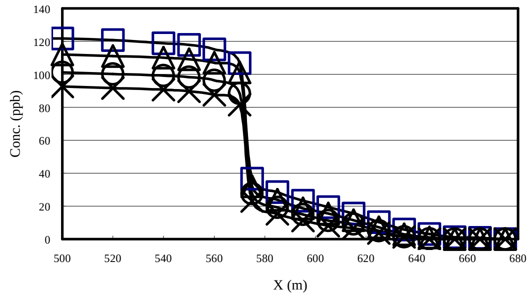


Figure 8 TCE concentration distributions when employing the funnel and gate system with zero-valent iron in the gate. (- : 750 days; 780 days; ß : 810 days; * : 840 days)

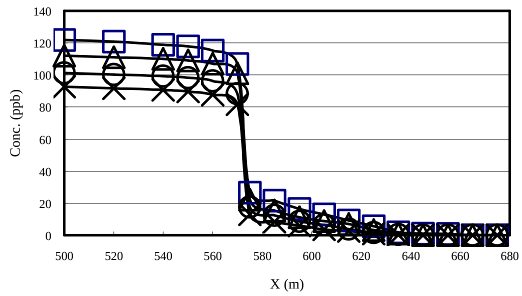


Figure 9 TCE concentration distributions when employing the funnel and gate system with zero-valent zinc (a) in the gate. (- : 750 days; 780 days; ß : 810 days; * : 840 days)

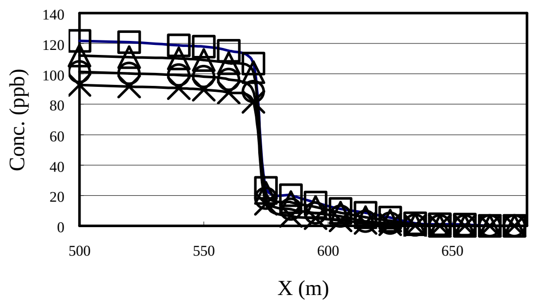


Figure 10 TCE concentration distributions when employing the funnel and gate system with zero-valent zinc (b) in the gate. (- : 750 days; 780 days; ß : 810 days; * : 840 days)

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