含氯有機化合物污染場址被動式復育系統研析(III)

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

計畫編號：NSC90-2621-Z-009-003
執行期限：90 **年** 8 **月** 1 **日至** 91 **年** 7 **月** 31 **日**

主持人：葉弘德教授　　　交通大學環境工程研究所
計畫參與人員：周子鈞　　交通大學環境工程研究所

中文摘要

關鍵詞：斗牆與阻門、零價鐵、污染傳輸

本研究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，透過有限元素法，模擬分析有機污染物於飽和地下水層中的傳輸及其宿命。並分別配合抽取處理法(pump & treat)以及斗閘系統（funnel and gate system**），以桃園** RCA **場址為對象，模擬分析** PCE **污染物分佈情形，並在阻門內加入零價鐵作為還原劑，以分解** PCE **污染物。模擬結果顯示，經過斗閘系統處理後，**RCA **場址下游濃度降為原抽取處理法的** 11**%，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

The 3DFATMIC model was employed to simulate the concentration distribution of PCE. A funnel and gate system, which adopts granular zero-valent iron 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 located 50 m downgradient from the gate reduce to about 11 % of those when using pump and treat method after five 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.

INTRODUCTION

The events of groundwater contamination due to chlorinated organic chemicals have been known for several years in Taiwan. The RCA Taoyuan site is one of the best-known cases. RCA Taoyuan, a televisoion assembly plant, operated from about 1970 until its shutdown in 1992. It is located southwest of the town of Taoyuan, 35 kilometers southwest of Taipei. The site was originally used for agricultural purpose, but was purchased and developed by RCA Taiwan, Ltd. The site layout is demonstrated in Fig. 1. In 1986, General Electric Company (GE) acquired the plant and property through the purchase of RCA. In 1987, Thomson Consumer Electronics (Thomson) purchased the plant and property from GE and continued to produce television sets and related electronics under the RCA name. Thomson sold this plant to the Hung-Yi Development and Construction Company Ltd. in 1992, which has been seeking re-zoning the property; so the land may be developed for residential and commercial uses.

In 1994, GE and Thomson took actions on environmental investigations and implemented some measures to protect potential human receptors. Results of investigations showed that chemicals, primarily chlorinated volatile organic compounds, were released into subsurface soil and groundwater in the period of 1990 to 1992. A sampling and site-specific chemical fate and transport analysis was conducted to estimate future behavior of the chemicals in groundwater and to evaluate the likelihood of additional receptors exposing to chemicals in groundwater.

The groundwater at RCA Taoyuan site was treated by pump-and-treat method for six months in the period of March 1997 to September 1997. The remediation results indicated that the pump and treat method was not an effective measure to clean up such chemicals at RCA site. The funnel and gate system has been considered to be a potentially viable alternative to conventional pump and treat method for remediation of chlorinated solvent-contaminated groundwater.

Field Simulation

The hydrogeological conditions of the study site are adopted form RCA report (Geomatrix, 1998). The study area is 750 m in length (x-direction) and 500 m in width (y-direction). Suppose a source, continuously leaching contaminants, is situated at the coordinate of (50,250,0). The model of 3DFATMIC is employed to predict the concentration distributions of contaminants being released after 1000 days. The bulk density of the first zone is 1700 kg/m^3, the effective porosity is 0.25, the distribution coefficient is 0.252, and hydraulic gradient is 0.005. The aquifer hydraulic conductivity is 12 m/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 scenario which essentially follows the history of RCA event. The simulation period is from April 1989 to December 2005. Assume the contaminants were released into groundwater in the period of March 1989 to 1992. The aquifer was being remediated for six months under the pump and treat method. Two cases of remediation using funnel and gate system are assumed. In case 1, the groundwater is remediated in the period of March 1997 to March 2003 and the results are compared with those by pump and treat method. In case 2, the aquifer is remediated for two years in the period of March 2003 to December 2005 and the results are compared with those by natural attenuation.

Table 1 Simulation scenarios

Scenario	Period
Source release	1989/04 ~ 1991/12
Natural attenuation	1992/01 ~ 1997/03
Pump and treat	1997/03 ~ 1997/09
Natural attenuation	1997/09 ~ 2003/03
F. G. case 1	1997/03 ~ 2003/03
F. G. case 2	2003/03 ~ 2005/12

Note: F. G. represents Funnel and gate system.

Sedivy *et al.* (1999) provided reasonable dimensions for the funnel-and-gate system. Funnel usually ranges from 6.7 to 37.1 m (22 to 122 feet) in length. Treatment gate, designed being parallel to the direction of flow, usually ranges from 1.2 to 12.2 m (4 to 40 feet) in length and 1.2 to 7.3 m (4 to 24 feet) in width. The lengths of the funnel and the gate are chosen 30 m and 10 m respectively, and the width for both funnel and gate is 5 m. Besides, the gate is located 220 m down-gradient from the source.

Starr and Cherry (1994) compared the remediation efficiency of funnel apex with different degrees. They found that funnels with 90-degree apex had better remediation efficiency because the capture zone was the widest. The optimum hydraulic conductivity of the gate is about 10 times that of the aquifer. Thus, a funnel and gate system with a 90 degrees angle to produce a large composite capture zone is designed to explore the feasibility of implementing such as a system at RCA site. The gate conductivity is chosen as 120 m/day that is one order of magnitude larger than the aquifer conductivity. 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 design parameters of funnel and gate system are given in Table 2. The relevant degradation parameters of PCE when using funnel and gate system for aquifer remediation are listed in Table 3.

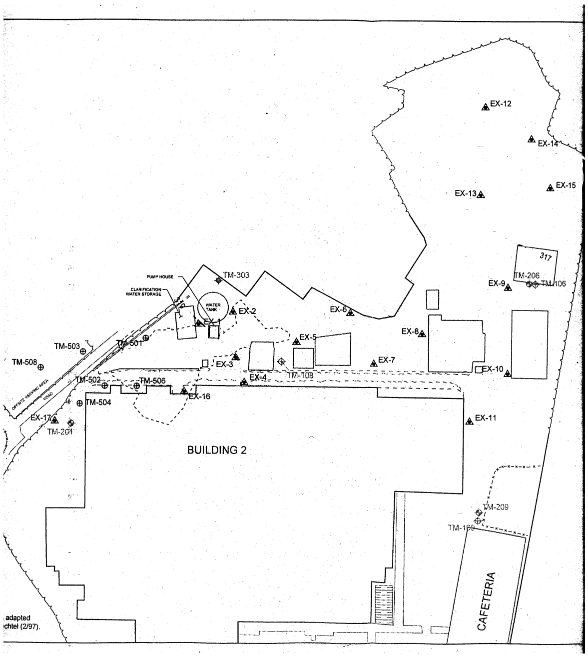

Figure 1. Site layout and well locations. (Source: Geomatrix, 1998)

The target contaminants in this study are chlorinated organic chemicals and assumed to be 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. Recently, zero-valent metal such as iron are considered to use in the reactor to remove the VOCs concentrations. Wu (2000) reported the results of batch tests from which the rate of the first order decay of granular zero-valent iron for PCE is 0.0029 day^{-1}. The rate of the first order decay derived from the batch tests is assumed suitable for Taoyuan RCA site and used in the simulations.

Table 2 Designed funnel and gate system

Parameter	Value/unit
Site conductivity	12.0 m/day
Gate conductivity	120.0 m/day
Gate length	5 m
Funnel conductivity	8.64E-16 m/day
Funnel degree	90 °
Funnel length	60 m

Table 3 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

SIMULATION RESULTS

The concentrations sampling at extraction wells, EX-7, EX-13 and EX-14, are used to verify the simulation results. The well locations are indicated in Figure 1. Before using the pump and treat method, the simulated PCE concentrations at EX-7, EX-13 and EX-14, are 128, 385, and 138 ppb, respectively, at the end of March 1997. The site sampling data of EX-7, EX-13 and EX-14, are 360, 330, and 580 ppb on March 31, 1997. It indicated that the simulated PCE concentrations has the same order of magnitude as sampled concentrations.

Figures 3, 4, and 5 respectively show the PCE contaminant in EX-7, EX-13, and EX-14 while using the pump and treat method. In EX-7 the maximum concentration is 127.77 ppb on March 31, 1997; in EX-13 the maximum concentration is 22.4 ppm on February 25, 2002; in EX-14, the maximum concentration is 61.0 ppm on October 25, 2003.

It is important to know whether the contaminant concentrations at the downstream of the funnel and gate system are lower than the cleanup standard or goal after remediation. High concentrations may endanger the resident health that lives in the down gradient of the RCA Taoyuan site. Thus, a well located at 50 meters down-gradient from the gate, is chosen to monitor the concentrations distribution of PCE. The result is to evaluate the remediation performance of the pump and treat method and the funnel and gate system. Figure 6 shows the temporal concentration of PCE under the three remediation methods. The figure indicates that the concentration will be 10.6 ppm on April 5, 2003 if using the pump and treat method; on the other hand, the concentration drop to 1.49 ppm on April 5, 2003 if using the funnel and gate system for performing over six-year period. The simulation results indicate that the concentrations of PCE located 50 m down gradient from the gate will be only 14 % of those if using pump and treat method.

Furthermore, the funnel and gate system will be employed from April 5, 2003 for two years. After the remediation period of two years and nine months, the PCE concentration will be 44.4 ppm on January 15, 2006 if using the natural attenuation and the concentration reduce to 27.3 ppm if using the funnel and gate system. The concentrations of PCE located 50 m down gradient from the gate reduce 61 % when applying pump and treat method over two years and nine months from January 15, 2003. It indicates that the concentration plume will migrate downstream and the funnel and gate system dose not have enough time to degrade the pollutants. The plume flow through the system will have higher concentration than that remediated from March 1997. The simulation results demonstrate that the funnel and gate system with zero-valent iron as reducing agent in the reactor may effectively remove the dissolved chlorinated organic chemicals at the RCA Taoyuan site.

CONCLUDING REMARKS

The 3DFATMIC model was employed to simulate the concentration distribution of PCE at RCA Taoyuan site. The simulation results for PCE, when using the pump and treat method as the cleanup measure, are close to the well sampling data.

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

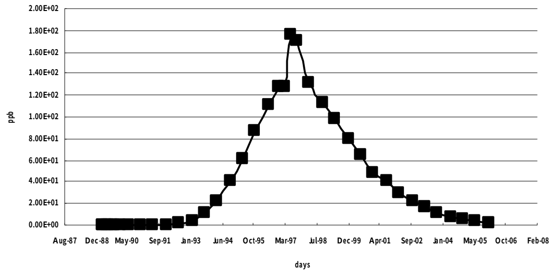

Figure 3 The temporal concentration distribution of PCE at EX-7 while implementing the pump and treat method during the period of April 1989 to January 2006.

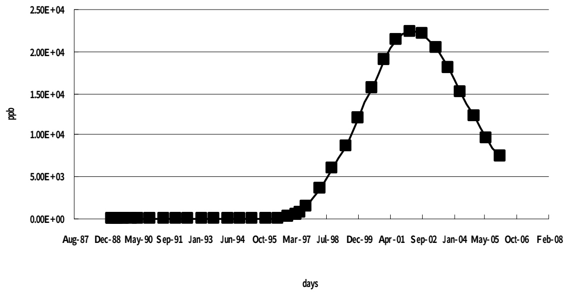

Figure 4 The temporal concentration distribution of PCE at EX-13 while implementing the pump and treat method during the period of April 1989 to January 2006.

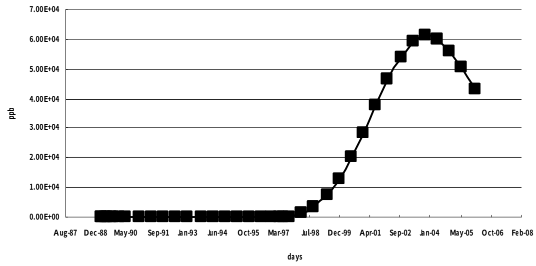

Figure 5 The temporal concentration distribution of PCE at EX-14 while implementing the pump and treat method during the period of April 1989 to January 2006.

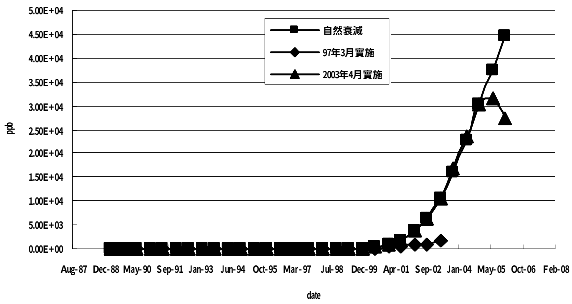

Figure 6 The PCE concentration located behind the gate 50 meters versus time under the three cases

Reference

吳先琪、陳世裕，「以健康風險管理為依據之含氯有機化合物污染廠址地下水復育技術及決策支援系統架構之研發-子計畫五：金屬還原技術用於含氯有機化合物污染廠址復育之機制及評估預測模式(Ⅰ)」， 89 **年。**

Geomatrix, Groundwater Remediation Technical Practicability Evaluation Report: Taoyuan Site, Republic of Taiwan, Prepared for: General Electric Company and Thomson Consumer Electronics, 1998.

Gupta, N., and T. C. Fox, Hydrogeologic modeling for permeable reactive barriers, *Journal of Hazardous Materials*, 68, 19-39, 1999.

Sedivy, R. A., M. Shafer, and L. C. Bilbrey, Design screening tools for passive funnel and gate Systems, *Groundwater Monitoring and Remediation*, *19*(1), 125-133, 1999.

Starr, R. C., and J. A. Cherry, In situ remediation of the contaminated Ground Water : the funnel-and-gate system, *Ground Water*, 32(3), 465-476, 1994.

Widdowson, M. A., F. J. Molz, and L. D. Benefield, A numerical transport model for oxygen- and nitrate-based respiration linked to substrate and nutrient availability in porous media, *Water Resour. Res.*, 24(9), 1553-1565, 1988.

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※※
※　　　　　　　　　　　　　　　　　　　　　　　　※
※　含氯有機化合物污染場址被動式復育系統研析(III)　※
※　　　　　　　　　　　　　　　　　　　　　　　　※
※※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：□個別型計畫　　　整合型計畫
計畫編號：NSC90-2621-Z-009-003
執行期間：90 年 8 月 1 日至 91 年 7 月 31 日

計 畫 主 持 人 ： 葉 弘 德 教 授

本成果報告包括以下應繳交之附件：

- □ 赴國外出差或研習心得報告一份
- □ 赴大陸地區出差或研習心得報告一份
- □ 出席國際學術會議心得報告及發表之論文各一份
- □ 國際合作研究計畫國外研究報告書一份

執行單位：國立交通大學環境工程研究所

中　華　民　國　91 年 10 月