

Application of solid potassium permanganate to remove volatile organic compounds in air

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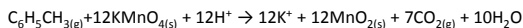
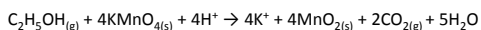
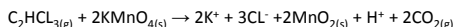
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Introduction

Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings. Dissolved permanganate has been used increasingly during the last decade as an oxidant for the remediation of aquifers contaminated with chlorinated solvents. But the use of solid permanganate for the oxidation of contaminant vapors relatively new. The purpose of our study is to investigate the use of solid phase oxidants in the unsaturated zone as a reactive barrier for vapour intrusion. Currently, the literature lacks data on the reaction between solid oxidants, such as permanganate and vapour phase of contaminants. The objectives of this batch study were two fold: (1) to evaluate the ability of solid potassium permanganate to remediate TCE, ethanol and toluene in the vapour phase and (2) to determine the kinetics of the process.

Material and Methods

The contaminates used in this batch study were TCE, toluene, and ethanol. Contaminant vapors (CVs) were obtained from their highly pure liquid phases without further purification. Potassium permanganate of 99% purity was obtained from Sigma-Aldrich. The required potassium permanganate for complete oxidation of VOCs was calculated based on the following reactions :



Solid potassium permanganate was put inside 12-ml glass vials, and they were capped with a hard septum to prevent any leakage. Vapour of VOCs was injected using gas tight syringes. All experiments were carried out at constant room temperature, $\sim 20 \pm 1$ °C, air humidity 37 ± 1 % and in a vertical rotary shaker. The gas phase of control and reaction vials were sampled over time for determining TCE, toluene and ethanol concentration (Fig.1 to 3).



Fig.1. Preparation of batch

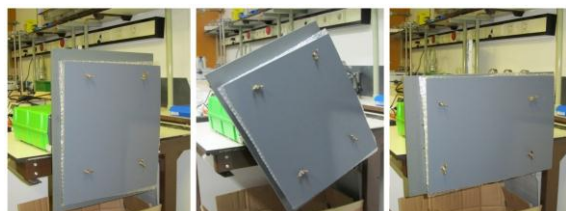


Fig.2. A vertical rotary shaker



Fig.3. Gas chromatography (GC)

Discussion and conclusions

This study shows that TCE and ethanol in vapour phase can be rapidly oxidized by solid potassium permanganate. Toluene, however, is degraded slower. A nonlinear reaction formula simulates experimental results satisfactorily. While potassium permanganate shows promise for the remediation of TCE and ethanol vapour, further investigation of its applicability for toluene is needed.

References

- Hoskinson, C., 2011, DRAFT Petroleum Vapor Intrusion Information Paper, How does the vapor intrusion pathway differ for petroleum and chlorinated hydrocarbons?
- Kao, C.M., Huang, K. D., Wang, J.Y., Chen, T.Y., and Chien, H.Y., 2008, Application of potassium permanganate as an oxidant for in situ oxidation of trichloroethylene-contaminated groundwater: A laboratory and kinetics study, Journal of Hazardous Materials 153 (2008) 919–927.

Results

Fig.4 depicts the normalized concentration (C/C_0) of target compounds, as a function of time. It is clear that potassium permanganate was able to rapidly oxidized vapour-phase of TCE and ethanol. Toluene was degraded also but more slowly. As shown in the Fig.4, the oxidation of toluene took around 70 hours.

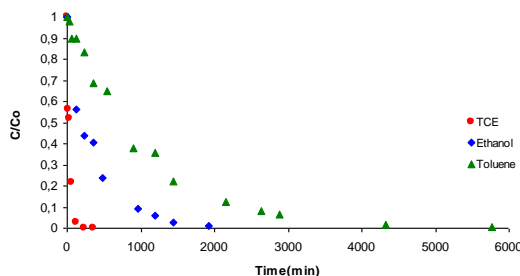


Fig.4. Degradation of TCE, ethanol and toluene vs. time

For the analysis of data, the following kinetic equation was used:

$$\frac{dC}{dt} = k_b A C^\alpha M^\beta$$

where k_b denotes the reaction rate constant, A is the specific surface area of potassium permanganate ($L^2 M^{-1}$), C is the vapour concentration of the compound ($mol L^{-1}$), M is the mass of potassium permanganate per volume of gas ($M L^{-3}$), α and β are constant parameters.

In this equation, the surface area of potassium permanganate is included because reactions occur at the available solid surface. We assumed that the concentration of potassium permanganate indeed surface area of potassium permanganate during the experiment doesn't change.

This equation was fitted to experimental data by Chi-Square Curve Fitting Model in order to obtain values of k , α , and β for each compound (Fig.5).

Table1: kinetic parameters for target compounds

Compound	α	β	k	R^2
TCE	0.9	1	6.92×10^{-7}	0.99
Ethanol	1.09	1	5.68×10^{-7}	0.99
Toluene	0.94	1	2.99×10^{-8}	0.99

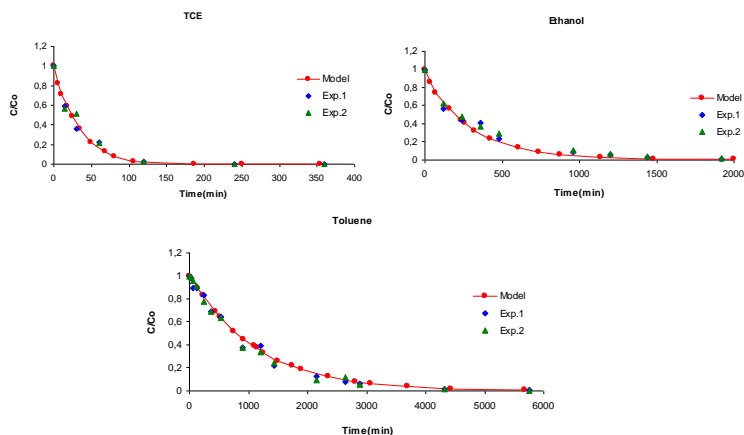


Fig.5. Comparison of experimental and model