Chemical Engineering Journal 219 (2013) 311–318

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Synergistic effect of zero-valent copper nanoparticles on dichloromethane degradation by vitamin B_{12} under reducing condition

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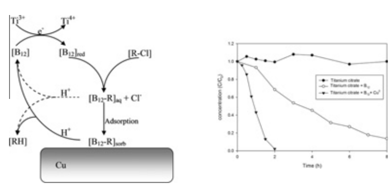
HIGHLIGHTS

- The synergistic effect of Cu^0 on DCM degradation by vitamin B_{12} was found.
- Increasing vitamin B_{12} or Cu^0 dose will increase DCM degradation rate.
- The excessive amount of copper did not increase the reactivity.
- DCM was degraded reductively to methane.
- Copper ions were lower than the WHO-specified limit for drinking water.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 July 2012
Received in revised form 3 January 2013
Accepted 5 January 2013
Available online 11 January 2013

Keywords:
Cobalamin
Catalytic dechlorination
Groundwater remediation
Zero-valent iron
ZVI

ABSTRACT

While zero-valent iron (ZVI, an electron donor) can degrade many kinds of chlorinated organic contaminants and vitamin B_{12} (an electron mediator) is capable of enhancing the degradation, both are ineffective in degrading dichloromethane (DCM). In this study, we found that a combination of zero-valent copper (Cu^0) nanoparticles and vitamin B_{12} can catalyze the degradation of DCM effectively under reducing conditions when titanium citrate was used as the reducing agent. Batch experiments were performed to test the effectiveness of the Cu^0–B_{12} system in DCM degradation. Approximately 99% of 26 mg/L DCM was degraded rapidly within 2 h by the Cu^0–B_{12} system. The observed pseudo-first-order rate constant was 1.35 h^{-1}, which was five times greater than that of using vitamin B_{12} alone. A synergistic effect of Cu^0 nanoparticles on the reductive degradation of DCM by vitamin B_{12} was found. Soluble copper ions generated by the dissolution of Cu^0 nanoparticles were lower than the WHO-specified limit for drinking water. It is expected that the combination of Cu^0 nanoparticles and electron mediator system may have the potential for treating recalcitrant groundwater contaminants that cannot be degraded by ZVI technology.

1. Introduction

Dichloromethane (DCM) is widely used as a solvent in chemical processing and in many consumer products such as paint strippers and adhesives. DCM is an environmental contaminant, and its origin in the environment, for example, in soil and groundwater, can be traced to leaks and discharges from industrial sources. It has been detected in surface water and groundwater, and its concentration in these water sources in the United States has been reported to range from 0 to 3600 μg/L [1]. Recently, the concentration of DCM in groundwater in Taiwan has been reported to be 1120 mg/L, which is higher than the groundwater quality standard set by the Taiwanese Environmental Protection Administration by a factor greater than 20,000 [2]. The toxic effects of DCM in humans manifest mainly as disturbances of the central nervous system and hepatotoxic effects. In addition, DCM is potentially carcinogenic to humans. Therefore, it is important to remove DCM from the environment.

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http://dx.doi.org/10.1016/j.cej.2013.01.016