Kossge International Symposium on Soil & Groundwater Environment
October 27-28, 2005 Mayfield Hotel, Seoul, Korea

Removal of Contaminants in Leachate from Landfill Using Wasted Steel Scrap and Converter Slag

Byung-Taek Oh[1]* · Jai-Young Lee[2]* · Jeyong Yoon[3]

[1] *Dept. of Environmental Sciences & Biotechnology, Hallym University, Chuncheon, Gangwon-do 200-702, South Korea (*Corresponding authors: btoh@hallym.ac.kr, leejy@uos.ac.kr),*
[2] *Dept. of Environmental Engineering, The University of Seoul, Seoul 130-743, South Korea,*
[3] *School of Chemical Engineering, Seoul National University, Seoul 151-742, South Korea*

ABSTRACT

To the best of our knowledge, this study is the first investigation to be performed into the potential benefits of recycling industrial wastes in controlling contaminants in leachate. Batch reactors were used to evaluate the efficacy of wasted steel scrap and converter slag to treat contaminants in leachate from landfill. The wasted steel scrap was prepared through pretreatment of acid-washed step, which retained both zero-valent iron site and iron oxide site. Extensive trichloroethene (TCE) removal (95%) occurred by acid-washed steel scrap within 48 h. In addition, dehalogenation (Cl^- production) was observed above 7.5% of the added TCE on a molar basis for 48 h. Heavy metals (Cr, Mn, Cu, Zn, As, Cd, and Pb) were extensively removed by both acid-washed steel scrap and converter slag through adsorption process. Among salt ions (NH_4^+, NO_3^-, and PO_4^{3-}), PO_4^{3-} was removed by both wasted steel scrap (100% for 8 h) and converter slag (100% for 20 min), whereas NO_3^- and NH_4^+ were removed by wasted steel scrap (100% for 7 d) and converter slag (up to 50% for 4 d), respectively. This work suggests that permeable reactive barriers (PRB) with wasted steel scrap and converter slag might be an effective approach to intercept contaminants in leachate from landfill.

Municipal solid waste landfills contain mainly a mixture of various organic compounds and heavy metals. The decomposition of waste in the landfill may result in producing environmentally harmful substances. Landfill leachate treatment has received significant attention in recent years since landfill leachate is a frequent source of groundwater contamination. It has been emphasized by the identification of chlorinated solvents such as trichloroethylene (TCE) and tetrachloroethylene (PCE) in leachate-contaminated groundwater. Encouraging results in laboratory experiments have stimulated a rapid increase in the use of zero-valent iron (Fe^0) as a reactive material to remove chlorinated solvents from groundwater. With a standard reduction potential ($E_h°$) of –409 mV, Fe^0 primarily acts as a strong reducing agent ($Fe^0 \rightarrow Fe^{2+} + 2e^-$). One byproduct reported in PCE and TCE reaction with Fe^0 is acetylene. This reaction is raised

through the sequential hydrogenolysis (replacement of a halogen (Cl^-) by a hydrogen) of PCE to TCE, dichloroethylenes (DCEs), and vinyl chloride (VC), followed by VC dehydro-halogenation to acetylene. Industrial wastes such as fly ash, bottom ash, and granulated slag of steel plans have been studied as cost-effective and convenient adsorbents for the treatment of wastewater containing heavy metals. Converter slag composed of magnetite (Fe_3O_4) is suitable for use as a metal adsorber in wastewater treatment. The main objective of this study was to evaluate the efficacy of wasted steel scrap and converter slag to treat contaminants in leachate from landfill. Emphasis was placed on determining whether wasted steel scrap is used as reducing agent and heavy metal adsorber after pretreatments.

Converter slag as a steel plant residue was obtained from steel company. Wasted steel scrap was obtained from industrial complex and washed with solvent in order to remove oil on the surface. Two different types of wasted steel scraps, scratched with sand paper (RD) and acid-washed with hydrochloric acid solution (AD), were prepared through pretreatment. Zero-valent iron powder (FB) was also used to give a baseline to evaluate the efficacy of wasted steel scrap. Batch degradation assays were subsequently run to test the reactivity of the wasted steel scrap and converter slag (5%, w/v each) towards TCE (10 mg/L), ion salts (NH_4^+, NO_3^-, and PO_4^{3-} at 10 mg/L each), and heavy metals (Cr, Mn, Cu, Zn, As, Cd, Pb, and CN at 10 mg/L each) pollutants that are commonly present in learchate from landfill. Reactors were shaken on a reciprocating shaker (150 rpm, 25°C) and periodically analyzed for each pollutant. In order to prove hydrogenolysis (Cl^- production) by Fe^0, 100 mg/L of TCE was applied. TCE, salt ions and chloride, and heavy metals were quantified using GC, IC, and ICP, respectively.

Batch experiments suggest that wasted steel scrap can effectively remove chlorinated compound. While there were no significant volatilization losses of TCE in no-treatment controls, extensive TCE removal occurred by RD, AD, and FB for 48 hr, demonstrating that TCE removal was due to degradation by zero-valent iron. For 4 and 48 hr of reaction time, AD showed almost same capability to remove TCE with FB (Fig. 1a). In preliminary experiments, wasted steel scrap itself before pretreatment step did not show any activity to contaminants including TCE. Note that wasted steel scrap was reactive through pretreatments such as sandpapered and acid-washed steps, which resulted in removal of chlorinated compounds. Previous studies have reported that zero-valent iron can dechlorinate halogenated aliphatic organic compounds. Batch experiments show that extensive dechlorination occurred by AD and FB for 48 hr (Fig. 1b). The value of dechlorination extent was approximately 7.5% (AD) and 11.5% (FB) of the added TCE on a molar basis. AD, which was originated from wasted steel scrap, exhibited extensive activity to be used as reactive material in PRB system, although dechlorination of TCE by AD was less than that by FB. Wasted steel scrap through pretreatment showed the high reactivity to remove salt ions. Among the tested salt ions (NH_4^+, NO_3^-, and PO_4^{3-}), PO_4^{3-} was the most reactive by RD, AD, FB (100% for 8 hr each), and converter slag (100% for 20 min), followed by NO_3^- while NH_4^+ removal by converter slag (50% for 4 d) was relatively slow. The fast removal of PO_4^{3-} by converter slag may be due to the formation of

precipitate after PO_4^{3-} reacts with cations (Al^{3+}, Fe^{2+}, Fe^{3+}, Ca^{2+} etc.). Heavy metals removal assays were also conducted in additional batch reactors to investigate the ability of AD and converter slag to remove heavy metals. Based on adsorption results, significant heavy metals removal (Cr, Mn, Cu, Zn, As, Cd, and Pb) was observed by AD and converter slag. Interestingly, AD, which is known to remove TCE as described above, removed to a great extent except Mn. This removal may be due to adsorption by iron oxide on AD surface that was formed through pretreatment. Mn and Cd were almost completely removed in 20 min by converter slag.

As machine tool and steel plant residues, wasted steel scrap and converter slag are abundant and can be obtained at low cost. Laboratory experiments suggest that wasted steel scrap and converter slag can be used as reactive materials in PRB system to remove contaminants in leachate from landfill. This approach may also be practical and effective to treat other redox-sensitive groundwater pollutants, such as nitroaromatic compounds, chlorinated solvents, hexavalent uranium, and some pesticides.

Key words: PRB, zero-valent iron, leachate, TCE, converter slag

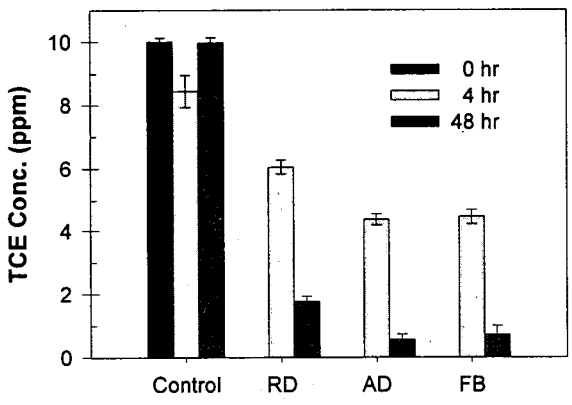

Fig. 1a. Removal of TCE by wasted steel scraps and zero-valent iron powder (C_0= 10 mg/L).

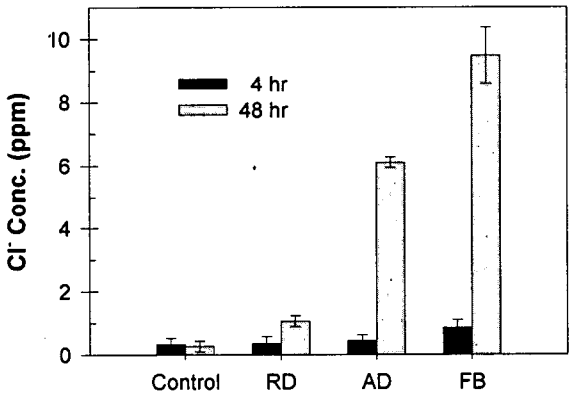

Fig. 1b. Dechlorination of TCE by wasted steel scraps and zero-valent iron powder (C_0= 100 mg/L).