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Emerging Technology Bulletin

Institute of Gas Technology

(Chemical and Biological Treatment)

Technology Description: The institute of Gas Technology's (IGT) Chemical and Biological Treatment (CBT) process remediates sludges and soils contaminated with organic pollutants, such as polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). The treatment system combines two remedial techniques: (1) chemical oxidation as pretreatment, and (2) biological treatment using aerobic and anaerobic biosystems either in sequence or alone, depending on the waste. The CBT process uses mild chemical treatment to produce intermediates that are biologically degraded, reducing both the cost and risk associated with more severe treatment process, such as incineration.

The figure below shows some of the options available for application. The contaminated material is treated with a chemical reagent that degrades the organopollutants to carbon dioxide, water, and more biodegradable partially-oxidized intermediates. In the second stage of the CBT process, biological systems are used to degrade the hazardous residual materials and the partially-oxidized material from the first stage. Chemically-treated wastes are subject to cycles of aerobic and anaerobic degradation if aerobic or anaerobic treatment alone is not sufficient. Also, several cycles of chemical and biological treatment are used for extremely recalcitrant contaminates.

Waste Applicability: The CBT process can be applied to soils and sludges containing high waste concentrations that would typically inhibit bioremediation and low waste concentrations when bioremediation alone is too slow. The process is not adversely affected by radionuclides or heavy metals. Depending on the types of heavy metals present, these metals will either bioaccumulate in the biomass, complex with organic or inorganic material in the soil slurries, or solubilize in the recycled water. The CBT process can be applied to a wide range of organic pollutants, including alkenes, chlorinated alkenes, aromatics, substituted aromatics, and complex aromatics. Applicable matrices include soil, sludge, groundwater, and surface water.

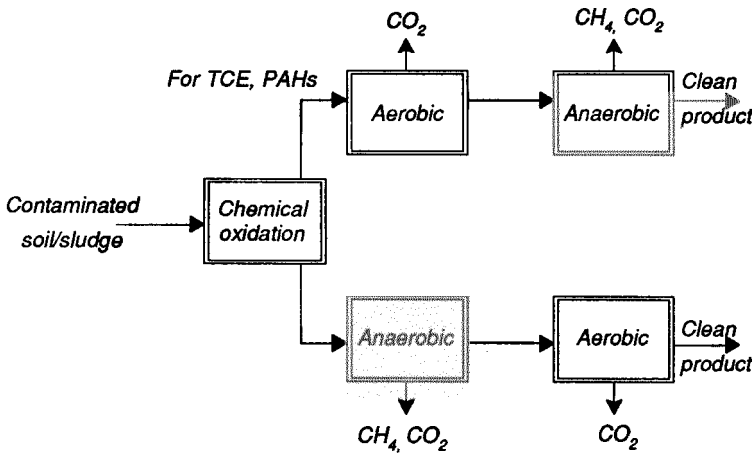

***Figure** 1. Chemical and biological treatment (CBT Process).*

Test Results: IGT has completed two yr of evaluation of the CBT process within the SITE Emerging Technology Program. This evaluation has included bench-scale studies of important operational parameters for applying the CBT technology to soils and sludges contaminated with PCBs. Table 1 shows the PCB degradation for a single-cycle of the chemical/biological treatment process. Results indicate that this technology can treat various PCB-contaminated matrices with modifications to the original treatment protocol that increases the availability of the PCBs.

During the evaluation of the CBT process, a nonstandard GC/ECD method for PCB analyses was developed at IGT for quantification of individual PCB congeners. Although there are several EPA methods for analyses of PCBs, no method is currently approved for quantitative analyses of PCBs which have been chemically altered by chemical, biological, or thermal reaction. Protocol development and verification was necessary before beginning experiments with PCB contaminated soils.

Initial studies indicated that 30-40% of 2,2',4,4' tetrachlorinated-^{14}C–biphenyl could be mineralized to $^{14}CO_2$ by chemical oxidation. Equally as important, 30-35% of 2,2',4,4' tetrachlorinated-biphenyl is modified to a water soluble, more easily degradable product. As expected the higher the chlorination of the biphenyl, the lower the amount of mineralization. Chlorine groups in the 3-position inhibited mineralization by 50% when compared with the 2-position. Chlorines in the 4-position appear to be sightly more susceptible (=8%) to chemical degradation than chlorines in the 2-position. This difference is statistically significant as measured by $\pm$ the standard deviation. This study indicated that the majority of the chemical mineralization of PCBs occurs in the first 45-60 min of the reaction.

The standard reagent concentration of 2.5% H_2O_2 and ferrous sulfate, 10mM, resulted in the greatest degradation in both the

Table 1. *PCS* Degradation *by IGT's Chemical and Biological Treatment* Process

Single-Cycle

*Treatment**	*Water*	*Sludge*	*Soil*
Biological (Aerobic)	*30%*	*<5%*	*<5%*
Chemical	*90%*	*65%*	*50%*
Chemical/ *Biological (Aerobic)*	100%	65%	30%

- *Chemical Treatment = 5% H_2O_2 for 1hr. Biological (Aerobic) Treatment = 10% inoculum of a mixed consortium for approximately 15 Days*

lower and higher chlorinated compounds. When compared to the control, 40% of total PCBs were removed by chemical degradation and as much as 90% of some PCB congeners were removed. As the reagent concentration increases the degradation of PCBs increases; however, the PCBs with less than 5 chlorine groups are more susceptible than PCBs with greater than 5 chlorine groups. This pattern complements the anaerobic and aerobic biodegradation of PCBs in that it aggressively attacks the intermediate biphenyl compounds with 3-5 chlorine groups, anaerobic biodegradation effectively reduces the concentration of higher chlorinated biphenyls (4-8 chlorine groups) by 44-70% and aerobic biodegradation efficiently removes mono- and di-chlorinated biphenyls. Experiments conducted using actual contaminated soil demonstrated greater than 50% of all congeners were removed with a single cycle of the integrated chemical/biological degradation.

IGT's CBT technology continues to be successfully applied to PAH-contaminated soils. The CBT process consistently outperforms conventional bioremediation, especially with multi-ring (4-6) PAH compounds. The CBT process increases both the rate and extent of removal of contamination from various types of soils. Two successful field tests, one solid-phase land treatment and one in the soil slurry mode, have been conducted under other gas industry supported programs. The field experiment showed that the integrated treatment system resulted in about *50%* greater removal of total PAHs and 90% greater removal of carcinogenic PAHs than those of conventional biotreatment. The integrated system's results exceed the treatment goals which had been established and were reached in 42 days. This field study verified the effectiveness of the integrated biological-chemical treatment process on a large- scale demonstration. Also, the field data show that the integrated process results in higher cleanup levels and at faster rates as compared with biological treatment alone.

The CBT technology has been admitted into the SITE Demonstration Program and IGT is evaluating possible sites for a full-scale demonstration.

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