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In-situ Respiration Test Application for Contaminated Site

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Ⅰ. Introduction

In situ respiration test was typically used to provide rapid field measurement of biodegradation rates for determining potential applicability of bioventing at a contaminated site and to provide basic information for a full-scale bioventing system design (Hinchee and Ong, 1992; Davis et al., 1998). This respiration test has been used at numerous sites throughout the United States, including all bioventing initiative sites.

Oxygen utilization rate greater than 1.0 %/day is a good indicator that bioventing may be feasible at the site and proceeding to soil gas permeability testing is appropriate. If oxygen utilization rate is less than 1.0 %/day, yet significant contamination is present, other factors may be involved in limiting biodegradation.

Ⅱ. Materials and methods

The in situ respiration test consists of placing narrowly screened soil gas monitoring points into the unsaturated zone of contaminated soils and venting these soils with air containing an inert tracer gas (typically helium) for a given period. In a typical experiment, a cluster of three to four soil gas probes are center of contaminated areas where low oxygen gas and high contaminant concentrations have been measured. Test conditions are presented in Table 1.

TABLE 1. Summary of test conditions for respiration tests

Test No.	Test date	Injection duration (hrs)	Injection rate (L/min)	Remark
1	Apr., 1998	24	30	Spring (moderate temp.)
2	Dec., 1999	48	28	Winter (low temp. season)
3	June, 1999	48	48	Summer (high temp. season)

Carbon dioxide, oxygen, and methane concentrations in soil gas were measured prior to injection of air and inert gas. Inert gas of 1% to 3% concentration was added to the injection air, which was injected at flow rates ranging from 1.0 cfm to 1.7 cfm (28 L/min to 48 L/min). He of 2% as a tracer and flow rate of 30 L/min was adopted in the first respiration experiment. The air provides oxygen to the soil, and the inert gas provides information on the diffusion of oxygen from ground surface and surrounding soil, and on the possible leakage of the soil gas sampling system. Background control location was selected in an upgradient uncontaminated area to monitor natural background respiration rate. During and after the injection of air and inert gas, changes in concentrations of oxygen, carbon dioxide, methane, and inert gas were monitored.

Ⅲ. Results and discussion

Oxygen utilization rates were computed using data obtained from the in situ respiration test. The rates were calculated based on zero-order relationship between oxygen concentration and time. In general, a rapid linear decrease in oxygen concentration occurs after stop of air injection, and oxygen concentration drop to below 5% is followed in a certain amount of lag period. To calculate oxygen utilization rates, only the first linear portion of the data was used because this would represent oxygen utilization when oxygen is not limiting, as is the case during active bioventing.

The oxygen utilization rate is determined using the slope of the curve of the decrease in oxygen concentration. A zero-order respiration rates as seen in this site are typical of most sites(Figure 1). Calculated oxygen utilization rates and corresponding biodegradation rates for these data are presented in Table 2. The oxygen utilization rate ranged from 0.29 at highly contaminated depth to 0.033 %/hr at relatively low contaminated depth. Results of this test indicate that this site is an excellent candidate for bioventing remediation. At the background location in the upgradient uncontaminated area, no discernible decrease in oxygen was detected at any depth in the soil zone during 67 hrs after cease of aeration. This indicated that the background oxygen consumption rate was almost zero.

The helium data collected at a site can provide insight into whether observed oxygen utilization rates are caused by microbial utilization or by other effects such as leakage or diffusion. Although helium is a conservative tracer, its concentration would decrease with time. As a general rule of thumb, any in situ respiration test in which the rate of helium loss is less than the oxygen loss rate should be considered acceptable. If the helium loss rate is greater than the oxygen loss rate, the test result from that monitoring point should be disregard. In this site, the data show acceptable results.

At nearly all sites included in the bioventing initiative sites, oxygen utilization has proven to be a more useful measure of biodegradation rates than carbon dioxide production. The biodegradation rate in mg of hydrocarbon-equivalent/kg of soil per day based on carbon dioxide production usually is less than that can be accounted for by the oxygen disappearance, which is true in this site. At virtually all bioventing initiative sites, oxygen utilization rates have been higher than carbon dioxide production rates. The ratio of the oxygen utilization to carbon dioxide production rate will not be 1 because for every 9 moles of oxygen consumed, 7 moles of carbon dioxide are produced. An important consideration is whether the respiration rate was measured at the time of year when microbial respirations were at their maximum or it was measured when microbial activity was low. Two additional in situ respiration tests were conducted in different seasons (summer and winter). The oxygen consumptions shown in Figures 3.29 and 3.30 are 0.18 %-O_2/hr or 4.32 %-O_2/day in winter and 7.68 %/day in summer and estimated biodegradation rates ranged from 2.72 to 4.84 mg/kg-day. The site would require approximately 1.8 times greater oxygen delivery rate in the summer. This data imply that bioventing technology is potentially good for this area. In situ respiration testing should be conducted periodically as a means of monitoring the progress of site remediation.

In situ respiration testing can also be used as a primary indicator for site closure. The fact that an in situ respiration rate in the contaminated area similar to that in the uncontaminated area is a good indication that the site is fully remediated and that final soil sampling can be conducted. In situ respiration testing for determining remediation success is economically significant because soil sampling is not relied upon as the sole indicator of site remediation, thus it can eliminate the high cost of intermediate soil sampling(Lee, 2000).

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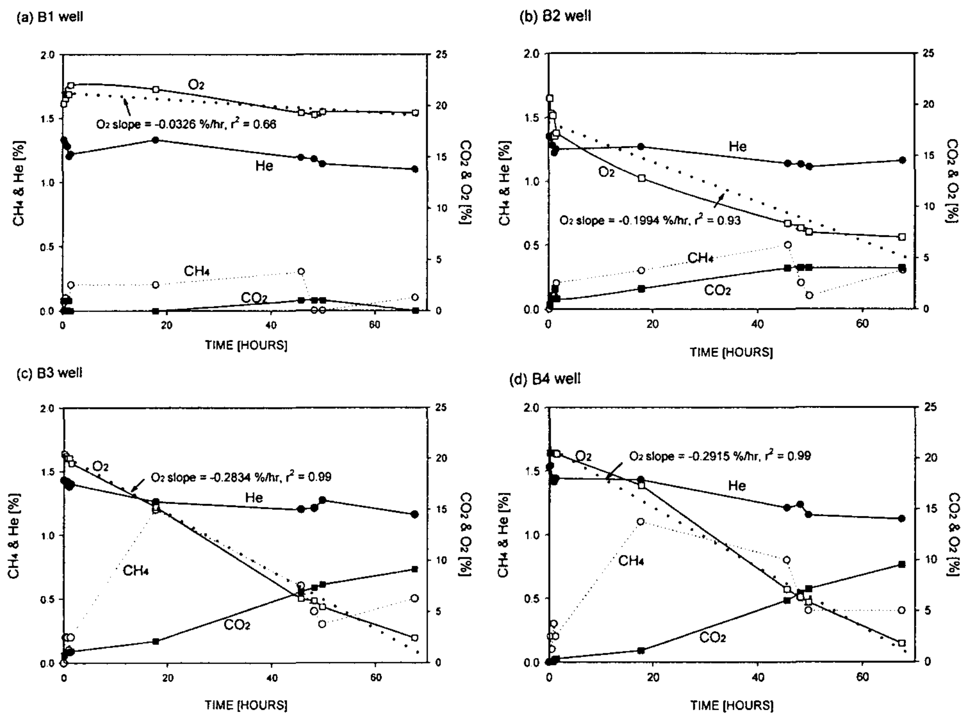

Figure 1. Results of in-situ respiration tests showing concentrations of O_2, CO_2, CH_4 and He versus time measured at each gas probe.

TABLE 2. Oxygen utilization and carbon dioxide production rates computed from the first in-situ respiration test

Probe point	Screen depth (m, bgs)	O_2 utilization rate (%/hr: %/day)	CO_2 production rate (%/hr: %/day)	Estimated biodegradation rate (mg-toluene/kg-day)	Remarks
B1	1.0	0.033: 0.8	0.0027: 0.065	0.49	less contaminated
B2	1.5	0.20: 4.8	0.054: 1.296	3.02	
B3	2.0	0.28: 6.7	0.13: 3.12	4.23	Highly contaminated
B4	2.5	0.29: 7.0	0.14: 3.36	4.38	
B5	3.0	-	-	-	Venting point