Electrolytic Respirometry Monitors Groundwater Biotreatment

Electrolytic respirometry (ER) has proven a valuable tool in evaluating the biological treatment of contaminated groundwater. The technique is used initially to determine the treatability of the compounds contaminating the water plus the amounts of additives, such as nutrients and commercially grown bacterial strains, required to optimize biodegradation. Results of ER analyses are used to design the treatment program.

After biotreatment is underway, ER analysis of extracted groundwater can determine the progress of biodegradation, duplicating on-site conditions in the laboratory. It can also assess the relative degradation rate over time to determine the length of the program required to reach the desired levels of target compounds.

What Is ER?

Respirometry is the measurement of the respiration of organisms. Aerobic respiration is the energy production mechanism for most organisms and commonly involves consumption of oxygen and release of carbon dioxide..Other types of respiration (anaerobic, in which nitrate, sulphate, ferric ion, manganic ion, or carbonate are used in place of oxygen; and aerobic autotrophic respiration in which reduced inorganic compounds, such as ammonium or sulfide, are used in place of organic compounds) are found in microbes. For evaluating bioremediation, respirometers usually measure the oxygen consumption and production of product gases, such as carbon dioxide or methane, of microorganisms to determine their activity in various environments. The technique can also be used, with appropriate modifications, to measure the metabolic rate of anaerobic bacteria.

Short of building a pilot plant, ER provides the closest approximation to what happens in groundwater, or at the site of a chemical or petroleum spill. One BI-2000 base module, the type of ER unit made by Bioscience, Inc., contains eight reactors and a computer that can accommodate and analyze data for up to 16 reactor vessels. Therefore it is possible to experiment with a large number of environments at the same time, something that cannot be done in a pilot plant. Aerobic microorganisms, primarily bacteria, consume oxygen and give off carbon dioxide as they convert the available food supply into cell mass. The amount of oxygen consumed, over and above the base rate of respiration (known as the endogenous rate), is a measure of the activity of the biomass and its metabolism of the food supply.

The heart of the process is the reactor vessel, (Figure 1) that contains measured amounts of a microbial culture and the compounds–usually in an aqueous solution–to be digested. The culture may be a sample of an existing biomass, microorganisms from soil or groundwater, or specific microbial strains selected for activity on certain classes of compounds. Calculated amounts of nutrients may also be added to provide the proper environment for microbial growth or to ascertain the optimum on-site conditions.

When (and if) metabolism begins to take place, the microbes consume the existing oxygen inside the reactor and give off carbon dioxide. The carbon dioxide is absorbed by a potassium hydroxide solution in the reactor vessel head, resulting in a slight negative pressure. The partial vacuum triggers the electrolytic cell, also in the reactor, that supplies oxygen by means of electrolysis of a dilute acid solution until the original headspace pressure is restored. The electrical power consumed, in coulombs, is proportional to the produced oxygen. ER is an extremely accurate measure of the amount of oxygen metabolized by the microbes.

The electrical readings are digitized and sent to a computer which records and displays them. The data may be graphed directly, imported into a spreadsheet to perform calculations, or inserted into a program written to assist in bioremediation project design.

The results of respirometry correlate closely with those of pilot plants and with actual studies in the field, at relatively low cost.

ER is often used to determine the feasibility and effectiveness of various soil and groundwater bioremediation methods. Groundwater samples from wells in the contaminated area can be evaluated rapidly at intervals to ensure that the biotreatment program continues to work and to provide a time frame for its completion, by extrapolating degradation rates to the endogenous level of micro-organisms in the sample. Regular sampling is necessary, because metabolic processes can reduce the levels of required nutrients (in addition to the target compound) or generate inhibitory by-products.

While standard ER reactor vessels are usually appropriate for groundwater monitoring, special reactors are also available to evaluate samples with very low levels of microbial activity or to measure respiration in soils rather than water solutions.

Case Study

A site remediation for dichloromethane from a ruptured pipeline at a chemical plant used ER to determine biodegradability .There was a possibility that unknown compounds in the soil might inhibit microbial growth, even though the compound had been shown to be readily biodegradable in laboratory studies.

The test parameters were dichloromethane loss and chloride release from biodegradation. Groundwater from the site was used for the studies. Two of the reactors were inoculated with sludge from a treatment plant that had been exposed to low levels of the compound over the years, and was thought to contain an acclimated microbial population.

Dichloromethane was added to all reactor vessels at 100 ppm, approximating the average concentration in groundwater. Another two reactors included indigenous microbes, while two served as abiotic controls to quantify non-biological loss of dichloromethane.

No dichloromethane loss nor chloride release was detected in the abiotic reactors**.** The same was true of the reactors seeded with indigenous microbes, after two weeks of observation. In the reactors containing microbes from the treatment plant, acclimation and degradation of dichloromethane occurred after just one day.

Based on the treatability studies, biological treatment at the site was begun using a batch reactor seeded with bacteria from the plant's wastewater treatment system.. Continuous treatment of the compound was initiated after two weeks. Removal of dichloromethane from groundwater occurred in a total of 50 days–after a hiatus due to freezing weather-- reducing levels to 1 part per billion.

A similar ER study was also performed on a site contaminated with ethylene glycol. In this case, the indigenous microorganisms were shown to be able to degrade ethylene glycol if proper nutrients were supplied and pH was regulated. The groundwater was treated in an above-ground reactor and its effluent re-injected into the vadose zone, to create a closed-loop system in which biodegradation occurred in the soil, groundwater and the reactor, Between 85 and 93 percent of the ethylene glycol was removed during the first 26 days of treatment. After a six-month maintenance program, the level was reduced throughout the site to below the analytical limit of detection.

Using ER in preliminary site studies provides a cost-effective tool to measure bioremediations's potential for cleaning a site. The method determines biodegradation rate, molecular oxygen and nutrient requirements and allows comparison of treatment methods to enhance the natural biodegradation rate. The results are readily transferrable to full-scale treatment, while its predictability allows use of the parameters obtained for process design.