Biogeosciences

B51A MCC: Hall C Friday 0830h

Biotreatment of Waste During Landfilling and Long-Term Storage Posters *(joint with H)*

Presiding: **S E Borglin,** Lawrence Berkeley National Laboratory; **J Y Wang,** Northeastern University; **R Yazdani,** Yolo County Central Landfill

B51A-0700 0830h POSTER

Biodegradation of PAHs and PCBs in Soils and Sludges

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Results from a multi-year, pilot-scale land treatment project for PAHs and PCBs biodegradation are evaluated. A mathematical model, capable of describing sorption, sequestration, and biodegradation in a soil/water system, is applied to interpret the efficacy of a sequential active-passive biotreatment process of organic chemicals at remediation sites. To account for the recalcitrance of PAHs and PCBs in soils and sludges during long-term biotreatment, this model comprises a kinetic equation for organic chemical intraparticle sequestration. Model responses were validated by a favorable match to measurements of biodegradation of PAHs and PCBs in a land treatment unit operated by Aluminum Corporation of America Model simulations were performed to predict on-going biodegradation behavior of PAHs and PCBs in land treatment units. Simulation results indicate that complete biostabilization will be achieved when the concentration of reversibly sorbed chemical (SRA) reduces to zero (i.e., undetectable), with a certain amount of irreversibly sequestrated residual chemical (SIA) remaining within the soil particle solid phase. The residual fraction (SIA) tends to lose its original chemical and biological activity, and hence, is much less available, toxic, and mobile than the free compounds. Therefore, PAHs and PCBs will leach only slightly, if at all from the treatment site and thus, they constitute no threat to human health or the environment. Biotreatment of PAHs and PCBs can be terminated accordingly. Results from the pilot-scale testing data and model calculations also suggest that a significant fraction (10-30%) of high-molecular-weight PAHs and PCBs could be sequestrated and become unavailable for biodegradation. Bioavailability (large Kd, i.e., slow desorption rate) is the key factor limiting the PAHs degradation. However, both bioavailability and bioactivity, K (as described by Monod kinetics parameters), regulate PCBs biodegradation. The sequential active-passive biotreatment can be a cost-effective approach for remediation of highly hydrophobic organic contaminants. The mathematical model proposed here should be useful in the design and operation of such organic chemical biodegradation processes on remediation sites.

Keywords: PAHs; PCBs; Biodegradation; land treatment; Mathematical model and application

B51A-0701 0830h POSTER

Non-Controlled Biogenic Emission of CO, H_2S, NH_3 and Hg^0 from Lazareto's Landfill, Tenerife, Canary Islands

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Landfills are important sources of contaminant gases to the surrounding environment and a significant amount of them could be released to the atmosphere through the surface environment in a diffuse form, also known as non-controlled emission of landfill gases. CH_4 and CO_2 are major components in landfill gases and other gas species are only present in minor amounts. Trace compounds include both inorganic and a large number of volatile organic components. The goal of this study is to evaluate the non-controlled biogenic emission of inorganic toxic gases from Lazareto's landfill. Which is located in the city of Santa Cruz de Tenerife, with a population of about 150,000, and is used as a Palm tree park.

Lazareto's landfill has an extension of 0.22 Km^2 and it is not operative since 1980. A non-controlled biogenic gas emission survey of 281 sampling sites was carried out from February tod March, 2002. Surface CO_2 efflux measurements were performed by means of a portable NDIR sensor according with the accumulation chamber method. Surface CO_2 efflux ranged from negligible values up to 30,600 $gm^{-2}d^{-1}$. At each sampling site, surface landfill gas samples were collected at 40 cm depth using a metallic soil probe. These gas samples were analyzed within 24 hours for major and inorganic toxic gas species by means of microGC and specific electrochemical sensors. The highest concentrations of CO, H_2S, NH_3 and Hg^0 were 3, 20, 2,227, 0.010 ppmV, respectively. Non-controlled biogenic emission rate of CO, H_2S, NH_3, and Hg^0 were estimated by multiplying the observed surface CO_2 efflux times (Inorganic Toxic Gas)$_i/CO_2$ weight ratio at each sampling site, respectively. The highest surface inorganic toxic gas efflux rates were 699 $gm^{-2}d^{-1}$ for NH_3, 81, 431 and 4 $mgm^{-2}d^{-1}$ for CO, H_2S and Hg^0, respectively. Taking into consideration the spatial distribution of the inorganic toxic gas efflux values as well as the extension of the landfill, the non-controlled biogenic emission of CO, H_2S, NH_3 and Hg^0 to the atmosphere by Lazareto's landfill are 0.1, 0.9, 0.7, and 0.7 Kgd^{-1}, respectively.

URL: http://www.iter.es

B51A-0702 0830h INVITED POSTER

Dynamics of Non-Controlled Emission of Methane from Arico's landfill, Tenerife, Canary Islands

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Landfills are one of the largest anthropogenic source of methane emissions to the atmosphere. In order to achieve CH_4 emission control at landfills, avoiding gas migration into the near surroundings and reducing gas emission through its surface, landfill gas has to be collected and either flared or utilized by means of gas extraction systems. However, these systems might not reach a high efficiency and non-controlled biogenic CH_4 emissions to the atmosphere could be an important fraction of the CH_4 produced by a landfill. The goal of this study is to evaluate the non-controlled biogenic CH_4 emission from Aricos landfill (0.33 Km^2; Tenerife, Canary Islands) where urban solid waste disposal rate is about 1,500 td^{-1}.

In order to estimate the temporal evolution of non-controlled biogenic CH_4 emissions from Aricos landfill, two surface flux surveys of about 500 sampling sites were performed in 1999 and 2001. Non-controlled biogenic CO_2 emission rate measurements were performed by means of a NDIR spectrophotometer according to the accumulation chamber method. At each sampling site, landfill gases were also collected at 40 cm deep using a metallic probe. Samples were analyzed within 24 hours for major, minor and trace gas components using a VARIAN microGC QUAD. Non-controlled biogenic CH_4 emission rate was estimated by multiplying surface CO_2 efflux times CO_2/CH_4 weight ratio at each sampling site, respectively. Surface CH_4 efflux rates for the 1999 and 2001 surveys ranged from negligible values up to 1,647.3 and 103.2 $gm^{-2}d^{-1}$, respectively. Spatial distribution of the surface CH_4 efflux rate showed a non-uniform pattern in the landfill for both surveys. This observation is related to the actual use of the landfill, which is still operative, as well as to the evolution of the landfills heterogeneity and anisotropy through time. For the 1999 and 2001 surveys, the total output of non-controlled biogenic CH_4 emission from Aricos landfill were estimated about 15.7 and 1.2 td^{-1}, respectively.

URL: http://www.iter.es

B51A-0703 0830h POSTER

Global Biogenic Emission of Carbon Dioxide from Landfills

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Human-induced increases in the atmospheric concentrations of greenhouse gas components have been underway over the past century and are expected to drive climate change in the coming decades. Carbon dioxide was responsible for an estimated 55 % of the antropogenically driven radiactive forcing of the atmosphere in the 1980s and is predicted to have even greater importance over the next century (Houghton et al., 1990). A highly resolved understanding of the sources and sinks of atmospheric CO_2, and how they are affected by climate and land use, is essential in the analysis of the global carbon cycle and how it may be impacted by human activities.

Landfills are biochemical reactors that produce CH_4 and CO_2 emissions due to anaerobic digestion of solid urban wastes. Estimated global CH_4 emission from landfills is about 44 millions tons per year and account for a 7.4 % of all CH_4 sources (Whiticar, 1989). Observed CO_2/CH_4 molar ratios from landfill gases lie within the range of 0.7-1.0; therefore, an estimated global biogenic emission of CO_2 from landfills could reach levels of 11.2-16 millions tons per year. Since biogas extraction systems are installed for extracting, purifying and burning the landfill gases, most of the biogenic gas emission to the atmosphere from landfills occurs through the surface environment in a diffuse and disperse form, also known as non-controlled biogenic emission. Several studies of non-controlled biogenic gas emission from landfills showed that CO_2/CH_4 weight ratios of surface landfill gases, which are directly injected into the atmosphere, are about 200-300 times higher than those observed in the landfill wells, which are usually collected and burned by gas extraction systems. This difference between surface and well landfill gases is mainly due to bacterial oxidation of the CH_4 to CO_2 inducing higher CO_2/CH_4 ratios for surface landfill gases than those well landfill gases. Taking into consideration this observation, the global biogenic CO_2 emission from landfills could be estimated about 8.8-13.2$\times10^3$ million tons per year, equivalent to a 0.04-0.06 % of the fossil fuel emission of CO_2.

URL: http://www.iter.es

B51A-0704 0830h POSTER

Simulations of Flow, Transport, and Biodegradation in Landfills

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Biotreatment of landfill materials may involve coupled nonisothermal flow and transport of water and gas in the refuse mass. With the objective of carrying out analyses that depend on flow and transport processes, we are developing T2LBM, a module for the TOUGH2 multiphase flow and transport simulator that implements a Landfill Bioreactor Model. T2LBM models the processes of aerobic and anaerobic biodegradation of municipal solid waste and the associated three-dimensional flow and transport of gas, liquid, and heat through the refuse mass. The components modeled in T2LBM are water, acetic acid, carbon dioxide, methane, oxygen, and nitrogen in aqueous and gas phases, with partitioning specified by temperature-dependent Henrys coefficients. The local oxygen concentration is used to control whether aerobic or anaerobic biodegradation reactions occur to produce carbon dioxide, or methane and carbon dioxide, respectively. Acetic acid is used as a proxy for all of the biodegradable components in the refuse. The biodegradation rate of acetic acid is modeled using a Monod kinetic rate law for the exothermic reactions in the aqueous phase. The compaction rate is specified by the user and modeled as a linear decrease with time of porosity and contraction of the vertical grid dimension by generation of a new grid at each time step. Local differences in moisture content, pressure, gas composition, aerobicity, and temperature, among other properties, within the heterogeneous refuse can be modeled with T2LBM. Comparison of simulation results against observations of an aerobic landfill bioreactor laboratory experiment and an anaerobic field pilot study show good agreement for oxygen consumption and gas production. Predictions and sensitivity analyses of different biotreatments can be made using this new simulation capability.

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B51A-0705 0830h POSTER

Comparison of Leachate Quality from Aerobic and Anaerobic Municipal Solid Waste Bioreactors

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Municipal solid waste landfills are becoming a drain on the resources of local municipalities as the requirements for stabilization and containment become increasingly stringent. Current regulations limit the moisture in the landfill to minimize leachate production and lower the potential for release of leachate to the environment. Recent research has shown that addition and recycling of moisture in the waste optimizes the biodegradation of stabilization and also provides a means for leachate treatment. This study compares the characteristics of leachate produced from aerobic and anaerobic laboratory bioreactors, and leachate collected from a full-scale anaerobic bioreactor. The laboratory reactors consisted of 200-liter tanks filled with fresh waste materials with the following conditions: (a) aerobic (air injection with leachate recirculation), (b) anaerobic (leachate recirculation). The leachate from the reactors was monitored for metals, nutrients, organic carbon, and microbiological activity for up to 500 days. Leachate from the aerobic tank had significantly lower concentrations of all potential contaminants, both organic and metal, after only a few weeks of operation. Metals leaching was low throughout the test period for the aerobic tanks, and decreased over time for the anaerobic tanks. Organic carbon as measured by BOD, COD, TOC, and COD were an order of magnitude higher in the leachate from the anaerobic system. Microbiological assessment by lipid analysis, enzyme activity assays, and cell counts showed high biomass and diversity in both the aerobic and anaerobic bioreactors, with higher activity in the anaerobic leachate. Results from the full-scale anaerobic bioreactor were not significantly different from those of the laboratory anaerobic bioreactor. The reduction in noxious odors was a significant advantage of the aerobic system. These results suggest that aerobic management of landfills could reduce or eliminate the need for leachate treatment systems, reduce odor, and reduce the need for extensive containment strategies.

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URL: http://esd.lbl.gov/CEB/landfill/

B51A-0706 0830h POSTER

Can Indigenous and Introduced Bacteria Affect the Performance of an Engineered Barrier System in the Designated Yucca Mountain Nuclear Waste Repository?

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The U.S. Department of Energy has been tasked with establishing a high level nuclear waste repository at Yucca Mountain, NV and assessing the effects of long-term storage of the waste. Studies are being performed to identify the role of microorganisms, both indigenous and introduced during the construction phase, to waste package material corrosion. Some microorganisms produce by-products that may be deleterious to waste package materials, such as bacteria that produce hydrogen and mineral acids, or reduce sulfate, and fungi that produce organic acids. Long-term and accelerated tests in continuous flow reactors were conducted to assess the biogenic effects on waste package materials, and batch tests were implemented to identify corrosion products and biochemical changes to ground water chemistry. Surfacial and gravimetric analyses of the metal samples coupled with water chemistry analysis allow us to determine the overall contribution that organisms may make to waste package corrosion. Metal samples were periodically removed from the reactors and examined with scanning electron and atomic force microscopy. Effluent samples were also collected and analyzed using inductively coupled plasma spectroscopy-mass spectrometry and ion chromatography. Sterile controls were run in parallel to understand abiotic contributions to metals corrosion. In addition, we have characterized the microbial community at Yucca Mountain in order to define the physiological potential of the organisms extant at the site and evaluate the conditions required for growth (we have determined that water availability will be the major limiting factor).

Analysis of the fluids from batch tests containing the Alloy 22 (Ni-Cr-Mo alloy) metal suggest the solubilization of Mo, albeit in very low concentrations. Because we did not observe the solubilization of other metal components, it is unclear whether selective solubilization or dealloying is occurring. Endpoint analysis of precipitated particles in the reactors may help establish the specific corrosion process. Surfacial analysis of reacted Alloy 22 samples indicates a redistribution of polishing lines. Surface features appear smoother compared to unreacted samples and root mean square values verify this observation. Because these samples were originally finished with a 600-grit polish, mirror-finished samples were added to the reactors at a later date to better quantify the observed results. In contrast to the Alloy 22 results, atomic force microscopy of the reacted Titanium grade 7 samples suggests that the polishing lines have become coarser; the peak to valley depth is increasing. Root mean square values also indicate a coarsening of the metal surface. The data collected to date may suggest that microorganisms have the potential to alter metal performance. The extent of this alteration appears to be minor, however final assessment of the role of microorganisms will not be realized until ongoing, long-term experiments are completed and analyzed.

B51A-0707 0830h POSTER

Degradability of Chlorinated Solvents in Landfill Environment

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The use of landfills as an in situ remediation system represents a cost-effective alternative for groundwater remediation in the source area. This research was conducted to investigate the intrinsic bioattenuation capacity of the landfill ecosystem for chlorinated aliphatic hydrocarbons (CAHs). This research, using excavated refuse samples, studied how the reductive dechlorination of CAHs is linked to the decomposition of solid waste in landfills. Most research effort in groundwater remediation has focused on the contaminant plumes beneath and downgradient from landfills, while the source area remediation has received increasing attention. Bioreactor landfill and leachate recirculation projects have been planned and implemented by the USEPA and some states. However, the use of bioreactor landfill has primarily been considered only to expedite refuse decomposition. This research provides an understanding of the biological fate of CAHs in landfills, an understanding that can lead to the bioreactor landfill system designed to promote the degradation of pollutants right at the source.

The research was conducted in two complementary systems: simulated landfill bioreactors and batch degradation experiment in serum bottles. Refuse samples were excavated from a municipal solid waste landfill located in Wayland, Massachusetts, USA. Bioreactors were designed and operated to facilitate refuse decomposition under landfilling conditions. For each reactor, leachate was collected and recirculated back to the reactor and gas was collected into a gas bag and the methane production rate was monitored. Target CAHs, tetrachloroethene (PCE) and trichloroethene (TCE), were added to selected reactors and maintained at about 20 uM each in leachate. The design is to study the effect of long-term exposure of refuse microorganisms to CAHs on the degradation potential of these chemicals in landfills.

Changes of biochemical conditions in bioreactors, including leachate pH, leachate COD, and methane production, were monitored throughout the refuse decomposition process. At two different stages of refuse decomposition, active refuse decomposition representing young landfills and maturation phase representing aged landfills, anaerobic microbial cultures were derived from selected bioreactors and tested in serum bottles for their abilities to biodegrade target CAHs. Complementary to the bioreactor experiment, the serum bottle experiment was designed to investigate specific conditions that potentially control or limit the reductive dechlorination of CAHs in landfills. The conditions tested include 1) inhibited refuse methanogenesis, 2) enhanced methanogenic refuse decomposition, 3) presence of other organic carbons commonly found in landfills such as cellulose, lactate, ethanol, and acetate and 4) presence of yeast extract and humic acids which are commonly found in aged landfills.

This research investigated the degradability, the degradation rate, and the extent of dechlorination of CAHs in a landfill ecosystem as the refuse decomposition progresses. The results can lead to a broader application of the intrinsic bioattenuation capacity of landfills. An in situ remedial strategy directly tackling the contaminant source can minimize the risk of future impact and achieve a significant saving in remediation cost. The information of contaminant fate in landfills can also help regulatory agencies formulate risk-based guidelines for post-closure monitoring programs and potential re-development projects.

B51A-0708 0830h POSTER

Partitioning Gas Tracer Technology for Measuring Water in Landfills

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Unstable landfills can result in significant environmental contamination and can become a risk to public health. To reduce this risk, water may be added to landfills to ensure that enough moisture exists for biodegradation of organic wastes. In this case risks associated with future breaks in the landfill cap are significantly reduced because organic material is degraded more rapidly. To modify moisture conditions and enhance biodegradation, leachate is typically collected from the bottom of the landfill and then recirculated near the top. It is difficult, though, to know how much leachate to add and where to add it to achieve uniform moisture conditions. This situation is exacerbated by the heterogeneous nature of landfill materials, which is known to cause short circuiting of infiltrating water, a process that has been virtually impossible to measure or model.

Accurate methods for measuring the amount of water in landfills would be valuable aids for implementing leachate recirculation systems. Current methods for measuring water are inadequate, though, since they provide point measurements and are frequently affected by heterogeneity of the solid waste composition and solid waste compaction. The value of point measurements is significantly reduced in systems where water flows preferentially, such as in landfills. Here, spatially integrated measurements might be of greater value.

In this research we are evaluating a promising technology, the partitioning gas tracer test, to measure the water saturation within landfills, the amount of free water in solid waste divided by the volume of the voids. The partitioning gas tracer test was recently developed by researchers working in the vadose zone. In this methodology two gas tracers are injected into a landfill. One tracer is non-reactive with landfill materials, while the second partitions into and out of free water trapped within the pore space of the solid waste. Chromatographic separation of the tracers occurs between the point of tracer injection and tracer extraction because the partitioning tracer is retarded due to water in the landfill. The degree of tracer retardation can be used to determine the average water saturation between the injection and extraction points. This partitioning gas tracer test yields a large-scale estimate of the water saturation, is not affected by solid waste compaction or heterogeneity in the composition of the solid waste, and has been successfully tested in a recent field experiment in soils.

We report the results from a series of laboratory experiments designed to evaluate this technology with various trash mixtures. Experimental conditions were selected to mimic the range of moisture conditions that may exist within municipal landfills. The influence of leachate composition and temperature on gas tracer partitioning were also evaluated. In our trash mixtures, the partitioning gas tracer test determined volumetric water contents that were within 12% of actual values. We discuss these data in detail and describe environmental conditions (e.g., temperature variations) that may affect the utility of the partitioning gas tracer test.

B51A-0709 0830h POSTER

Yolo County's Accelerated Anaerobic and Aerobic Composting (Full-Scale Controlled Landfill Bioreactor) Project

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Sanitary landfilling is the dominant method of solid waste disposal in the United States, accounting for about 217 million tons of waste annually (U.S. EPA, 1997) and has more than doubled since 1960. In spite of increasing rates of reuse and recycling, population and economic growth will continue to render landfilling as an important and necessary component of solid waste management. Yolo County Department of Planning and Public Works, Division of Integrated Waste Management is demonstrating a new landfill technology called Bioreactor Landfill to better manage solid waste. In a Bioreactor Landfill, controlled quantities of liquid (leachate, groundwater, gray-water, etc.) are added and recirculated to increase the moisture content of the waste and improve waste decomposition. As demonstrated in a small-scale demonstration project at the Yolo County Central Landfill in 1995, this process significantly increases the biodegradation rate of waste and thus decreases the waste stabilization and composting time (5 to 10 years) relative to what would occur within a conventional landfill (30 to 50 years or more). When waste decomposes anaerobically (in absence of oxygen), it produces landfill gas (biogas). Biogas is primarily a mixture of methane, a potent greenhouse gas, carbon dioxide, and small amounts of Volatile Organic Compounds (VOC's) which can be recovered for electricity or other uses. Other benefits of a bioreactor landfill composting operation include increased landfill waste settlement which increases in landfill capacity and life, improved leachate chemistry, possible reduction of landfill post-closure management time, opportunity to explore decomposed waste for landfill mining, and abatement of greenhouse gases through highly efficient methane capture over a much shorter period of time than is typical of waste management through conventional landfilling. This project also investigates the aerobic decomposition of waste of 13,000 tons of waste (2.5 acre) for elimination of methane production and acceleration of waste decomposition. In the first phase of this project a 12-acre module that contains a 9.5-acre anaerobic cell and a 2.5-acre aerobic cell has been constructed and filled with over 220,000 tons of municipal solid waste. Water and leachate addition began in April 2002 and to date less than 200,000 gallons of liquid has been added to the 3.5-acre anaerobic cell. The waste filling phase of the aerobic cell was completed in June of 2002 and a 12-inches soil cover and 12-inches of greenwaste compost cover was placed on top of the cell. A vacuum will be applied to the piping within the waste to draw air through the landfill. Instrumentations have been installed to monitor the following parameters: waste temperature, moisture, leachate volumes, leachate hydraulic head over the primary liner, leachate composition, gas volumes and composition. A supervisory Control and Data Acquisition (SCADA) system has been installed to monitor and control the operation of the bioreactor cells. Waste samples were taken from each cell for laboratory testing in early June 2002.

URL: http://www.yolocounty.org/org/PPW/diwm/bioreactor.htm

B51A-0710 0830h INVITED POSTER

Engineered Municipal Waste Landfills: Climate Significance, Benefits, and some Landfill Geophysics

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Municipal Solid Waste (MSW) landfills have unique features: Wastes worldwide emit biogenic methane to the atmosphere of magnitude comparable to the total atmospheric buildup between 1980 and 1990. Carbon sequestered in landfills is large in geologic terms

Management of decomposition in landfilled waste is desirable: (a) Control of waste decomposition and methane promises over tenfold cheaper greenhouse gas abatement compared to most other greenhouse gas abatement strategies. This is due in part to carbon sequestration and landfill gas energy offset of fossil fuel consumption (b) Landfill gas energy potential worldwide, is up to 1% of world energy. Use of landfill gas conserves a resource otherwise wasted (c) Monetary benefits of landfill life extension from decomposition and rapid volume reduction can be quite attractive This is a benefit for the US, where landfills are increasingly difficult and expensive to site. (d) Landfills containing mixed waste can be significant sources of atmospheric and groundwater pollutants needing control. Control is possible from advancing landfill management approaches (e) The stabilization of waste lessens pollutant risk and needs for costly long-term landfill aftercare.

Greater control of landfill decomposition has been advocated in the form of controlled or bioreactor landfills. (SWANA, 1999; Reinhart and Townsend, 1996). Field trials are encouraging by several environmental/monetary criteria. Control of moisture and temperature have given fivefold or more acceleration of methane generation (Augenstein et al, 1998, 2000). There has been rapid volume loss of the landfilled waste as well, with conversion of waste organics to gas. Many trials over years have shown potential for abatement of pollutants in landfill leachate. Demonstration work by the solid waste management community attests to the benefits potential.

Increasing field demonstrations, have been accompanied by observation and/or solution of several issues. As noted the heat generation in landfills may become controlling, Heat can be dissipated, but at energy and monetary cost. Increased waste liquid content, required for biological activity has been a concern. Offsetting risk is the accelerated treatment of many dissolved contaminants in landfill liquid with time. It has proven possible to manage liquid flows within environmental and regulatory constraints. There have been concerns about containment by chemosynthetic lining of leachate liquids draining from landfills. Yet molecular bonds of lining under anaerobic conditions could be expected to last for centuries (and in fact up to millenia). There is of course no landfill experience over millenia but analogous compounds of geologic relevance have shown very desirable long term stability. Two other areas being investigated are waste slope stability and the precipitation of carbonate salts

The climate significance and geophysical issues with landfills will be discussed, and some experimental findings leading to conclusions will be reviewed

B51A-0711 0830h POSTER

Two Bioreactors for Removing Methyl Bromide Following Contained Fumigations

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The continued use of methyl bromide (MeBr) as a quarantine, commodity or structural fumigant is in question because its release to the atmosphere contributes to depletion of stratospheric ozone. However, no single alternative to the use of MeBr as a fumigant has been identified. Nonetheless, future regulation of the amount of MeBr released by structural and commodity fumigations is likely. Hence, if MeBr use is to continue, it is imperative to lower the amount released to the atmosphere by collecting the gas following fumigation for eventual recycling or destruction. We report here on two bioreactors that remove MeBr from waste air streams. The bioreactors utilize the enzymatic activity of a previously described, methylotrophic bacterium, strain IMB-1, to oxidize MeBr directly during growth. The first bioreactor, operated as a closed system, consisted of 0.5 L of growing culture of strain IMB-1 which removed MeBr (>2,500 ppm) from recirculating air. Strain IMB-1 grew to high cell densities in this bioreactor by using pulsed additions of MeBr as its sole carbon and energy source. Bacterial oxidation of MeBr produced CO_2 and hydrobromic acid (HBr) which required continuous neutralization with NaOH for the system to operate effectively. Addition of oxygen was required for long-term (>30 days) operation of the closed-system bioreactor. Strain IMB-1 was capable of oxidizing large amounts of MeBr (170 mmol in 46 days). The second bioreactor, operated as an open system, consisted of a 10-L flow-through fermenter, in which strain IMB-1 oxidized a continuous supply of MeBr (5,000 ppm in air). NaOH was added by pH stat to maintain neutrality. Growth was continuous and 500 mmol (46 g) of MeBr was removed from the air supply in 14 days. Bioreactors using strain IMB-1 can therefore be used to remove large quantities of contaminant MeBr. Considerable range in the inlet concentration of MeBr can be tolerated, however very high concentrations of MeBr (>10,000 ppm) are toxic to the organisms comprising the bioreactor. Strategies for limiting the range of inlet concentrations may include load dampening by adsorption of MeBr on solids such as activated charcoal or zeolite, followed by desorption and subsequent controlled introduction of MeBr, along with a supply of air, into the bioreactor.

B51B MCC: Hall C Friday 0830h

Merging Molecular Techniques and Genomics With Biogeochemistry I Posters *(joint with H, OS)*

Presiding: **Y Fujita,** Idaho National Energy and Environmental Laboratory**;** **E Shock,** Arizona State University

B51B-0712 0830h POSTER

Biomarkers of Microbial Metabolism for Monitoring in-situ Anaerobic PAH Degradation

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Monoaromatic and polycyclic aromatic compounds found in petroleum and its products are subject to biodegradation in the absence of oxygen. These anaerobic pathways reveal novel mechanism of microbial transformation through a series of metabolites and intermediates which are unique to the anaerobic degradation process. The presence of these compounds in-situ, then conceptually can serve as indicators that anaerobic degradation is taking place. We have laboratory studies and field samples which support this concept for BTX and PAH compounds.

Environments in which these anaerobic degradation processes have been observed include freshwater and estuarine sediments, groundwater from impacted aquifers at a former manufactured gas plant and gasoline station, and a creosote-contaminated aquifer. Analytical protocols were developed to detect nanomolar concentrations from soil slurries and groundwater samples and microcosm studies verified their formation from field samples and use as biomarkers of activity.

Recent studies on the mechanisms of anaerobic naphthalene and methylnaphthalene metabolism have identified several unusual compounds that can serve as biomarkers for monitoring in situ PAH biodegradation. For naphthalene these include 2-naphthoic acid (2-NA), tetrahydro-2-naphthoic acid (TH-2-NA), hexahydro-2-naphthoic acid (HH-2-NA) and methylnaphthoic acid (MNA) generated by sulfate-reducing bacteria degrading naphthalene or methylnaphthalene. Groundwater samples were analyzed from wells distributed throughout an anaerobic, creosote-contaminated aquifer and also from a leaking underground storage site. Samples were extracted, derivatized and analyzed by GC/MS. The concentration of 2-NA at each monitoring well was quantified and correlated to the zones of naphthalene contamination. Taken together with measurements of the aquifer's physical characteristics, these biomarker data can be used to describe the extent of naphthalene biodegradation at these site.

B51B-0713 0830h POSTER

Potential for Methanotroph-Mediated Natural Attenuation of TCE in a Basalt Aquifer

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Methanotrophic bacteria are one of the microbial communities believed to be responsible for natural attenuation of a trichloroethylene (TCE) plume in the Snake River Plain Aquifer (SRPA). To better understand the role that indigenous methanotrophs may have in TCE degradation in the aquifer, groundwater was