## Abstract

# Title: Bio-Reactive Landfill Cover Systems


## Investigators: Tarek Abichou, and Danuta Leszczynska
## (FAMU – FSU College of Engineering)


## Pre-proposal to: Florida Center for Solid and Hazardous Waste Management

## Project Period: September 1, 2002 – August 31, 2003


**Objectives**: The main objective of this study is to investigate the feasibility of incorporating a reactive barrier layer to earthen landfill covers to mitigate odor nuisance and green house gases form landfills.

**Methodology:** The proposed study consists of performing column experiments using soils-compost mixtures as media for growth of micro-organisms that are capable of oxidizing biologically landfill emissions. The effects of water content, temperature, and gas generation flux on the rate of oxidation will be assessed. The performance of different types of composts and bio-solids will be evaluated. The second objective of this project is to develop practical design guidelines for incorporating a bio-reactive layer into the design of alternative landfill covers.

**Rationale:** In Florida and other states, several old landfills were closed and/or in need closing with no gas management plans. At the same time, alternative earthen landfill covers that use the storage capacity of soil and plant water uptake to control percolation were proven to be effective in some regions of the country. However, these types of covers were criticized for not addressing landfill gas management. Gas extraction, with or without energy recovery from landfills is currently being used to control gas emissions from landfills. However, this approach tends to be expensive and out of the reach of most small communities managing their solid waste facilities. An attractive alternative is to incorporate a bio-reactive layer into the design of a landfill cover or in areas with significant release of gas into the atmosphere (typically referred to as hot spots).

**Accomplishments:** Dr. Abichou is presently involved in a national research project named Alternative Cover Assessment Project (ACAP) investigating alternative ways to cover solid waste facilities This study, along with the researcher's past and present experience with alternative cover design and evaluation, will provide a first step effort into the use of bio-reactive layers in landfill covers.

## Introduction and Background

Traditionally, landfill cover systems are deigned solely to reduce water infiltration into the underlying waste. The PI on this project has been involved in researching the possibility of using alternative earthen landfill covers that use the water storage capacity of the soil and the plant water uptake capabilities to control percolation. The top layer of such cover system consists of a heavy rooted zone. Roots and vegetation in this layer have been known to be suitable media for a natural bacteria called "Methanotrophs". These bacteria are known to oxidize landfill gases and specifically methane ($CH_4$) to carbon dioxide ($CO_2$) because they possess the $CH_4$ mono-oxygenase enzyme which enable them to use $CH_4$ as a source of energy and as a major carbon source. Landfills are estimated to account for approximately 25% of annual $CH_4$ emissions (Nozhevnikova et al. 1993). Methane has 23 times the global warming potential of that of carbon dioxide, and has a shorter atmospheric residence time than $CO_2$ (Hettiaratchi and Stein (2001). The same micro-organisms are more abundant in compost and other types of by-solids. Therefore, a layer where these bacteria can grow can be designed as a part of a landfill cover to address gas emissions form landfills.

Previous research has shown that methanotrophic bacteria found in agricultural soils, forest soils, and bongs are capable of oxidizing $CH_4$ to carbon dioxide (Whalen et al, 1990). These same bacteria was also found in landfill covers as reported by Bogner et al. (1197), Straka et al. (1999), Humer and Lechner (1999), and Dammann et al. (1999). Stein and Hettiaratchi (2001) have conducted laboratory-scale tests to characterize the bio-oxidation potentials of several soils, peat, glass beads, and several types of compost. They concluded that compost is the most effective media capable of oxidizing $CH_4$ at rates two to three times higher than that of soil or peat, but only for 150 days. Then after the compost performed only slightly better than soil. Hettiaratchi and Stein (2001) also reported that after remixing the compost layer, its oxidation capacity increases back to higher values.

For field scale implementation, the challenge is to provide suitable conditions for these organisms to thrive and maximize $CH_4$ oxidation to carbon dioxide **without undermining the hydraulic properties** of the landfill cover. That is, the percolation through these covers should not increase due to the presence of a bio-reactive layer in the cover design. At the same time, the rate of biological oxidation of $CH_4$ depends on temperature, and moisture content. The moisture content profile inside a landfill cover at different depth of the cover can be predicted using water balance models that incorporate meteorological conditions and vegetation to sub-divide the water balance into runoff, evapo-transpiration, soil water storage, and percolation. The average temperature across a landfill cover can be determined using heat flow models. In addition, depth of oxygen penetration which in itself affected by the $CH_4$ generation at the landfill have an influence on the oxidation potential of $CH_4$.

## Objectives

The main objective of this study is to investigate the feasibility of incorporating a reactive barrier layer to earthen landfill covers to mitigate odor nuisance and green house gases form landfills. For instance, design guidelines for bio-reactive layer into landfill covers such as the type of material, its thickness, and its location with respect to the surface will be developed. This will lower the cost of landfill and reduce odor nuisance.

## Methods

The proposed research plan is divided in five major tasks. Task 1 consist of a literature review to determine landfill gas generation rates associated with landfills. The range of landfill gas generation is needed in order to design lab experiments to be performed in Task 2. Once the range of landfill gas generation rates are determined, Task 2 will consist a laboratory testing to investigate the optimal mix design of soil-compost mixtures and thickness of the bio-reactive layer that lead to a maximum oxidation rate for different landfill gas fluxes. Task 3 will also consist of a laboratory study to investigate the variation of the hydraulic properties of the optimal design obtained in Task 2. Task 4 involve a modeling study that combines water balance models, heat flow models, and gas generation models to assess different design of covers with a bio-reactive component. Their hydraulic effectiveness along with their landfill gas oxidation capacity will be evaluated simultaneously. Task 5 will consist of technology transfer of results and recommendations.

**Task 1 – Landfill Gas Generation Data Collection**

The first step of the project will be to conduct an extensive literature review to define the range of landfill gas generation for the different types of landfills. Literature to be considered will include (but will not be limited to) technical journals and industry publications. Other sources of information will be as follow:

- ? Representatives from environmental protection agencies
- ? Public and private landfills in the state

In addition to the range of landfill gas generation, it will be very beneficial to the project to focus on location were continuous collection of gas generation data is available such as daily or weekly values. The later data will be of value for Task 4.

**Task 2 – Column Experiments**

Column experiments will be conducted with different types of compost and compost-soil mixtures. Special emphasis will be placed on compost generated at solid waste facilities. Methane will be fed through the bottom of these columns at fluxes consistent with the range obtained in Task 1. Several column tests will be performed at the same time. The concentrations and flow rates will be measured at the inflow and outflow sides of the columns. Gas samples from ports along the reactive column will also be collected and their concentration measured. In addition to varying the flux of influent, the thickness, moisture content, and density of each mix will be varied. Varying these factors will result in developing oxidation rates for the different mixes as a function of flux, thickness, temperature, and moisture content.

**Task 3 – Hydraulic Property Evaluation**

For every mix design performed in Task 3 that shows acceptable value of landfill gas oxidation, there is a need to determine its hydraulic property that are relevant to the primary function of a landfill cover, which is the reduction of percolation through the cover, along with each compaction characteristics. Index properties such as grain size analysis, Atterberg limits, and specific gravity, and compaction characteristics for each sample will be determined in the laboratories. Additional samples will be compacted to same densities and water contents as in Task 2. The saturated hydraulic conductivity, and soil water characteristics curve at the target compaction will be determined. The saturated hydraulic conductivity will determined using flexible wall permeameters with backpressure as described in ASTM D 5084 and/or rigid wall permeameters. The soil water characteristics curve (referred to as soil moisture retention by soil scientists) will be determined using the hanging column method as described by Clute (1986), and using the pressure plate method.

**Task 4 – Simulations**

This step of the proposed research plan is to combine the findings of a study currently underway by the PI dealing with assessing the feasibility of using Evapo-Transpiration (ET) covers in Florida (funded by the center) with the results obtained in Task 1, 2, and 3 to incorporate a bio-barrier to ET covers. This task is envisioned to start once both studies are complete.

**Task 5 – Synthesis of Results, Recommendations, and Technology Transfer**

The final task, Task 5, of the project will consist of preparing final report, and developing preliminary alternative cover designs for the different regions of the state incorporating bio-barrier as an integral part of the design. A draft of this report will be reviewed by the pier review group assembled for the project. Based on the simulations performed in Task 4 of the proposed project, a set of guidelines, that engineers and regulators can use when considering the use of alternative covers and bio-reactive barriers, will be developed.

## Project Schedule and Deliverables

A one-year schedule is anticipated for the proposed project. The project starting date is September 1st, 2002. A schedule of activities is shown in Fig. 2.

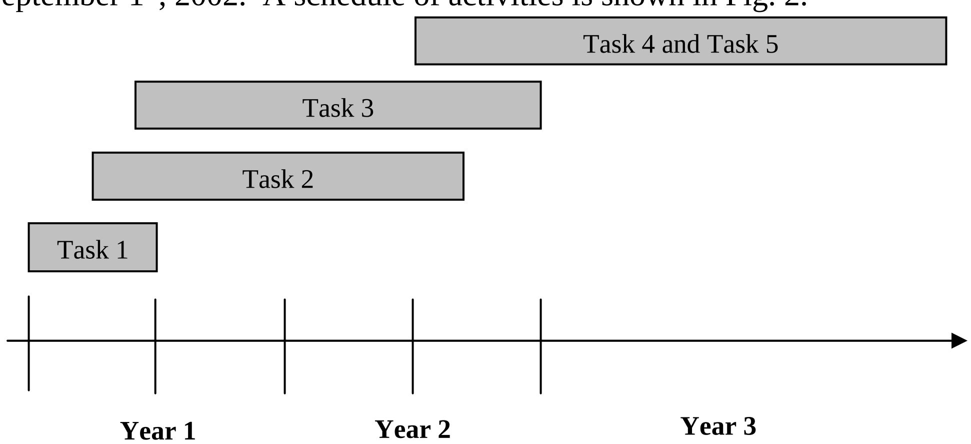


Fig. 2 Project Timeline

## Deliverables

Quarterly progress reports will be prepared to inform the center of the status of the project. A yearly report will also be prepared to summarize research activities performed each year. A final report will be then be prepared at the end of the project to provide a concise compilation of the project results. In addition, a Technical Advisory Group (TAG) will be formed to provide guidance in addressing practical objectives.

## Importance of Project to Local, State, and Private Sectors

In the state of Florida, several landfills are in need of closure. This research helps breaking the ground toward the introduction of the use of more cost effective mitigation of landfill odor and green house gas emissions using a bio-reactive barrier to be designed as an integral part of a landfill cover. Combined with research currently performed on ET covers, the results of this project will lead the development of landfill solutions that are available to a wide range of landfill owners and operators.

## Budget Justification

This budget for the entire project is estimated to be $115,932. The budget for Year 1 is $42,904, and $36,514 for Year 2 and 3. The budget includes 1 month of summer salary for the investigators for each year. The salaries for the investigators are warranted given the level of effort required, particularly during weekly meetings, laboratory testing, and data analysis. The fringe benefit rate is 17.1%. One graduate Master's student will be appointed at 50% time at the FAMU-FSU College, to conduct laboratory work and run simulations. The fringe benefit rate for the graduate student is 0.6%. Various supplies will be needed for laboratory work. The amount allocated for supplies was estimated based on past experience. Travel budget is also included to cover travel associated with the presentation of the results of the project in conferences and meeting.

## Reference


Bogner, J., Meadows, M., and Czepiel, P. (1997), "Fluxes of $CH_4$ between landfills and the atmosphere: Natural Engineered Control," *Soil Use and Management*, Vol.3, pp. 268-277.

Dammann, B., Streese, J., and Stegmann, R. (1999), "Microbial Oxidation of $CH_4$ from landfills in Bio-Filters," Proceeding of Seventh International Waste Management and Landfill Symposium, Cagliari, Italy.

Hettiaratchi, J., and Stein, V. (2001), "Methanobiofilters (MBFs) and Landfill Cover Systems for $CH_4$ Emission Mitigation," Proceedings of the Seventeenth International Conference on Solid Waste Technology and Management, Philadelphia, PA, pp. 465-476.

Humer, M., and Lechner, P. (1999), "$CH_4$ oxidation in compost cover layers on Landfills," Proceeding of Seventh International Waste Management and Landfill Symposium, Cagliari, Italy.

Klute, A. (1986), "Water Retention: Laboratory Methods of Soil Analysis," Soil Society of America, Madison, Wisconsin, 635-660.

Nozhevnikova, A., Lifshitz, A., Lebedev, V., and Zavarzin, G. (1993), "Emission of $CH_4$ into the Atmosphere from Landfills in the Former USSR," *Chemosphere*, Vol. 26, pp. 401-417.

Stein, V., and Hettiaratchi, J. (2001), "$CH_4$ Oxidation in three Alberta Soils: Influence of Soil Parameters and $CH_4$ Flux Rates," *Journal of Environmental Technology* (In Press).

Straka, F., Crha, J., Musilova, M., and Kuncarova, M. (1999), "LFG-Biofilters on Old Landfills," Proceeding of Seventh International Waste Management and Landfill Symposium, Cagliari, Italy.

Whalem, S., Reeburgh, W., and Sandbeck, K. (1990), "Rapid $CH_4$ Oxidation in a Landfill Coversoil," *Applied and Environmental Microbiology*, Vol. 56, pp. 3405-3411.

**State University System of Florida**

**Center for Solid and Hazardous Waste Management**

**Project Budget Form for Year 1**

**Project: Bio-Reactive Landfill Cover Systems**

Proposed Dates:

From9/01/2002

To8/31/2003

| | | | | | | Year 1 |
|---|---|---|---|---|---|---|
| **Senior Personnel** | | | | | | |
| 1. | PI: Tarek Abichou | Yr 1 | | 1.0P-Mos per year | | $5,846 |
| 2. | Co-PI: Danuta Leszczynska | Yr 1 | | 1.0P-Mos per year | | $5,846 |
| | | | | | Total Senior Personnel | $11,692 |
| **Other Personnel** | | | | | | |
| 1. | Grad Students - MS | Yr 1 | 1 @ | 12.00P-Mos per year | | $14,400 |
| 2. | Undergraduates | Yr 1 | 1 @ | 0.00P-Mos per year | | $0 |
| | | | | | Total Other Personnel | $14,400 |
| | | | | | **Total Salaries and Wages** | **$26,092** |
| **Fringe Benefits** | | | | | | |
| 1. | Salaried Staff | | | 17.40 % | | $1,988 |
| 2. | OPS Student Staff | | | 0.60% | | $86 |
| | | | | | **Total Fringe Benefits** | **$2,074** |
| **Group Insurance** | | | | | | |
| 1. | PI: Abichou, Tarek | Yr 1 | 0.00 P-Mos @ | $363per month | | $363 |
| 2. | Co-PI: Danuta Leszczynska | Yr 1 | 0.00 P-Mos @ | $363per month | | $363 |
| | | | | | **Total Group Insurance** | **$726** |
| | | | | | **Total Salaries, Wages, Fringe Benefits & Group Insurance** | **$28,892** |
| **Travel** | | | | | | |
| 1. | Domestic Travel | | | | | $2,440 |
| | | | | | **Total Travel** | **$2,440** |
| **Other Direct Costs** - All included in F&A Base | | | | | | |
| 1. | Materials & Lab Supplies For Flux control and concentration measurements | | | | | $5,000 |
| 2. | Computer Software | | | | | $2,000 |
| 3. | Lab Equipment under $500/unit (pipes, fittings, etc) | | | | | $450 |
| 4. | Equipment Use/Rental Fees | | | | | $0 |
| 5. | Other (Tuition and other project supplies) | | | | | $4,122 |
| | | | | | **Total Other Direct Costs** *Included in F&A Base* | **$11,572** |
| **Other Direct Costs -** | | | | | | **$0** |
| **Modified Total Direct Costs** (MTDC) | | | | | | **$42,904** |
| **Total Direct Costs** | | | | | | **$42,904** |
| **Total Project Costs** | | | | | | **$42,904** |

Raymond E. Bye, Jr.
Vice President for Research

**State University System of Florida**

**Center for Solid and Hazardous Waste Management**

**Project Budget Form for Year 2 and 3**

**Project: Bio-Reactive Landfill Cover Systems**

Proposed Dates:
From9/01/2003
To8/31/2004

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Year 2&3 |
| **Senior Personnel** | | | | | |
| 1. | PI: Tarek Abichou | Yr 1 | 1.0P-Mos per year | | $5,846 |
| 2. | Co-PI: Danuta Leszczynska | Yr 1 | 1.0P-Mos per year | | $5,846 |
| | | | | Total Senior Personnel | $11,692 |
| **Other Personnel** | | | | | |
| 1. | Grad Students - MS | Yr 1 1 @ | 12.00P-Mos per year | | $14,400 |
| 2. | Undergraduates | Yr 1 1 @ | 0.00P-Mos per year | | $0 |
| | | | | Total Other Personnel | $14,400 |
| | | | | **Total Salaries and Wages** | **$26,092** |
| **Fringe Benefits** | | | | | |
| 1. | Salaried Staff | | 17.40 % | | $1,988 |
| 2. | OPS Student Staff | | 0.60% | | $86 |
| | | | | **Total Fringe Benefits** | **$2,074** |
| **Group Insurance** | | | | | |
| 1. | PI: Abichou, Tarek | Yr 1 | 0.00 P-Mos @ | $363per month | $363 |
| 2. | Co-PI: Danuta Leszczynska | Yr 1 | 0.00 P-Mos @ | $363per month | $363 |
| | | | | **Total Group Insurance** | **$726** |
| | | | | **Total Salaries, Wages, Fringe Benefits & Group Insurance** | **$28,892** |
| **Travel** | | | | | |
| 1. | Domestic Travel | | | | $3,500 |
| | | | | **Total Travel** | **$3,500** |
| **Other Direct Costs** - All **i**ncluded in F&A Base | | | | | |
| 1. | Materials & Lab Supplies For Flux control and concentration measurements | | | | $0 |
| 2. | Computer Software | | | | $0 |
| 3. | Lab Equipment under $500/unit (pipes, fittings, etc) | | | | $0 |
| 4. | Equipment Use/Rental Fees | | | | $0 |
| 5. | Other (Tuition and other project supplies) | | | | $4,122 |
| | | | | **Total Other Direct Costs** *Included in F&A Base* | **$4,122** |
| **Other Direct Costs -** | | | | | **$0** |
| **Modified Total Direct Costs** (MTDC) | | | | | **$36,514** |
| **Total Direct Costs** | | | | | **$36,514** |
| **Total Project Costs** | | | | | **$36,514** |

Raymond E. Bye, Jr.
Vice President for Research

State University System of Florida
Center of Solid and Hazardous Waste Management
Biographical Data Sheet

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**EDUCATION**

| | | | |
|---|---|---|---|
| M.S. | University of Wisconsin-Madison | 1993 | Geotechnical Engineering |
| Ph.D. | University of Wisconsin-Madison | 1999 | Geotechnical Engineering |

**PROFESSIONAL EXPERIENCE**

| | |
|---|---|
| 2000 – 2001 FAMU-FSU | Assistant Professor |
| 1999 – 2000 University of Wisconsin | Post-Doctoral Research Associate |
| 1996 – 2000 University of Wisconsin | Research Assistant |
| 1994 - 1996 Andrews Environmental Engineering | Geo-environmental Engineer |
| 1992 - 1993 University of Wisconsin | Research Assistant |
| 1989 – 1992 Marathon Petroleum | Resident Engineer |

**PERTINENT RESEARCH, TEACHING AND/OR RELATED ACTIVITIES**

**Courses:** Soil Mechanics, Environmental Geotechnics, Geotechnical Design

**PERTINENT PUBLICATIONS**

Benson, C., Abichou, T., Albright, W., Gee. G., and Roseler, A. (2001), Field Evaluation of alternative earthen Final Covers, International J. of Phytoremediation, (Accepted for Publication).

Abichou, T., Benson, C., and Edil, T. (2000), “Foundry Green Sand as Hydraulic Barriers: Laboratory Study,” J. of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 126, No. 12, pp. 1174-1183.

Benson, C., Abichou, T., Wang, X., Gee, G., and Albright, W. (1999), Test Section Installation Instructions – Alternative Cover Assessment Program, Environmental Geotechnics Report 99-3, Dept. of Civil & Environmental Engineering, University of Wisconsin-Madison.

Abichou, T., Benson, C., and Edil, T. (1998), “Using Waste Foundry Sand for Hydraulic Barriers,” Recycled Materials in Geotechnical Applications, GSP 79, ASCE, pp. 86-99.

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**EDUCATION.**

**Ph.D**. *in Environmental Engineering, 1978*, Technical University of Wroclaw, Poland.
**M.S./B.S**. *in Organic Chemistry/Chemical Engineering*, 1974, Technical University of Wroclaw, Poland.

**EXPERIENCE.**

- ? Department of Civil and Environmental Engineering, FAMU-FSU College of Engineering, Tallahasse Florida: **Associate Professor of Environmental Engineering**: 1995-Present.
- ? Department of Chemistry, Jackson State University, Jackson, Mississippi: **Assistant Professor**: 1991- 1995.
- ? Department of Environmental Sciences and Engineering, University of Florida, Gainesville, Florida: **Post Doctorate Associate**: 1987- 1990.
- ? Department of Sanitary Engineering, Institute of Environmental Protection Engineering, Technical University of Wroclaw, Poland: **Assistant/Associate Professor**: 1978-1987.

**RESEARCH EXPERIENCE**: ***Active research fields at present (major fields only).***

- ? Stormwater: Contamination and Treatment.
- ? Closed Natural Systems for Wastewater Treatment.
- ? Trace Elements as Pollutants: Mechanisms, Monitoring and Treatment.
- ? Sorption Mechanisms on the Clay.
- ? Enhanced Filtration: Mechanisms.
- ? Magnetic Field for Biosciences and Biotechnology.
- ? Hazardous Waste: Soil and Groundwater Contamination

**PUBLICATIONS (Current, relevant to the project).**

1. D. Leszczynska, A. Dzurik, R.M. Markey, "Arsenic Contamination in Soil and Groundwater: Review of Remediation Methods", *Proceeding of the Fifth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe*, Prague, Czech Republic, **2000.**
2. A. Dzurik, D. Leszczynska, "Stormwater Runoff Quality Issues at Transit Operation and Maintenance Facilities", *Proceeding of the Fifth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe*, Prague, Czech Republic, **2000.**
3. A. Dzurik, D. Leszczynska, A. Benner, "Modern Technology's Applicability to Mass Transit and Sustainable Urban Environments", *City Development Strategies*, on-line, section**: Urban Environment, 02, 2000,** *www.citydev.org/journal_cf.html*.
4. D.Leszczynska, "Wastewater Reclamation and Reuse: Water Quality Requirements, Health Concerns and Public Acceptance" *Proceeding of the Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe*, Warsaw, Poland, **1998**.
5. A.Dzurik, D.Leszczynska, T.Kelly, "Water and Soil Contamination from Auto Salvage Facilities and their Regulations" " *Proceeding of the Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe*, Warsaw, Poland, **1998**.
6. D.Leszczynska, A.Dayama, "Ion Chromatography as an Environmental Analytical Tool for Trace Elements in Water Supply Systems" SAAS *Bulletin Biochemistry and Biotechnology*, **11,** 9-15, **1998.**