State University System of Florida
Florida Center for Solid and Hazardous Waste Management
PROJECT SUMMARY

TITLE: The feasibility of removing inorganic arsenic from landfill leachate via sorption to mineral oxide surfaces.

COMPLETION DATE: 8/14/06 **PRINCIPAL INVESTIGATOR:** Dr. Maya A. Trotz

AFFILIATION: Department of Civil and Environmental Engineering, University of South Florida

STUDENTS: Ryan Locicero (Master's/PhD student)

OBJECTIVES: 1. To identify Class 1 landfills in Florida with potential leachate disposal problems due to arsenic and select experimental conditions based on leachate characterization information, 2. To determine the influence of geochemical conditions (pH, temperature, ionic strength, competing ions) on the removal of arsenic from landfill leachate solutions using mineral oxide surfaces, 3. To establish an equilibrium modeling dataset that can be used to predict the feasibility of arsenic removal under a range of geochemical conditions.

METHODOLOGY: This proposed research will examine the viability of using sorbents for removing arsenic from the leachate of landfills containing CCA-treated wood. Batch equilibrium sorption and rate of uptake laboratory studies will be conducted with commercially available Granular Ferric Hydroxide (GFH), Activated Alumina (AA), and zero valent iron filings using both simple solutions and actual landfill leachate solutions. The influence of geochemical conditions like pH, ionic strength, temperature, and the presence of major competing ions on arsenic removal will be examined in the laboratory using both clean systems and actual landfill leachate.

RATIONALE: CCA-treated wood or its combustion products in landfills in Florida are potential sources of arsenic. Arsenic in landfill leachate solutions raises concerns over groundwater contamination for unlined landfills and proper disposal or management for lined landfills. This study will identify the conditions under which arsenic can be removed from leachate on site through sorption processes. My previous research showed that porous activated alumina particles removed arsenic, that competitive sorption from anions like phosphate and silicate occurs and that the process is feasible for fixed bed reactors. That research will be expanded to geochemical conditions of landfill leachate solutions.

ACCOMPLISHMENTS: The results of this research will benefit landfill operators who have costs associated with disposal of their arsenic containing leachate. The results from this one year study will help to develop a cost effective onsite treatment process that efficiently and effectively removes arsenic from landfill leachate.

THE FEASIBLTY OF REMOVING INORGANIC ARSENIC FROM LANDFILL LEACHATE VIA SORPTION TO MINERAL OXIDE SURFACES

Introduction

The use of copper-chromate-arsenate (CCA) as a wood preservative and the potential leaching of arsenic from that wood have raised major concerns in Florida, especially with respect to the disposal of the wood and its combustion products at landfills where geochemical conditions could mobilize the more toxic inorganic arsenic species. Leachates from new and weathered CCA-treated wood in Florida exposed to Toxicity Characteristic Leaching Procedure (TCLP) tests indicate that the most dominant species were the inorganic arsenic forms, especially As(V) though weathered samples did show higher As(III) concentrations than new samples; and that these woods would be classified as hazardous waste based on regulatory limits for arsenic (1). Unlike discarded CCA-treated wood which is not treated as a hazardous waste and ends up in unlined non hazardous landfills, ash from incinerated CCA-treated wood that exceeds the regulatory limit is disposed of in hazardous landfills. The total TCLP leached arsenic concentrations in the ash of incinerated CCA-treated wood was as much as 100 times greater than unburned samples (1). Ghosh et al. (2) found that the TCLP is conservative at estimating the arsenic leached from artificially contaminated activated alumina and granular ferric hydroxide that would be placed in a landfill and it is highly likely that the studies done on the leaching of arsenic from CCA-treated wood in Florida underestimate the potential arsenic that will leach under landfill conditions. Hence, the disposal of unburned CCA-treated wood and the ash from incineration at landfills could provide significant sources of inorganic arsenic species in the leachate depending on the geochemical conditions in the landfill.

The leachate from lined landfills is either sent to an external waste water treatment facility, recycled back through the landfill, or treated on site (e.g. reverse osmosis at the Martin County landfill). Wastewater treatment facilities have limits on the volume of leachate they can process based on the leachate quality which leads to expensive disposal costs for some Florida landfill facilities. For example, the Polk County Landfill in Lakeland transports approximately half of its leachate to a treatment facility in Jacksonville at a significant cost to the landfill facility because the local waste water treatment plants do not have the capacity to accept the high total dissolved solids concentration coupled with the concentrations of toxic metals like arsenic. Heavy metal concentrations in leachate from a municipal solid waste landfill cell in Florida showed decreasing trends over a twelve year period (3) suggesting that the more mobile forms of these metals had been removed from the landfill cell. Recycling of the leachate through the landfill is a low cost option for disposal, but the non-degradable nature of heavy metals like arsenic means that the landfill will be a continual source of arsenic susceptible to changing geochemical environments and will always have to be monitored, even after the degradation of toxic organic compounds. Recycling of heavy metals through the landfills may also increase their concentration to levels where microbial activity is significantly reduced. On site treatment of leachate to remove heavy metals could employ a suite of technologies based on precipitation, sorption, electroplating, reverse osmosis or ion exchange. On site removal would reduce the volume of the heavy metal contaminant which can then be recycled or disposed of in a controlled space at the landfill where the leachate is prevented from contaminating other leachate streams or landfill cells.

The recent reduction in the U.S. Maximum Contaminant Level (MCL) for arsenic in drinking water to 10 ppb (0.13 μM) coupled by the urgent need for remediation technologies for small drinking water distribution systems in Asia has led to a surge in research on the most efficient technologies for removing arsenic from aqueous systems, sorption being one of the most promising. By careful examination of the conditions influencing sorption it may be possible to adapt these technologies from drinking water treatment applications to remediate arsenic from more complex landfill leachate solutions. Table 1 shows some geochemical characteristics of leachate from the Polk County Landfill in Florida (as stated in the Report of Analysis by the Polk County Natural Resources Lab) which does not include speciation information.

Researchers have studied the sorption of arsenic to mineral oxide surfaces under various geochemical conditions like pH, ionic strength, and surface and arsenic concentration, either in an attempt to develop a treatment technology for arsenic (As) contaminated waters (4-17), or to understand the fate of arsenic in the natural environment (18-26). Sorption capacities of over 50 mg As/ g sorbent have been observed and granular ferric hydroxide and activated alumina are two of the most promising sorbents to date. When these materials are packed into fixed beds the number of bed volumes that can be treated make it an attractive treatment technology (4,27). Figure 1 shows typical sorption edges for binary systems containing either the anions arsenate or arsenite or the cation cadmium on an activated alumina ALCOA by-product, DD660. Arsenate and arsenite sorption increases as pH decreases whereas cadmium sorption increases as pH increases. In some pH regions the sorption of each of those ions overlaps and experimental data would tell the influence of one on the other. The data in Table 1 shows that there are other heavy metals like nickel in the leachate which could influence the sorption of arsenic. The data reported in Table 1 are for samples that were acid digested without any prior treatment for the removal of particles or bacteria.

Table 1: Select geochemical parameters of the leachate from the Polk County North Central leachate tank (Data obtained from Polk County Environmental Services Department, Solid Waste Division).

Date	**As (μM)**	**Ni (μM)**	**Fe (μM)**	**Cr (μM)**	**Bicarbonate (mg/L as $CaCO_3$)**	**pH**	**DO (mg/L)**
3/14/02	1.60	1.44	465.79	0.14	1318	6.92	2.83
3/06/03	0.53	1.23	486.33	< 0.02	1873	7.21	6.21
3/26/04	0.95	2.52	112.80	0.38	2913	7.51	4.82

Various researchers have studied the effect of phosphate, sulfate, carbonate and silicate on inorganic arsenic sorption to aluminum and iron oxide surfaces and found that these anions could decrease arsenic sorption depending on the pH and their concentrations relative to that of arsenic (22,27-29). Figure 2 plots the effect of phosphate and carbonate on As(V) and As(III) sorption to ALCOA DD660; the effect of sulfate is less than these two anions. Anions can potentially affect the sorption behavior of arsenic onto the mineral oxide surface by competing for surface sites, forming mobile complexes, modifying the surface electrostatics, and through other mechanisms like surface dissolution. Actual landfill leachate has complex geochemical matrices that include microbial communities and potential competing anions and cations that can affect the removal of arsenic (3,30,31), however, experimental studies are needed to assess whether removal via sorption would be a viable remediation technique for the arsenic contaminated leachate at landfills. Once the right sorptive media and conditions under which removal of arsenic is favored given the leachate composition are identified, a treatment system that packs that media into fixed bed reactors can be installed on site to remove the arsenic species from the leachate solutions.

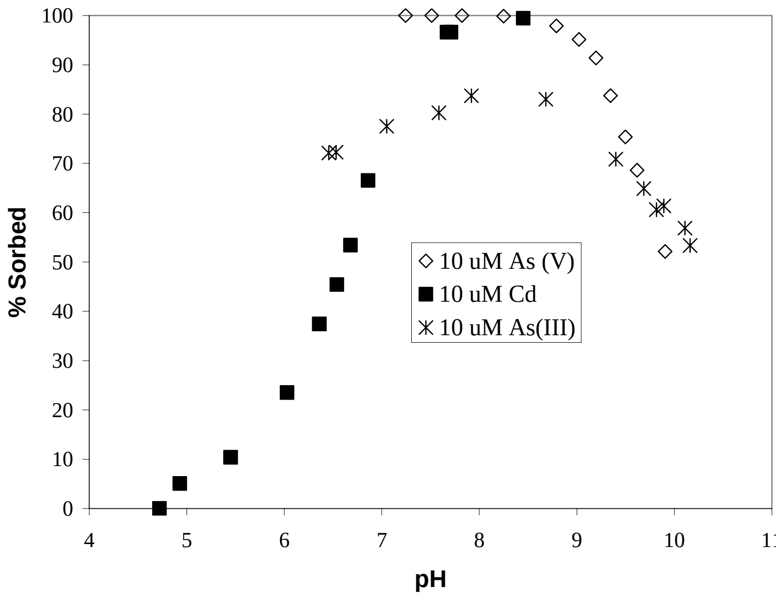


Figure 1: 10 µM As(V), As(III) and Cd(II) sorption to 0.5 g/L ALCOA DD660 alumina in 0.01 M $NaNO_3$. CO_2 excluded. Total alumina surface area in solution = 200 m^2/L. As(V) and As(III) data taken from Trotz, 2002 (27) and Cd(II) data taken from Prasad, 2000 (32).

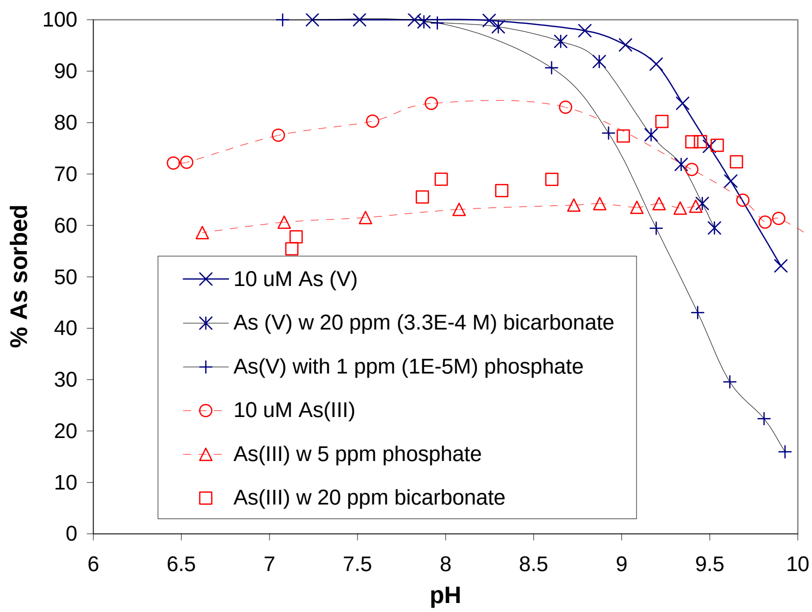


Figure 2: The effect of phosphate or carbonate on As(V) and As(III) sorption to 0.5 g/L ALCOA DD660 alumina in 0.01 M $NaNO_3$. Total alumina surface area in solution = 200 m^2/L. As(V) and As(III) data taken from Trotz, 2002 (27).

Objectives

The overall goal of this project is to determine the applicability of removing arsenic from landfill leachate via sorption to mineral oxide surfaces as a cost reduction option for landfill facility operations in Florida. The research will establish a logical framework for the assessment of this process. The main objectives are:

1. To identify Class 1 landfills in Florida with potential leachate disposal problems due to arsenic and select experimental conditions based on leachate characterization information.

2. To determine the influence of geochemical conditions (pH, temperature, ionic strength, competing ions) on the removal efficiency of arsenic from landfill leachate solutions using mineral oxide surfaces.

3. To establish an equilibrium modeling dataset for the best sorbent that can be used to predict the feasibility of arsenic removal under a range of geochemical conditions so that informed decisions could be made based solely on leachate data.

Methods

This 1 year project contains four main research tasks which are described below:

1. Identification of Florida landfills with arsenic leachate concentrations greater than 10 ppb, evaluation of their leachate composition and chemical parameters, and assessment of their leachate disposal practice and cost. A literature review of available leachate disposal technologies.
2. Characterization of sorbents and landfill leachate solutions.
3. Batch adsorption experiments (equilibrium and rate of uptake).
4. Modeling of batch equilibrium sorption data.

Task 1: Identification of Florida landfills with arsenic leachate concentrations greater than 10 ppb, evaluation of their leachate composition and chemical parameters, and assessment of their leachate disposal practices and costs. The following series of sub tasks must be accomplished during Task 1:

a. During this phase the Floridian landfills that have leachate containing arsenic concentrations above 10 ppb (0.13 μM) will be identified based on leachate data compiled by the Florida Department of Environmental Protection. This list will be compared with the 100 registered Class 1 landfills in Florida and where insufficient data exists or only data prior to 2000 is reported the landfill will be contacted directly for information. We will then contact each facility identified to tabulate current and historical information on the leachate volume, and the current treatment option coupled with the cost of handling the leachate. These results will be used to rank the facilities that would most benefit from an on site treatment facility for leachate containing arsenic. Given the close proximity of the Polk County North Central Landfill to USF and their current leachate disposal problem due to arsenic, they will automatically be included in this study.
b. An extensive review and compilation of leachate concentrations for the top ten landfills identified in Task 1 (a) will be done to identify some major geochemical parameters that are common or of concern to all. This will also help to assess the applicability of the experiments conducted during this project to conditions at other landfills.
c. Literature review of treatment options for landfill leachate containing arsenic.

Task 2: Characterization of sorbents and landfill leachate solutions. During this phase of the project the sorbents (commercially available Granular Ferric Hydroxide (GFH) and Activated Alumina (AA), and Zero Valent Iron filings) will be characterized for surface area, mineral phase, charging behavior, and particle size using equipment that is either in the PIs lab or available on the USF campus. These three sorbents were chosen because they are representative of material currently being used in pilot studies for groundwater treatment and would be most readily available and affordable for a future pilot study. The activated alumina DD660 has already been characterized from previous work (27) and only a limited set of characterizations will have to be done for the sodium chloride background electrolyte. Based on leachate data provided by the Florida Department of Environmental Protection sodium chloride will be used as the background electrolyte. Once the landfills have been identified in Task 1, leachate samples will be obtained to run additional characterization tests that include arsenic speciation and dissolved versus total concentrations of ions.

Heavy metal concentrations will be measured using atomic absorption spectrometry (graphite furnace and flame analysis), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). HPLC will be used as a pretreatment step for arsenic speciation. The PI owns a VARIAN DUO AA240/ AA240 Zeeman with a VGA77 hydride generator and has access to an ICP-MS. This proposal budget covers the cost of a HPLC unit plus columns for arsenic speciation work. The PI has access to a surface area analyzer and Xray diffractometer for sorbent characterization.

Task 3: Batch adsorption experiments. During this phase of the project experiments will be conducted using the different sorbents under very controlled conditions so that they are easily compared and the effects of specific parameters can be examined (pH, sorbent, temperature, ionic strength, As concentration, competing ions). Both equilibrium sorption experiments and rate of uptake experiments will be conducted since data from both will help to understand the feasibility of using these sorbents in packed bed reactors. For the batch equilibrium sorption experiments sorbent fines will be used whereas for rate of uptake experiments actual particle sizes that would pack in a fixed bed reactor would be used. Equilibrium sorption experiments will be conducted to produce sorption edges that are a function of pH whereas the pH will be maintained at a set value for rate of uptake experiments. In a typical sorption experiment, the solid slurry will be made at a given ionic strength and purged of CO_2 prior to the addition of the ions of interest after which pH changes will be made with either the addition of sodium hydroxide or hydrochloric acid. Samples will be taken at different pH values and equilibrated for a period determined from an initial rate of uptake experiment using fines. They will then be centrifuged, filtered and acidified until analysis. Blank experiments will be conducted to determine sorbent solubility and solute loss to container surfaces and filters. Temperature will also be varied for a subset of experiments to reflect the range reported by the various facilities identified in Task 1. Rate of uptake experiments will be conducted on a small subset of the equilibrium sorption experiments that show the least interference from competitive ions. Batch rate of uptake and equilibrium sorption experiments will also be conducted using the filtered, complex matrix of actual leachate solutions obtained from the Polk County North Central Landfill plus others identified in Task 1.

Table 2: Equilibrium sorption experimental matrix. A, B and C represent competing ions to be

selected from Task 1.

Sorbent	As(V) μM	As(III) μM	A	B	C	I N
GFH, AA, Zero valent Fe	10-1000					0.01
GFH, AA, Zero valent Fe	10					0.30
GFH, AA, Zero valent Fe	10		A1, A2			0.01
GFH, AA, Zero valent Fe			A1, A2			0.01
GFH, AA, Zero valent Fe			A1			0.30
GFH, AA, Zero valent Fe	10			B1, B2		0.01
GFH, AA, Zero valent Fe				B1, B2		0.01
GFH, AA, Zero valent Fe				B1		0.30
GFH, AA, Zero valent Fe	10				C1, C2	0.01
GFH, AA, Zero valent Fe					C1, C2	0.01
GFH, AA, Zero valent Fe					C1	0.30
GFH, AA, Zero valent Fe		10-1000				0.01
GFH, AA, Zero valent Fe		10				0.30
GFH, AA, Zero valent Fe		10	A1, A2			0.01
GFH, AA, Zero valent Fe		10		B1, B2		0.01
GFH, AA, Zero valent Fe		10			C1, C2	0.01

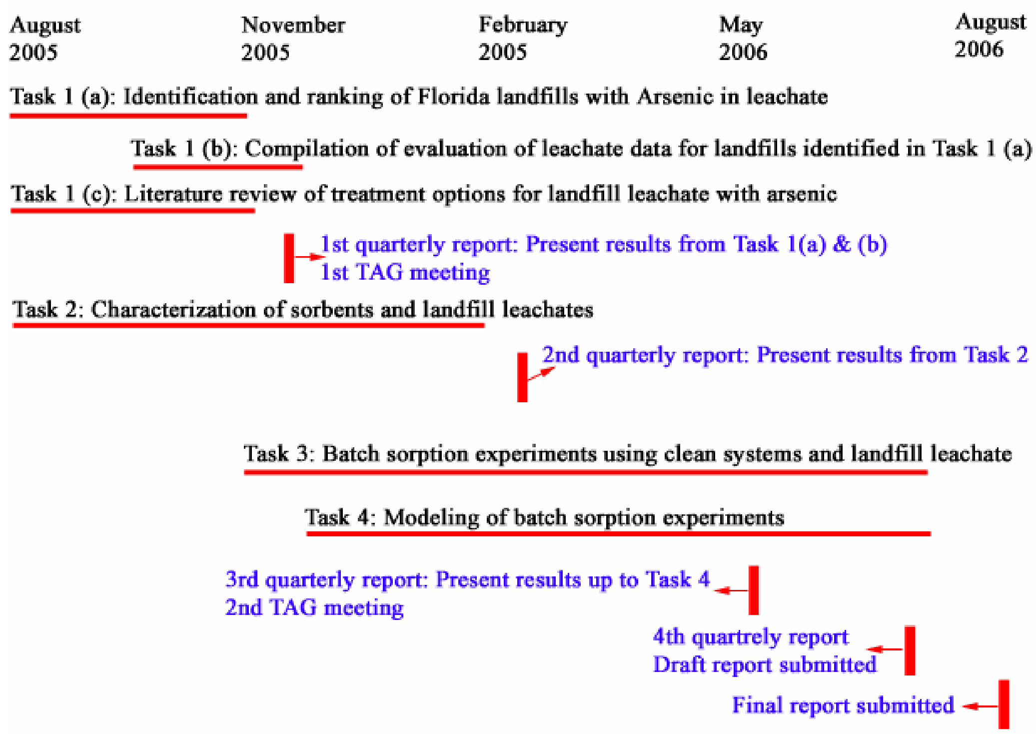
Task 4: Batch Equilibrium Modeling. The data obtained in Task 1 and 2 will be used to obtain surface complexation constants for the ions studied in Task 3. Various surface complexation models have been developed to describe the adsorption behavior of ions to mineral oxide surfaces (33-37). These models treat the mineral oxide as having specific surface sites for adsorption (amphoteric surface hydroxyl groups that can form surface complexes with aqueous species). The Triple Layer Model will be used to describe the experimental equilibrium surface complexation behavior because of its versatility, ability to incorporate ionic strength behavior and its successful application to similar systems (27,32,34). The constants obtained from the single solute systems will provide a self consistent dataset that can be used to test multi-solute systems.

Deliverables

The deliverables for this one year study include:

1. A literature review of landfill leachate treatment practices with particular attention to those containing arsenic or other toxic heavy metals.
2. A compilation of Florida landfills with arsenic in leachate with their leachate disposal practices and costs and their leachate composition as a function of time using historic laboratory data from the landfill facilities.
3. 4 quarterly progress reports due in November 2005, February 2005, May 2006 and August 2006.
4. A database of sorption parameters for select ions found at landfill facilities that could influence arsenic removal.
5. A peer reviewed final report due in August 2006.
6. Peer reviewed journal articles and at least 1 conference presentation.

Timeline/Milestones



There are two scheduled TAG meetings which will be coordinated to occur in a location most accessible to members of the TAG team. Where possible a web/phone conference will also be used given the geographical location of some of the identified members. During the first TAG meeting the experimental matrix will be presented based on the results of Task 1 and 2.

Expected Technical Results

The expected technical results for this project include arsenic equilibrium sorption data and modeling parameters for three sorptive media under geochemical conditions pertinent to landfills. This information can be used to indicate the optimum conditions for on site arsenic removal from landfill leachate once the geochemical parameters of the leachate are quantified. The availability of equilibrium modeling parameters can be used by environmental engineers to determine whether the geochemical conditions in a given leachate lend to arsenic removal.

Anticipated Benefits

This work will have a direct benefit to landfill operators who face high costs of disposal of leachate solutions that have high arsenic concentrations if it is shown that the leachate waste can be effectively treated on site. It can also have implications for solutions to treat leachate from unlined landfills that may be migrating towards groundwater resources. Any results obtained from Task 1 (a) with updated leachate information will be shared with the Florida Department of Environmental Protection for their extensive database on Class 1 landfills.

Further funding for this project will be sought from NSF unsolicited grants provided the preliminary data looks promising. The data acquired will be incorporated into a proposal to develop a model of inorganic ion sorption to porous particles packed into fixed bed reactors and to conduct pilot studies on a landfill site.

Related Work

This is the PI's first time applying for a Center grant. Appendix A-3 lists the PI's current and pending funding of which one project would provide complementary information: *Engineering Smart Nanoparticle Polymer Composites for Environmental Remediation.* Arsenite oxidation to arsenate will be studied in that proposal which, if successful, can be incorporated into the treatment technology for landfill leachate since arsenate tends to adsorb better than arsenite. The PI's previous research on arsenic removal from drinking water using porous alumina particles provided a complete, self consistent dataset for model development of the fixed bed process. It also provided a methodical approach for surface complexation modeling using the Triple Layer Model which will be applied to the research in this proposal.

Possible Follow-up

Possible follow up for this project will be laboratory column tests using the most promising sorbent plus a pilot scale demonstration of the treatment technology at one of the landfill sites identified in this work. The data will also be used for the development of a model for inorganic ion removal by particles, porous particles in particular, by fixed bed reactors - something that has widespread application in the field.

List of Appendices

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B. Biographical Data
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C. Reviewers
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D. Project References

APPENDIX A

A-1: Project Budget Summary
A-2: Project Budget Narrative
A-3: Project Funding History

A-1: PROJECT BUDGET FORM

PROJECT TITLE: Experimental Investigation to Determine the Feasibility of Removing Inorganic Arsenic from Landfill Leachate via Absorption Mechanisms.

INSTITUTION: The University of South Florida **BUDGET PERIOD:** Begin 08/01/05 End 07/31/06

SALARIES AND WAGES List by position beginning with the PI. Provide names for PI and Co-PIs.	PERSON-MONTHS Funded by FCSHWM	PERSON-MONTHS Funded by GRANTEE + EXTERNAL	FUNDING From FCSHWM	FUNDING From GRANTEE + EXTERNAL
Dr. Maya Trotz, PI	.30		$ 2,333	
Ph. D. Research Assistant	12.00		$11,800	
FRINGE BEN: (Rate = 18.58 % of PI Base = $433) + (Rate = 1% of RA Base = $118)			$ 551	
PERMANENT EQUIPMENT (Itemize and justify in text of proposal)				
HPLC & Columns			$15,000	$ 5,000
EXPENDABLE SUPPLIES				
TRAVEL (Domestic only from FCSHWM)			$ 300	
OTHER COSTS (Itemize with units and unit rates.)				
Tuition			$ 4,610	
TOTAL PROJECT DIRECT COSTS				
INDIRECT COSTS				
ON CAMPUS (Rate = 5% of Base = $ 39,594)			XXXXX XXX	$ 1,980
OFF CAMPUS (Rate = ___% of Base = $ _______)			XXXXX XXX	
TOTAL COSTS (Report by funding source.)			$35,594	$ 6,980
TOTAL COSTS (Report grand total from all sources)				

A-2: PROJECT BUDGET NARRATIVE

The budget required for this 1 year project is $42,574 of which the University of South Florida will provide $1,980 in un recovered indirect cost and $5000 in equipment cost share. The budget includes salaries, equipment and travel to landfill sites. In terms of salary the center will fund 0.3 months of the PI's salary ($2,333) and 75% of a doctoral student's salary ($11,800). In terms of equipment the money will be used to help pay for the purchase of an HPLC unit and columns for arsenic speciation work. The PI will contribute out of her start up money to the other costs associated with the instrument. The proposal also asks for $1,000 of funds for expendable supplies such as gases, ICP, HPLC and AA supplies. The PI will contribute funds from her start up to instrument maintenance. Travel funding is requested for visits to landfills by the PI and her student for sample collection and site visits. A budget estimate is shown in Appendix A-1.

A-3: PROJECT FUNDING HISTORY

This project has not been previously funded.

APPENDIX B

B-1: BIOGRAPHICAL DATA SHEET
B-2: CURRENT AND PENDING SUPPORT

B-1: BIOGRAPHICAL DATA SHEET

Name: Maya Trotz **Professional address:** 4202 East Fowler Avenue, ENB118, Tampa Fl, 33620

Position: Assistant Professor **Telephone#:** (813) 974-3172 **Soc. Sec.#:** 096-74-9493

Education (Most recent first):

College or University	Dept. and/or Major	Dates Attended	Degree
Stanford University	Environmental Engineering	1/1996-6/2002	PhD.
Stanford University	Environmental Engineering	9/1994-1/1996	MSc.
MIT	Chemical Engineering	9/1990-6/1994	Bsc.

PROFESSIONAL EXPERIENCE

(A) Positions (Most recent first):

Dates	Organization	Position
7/2004-present	University of South Florida	Assistant Professor
7/2002-7/2004	Stanford University	Post Doctoral Researcher
8/2003-12/2003	Nanyang Technological University	Post Doctoral Researcher/lecturer
1/996-7/2004	Stanford University	Graduate Research/Teaching Assistant

(B) Pertinent Research, Teaching and/or Related Activities (Recent Grants By Title, Source and Amount, Courses Taught, Society Offices, etc.):

(C) Supervision of ____ Theses and ____ Dissertations. Membership on ____ Total Graduate Student Committees.

(D) Pertinent Publications:

Trotz, M.A.; Leckie, J. O. (2004) An experimental and modeling study of the effect of competing anions (sulfate, phosphate, silicate, carbonate) on the equilibrium sorption behavior of As(V) and As(III) on activated alumina. To be submitted, Environmental Science and Technology.

Trotz, M. A. Porous alumina packed bed reactors: A treatment technology for arsenic removal. *Civil and Environmental Engineering*; Stanford University: Stanford, 2002; Ph.D. thesis.

Villalobos, M.; Trotz, M. A.; Leckie, J. O. (2003) Variability in goethite surface site density: evidence from proton and carbonate sorption. Journal of Colloid and Interface Science, 268 (2).

Villalobos, M.; Trotz, M., Leckie, J. O. (2001) Surface complexation modeling of carbonate effects on the adsorption of Cr(VI) and Pb(II) on goethite. Environmental Science and Technology, 35 (19)

B-2: CURRENT AND PENDING SUPPORT

FUNDED RESEARCH

TITLE: *New Researcher Award: Study of Heavy Metal Dist. In Water Sediment near Guyana's OMAI Mine*
FUNDING AGENCY: University of South Florida
TOTAL FUNDING: $10,000
DURATION: 01/21/05 – 01/20/06
INVESTIGATOR COMMITMENT TO PROJECT:
Name: Maya Trotz, Ph.D. %Time: 0%

PROPOSALS PENDING

TITLE: *The feasibility of removing inorganic arsenic from landfill leachate via sorption to mineral oxide surfaces.*
FUNDING AGENCY: Florida Center for Solid and Hazardous Waste Management
TOTAL FUNDING: $41,574
DURATION: 06/01/05 – 05/30/06
INVESTIGATOR COMMITMENT TO PROJECT:
Name: Maya Trotz, Ph.D. %Time: 2.5%

TITLE: *Developing Research and Educational Infrastructure for Sustainable Management of Water Resources in Guyana and Nearby Countries*
FUNDING AGENCY: SANREM CRSP, Virginia Polytechnic and State University
TOTAL FUNDING: $49,414
DURATION: 04/01/05 – 09/30/05
INVESTIGATOR COMMITMENT TO PROJECT:
Name: Maya Trotz, Ph.D. %Time: 11%

TITLE: *Water Quality of Indo and Afro Guyanese Villages Along the East Coast of Guyana*
FUNDING AGENCY: Teachers College, Columbia University
TOTAL FUNDING: $16,704
DURATION: 06/01/05 – 06/30/05
INVESTIGATOR COMMITMENT TO PROJECT:
Name: Maya Trotz, Ph.D. %Time: 0%

TITLE: NER: *Engineering Smart Nanoparticle Polymer Composites for Environmental Remediation*
FUNDING AGENCY: National Science Foundation
TOTAL FUNDING: $160,000
DURATION: 06/01/05 – 05/31/06
INVESTIGATOR COMMITMENT TO PROJECT:
Name: Maya Trotz, Ph.D. %Time: 4%

APPENDIX C

C-1: PEER REVIEWERS
C-2: TAG MEMBERS

C-1: PEER REVIEWERS

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C-2: TECHNICAL ASSESSMENT GROUP MEMBERS

Potential TAG members include:

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APPENDIX D

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