SUMMARY: INTERACTIVE DECISION SUPPORT TOOL FOR LEACHATE MANAGEMENT

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According to Nabil Muhaisen (Florida Water Environment Association) and Patrick Victor (American Water Resource Association), today's need for technological innovation has sparked a technical information revolution of endless change and continuous discovery, threatening to encompass all aspects of our lives. How will busy environmental professionals keep up with the accelerated pace of technological advances and deal with the challenges of an ever-changing regulatory environment is the question that must be answered for Florida to remain at the leading edge of socially and environmentally responsible management of solid waste going forward. This proposal describes the development of web-based, internet-accessible municipal solid waste leachate management decision support tool for utilities, consultants, and regulators. The tool will address the need for: 1) improving the measurement and evaluation of current leachate management practices, 2) improving the design and implementation of new or upgraded systems, 3) improving the regulatory framework to adequately deal with changing technologies and lessons learned, and 4) enhancing access to vital information on leachate management strategies and applications.

The key component of the decision support tool will be the online database application that will house a Best Management Practice (BMP) guide. This guide will be constantly updated with information collected from the user profiles entered into the web-based decision support interface, allowing access to the latest information on the performance of new innovative technologies or new applications.

An exhaustive survey of existing decision support systems revealed that no system exists for identification of best management strategies and solutions for the solid waste industry. The strong motivation for the proposed tool is based on the need to meet two main objectives: 1) the solid waste industry must become better informed about the new technologies and strategies that are becoming available to address their long-term needs and 2) the proposed tool will provide a methodology to design, implement, evaluate, and modify user-specific leachate management programs.

The goal is to collect, analyze, and make available technical data for use in developing effective and sustainable long-term solutions for the solid waste management industry. At the heart of the system will be the four module components: 1) user interface, 2) profile module, 3)best management practice module, and 4) report module. The tool will be accessed through a user login screen. The utility will be asked to input a user profile. The user will be prompted to answer detailed questions about critical

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characteristics needed to assess alternatives. These will include climate conditions, generation rates, waste characteristics, customer characteristics, age of facilities, size, type of landfill, regulatory requirements, costs of operation, and current disposal practices. It will also ask for subjective inputs such as desired range of costs and technologies to exclude, for instance. During this consultation phase, the tool elicits the user's objectives, resources, preferences, constraints, etc. that must be factored into the selection of the appropriate strategies for a particular application. As a knowledge-based system, the tool balances the multiple criteria that need to be weighted and prioritized to choose the best strategies from the BMP guide. The user profile will interface with the BMP database and match the best fit technologies to generate a recommended set of alternatives. Once the appropriate technology has been selected by the user and implemented, its performance must be tracked against the initial goals set by the user profile. The user will continue to update the profile with specific measures to provide the feedback necessary to keep the BMP database and ranking system current, thus closing the loop. Performance measures can then be assessed against other participating utilities, which will allow the database to be continually refined and adjusted to be as realistic and as useful as possible.

This proposal tackles the major technological need for addressing the communication gap in bringing sustainable, economical options for routine leachate management into the hands of the end users in the solid waste management industry. The Florida Atlantic University research team is uniquely positioned to deliver the proposed decision support tool because we have experience in assessing engineering alternatives for long-term leachate management from our recently-completed HCSHWM-funded two-year study entitled, "Investigation of Energized Options for Leachate Management, Report #0632018" (Meeroff et al. 2008), and we have extensive expertise relating to developing decision support and knowledge-based systems for similar applications.

The objective of the proposed research is to identify viable options for leachate management and rank them according to sustainability, performance, risk, and cost criteria. The assessment will not be limited to current practices. Futuristic technologies, such as plasma arc or photocatalytic oxidation using iron-mediated aeration or TiO_2-coated magnetite (under development at FAU), must also be evaluated to forecast which alternatives will be employed by the solid waste community in the years to come. Knowledge gained from these studies will also be included in the BMP database for the decision support tool. From the assembled matrix of engineering alternatives that are innovative, practical, and environmentally-sound, we propose to develop an interactive, web-based decision support tool to aid solid waste managers in long-term decision-making with regards to leachate management.

PROGRESS REPORT
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Project Title: Interactive Decision Support Tool for Leachate Management
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Progress to Date:

Task 1. An ongoing literature review is being conducted focusing on viable leachate treatment methods, including the photochemically-assisted iron-mediated aeration (PIMA) process and the TiO_2-magnetite photocatalysis process. The review began with FAU graduate students, Courtney Skinner, Adriana Toro, François Gasnier, and Tammy Martin in 2005. A visiting researcher from the Indian Institute of Technology in Bombay, Mr. Swapnil Jain, continued the work by conducting an exhaustive search of the photocatalytic literature [1990 and beyond] with the aid of the FAU S.E. Wimberley Library Information Services Department. Mr. Jain prepared an annotated bibliography, which was refined by two other visiting scholars, one from Japan, Ms. Hatsuko Hamaguchi, and the other from Stanford University, Mr. Joseph Vasquez. Currently, Ms. Benazir Portal, Mr. Anthony Ruffini, and Mr. André MacBarnette are updating the existing annotated bibliography focusing on technological innovations of the past three calendar years including Dr. Hala Sfeir's work on a statewide survey of leachate management options that were presented at the SWANA Conference in July 2007.

The main focus of this targeted literature review is to identify precedents using TiO_2-magnetite and other advanced technologies for wastewater treatment applications. Specific questions to be addressed are: 1) advanced oxidation process efficacy for various pollutants, 2) appropriate UV intensity range, 3) appropriate reactor conditions (i.e. pH, temperature, etc.), 4) appropriate range of catalyst dose (in grams or m^2), 5) appropriate hydraulic retention times or reaction/exposure times, 6) catalyst reconditioning, 7) reasons for catalyst poisoning, and 7) appropriate mixing regime. In addition, any factors that could impact the efficiency of the process such as catalyst poisoning, pH/temperature effects, etc. were identified in preparation for photocatalytic oxidation laboratory scale testing at FAU.

A list of available and experimental long-term alternatives are currently being assembled and ranked according to the following selection criteria based on environmental sustainability, efficiency, risk, feasibility, and economic factors:

- Efficiency of treatment, regarding pollutant removal performance
- Residuals, regarding solids or liquids generated during treatment
- Footprint, regarding space needed for a unit process design for a capacity of up to 1.0 MGD
- Other parameters, included in this category are environmental impacts, odor generation, dependency on climate conditions, etc.
- Preliminary cost estimates

This work is underway and ongoing. The selection criteria and the mapping of user profile information to the selection criteria is under development and is under refinement after peer review from the TAG meeting on April 14, 2009. Table 1 presents some preliminary results concerning this part of the literature review. They clearly demonstrate the benefits of using AOPs over traditional on-site techniques. Furthermore, the addition of UV energy improves the performance of AOPs. This will serve as the BMP database, which is at the heart of the decision support tool. The working version is located on-line for public comment at http://labees.civil.fau.edu/LeachateMatrix.pdf (see Figure 1). We are actively soliciting responses from the HCSHWM research review committee, our TAG members, and trying to organize a meeting with the landfill committee of Florida SWANA.

Table 1: Initial ranking of leachate management options

	Technology	Type	Total
Conventional Treatment Techniques	Deep well injection	On-site	14
	Hauling off-site	Off-site	15
	Evaporation	On-site	27
	Municipal sewer discharge without pre-treatment	Off-site	39
	Aerobic and Anaerobic biological process	On-site	24
	Air stripping	On-site	29
	Coagulation, precipitation, flocculation, and sedimentation	On-site	34
	Ion exchange	On-site	36
	Filtration	On-site	38
	Carbon adsorption	On-site	39
Innovative Treatment Techniques	Bioreactor: leachate recirculation	On-site	43
	Ozone and hydrogen peroxide	AOP	25
	Ozone	AOP	26
	Hydrogen Peroxide	AOP	35
	Fenton	AOP	36
	Iron-Mediated Aeration	AOP	41
	Ultraviolet light	EP	29
	UV and ozone	EP	31
	Photo-Fenton	EP	36
	UV and hydrogen peroxide	EP	36
	Ultraviolet light, ozone and hydrogen peroxide	EP	36
	Photocatalytic oxidation	EP	47

"Interactive Decision Support Tool for Leachate Management"

Florida Atlantic University
Daniel Meeroff, Ph.D.

Summary of Alternative Analysis Comparison Results

Technology	Efficiency		Preliminary Costs		Residuals		Footprint		Other		Total	
	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
On-Site Management Options												
Municipal Sewer Discharge without Pre-Treatment	2	10			4	8	5	5	4	16	15	39
Leachate Recirculation Bioreactor	4	20			2	4	3	3	3	12	12	39
Evaporation	2	10			2	4	1	1	3	12	8	27
Hauling Off-Site	0	0			5	10	5	5	0	0	10	15
Deep Well Injection (Natural Attenuation)	0	0			5	10	3	3	0	0	8	13
On-Site Treatment Options												
Photocatalytic Oxidation	4	20			4	8	3	3	4	16	15	47
Membrane Filtration	5	25			1	2	3	3	2	8	11	38
Iron-Mediated Aeration	4	20			1	2	3	3	3	12	11	37
Photochemical Iron Mediated Aeration	4	20			1	2	2	2	3	12	10	36
Hydrogen Peroxide	3	15			3	6	2	2	3	12	11	35
Ion Exchange	3	15			2	4	3	3	3	12	11	34
Physical/Chemical Processes (Coagulation, Flocculation, Precipitation, Sedimentation)	3	15			2	4	2	2	3	12	10	33
Fenton Process	3	15			1	2	2	2	3	12	9	31
UV and Hydrogen Peroxide	3	15			3	6	2	2	2	8	10	31
Photo-Fenton Processes	3	15			1	2	2	2	3	12	9	31
Carbon Adsorption	3	15			2	4	3	3	2	8	10	30
Ultraviolet Processes	2	10			4	8	3	3	2	8	11	29
UV and Ozone and Hydrogen Peroxide	3	15			2	4	2	2	2	8	9	29
UV and Ozone	3	15			2	4	2	2	2	8	9	29
Ozone	2	10			2	4	3	3	2	8	9	25
Aerobic and Anaerobic Biological Processes	2	10			2	4	2	2	2	8	8	24
Ozone and Hydrogen Peroxide	2	10			2	4	2	2	2	8	8	24
Air Stripping	1	5			3	6	3	3	2	8	9	22

Weighting Scale	
Efficiency	5
Costs	3
Residuals	2
Footprint	1
Other	4

Ranking Scale	
Best	5
Better	4
Average	3
Worse	2
Worst	1
N/A	0

Weighting Scale	
Max Score	75

Description of Ranking Criteria	
Efficiency	Pollutant removal performance for the major contaminants of interest in leachate.
Costs	Capital and O&M costs for the proposed treatment process. *However, with only pilot-scale and no full-scale demonstration testing results, the determination of capital and operating costs for each of the selected landfill leachate treatment alternatives is preliminary at this stage.*
Residuals	Solid or liquid by-products generated during treatment or as a consequence of treatment.
Footprint	Physical size requirements of the proposed treatment process.
Other	Catch-all criterion includes environmental impacts, odor generation, dependency on climate conditions, etc.

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Figure 1. Screenshot of the alternative analysis comparison results.

The database to organize information related to the existing landfill facilities in Florida is under development including geospatial shape files using ArcGIS platform. The geospatial information is gathered from Florida Geographical Data Library (FGDL) online source. The task of gathering spatial data is now completed. Incorporation of this data into the decision support system is being carried out. Dr. Meeroff met with William "Lee" Martin and Clark B. Moore at FDEP in Tallahassee to discuss new available sources of data needed for developing the user interface. We are currently trying to populate the database for the 52 landfills that we randomly selected as a representative dataset for this process. Mr. Martin gave Dr. Meeroff a tutorial on using OCULUS and downloading data from electronic solid waste reports.

On May 27, 2009 Dr. Meeroff received permission from Ray Schauer to conduct pilot testing at the SWA facility in Palm Beach Gardens, FL. The contact person for this work will be Mr. Carroll, Director of Project Management and Facilities Development, and we are to coordinate the details directly with him. Also, Dr. Meeroff is presenting the initial results at a meeting scheduled for June 3, 2009 at the Central Broward Solid Waste Facility as a potential location for pilot testing. On the same date, Dr. Meeroff is presenting a proposal for pilot testing at Geosyntec Consultants in Boca Raton, FL.

At the TAG Meeting on April 14, 2009, Joe Lurix of the Southeast District Office of FDEP agreed to assist the research team in obtaining the appropriate permits for pilot testing with his office. He assured the TAG that the process would take less than 30-60 days.

TASK 2. The web-based decision support tool will require a host and a manager when it is ready to be launched. This institution will be identified with input from the stakeholder group, which will consist of a technical advisory group (TAG) from regulatory agencies, water managers, consulting engineers, private industry, as well as other individuals and organizations. Operational aspects such as a reliable environment, support services, server requirements, security issues, database updates, client information storage, and ownership rights will be specified according to the host institutions needs. The availability of the host web-based server to install and launch the decision support tool is being investigated. Operational aspects such as a reliable environment, support services, server requirements, security issues, database updates, client information storage, and ownership rights will be specified according to the host institutions needs are currently being evaluated. Dr. Teegavarapu has initiated discussions with the Director of the Technical Services Group of the College of Engineering and Computer Science at FAU, Mr. Mahesh Neelakanta. These discussions will help to outline the possibility of hosting the tool through the College server and to identify any issues, obstacles, or contingency plans with regards to the host institution.

Several software and operating platforms are being evaluated for the development of the decision support system. The software include: EXSYS, CORVID, CLIPS and others. Few standalone systems are also evaluated. The availability of host web-based server to install and launch the decision support tool is being investigated. Operational aspects such as a reliable environment, support services, server requirements, security issues, database updates, client information storage, and ownership rights will be specified according to the host institutions needs are currently being evaluated.

One of the systems being evaluated for the web-based portal is “expertise-2-go”. A temporary web site is set up to test the rules. The temporary web site hosted at FAU uses “e2gLite Expert System Shell” with Java interface. This web site and the expert system module is currently under testing. Rule base required for this shell is being developed. Preliminary results indicate that this system can be adopted as knowledge-based system. A simple interface for the web-portal is successfully tested. The decision support system is now being tested at http://www.civil.fau.edu/~ramesh/dss/dss.html

Task 3. The database system to organize the collected information related to existing landfill facilities in Florida is being developed using geospatial shape files within an ArcGIS platform. The geospatial information was gathered from the Florida Geographical Data Library (FGDL) online source.

Task 4. Decision trees in their simplest forms are being developed based on available knowledge from the case studies, literature review, and laboratory performance testing

(and also eventually TAG member feedback). A set of questions are already prepared that relate to several alternatives. The decision trees are developed in such a way that these trees can be used for knowledge base development for the envisioned decision support system. A matrix of alternatives along with a preliminary ranking scheme is developed and refined. The matrix development is being updated with information obtained from Technical Advisory Group (TAG) meeting and surveys. The decision trees are now used to extract knowledge in the form of rules that are required by the expert system shells and decision support environment.

Task 5. Dr. Meeroff, Mr. Ruffini, and Mr. MacBarnette are currently assembling a list of questions that will be useful for the development of the user interface module. These questions are mapped into a database for Florida landfills that was developed during our previous two-year study. This database was constructed with the support of the TAG members and in particular the efforts of Joe Lurix, FDEP Southeast District Solid Waste Management Program Director. The database collects information from major Florida landfills regarding:

1. Facility name
2. Location
3. Contact information
4. Facility class
5. Capacity in tons/day of MSW and permitted acreage
6. Service area characteristics
7. Years of operation
8. Liner systems
9. Leachate management history
10. Volumes generated
11. Assessment of performance
12. Leachate water quality
13. Identification of issues

The draft user profile information list was approved by the university Institutional Review Board for the Institutional Animal Care and Use Committee (IACUC), which governs the collection of data from human subjects, on February 18, 2009 (h09-38xm). We sent out the survey to the TAG members for comment and discussed its content at the TAG meeting on April 14, 2009 and also at the HCSHWM research review committee meeting on May 15, 2009. The survey is located on the web site at http://labees.civil.fau.edu/DST-tool.pdf (and is an interactive pdf form as shown in Figure 2). The comments and data will be collected and posted on the project web site for TAG members and interested stakeholders to supply information and feedback.

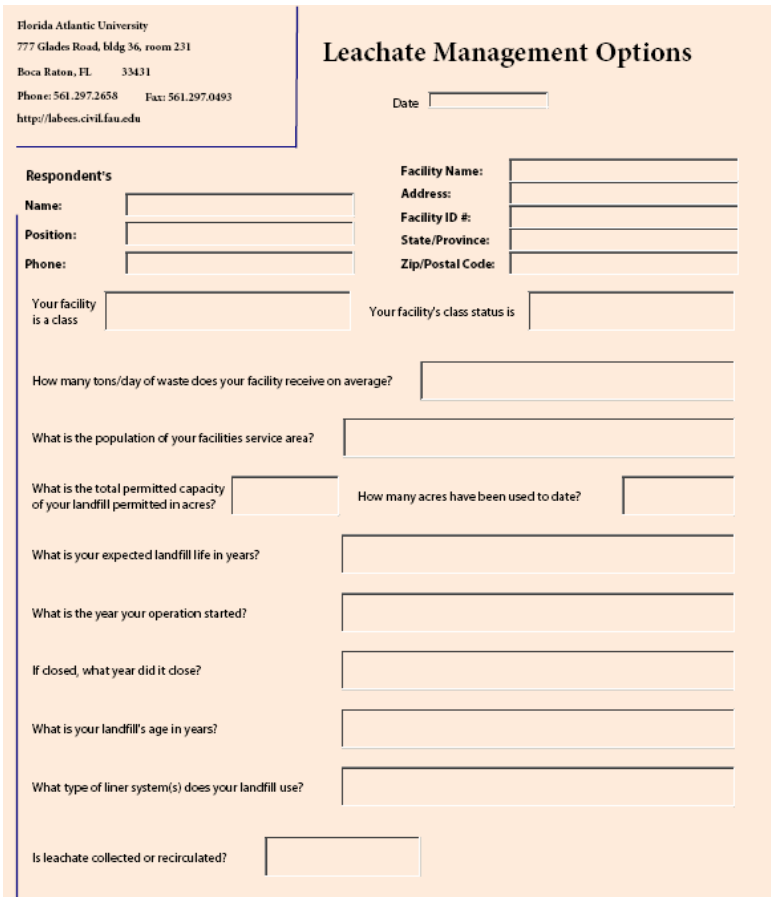

Figure 2. Screenshot of the decision support tool survey for landfill managers.

We took the initial comments and conducted an online TAG meeting (http://labees.civil.fau.edu/MeeroffSP.wmv) that was broadcast as a web-based video file hosted on the project website. The FAU long distance learning department agreed to produce the video and convert it for use on the web for this project.

Mr. MacBarnette, Mr. Ruffini, Ms. Portal, and Mr. Neal are also working to compile a list of data results from innovative treatment technologies conducted at laboratory scale. This data will be used to fill in the gaps required for performance testing of experimental technologies for ranking purposes to create the decision trees that are at the heart of the management tool.

Research planned for the upcoming months:

- Complete/refine the engineering alternative analysis of candidate technologies for the long-term management of leachate
- Collect/compile comments and feedback from technical advisory group
- Map TAG responses to refine matrix of technologies

- Testing of photocatalysis with actual leachate collected from the Orange County Solid Waste Management Facility is underway
- Testing of photocatalysis with artificial leachates is underway
- Conceptual design of scale-up for pilot testing is underway
- Data collection from the OCULUS and solid waste facility reports is underway