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MICROBIAL MAT LANDFILL LEACHATE TREATMENT SYSTEM

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MICROBIAL MAT LANDFILL LEACHATE TREATMENT SYSTEM

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) transmits the results of a technology demonstration conducted at Fort Hood, Texas. That study demonstrated the use of a pilot-scale microbial mat system to treat leachate from the Fort Hood landfill.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide (WBDG) Web page, which is accessible through the following Universal Resource Locator (URL):

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability.

This PWTB applies to all U.S. Army facilities where engineering activities have the responsibility to meet either pretreatment requirements for discharging landfill leachate to a wastewater treatment system, or, the requirements of a National Pollution Discharge Elimination System (NPDES) permit to discharge treated leachate to the environment.

3. References.

a. Army Regulation (AR) 200-1: Environmental Protection and Enhancement, 13 December 2007.

b. Title 40, Code of Federal Regulations (CFR), part 403 (40 CFR 403): EPA's (Environmental Protection Agency's) General Pretreatment Regulations for Existing and New Sources of Pollution.

4. Discussion.

a. AR 200-1 requires that Army installations comply with federal environmental regulations, including standards for the pretreatment of non-domestic sources of wastewater, established by the U.S. Environmental Protection Agency (EPA) under the authority of the Clean Water Act (CWA).

b. 40 CFR 403 describes both general and specific limitations on the discharge of wastewater to publicly owned treatment works (POTW). These limitations also apply to discharges to federally owned treatment works (FOTW). According to the general limitations defined in the CFR, a non-domestic user cannot introduce into a treatment works any pollutant that will cause interference with the operation of a wastewater treatment plant (WWTP).

c. While the Army has few active landfills such as the one at Fort Hood, Texas, numerous closed landfills on Army installations may at some time require the collection and treatment of leachate. Thus, it is valuable for Directorate of Public Works (DPW) personnel at Army installations to be knowledgeable of alternatives to treat landfill leachate discharges. These discharges may be transported off site for treatment, treated on site for discharge to the environment, or pre-treated and discharged to a wastewater treatment system. Leachate typically contains high concentrations of metals that exceed regulatory treatment and pre-treatment discharge limits set forth by local or state regulatory agencies. Discharging untreated leachate could cause the facility to be non-compliant with its NPDES permit and also could lead to a Notice of Violation (NOV) being given to the wastewater treatment works that serves the installation. If the Army installation wastewater is discharged to a POTW, the discharge of leachate into the public system could result in financial claims against the Army. Therefore, an effective means to reduce metal concentrations from landfill leachate may help reduce the liabilities of these discharges.

i. A study was conducted at Fort Hood under the Waste Minimization and Pollution Prevention (WMPP) program managed by the Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) in Champaign, IL to evaluate whether a pilot-scale microbial mat leachate treatment system could effectively reduce metal concentrations to within test goals based on regulatory requirements. The study was conducted in 2006 at Fort Hood, TX, by the prime contractor for executing the WMPP program, MSE Technology Applications, Inc. (MSE) of Butte, Montana.

ii. MSE evaluated leachate treatment systems and selected the microbial mat treatment system because, based on literature and bench-scale testing, it had potential for reducing metal concentrations. However, it was determined through the evaluation process that the microbial mat system needed the addition of a polishing system. MSE then conducted a pilot-scale demonstration of the microbial mat system, with constructed wetland polishing, at Fort Hood. The pilot study indicated that the microbial mat system, in conjunction with the polishing system, removed some metals (iron and manganese)but failed to reduce concentrations of all metals below the field test goals. In particular, the system was not able to withstand wide fluctuations in metals concentrations. Boron could not be removed in the polishing system, though boron's removal had been demonstrated successfully in bench-scale tests. Other problems that occurred during the field test were: (1) higher-than-expected iron concentration caused saturation in the biomats, (2) the design flow rate appeared to overwhelm the system, and (3) hot midsummer days may have impaired the acclimation of the wetland plants in the polishing system.

iii. Thus, use of the microbial mat treatment system cannot be recommended without a redesign based on actual influent characteristics and subsequent retesting. Due to the problems outlined above, proposed use of this system would require significant design adjustments to enhance system performance.

iv. MSE recommended additional testing because design adjustments, improvements, and system optimization were not possible during the short field test. MSE recommended repeating the pilot-scale testing with a lower flow rate and for a period of six months, believing a longer field test could also determine the effects of seasonal changes.

v. In addition to reporting this technology application study, MSE also provided a detailed comparison of the respective advantages and disadvantages of both the microbial mat technology and the constructed wetlands technology. This general discussion was based on MSE experience with the microbial mat in this project, and experience with wetland treatment in this and other projects. Details of both systems are in Appendix A.

d. Appendix A, "Fort Hood Landfill Leachate Treatment System Evaluation," gives details of the Fort Hood study. Appendix A is the final report submitted by MSE to ERDC-CERL, edited for format and clarity.

e. Appendix B is a list of acronyms and abbreviations used in this PWTB.

f. Appendix C contains references used in Appendix A.

5. Points of Contact.

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Appendix A:
Fort Hood Landfill Leachate Treatment System Evaluation

Foreword

This project was funded through the Waste Minimization and Pollution Prevention (WMPP) Program by the U.S. Department of Army, Office of the Assistant Chief of Staff for Installation Management (ACSIM). The WMPP was administered by the U.S. Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC–CERL). The study was conducted by MSE Technology Applications, Inc. (MSE) of Butte, Montana and their subcontractor, PLANTECO Environmental Consultants, LLC (PLANTECO).

The major contributors to this project include:

- Mr. Mike Lasher, MSE Project Manager
- Mr. Steve Antonioli, MSE Program Manager
- Dr. Walter O’Niell, PLANTECO Project Manager
- Dr. Valentine Nzengung, PLANTECO Program Manager
- Mr. Jeff Salmon, Fort Hood
- Mr. Gary Gerdes, ERDC-CERL WMPP Program Manager

Table of Contents

List of Tables and Figures

Tables

Figures

Introduction

Background

Fort Hood, Texas, is served by an approximately 154-acre landfill that was permitted in 1991. Waste materials began to be deposited in this landfill in 1994 with solid waste being deposited at a rate of 652 cubic yards per day. At this deposition rate, the landfill would have a useful life of about 60 years. Implementation of recycling programs and programs limiting disposal of material into the landfill may considerably extend the useful life of this facility.

Approximately 1.5 million gallons of leachate are produced per year within the currently occupied areas of the landfill. Leachate from the landfill is collected by a contractor and transported away from the landfill site by truck. Several studies have been performed to evaluate constituents in the leachate, and metals have been found to be of concern. Concentrations of manganese, iron, lead, and boron are elevated and may be increasing with the age and growth of the landfill. Table A-1 shows the average concentrations of the metals of concern found in landfill cells 1, 2, and 3, and the City of Killeen's corresponding regulatory limits for discharge to the sewer.

Table A-1. Leachate concentrations and regulatory limits of Fort Hood Landfill leachate.

Constituent	Average Concentration from Cells 1,2, and 3 (mg/L)*	City of Killeen Regulatory Limit (mg/L)
Iron	26	0.1
Lead	0.03	0.05
Manganese	1.5	1.0
Boron	1.6	0.5
mg/L = milligrams per liter		

In an effort to address the metals of concern, MSE Technology Applications, Inc. (MSE), under the former Waste Minimization and Pollution Prevention (WMPP) Program, was tasked to investigate alternatives to reduce the concentration of metals being discharged by the landfill (MSE was the prime contractor for the WMPP Program).

Objectives

The primary objectives of the project were to select a promising leachate treatment technology and then, to determine if the chosen leachate treatment system could effectively lower the metal concentrations in the Fort Hood landfill leachate to meet regulatory requirements.

Approach

Earlier studies had investigated mechanical treatment systems to reduce metals concentrations. Emphasis for this investigation was placed on "natural" or biological treatment technologies. MSE began investigating several applicable technologies in October 2005. Those treatment technologies were evaluated based on process treatment efficiency, system simplicity, project cost, prior system operation, system operability, and system maintainability.

MSE chose three leachate treatment systems for further evaluation to determine which would be technically suited for a pilot demonstration at Fort Hood. After selecting the most promising treatment system, MSE performed pilot-scale field tests and completed an evaluation of the chosen system.

Treatment System Selection

As a result of the preliminary investigation of several technologies, three technologies appeared to have potential to address the concentrations of metals contained in the leachate: (a) constructed wetlands, (b) a centrifugal clarifier, and (c) a microbial mat treatment system. Each system provided capabilities that were unique for the process, and each system was investigated to determine system advantages and disadvantages. Constructed wetlands and the microbial mat treatment system were the two systems shown to have potential for removing metals from the landfill leachate. The constructed wetlands technology was being investigated in a separate study by Savannah River National Laboratory (SRNL). Therefore, MSE chose the microbial mat treatment system for pilot-scale testing at the Fort Hood landfill. The following are discussions of the three technologies and some results from bench-scale studies.

Constructed Wetlands Treatment System

Constructed wetlands are frequently used as a water treatment system for coal and hard-rock mine discharges. Water from mines frequently contains elevated levels of metals, and constructed wetlands are often used to precipitate the metals prior to water discharge (Hedin et al. 1994).

Constructed wetlands normally use a biological process to reduce and precipitate metals. The process is generally anaerobic and must occur where limited oxygen is present. Thus, the precipitation of metals occurs below the surface of the wetland vegetation. A soil substrate provides the nutrients for the biological process. Mixing rocks or stones into the substrate material provides paths for the flow of treated water (Sobolewski 1997, 1999).

The Fort Hood Directorate of Public Works (DPW) contracted with SRNL in July 2006 to investigate the use of constructed wetlands for this type of treatment. SRNL was to evaluate samples of leachate and grease trap material for treatment, first by running a bench-scale system. At the time of this report, SRNL had not completed the bench-scale test (December 2006).

Centrifugal Treatment System

As part of MSE’s initial investigation of treatment technologies, Concurrent Technologies Corporation (CTC) proposed use of an ECONOVA (ECONOVA, Inc.) centrifugal clarifier to remove solids or semi-solids from the leachate. The solids and treated water would be discharged separately.

In November 2005, several leachate and grease trap samples were taken and shipped to CTC for a bench-scale treatment test. The samples were processed individually, and laboratory analysis was performed prior to and following treatment. In all, 5 gal of leachate were processed in the bench-scale centrifugal treatment system.

The laboratory analysis performed on the processed leachate revealed the following regarding metals concentrations:

- The concentration of hexavalent chromium and copper actually increased due to processing.
- Concentrations of barium and boron were unchanged.
- Iron, manganese, nickel, and zinc decreased.

Initially, the increases in concentration of various metals were thought to be anomalies in sampling and analysis procedures; consequently, additional analyses were performed with similar results being obtained. At this point, CTC withdrew the technology as a potential treatment system.

Microbial Mat Treatment System

A microbial mat leachate treatment system was proposed by PLANTECO Environmental Consultants, LLC (PLANTECO) for the treatment of the leachate. This type of system has been used on waste streams with similar metals concentrations with several successful tests performed at various mine sites (Bender, Lee, and Phillips 1995).

The microbial mat system uses living organisms to sequester and precipitate metals from a water stream. The organisms primarily consist of various bacteria, including cyanobacteria. The bacteria are contained in plants such as blue-green algae, which are grown on porous filter pads or mats.

The plants are photosynthetic and require an aerobic environment during daylight hours. The plants sequester the metals during daylight hours. In the absence of sunlight, the plants become anaerobic and precipitation of metals occurs.

The plants associated with the microbial mats are limited in the amount of metals they can sequester. As these limits are approached, bleed-through of metals will begin. Increasing the number of microbial mats or the size of the microbial mats allows treatment of water streams with higher concentrations of metals and/or higher water flow rates.

In February 2006, PLANTECO constructed a bench-scale system for processing leachate samples. The samples were processed, and laboratory analysis indicated significant removal of manganese, lead, and iron; concentrations of boron remained unchanged over the process of the treatment system.

PLANTECO reviewed the laboratory data and determined that a "polishing system" was required for additional treatment at the end of the microbial mat system. The polishing system recommended was a constructed wetland, which would provide an aerobic environment for the absorption of metals by the aquatic plants.

The laboratory analysis performed for the bench-scale microbial mat treatment system determined that iron, manganese, and lead were lowered by the process, and the addition of a polishing system lowered boron concentrations. The microbial mat treatment system could be easily scaled up from bench-scale operation to pilot-scale operation, and it also could be easily adapted to field testing.

Pilot-scale Microbial Mat Evaluation

Leachate Transport and On-Site Storage

Leachate was pumped to a transport vehicle from the landfill leachate collection sumps at each landfill cell (Figure A-1). The transport vehicle delivered leachate to the storage tank location at the maintenance building. A gasoline powered trash pump transferred leachate from the transport vehicle to two 1,500-gallon polyethylene storage tanks (Figure A-2). Inland Service Corporation, the operating contractor for the landfill, provided the transport vehicle, the trash pump, and significant labor for this operation. Both storage tanks were connected via 5/8-inch clear tubing to an electric pump. The pump provided leachate flow to the top of the microbial mat reactor.

Figure A-1. Leachate transport vehicle.

Figure A-2. Leachate storage tanks.

Leachate from the electric pump flowed through a strainer and a flowmeter (Figure A-3). The strainer removed large particles from the leachate.

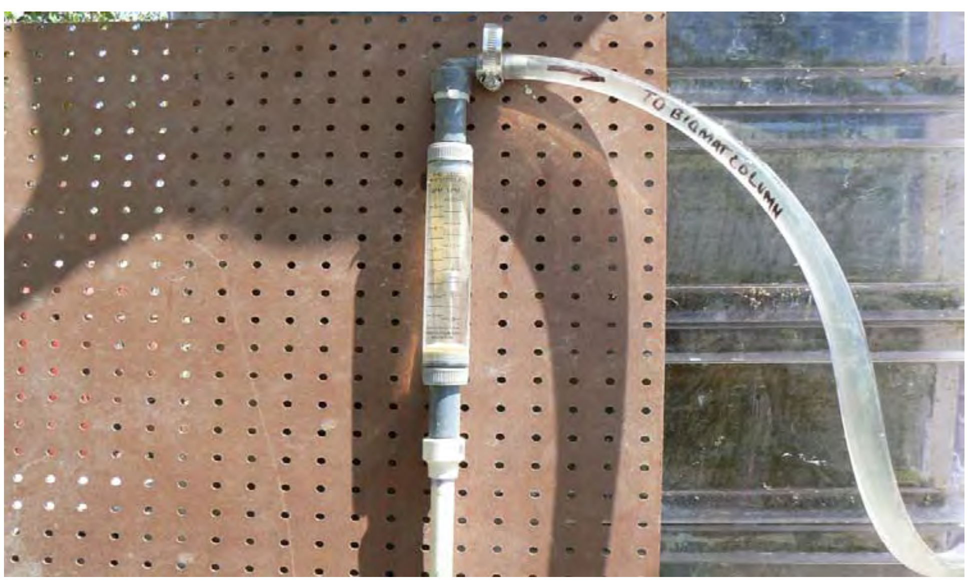

Figure A-3. System inlet flow meter.

Microbial Mat Treatment System Design

To treat the landfill leachate flow, PLANTECO designed and constructed a pilot-scale microbial mat treatment system at the Fort Hood landfill (Figures A-4 and A-5).

In late July 2006, PLANTECO delivered components of the leachate treatment system to the Fort Hood landfill. The system was set up near the southwest corner of the landfill equipment maintenance building. Several sampling and drain connections were available at different locations for system evaluation.

A commercially available aeration system was used to aerate the microbial mat reactor and two of the polishing tanks. The aeration system was an "off-the-shelf" system normally used for home fish tanks. The tanks contained polyvinyl chloride (PVC) tubing manifolds for distribution of air into the reactor and tanks.

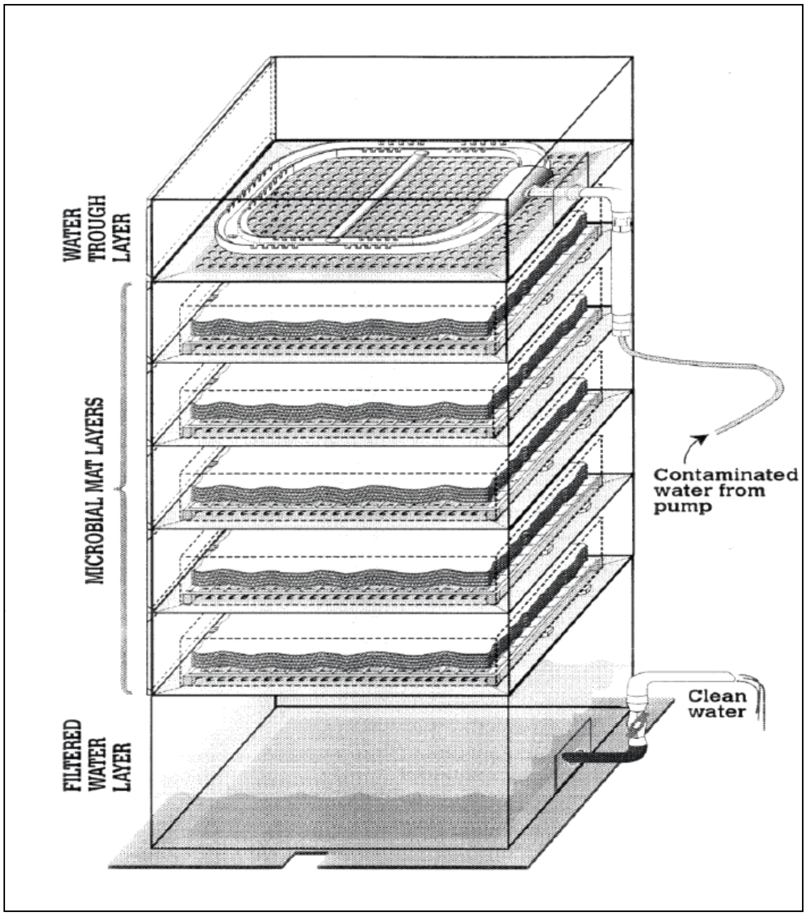

Figure A-4. Microbial mat bioreactor.

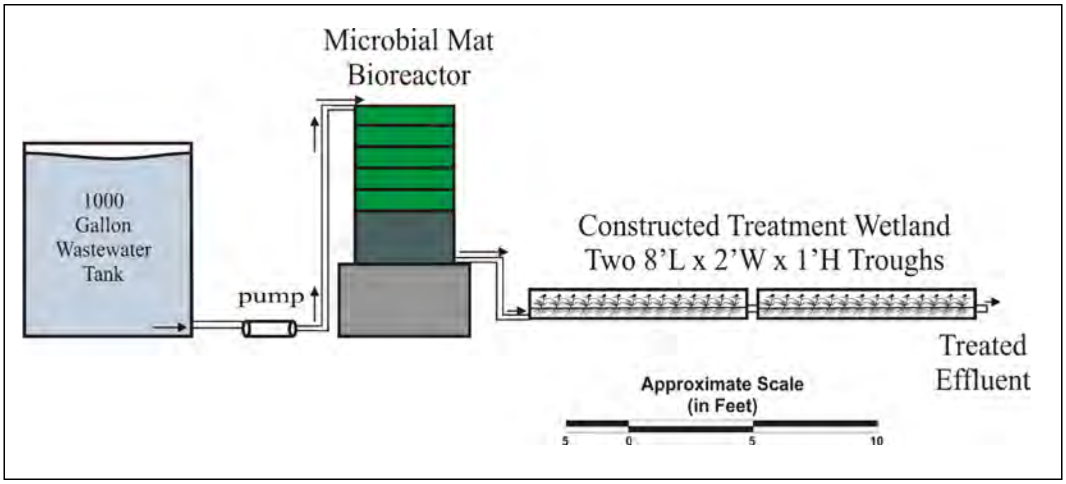

Figure A-5. Microbial mat bioreactor and polishing system.

The microbial mat bioreactor consisted of a Plexiglas-enclosed container capable of holding five microbial mats with living organisms (Figure A-6). Each mat was contained in a drawer to permit easy removal for cleaning or changing. The actual mat was made from commercially available filter material normally used for evaporative air coolers (swamp coolers). The organisms and plants placed on the mats were all native to Texas.

Figure A-6. Microbial mat bioreactor.

The reactor was approximately 2 ft square and 6 ft in height. The leachate was pumped to the top of the reactor and then flowed through a distribution manifold to provide even flow throughout the microbial mats.

Treated water was collected in the bottom of the reactor and pumped to the constructed wetland troughs, using a commercially available sump pump.

Polishing System Design

Additional tanks containing wetland plants were added to the two-tank polishing system provided by PLANTECO. This addition was primarily to ensure water quality in the effluent, but also to evaluate the suitability of various wetland plants (Figure A-7). Four of the five polishing system containers had ¾-in. round stone substrate at a depth of 8–12 in. This allowed flow of leachate through the container and provided a means for placement of the required plants. The final container in the polishing system was used to re-aerate the treated leachate prior to discharge. Each container held one type of plant with the intent that boron removal for each type could be measured.

The first treatment container in the polishing system contained duckweed (Figure A-8). Duckweed is a small plant with very small roots. It generally floats on the water's surface. This tank was aerated to minimize stagnation. The duckweed container held approximately 8 in. of stone and was equipped with an aeration manifold.

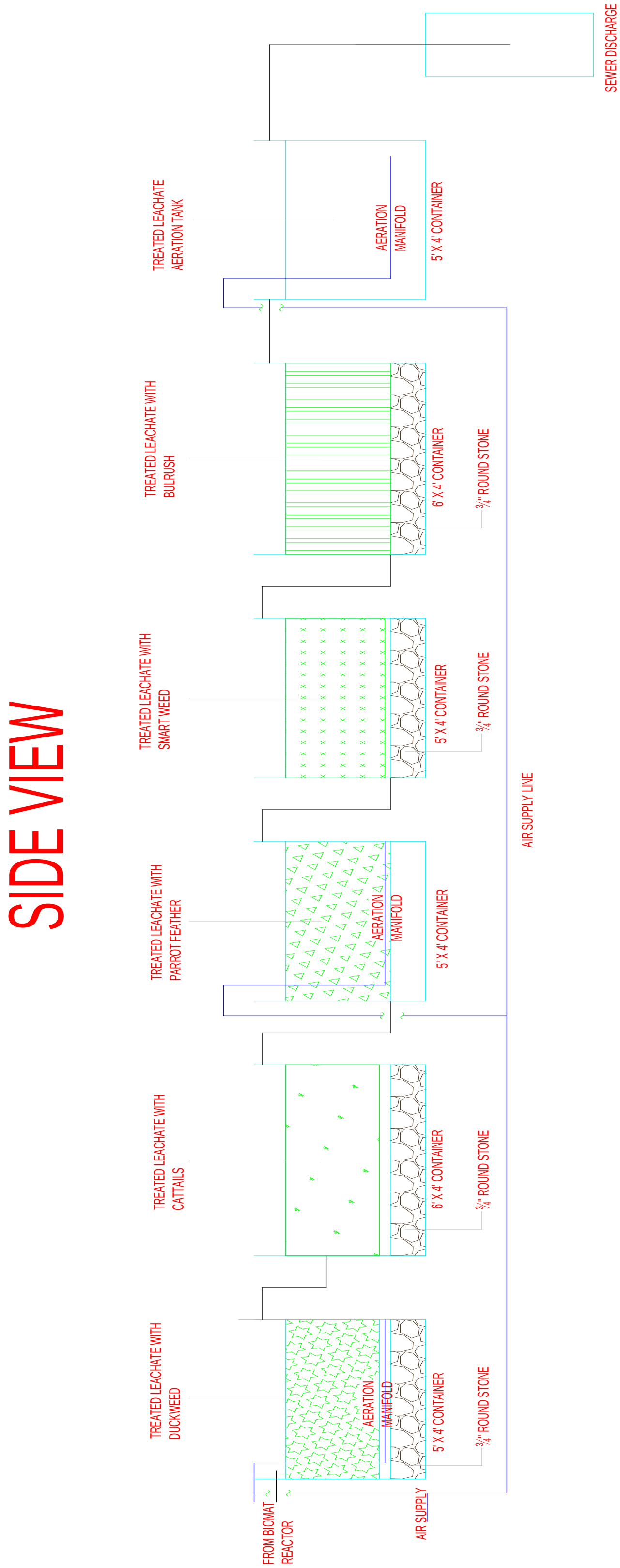

Figure A-7. Polishing system schematic.

Figure A-8. Duckweed container: step 1 in polishing system.

The second container held cattails (Figure A-9) that were planted close together. Water levels in this container needed to cover only the roots of the plant. A substantial amount of soil from transplanting was contained in this treatment. The ¾-in. stone in the cattail container was approximately 12 in. deep.

Figure A-9. Cattail container: step 2 in polishing system.

The third polishing system container held parrot feather (Figure A-10). This plant subsists in shallow water. The plant stems normally sprout from below water surface, and the leaves and remaining portion of the plant protrude above the water line. This container held no stones.

Figure A-10. Parrot feather container: step 3 in polishing system.

The fourth container held smartweed (Figure A-11). This plant also subsists in shallow water with stems below the water surface and plant leaves that float on or protrude above the water line. The plant roots were contained in a stone layer that was approximately 8 in. deep.

The fifth container contained bulrush (Figure A-12), which is similar to cattails in that most of the plant resides above the waterline. The root structure remained in very moist soil and a stone layer that was 12 in. deep.

A sixth (and final) container was used to re-aerate the water prior to discharge (Figure A-13). Discharge of the processed leachate was directed to a sanitary sewer next to the aeration tank. This container held only the aeration manifold; it contained no plants or organisms. No gravel was placed in this container.

Figure A-11. Smartweed container: step 4 in polishing system.

Figure A-12. Bulrush container: step 5 in polishing system.

Figure A-13. Aeration container: step 6 (final) in polishing system.

System Startup and Operation

Gravel was added to the first four polishing system containers, and the appropriate plants were placed inside. Microbial mats with living organisms were placed in the microbial mat reactor. Clean potable water was added to the entire system to equilibrate and maintain moisture for the microbial mats and plants. The water was aerated to minimize stagnation. A mosquito larvae pesticide was added to all the open tanks to prevent mosquito infestation. Figures A-14 and A-15 show the complete pilot-scale system.

The equilibration process lasted three weeks. Potable water was recirculated, and makeup water was added during the first two weeks to maintain levels in the reactor and tanks. After two weeks of equilibration, PLANTECO discontinued adding makeup water; however, the potable water continued to be recirculated through the system. During equilibration, fertilizers were added to promote plant growth.

Figure A-14. Complete microbial mat and polishing treatment system (View 1).

Figure A-15. Complete microbial mat and polishing treatment system (View 2).

Pilot-Scale Field Test

Field Test Goals

The treatment goals for the pilot-scale system are listed below.

- The pilot-scale system would treat 11,520 gal of leachate over a 4-day period.

- The system was to reduce iron concentrations to 0.1 mg/L from initial concentrations and boron concentrations to less than 0.5 mg/L from initial concentrations. Both of these limits would ensure no issues with regulatory limitations.

- The system was to reduce all other metal concentrations to less than 80% of their initial concentration. This limitation would ensure adequate metals removal and ensure there were no issues with future regulatory limitations.

System Operation

Leachate treatment began at a flow rate of 1 gal per minute (gpm) at 2:00 p.m. on 15 August 2006. Recirculation of the potable water continued until leachate flow was initiated to the treatment system.

The leachate flow rate was increased to 2 gpm at 10:00 a.m. on 16 August 2006. The system was monitored closely for any potential problems; however, no problems were noted.

As the test phase progressed, the storage tanks were filled as necessary, and leachate treatment continued. Minor flow problems in the polishing system were addressed as necessary. No significant flow problems were noted with the overall system operation during the test phase.

Through the test phase, it was visibly evident that iron concentrations were high; a rust-colored material assumed to be iron hydroxide precipitated in the microbial mat reactor (Figure A-16). PLANTECO replaced six microbial mats through the test phase as iron overloaded the biomats. Three mats were replaced on 17 August 2006, and three more were replaced 18 August 2006.

Figure A-16. Iron precipitation on microbial mats.

The system worked well for clearing suspended solids from the leachate. Samples became visibly clearer as leachate proceeded through the process (Figure A-17). Bottles were labeled at each step in the treatment chain: L – leachate; MM – micro mat; DW – Duckweed; CT – Cattails; PF – Parrot Feather; SW – Smartweed; BR – Bullrushes.

Figure A-17. Samples showing leachate clarity improvement through the treatment system.

Sampling and Analysis

Samples were drawn from the leachate storage tanks and the effluent of the microbial mat reactor when the system began processing leachate. The system flow rate at this time was 1 gpm. Leachate sample analysis showed that the system lowered concentrations of iron; influent concentration was 10.3 milligrams per liter (mg/L) with the effluent concentration at 1.28 mg/L. The concentration of manganese was reduced from 0.8 mg/L to 0.63 mg/L. Lead concentration was reduced from 13.3 micrograms per liter (μg/L) to 0.219 μg/L. The analysis did not show a reduction in boron concentration.

During the 2-gpm flow-rate test phase of the operation, samples were drawn once or twice a day from the leachate storage tanks, the effluent of the microbial mat reactor, and the end discharge. It should be noted that the system had an approximate 9-hr residence time, so that influent and effluent samples drawn at the same time may not accurately represented the true efficiency of the system. This became more of a concern when the influent concentration varied widely.

The first set of system sample analyses at full 2-gpm operation showed the greatest reduction in the concentrations of iron by the biomat. (See Table A-2: biomat effluent reading on 8/19 is considered an unexplained outlier at this time.) The sample analyses for the remaining portion of the test showed continuing excellent reduction in iron concentrations in the leachate. The reduction in iron occurred in both the biomat reactor and the polishing system (Figure A-18).

Table A-2. Leachate iron removal efficiency.

Leachate Metals Sampling Analyses								
Constituent	**Laboratory Analysis Result from Drawn Sample (units in μg /L)**							
Iron	8/16/06 11:00AM	8/16/06 4:00PM	8/17/06 11:00 AM	8/17/2006 5:00PM	8/18/2006 5:00PM	8/19/06 1:00PM	8/20/06 10:00AM	System Goal
Leachate Influent	6,980	12,500	13,400	9,040	15,700	9,570	8,480	
Biomat Effluent	1,560	4,300	9,370	5,610	7,530	18,000	5,670	**100**
System Effluent	491	2,040	380	401	977	844	1860	**100**
* Items in red did not meet required reduction in concentration								

The first three biomats were replaced in the reactor on 17 August and 18 August 2006. Replacement occurred because leachate iron concentrations were high enough to load the first three biomats, and iron bleed-through began to occur through the biomat reactor.

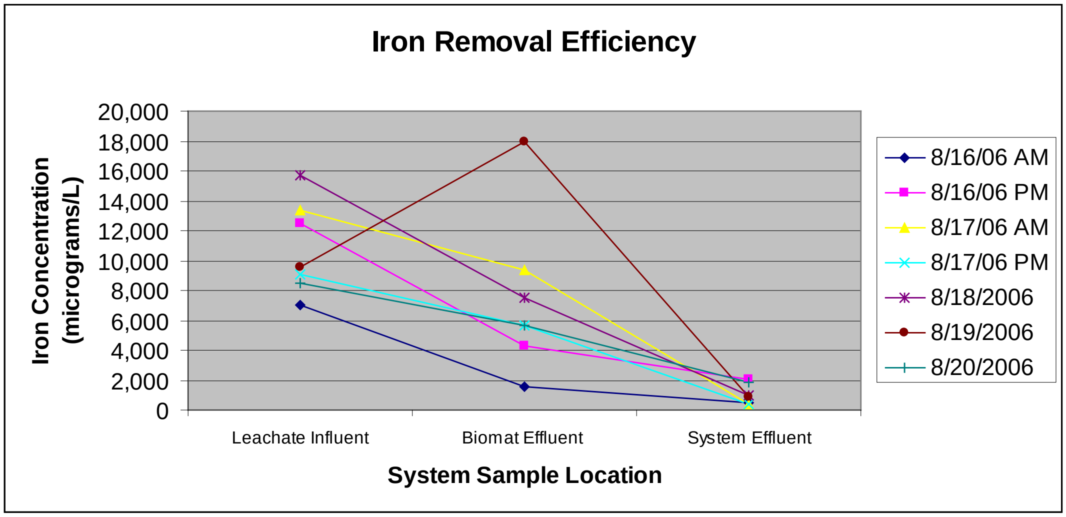

Figure A-18. Graph of iron removal efficiency.

Manganese concentration reductions were significant, and most removal occurred in the polishing system (Table A-3; Figure A-19).

Table A-3. Leachate manganese removal efficiency.

Leachate Metals Sampling Analyses								
Constituent	**Laboratory Analysis Result from Drawn Sample (units in µg/L)**							
Manganese	8/16/06 11:00AM	8/16/06 4:00PM	8/17/06 11:00 AM	8/17/2006 5:00PM	8/18/2006 5:00PM	8/19/06 1:00PM	8/20/06 10:00AM	System Goal
Leachate Influent	919	1,110	1,290	1,100	1,320	1,270	1,200	
Biomat Effluent	848	1,030	1,060	947	1,210	1,140	999	**80% Removal**
System Effluent	786	606	257	143	560	606	960	**80% Removal**
* Items in red did not meet 80% reduction in concentration								

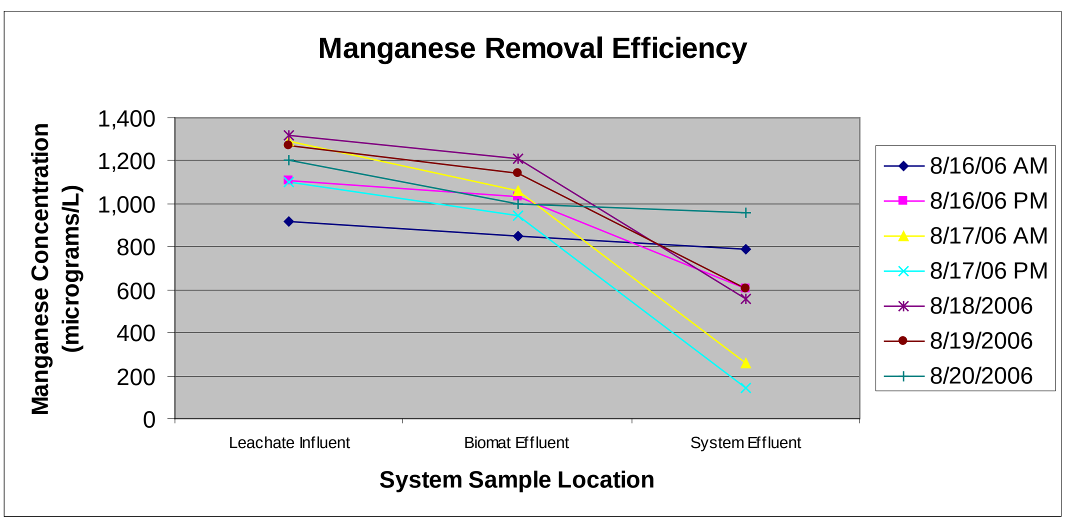

Figure A-19. Graph of manganese removal efficiency.

Lead removal was sporadic. The first- and third-day analyses actually showed increases in lead over the polishing system. There was no obvious explanation for this anomaly, but perhaps the system residence time was partly responsible. There were high influent concentrations measured on 17 August and a high effluent concentration measured on 18 August 2006 (Table A-4; Figure A-20).

Table A-4. Leachate lead removal efficiency.

Leachate Metals Sampling Analyses								
Constituent	**Laboratory Analysis Result from Drawn Sample (units in µg /L)**							
Lead	8/16/06 11:00AM	8/16/06 4:00PM	8/17/06 11:00 AM	8/17/2006 5:00PM	8/18/2006 5:00PM	8/19/06 1:00PM	8/20/06 10:00AM	System Goal
Leachate Influent	0.303	0.358	1.360	0.911	0.437	0.498	0.312	
Biomat Effluent	0.196	0.273	0.549	0.334	0.334	0.495	0.260	**80% Removal**
System Effluent	0.336	0.561	0.251	0.480	1.700	0.494	0.431	**80% Removal**
* Items in red did not meet 80% reduction in concentration								

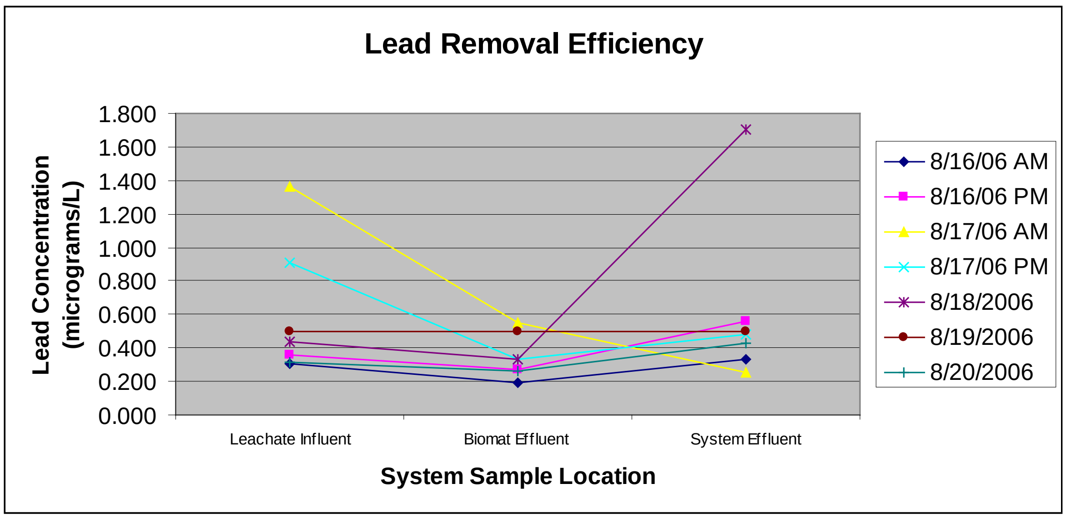

Figure A-20. Graph of lead removal efficiency.

Boron concentrations were reduced in only one set of analyses (Table A-5; Figure A-21).

Table A-5. Leachate boron removal efficiency.

Leachate Metals Sampling Analyses								
Constituent	Laboratory Analysis Result from Drawn Samples (units in µg/L)							
Boron	8/16/06 11:00 AM	8/16/06 4:00 PM	8/17/06 11:00 AM	8/17/06 5:00 PM	8/18/06 5:00 PM	8/19/06 1:00 PM	8/20/06 10:00 AM	System Goal
Leachate Influent	1,680	2,300	4,870	4,330	4,650	4,780	4,420	
Biomat Effluent*	1,680	2,300	4,780	4,260	4,710	4,510	4,360	500
System Effluent*	1,560	2,010	2,350	3,880	4,620	4,870	4,400	500
*Items in red did not meet required reduction in concentration.								

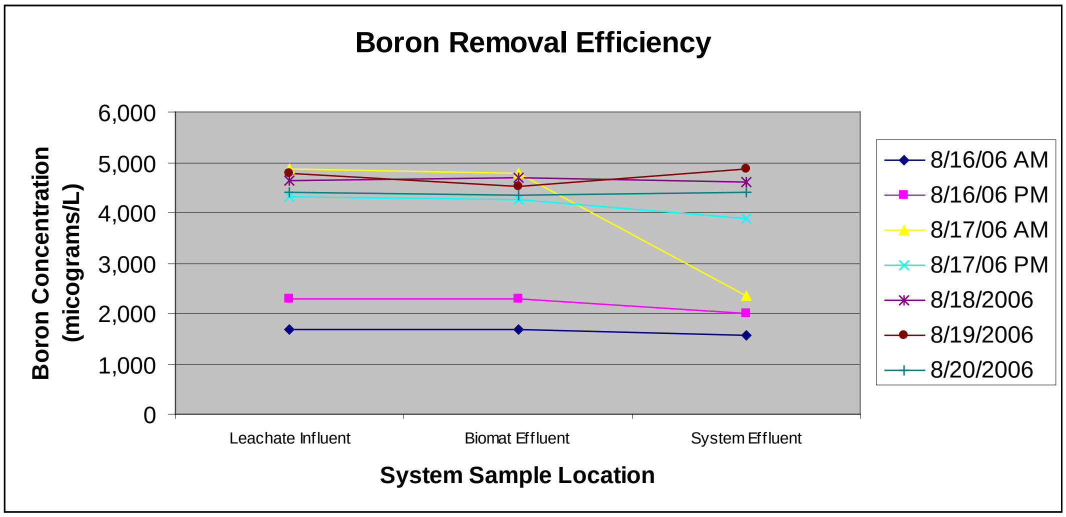

Figure A-21. Graph of boron removal efficiency.

Evaluation of Pilot System

Although the microbial mat bioreactor and polishing system removed some metals from the Fort Hood leachate, it was not successful in meeting the field test goals. Several factors may have contributed to the lack of success in the pilot-scale testing.

The iron concentrations in the leachate were higher than anticipated. Iron concentrations were expected to decrease as more leachate was pumped from the landfill cells; however, iron concentrations remained very high over the course of the test. The precipitation of iron on the biomats was visibly evident, and the mats were replaced on two occasions to minimize bleed-through. Mat replacement was permitted so that it could be determined if new mats would continue to remove all metals.

The system inlet screens also became loaded with iron during processing, and these screens were replaced once during operation. The iron loading on the biomats may have occupied "space" that would have been occupied by other metals. As the biomats were replaced, removal of lead and iron improved slightly, manganese removal remained constant, and boron levels were not affected.

The pilot-scale system seemed overwhelmed at the 2-gpm flow rate from the leachate storage tanks. Initial visual indications at a 1-gpm flow rate indicated the system performed better under that flow rate than under the 2-gpm rate. Visual clarity of the processed leachate was significantly better than leachate processed by the system at 2-gpm.

The system operated for a period of four days during the summer of 2006 at Fort Hood. Afterward, this time frame was determined inadequate to receive laboratory analyses and make adjustments to the system. In addition, the extremely hot midsummer climate conditions may have contributed to acclimation problems with plants in the system.

The system had an approximate 9-hr residence time so that influent and effluent samples taken at the same time probably did not accurately represent system efficiency. This may have contributed to some of the sporadic results shown by the data. The large variation in some of the influent concentrations increased the likelihood of this occurring. However, because the treatment efficiency was consistently below the goals, this did not affect the conclusions drawn from this study.

Technology Comparison with Constructed Wetlands

Even though MSE did not discover any published information regarding comparisons between the microbial mat treatment system and constructed wetlands, it is possible to make a qualitative comparison. MSE personnel previously supported the construction of wetlands in Butte, Montana, and the experience from those operations was used to compare the construction and operation of the two systems. In both cases, the potential issues with full-scale operations were identified. These issues may provide guidance in choosing an optimum treatment system.

Constructed Wetlands

The following outlines the advantages and disadvantages of constructed wetlands. The advantages and disadvantages will be discussed from the perspective of ecological impact, constructability, operations, and maintainability aspects.

Advantages

- Constructed wetlands have an established history of treating wastewater discharge and generally provide treatment for constant flow rates. Properly designed wetlands provide a great deal of treatment capacity and provide treatment for the life of the discharge being treated.

- Regulatory agencies and the general public perceive wetlands favorably. Constructed wetlands provide habitat for a variety of wildlife.

- Maintenance may be minimal. Although no system is maintenance-free, properly designed constructed wetlands may provide one of the lowest maintenance systems available.

- Operation of a wetland is very simple. Once fully operational, the system should not require significant attention.

Disadvantages

- Constructed wetlands are most useful in temperate climates as water can be disrupted in harsh climates. Constructed wetlands generally require a large area for treatment of water/ leachate. Wetlands can affect the existing ecosystems, and this may not be desirable in all cases.

- Constructed wetlands require significant design effort. Many considerations must be taken into account, including: flow rates and concentrations of contaminate to be treated, area of construction, discharge constraints, weather considerations, soil availability for construction, liner materials, substrate permeability and availability, native plants, etc.

- Wetlands require a large construction effort. Development of the wetlands requires several pieces of heavy equipment and substantial labor. Installation of wetlands usually requires lengthy construction schedules.

- The capital cost of wetlands as a treatment system is very high compared to other treatment alternatives. Although the system may require minimal maintenance, initial costs are high.

- Problems can arise during the course of operation, and some problems may be large. Substrate permeability degradation, insect infestation of the wetland, algae buildup, and plugging of piping are all potential maintenance issues.

- Wetlands may provide pest habitat: unwanted animals and mosquitoes thrive in wetland areas, and preventative measures may be necessary. The presence of these pests may also contribute to local health concerns.

- Constructed wetlands are difficult to expand for additional processing capacity. Removal of precipitated metals is a difficult task equivalent to a major construction effort.

- During times of drought, wetlands will require a certain level of moisture to maintain the bioorganisms and plants. This may require recirculation or a makeup water source.

- Careful consideration must be taken when using wetlands as a treatment alternative. Many of these disadvantages may be addressed and resolved during the design phase.

Microbial Mat Treatment System

The following outlines the advantages and disadvantages of the microbial mat treatment system. Included in this evaluation is the addition of the polishing system. To provide an equal evaluation, the advantages and disadvantages will be viewed only from the ecological impact, constructability, operations, and maintainability aspects.

Advantages

- The microbial mat treatment system provides a means of treating wastewater/leachate in a relatively simple system. The design effort should be minimal.

- The capital cost of the system is low in comparison to constructed wetlands. The capital cost of the microbial mat treatment system may be as low as one-tenth of the capital cost of constructed wetlands.

- The operation of the system is simple. Proper design may minimize operational requirements (i.e., gravity flow-through system).

- The system is relatively small. A full-scale system for this particular application may require an area of less than 150 sq ft.

- The system may be expanded if necessary with relative ease. The addition of biomat reactors may provide additional treatment capabilities.

- The impact to the existing environment is minimal.

Disadvantages

- The disadvantages associated with the microbial mat treatment system may be significant. This system does not have the treatment history of wetlands and consequently, more testing is required to ensure the system will provide adequate treatment for this particular application.

- This system will probably require a polishing system which will require some additional area. The polishing system behaves similarly to a wetland and could have problems similar to constructed wetlands, although at a lesser scale.

- The microbial mat system is more complicated than the constructed wetlands; therefore, the system will inherently require more maintenance. Personnel will be required to perform this maintenance.

- Operability of the system will also require more attention. The system is more prone to flow and concentration issues, and adjustments will be required more frequently.

- The biomat reactors are prone to algae buildup or precipitation of iron, which can potentially plug system components over time. This will need additional maintenance.

Technology Comparison Summary

Table A-6 compares the leachate treatment technology advantages and disadvantages.

Table A-6. Advantages/disadvantages.

Parameter	Microbial Mat System	Constructed Wetlands
Experience	Microbial mat has had limited history of implementation.	Extensive implementation in a variety of conditions
Regulatory Acceptance	Limited regulatory history	Regulators very familiar with system
Utility Infrastructure Requirements	Small water and power sources, water storage	Negligible power requirements, may need supplemental water to maintain wetland
Land Requirements	Small footprint	Large land area
Labor Inputs	Moderate	Low
Failure Impacts	Modular design allows rapid replacement of failed subsystems, little downtime.	High cost for excavation, disposal, and reconstruction if failure occurs. May need alternative treatment system for reconstruction period.
Capital Cost	Low	High
Maintenance Cost	Medium	Low

Conclusions and Recommendations

The use of the microbial mat treatment system cannot be recommended without redesign, based on actual influent characteristics and subsequent re-testing. The pilot-scale system used in this study lacked the capability to withstand wide fluctuations in metals concentrations at the design flow rate and was not able to remove the boron in the polishing system. Proposed use of this system would require significant design adjustments to enhance system performance.

The time allowed to complete this project was not sufficient. A longer field test of the microbial mat treatment system is recommended. The system used for this field test could be reused with lower flow rates and for a period of 6 months, which would allow adjustments to enhance system performance. It would also determine the effects of seasonal changes on system performance. A longer period of performance would permit the optimization of the system under real conditions. In addition, a longer field test would allow for more sampling to lower the effect of varying influent concentrations and residence time on overall data results.

Improvements in system configuration may permit the system to operate under full leachate flow rate from the landfill; the system is easily expanded to accommodate durations of increased flow. The leachate can be stored in surge tanks, allowing stable system inflow during periods of low flow rates from the landfill.

It is possible that after re-design and successful re-testing, the microbial mat bioreactor and polishing system could provide a cost-effective means to pre-treat leachate at the Fort Hood landfill. Overall ease of operation, effectiveness, maintainability, relatively small size, and low capital cost are the positive attributes of this system. The system is simple and can be easily upsized to provide the treatment for higher flow rates and metals concentrations.

Appendix B: Acronyms and Abbreviations

Term	Spellout
ACSIM	Assistant Chief of Staff for Installation Management
AR	Army Regulation
CECW	Directorate of Civil Works, U. S. Army Corps of Engineers
CEMP	Directorate of Military Programs, U. S. Army Corps of Engineers
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CTC	Concurrent Technologies Corporation
CWA	Clean Water Act
DA	Department of the Army
DPW	Directorate of Public Works
ECONOVA	ECONOVA, Inc.
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
FOTW	federally owned treatment works
gpm	gallons per minute
HQUSACE	Headquarters, U.S. Army Corps of Engineers
mg/L	milligrams per liter
MSE	MSE Technology Application, Inc.
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
PDF	portable document format
PLANTECO	PLANTECO Environmental Consultants, LLC
POC	point of contact
POTW	publicly owned treatment works
PVC	polyvinyl chloride
PWTB	Public Works Technical Bulletin
SRNL	Savannah River National Laboratory
URL	universal resource locator
WMPP	waste minimization and pollution prevention
WWTP	wastewater treatment plant
WWW	World Wide Web
µg/L	micrograms per liter

Appendix C:
References

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