**Waste Management Education and Research Consortium (WERC)
National Environmental Design**

Topical Report

Brian E. Reed

October 1994

Work Performed Under Contract No.: DE-FC21-92MC29467

U.S. Department of Energy
Office of Environmental Management
Office of Technology Development
Washington, DC

For

U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
West Virginia University Research Corporation
Morgantown, West Virginia

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October 1994

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1. EXECUTIVE SUMMARY

The 4th Annual Waste-Management Education and Research Consortium (WERC) for National Environmental Design was held on April 10 - 14 in Las Cruces, New Mexico. WERC is sponsored by the Department of Energy and is housed at New Mexico State University. Two student groups from West Virginia University's Department of Civil and Environmental Engineering traveled to New Mexico. Group 1 was composed of graduate students and Group 2 was composed of undergraduate students.

The graduate group received third place overall while the undergraduate group received first place for their Poster Presentation. Copies of the final reports from the two teams were provided in an earlier report.

Representatives from the two student groups traveled to the University of Delaware on August 7-10, 1994 to present their results at the 26th Annual Mid-Atlantic Industrial and Hazardous Waste Conference.

Students who participated in this program were exposed to all aspects of the solution of a real-life environmental problem. Two undergraduate students have entered Environmental Engineering graduate school in the Fall 1995 semester and several more will be attending graduate school in the Spring 1995 semester. All students reported that their decision to attend graduate school in Environmental Engineering was due in part to their exposure to this program. The DOE is encouraged to continue support of the WERC Environmental Design.

Work has begun on the 5th Annual Waste-Management Education and Research Consortium (WERC) for National Environmental Design to be held on April 18 - 21 in Las Cruces, New Mexico. As in the 4th Annual WERC Contest, there are multiple tasks to be completed. In Task 1, students must design a mobilization and retrieval system for highly radioactive waste that is stored in an underground tank. Task 1 mimics the situation at Hanford, WA. In Task 2, student must develop and demonstrate a process for the remediation of a hazardous, but nonradioactive, pond sludge. Separate reports, poster boards, oral presentations, and working bench-scale models are required for each task. A complete description of the 5th Annual WERC National Environmental Design is provided in the Appendix A to this report.

2. INTRODUCTION

The 4th Annual Waste-Management Education and Research Consortium (WERC) for National Environmental Design was held on April 10 - 14 in Las Cruces, New Mexico. WERC is sponsored by the Department of Energy and is housed at New Mexico State University. Two student groups from West Virginia University's Department of Civil and Environmental Engineering traveled to New Mexico. Group 1 was composed of graduate students and Group 2 was composed of undergraduate students.

3. PURPOSE

The purpose of the WERC is to train students in the area of site remediation and restoration. Consistent with the Cooperative Agreement's 3rd Task, the ultimate goal of WERC is to provide training for potential engineers and scientists for the DOE's remediation and restoration efforts.

4. BACKGROUND

As in the past, the 1993-1994 problem (*i.e.*, 4th Annual Contest) was very similar to a current DOE remediation and restoration need. A complete description of the WERC was provided in an earlier report. A short synopsis of the 1993-1994 problem is provided below.

Hundreds of square miles of an arid-sandy soil was contaminated about 1' deep with various organic compounds and several heavy metals. Contaminated soil was to be remediated and the decontaminated area was to be reclaimed by applying a UV and erosion resistant sealant. Sealing the soil will allow for water harvesting and the eventual growth of plants (*i.e.*, reclamation). The soil remediation method and sealant was demonstrated at Las Cruces, NM. A mechanized device to apply the sealant was developed on paper. A complete engineering report detailing the technical, economic, regulatory, and public participation aspects of the solution was developed. Equal weight was given to the remediation and reclamation portions of the report. The report was due several weeks before the April 10-14 visit to Las Cruces. A poster board and oral presentation was presented at Las Cruces. An undergraduate student group and graduate student group were involved. A total of 20 students participated in the program. Students received academic credit in the Spring 1994 semester.

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poster boards, oral presentations, and working bench-scale models are required for each task. A complete description of the 5th Annual WERC National Environmental Design is presented in Appendix A.

5. METHODOLOGY

Not Applicable

6. RESULTS AND DISCUSSION

The graduate group received third place overall while the undergraduate group received first place for their Poster Presentation. Copies of the final reports for the graduate and undergraduate groups were provided in an earlier report.

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7. CONCLUSIONS

Students who participated in this program were exposed to all aspects of the solution of a real-life environmental problem. Two undergraduate students have entered Environmental Engineering graduate school in the Fall 1995 semester and several more will be attending graduate school in the Spring 1995 semester. All students reported that their decision to attend graduate school in Environmental Engineering was due in part to their exposure to this program.

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8. REFERENCES

Not Applicable

APPENDIX A

Description of 5th Annual WERC National Environmental Design Problem

Raymond Lovett
NRCCE
PO Box 6064

Dear Ray,

Please find the Final Report for the project entitled **"WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM (WERC) NATIONAL ENVIRONMENTAL DESIGN"** (Contract No.: DE-FC25-92MC29467).

Thank you for your assistance and if you require further information, please contact me at 293.3031, ext. 613.

Sincerely,

Brian E. Reed

Enc.

WASTE-MANAGEMENT EDUCATION & RESEARCH CONSORTIUM

Administrative Office:

New Mexico State University, Box 30001, Department WERC, Las Cruces, New Mexico 88003-8001, (505) 646-2038, FAX (505) 646-4149

MEMORANDUM

DATE : August 25, 1994

TO : New Engineer

FROM : Ron Bhada, WERC Director
Abbas Ghassemi, Director, Special Programs

SUBJECT : Fifth Annual Environmental Design Contest

It is our pleasure to invite you to assemble a team, or teams, from your university to participate in the fifth annual Environmental Design Contest. The competition is sponsored by the Waste-management Education and Research Consortium (WERC) and will be held in Las Cruces, New Mexico, on April 18-21, 1995. This unique and innovative contest is the only university environmental design contest of its kind in the world that provides participants with design and practical experience on real environmental restoration issues.

This year's design challenge focuses on a combination of problems resulting from defense related processing and manufacturing. A large facility in operation over a period of 45 years led to the generation of a massive waste stream characterized by two broad categories:

1. radioactive mixed waste
2. hazardous waste (non-radioactive)

The change in operating focus at the facility and customer demand have resulted in a new mission for the site, namely environmental restoration. The resulting public demand and concern for environmental health and safety coupled with federal, state and local regulations have dictated that environmental cleanup proceed on an urgent basis with the first priority given to radioactive mixed waste.

This year's design challenge has the ultimate objective of mobilization and retrieval for underground tank waste and remediation/stabilization of pond sludge. Past practice at the site was to store radioactive waste in large underground tanks while the non-radioactive waste was pumped into open ponds.

A-3

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As your first assignment, please assemble a group of engineers, scientists, and other experts to address this environmental design challenge which includes the following tasks:

Task I: Design of a waste mobilization and retrieval system for the underground tank wastes, and

Task II: Development and demonstration of a process for remediation of the pond sludge.

All participating teams must address both tasks. The ideal team should consist of two groups: one for Task I and one for Task II. In addition to environmental scientists, health physicists, regulators and others, Task I requires members with strong backgrounds in mechanical and electrical engineering while Task II requires members with strong backgrounds in chemical and civil engineering. You are encouraged to form interdisciplinary teams utilizing engineers, scientists, and individuals with regulation, business planning, economics, and health physics backgrounds.

Additional information related to both of these tasks is presented in the attached problem statement. However, it should be emphasized that each task carries with it certain stipulations or exclusions that must be adhered to by the participating design teams.

For Task I, WERC has already developed two "baseline technologies" applicable to the underground tanks. These two existing systems, sluicing and an Arm-Based System described later in the problem statement, including modification or refinements thereof, must not be considered as part of the design solution. Solutions such as remote and internal manipulators, robotic devices, chemical and physical handling are, however, acceptable.

You are in charge of identifying, testing and evaluating innovative waste mobilization and retrieval systems. WERC has sufficient capacity to store the retrieved waste, subject to decisions regarding permanent disposal. However, WERC's ultimate objective is not to create additional waste by dilution or processes that generate more waste. The waste storage costs should be considered in the final project economics. Your team will be requested to demonstrate an effective waste mobilization and removal process using a tank waste simulant.

For Task II, stabilization using cementitious materials (e.g. Portland cement) and vitrification will not be acceptable remediation/stabilization processes. All other methods such as physical, chemical, biological, leaching, detoxification, etc. are acceptable. Your team will be requested to demonstrate an effective remediation process using a 1 kilogram sample of the pond sludge.

The samples to be used for demonstration purposes for both tasks will be provided to each design team in Las Cruces on April 18, 1995. In order to simulate the waste and test your proposed solutions, methods for simulating the waste will be sent with the next mailing. The expected deliverables are:

- 1) A separate written report for each task. The report must include:
 - the process design
 - the engineering basis for the design
 - the economics of the process
 - a discussion of the legal, health and safety implications
 - a plan for presentation to the community for public acceptance so that problems are minimized after construction and implementation
 - a discussion of selected process waste generation, disposal, and handling
- 2) A demonstration utilizing your equipment designed for each task on the samples provided by WERC.
- 3) A brief oral presentation of the design for each Task including economics, health, business development, regulatory, and other related issues.
- 4) A poster presentation containing highlights of the design, economics and other issues. You must prepare a separate poster for each task.

All of the design teams will gather at the WERC integrated demonstration grounds in Las Cruces, New Mexico on April 18 - 21, 1995, to demonstrate their process. The detail criteria for best designs will be sent to you on the next mailing. It will be based on factors such as cost, creativity, effectiveness, process design, functionality, and communications.

A team of experts from industry, academia and government organizations will make the final selection. The top four teams will receive the company's Meritorious Award plaque, and a cash bonus from the company's bonus plan. Other special awards of cash and trophies will also be presented.

If you have any questions, please contact the Director Special Projects, Dr. Abbas Ghassemi, at the following address:

WERC
New Mexico State University
Box 30001, Dept. WERC
Las Cruces, NM 88003-8001
Phone: (505) 646-1719
Fax: (505) 646-4149

TASK I: WASTE TANK RETRIEVAL SYSTEM

Introduction

The Waste-management Education and Research Consortium (WERC) is tasked with ensuring that radioactive wastes stored in underground tanks at the site are effectively and efficiently remediated. Pursuant to this objective, WERC established the Tank Waste Remediation System (TWRS) division. TWRS is conducting a comprehensive program to address the tank waste problem. To meet the objectives of the "retrieve waste" element of that program, TWRS identified two waste retrieval systems called the "baseline systems." Baseline systems, described below, are capable of retrieving any combination of three physical forms of waste. However, they are not necessarily the most cost-effective way to do so. To investigate the possibility of more cost-effective methods of retrieving the waste, WERC has initiated an Alternative Retrieval Program. You are in charge of this Alternative Retrieval Program.

Baseline Systems Description

The baseline retrieval systems are: (1) past-practice sluicing, which is considered a mature and proven technology, and (2) a remotely controlled articulated mechanical arm with exchangeable end-effectors.

- **Past Practice Sluicing**--The use of sluicing to retrieve waste from tanks has been used over the years in different scenarios, but most techniques involved the same principles. A waste recovery pump is installed in the waste tank through a central riser. The sluicing equipment is then installed through a second riser, with the sluicing nozzle positioned several feet above the waste. A second tank (the receiver tank) is charged with water to a predetermined level. The fluid in the receiver tank is then pumped through the sluicing nozzles inside the waste tank and the resultant slurry is then pumped back to the receiver tank. Periodically, the sluicing operations are halted and all liquids in the tank being sluiced are returned to the receiver tank. Solids suspended in the liquid are allowed to settle out before sluicing operations are resumed. Tank clean-out requires anywhere from several days to several weeks to complete.
- **Arm-Based System**--The use of arm-based systems for the retrieval of waste from the tanks has been the subject of study, evaluation, and development since the late 1960s. The baseline Arm-Based System consists of a remotely operated arm working through a 42 inch diameter opening in the top of the tank dome. A 42 inch diameter riser (i.e., pipe) connects the hole in the tank dome to a retrieval facility on the surface above the tank. The remote arm has the ability to place soft waste and hard waste end-effectors (tools) inside the tank to retrieve waste. Two interchangeable end-effectors are used in conjunction with an air conveyance system to remove the waste and liquids from the tank.

Problem Definition

Your task is to develop a more cost-effective system that mobilizes and retrieves radioactive wastes in the form of saltcake/sludge from buried tanks and convey that waste to a storage point.

Some objectives of the mobilization/retrieval process are:

- 1) Develop a system design for both mobilization and retrieval (other than designs based on the baseline retrieval system).
- 2) Demonstrate and test candidate mobilization systems using simulated waste forms.
- 3) Develop a transport system designed to convey retrieved waste to a Waste Receiving Facility (WRF).

Design Parameters

- 1) A total of 8 underground tanks with a capacity of 500,000 gallons each.
- 2) Each tank on average contains 350,000 gallons of saltcake and 32,000 gallons of sludge.
- 3) Retrieval time per tank (system operation) cannot exceed 6 months.
- 4) Residual waste allowed is 360 ft³ per tank. (In-tank hardware and other debris are not considered waste)
- 5) Tank integrity cannot be compromised.
- 6) Tank content is not homogeneous.
- 7) The radiation consists of α , β and "hard" gamma of unknown dosage; hence process designs must include appropriate shielding for all materials retrieved from tanks.

The next mailing will include additional information such as:

- tank: diameter, depth, shape, accessibility and burial depth
- penetrations: number, location, size, and separation distance in the tank

Other Information

Design teams should be cognizant of several aspects of the design challenge that are important but need not be addressed in detail. Among these items are:

- Heating, ventilating and air conditioning (HVAC) systems.
- Monitoring and control except as noted for the transport to the WRF.

Note: Tank contents include debris such as 50 foot steel tapes, other metal objects and solid materials that need not be removed.

Waste Properties

The waste exists as saltcake, sludge or liquid. Saltcake constitutes the largest part of the waste and consists primarily of sodium nitrate. Damp saltcake is a jelly-like form. Dried saltcake is a hard, abrasive, brittle material that has been described to be "as hard as weak concrete". It exists as large single crystals and also as conglomerates which form on in-tank hardware (ITH). Dried saltcake is similar in physical characteristics to the hard salt blocks used in the cattle industry. The saltcake will vary from wet to dry to damp and may contain pockets of liquids. The porosity of the saltcake is expected to vary from 10 to 50 percent. The physical properties of saltcake are given below:

Physical Properties of Saltcake

Saltcake (High Nitrate concentration)

Form	Consistency of slush to large masses of hard crystals
Bulk density	1.4 to 1.6 gm/cm ³
Chemical constituents	See Table 1

Some physical properties are listed in Table 2. Other physical properties will be provided at a later date.

The radioactive components consist primarily of fission product radionuclides such as ⁹⁰Sr and ¹³⁷Cs, and actinide elements such as uranium, plutonium, and americium. The wastes also have a high pH (approaching 12), which protects the carbon steel liners of the tanks from corrosion. The chemical constituents from typical core samples are given in Table 1.

TABLE 1

Typical Saltcake Chemical Constituents from Core Samples

Tank 1	Core 1 (wt.%)	Core 2 (wt.%)	Average (wt.%)
NaNO ₂	16.7	7.8	12.3
NaNO ₃	8.8	5.9	7.4
NaAlO ₂	2.7	13.1	7.9
Na ₃ PO ₄	7.0	0.3	3.8
SiO ₂	2.8	8.8	5.8
CaCO ₃	0.5	1.5	1.0
MgO	0.2	0.5	0.4
Fe(OH) ₃	0.7	0.3	0.5
MnO ₂	0.2	0.1	0.2
NaOH	0.1	0.1	0.1
H ₂ O	60.3	61.4	60.6

Tank 2	Core 1 (wt.%)	Core 2 (wt.%)
NaNO ₂	32.4	16.9
NaNO ₃	17.8	18.4
NaAlO ₂	5.1	7.3
Na ₃ PO ₄	1.0	1.0
SiO ₂	1.2	0.7
Fe(OH) ₃	1.2	0.2
NaOH	0.1	0.1
H ₂ O	41.2	55.4

Tank 3**(Wt. %)**

NaNO ₂	0.1
NaNO ₃	67.1
NaAlO ₂	0.1
Na ₃ PO ₄	5.0
SiO ₂	0.1
Na ₂ SO ₄	0.1
NaF	0.1
NaCl	0.1
Fe(OH) ₁	0.2
H ₂ O	27.1

Sludge consists primarily of iron, manganese, and aluminum precipitates. Sludges vary greatly in their physical properties and may contain pockets of liquid. In the past, the sludge in the tanks has been described as follows:

- Varying in consistency from cream of wheat to peanut butter
- Sandy with hard chunks of material
- Thick, sticky, dark brown paste
- Wet, musky solid with no structural strength

The physical properties of the sludge are given below:

TABLE 2**Physical Properties of Sludge**

FORM	CONSISTENCY (RANGE FROM PEANUT BUTTER TO SOLID)
Viscosity	Range 10,000 - 1,700,000 cp
pH	8.5 - 13
Specific Gravity	1.25 - 1.88
Particle Size	9 to 26 μ m (0.35 to 1.02 mils) mean by population 50 to 75 μ m (1.96 to 2.96 mils) at 50% total by volume

TASK II: Evaporation Pond Treatment

Introduction:

Sixteen miles from a large metropolitan center in a semi-arid region, an industrial complex had been discharging processing effluent into five single-lined outdoor evaporation ponds over many years. This effluent consisted primarily of nitrate processing solutions, sewage sludge, electroplating solutions, and landfill leachate. During this time sediments formed both as a result of precipitation of supersaturated solutions during evaporation and wind-blown dust collecting in the ponds. Attempts had been made over the years to clean the ponds and solidify the sludge for ultimate shallow burial land disposal in other locations. These attempts were met with mixed results. Recently, considerable work has been performed both on-site and off-site to characterize the waste form and develop improved cementation (grouting) formulas to improve the results. Hence, cementation (i.e. using Portland cement) should not be proposed as one of the options.

However, other alternatives are of interest due to the large waste product volume generated during treatment. An Interim Measure/Interim Remedial Action was required to expediently curb further introduction of water into the evaporation ponds. As a result, pond water and sediments from the evaporation ponds have finally been emptied and placed into storage tanks. **The combination of water, sediments, and both dissolved and undissolved salts is referred to as sludge.** Decisions are being made on the preferred treatment method for the sludge. For regulatory purposes, the pond contents have been classified as "non-wastewaters." According to EPA proposed solutions offering stabilization require a 30 year stability of treated waste form when buried in shallow land burials.

The design team is given the following tasks:

- 1) Develop and demonstrate a bench-scale process to put the waste sludge into a suitable form which meets land disposal restrictions (LDR) as defined by the EPA and the Department of Transportation (DOT) shipping requirements. Due to the nature of the sludge and constraints unrelated to this problem, actual samples of the sludge will not be available. Consequently, a formulation will be provided from which each team can prepare a surrogate of the sludge for preliminary testing at their respective universities. WERC will provide a sample of the sludge to be used during the bench-scale process in Las Cruces. A final analysis of the surrogate waste form is required to verify the concentration of constituents and physical form.

Since cementation (grouting) has been thoroughly investigated for this particular waste form, no further effort in this area is required. Other than the cementation processing techniques, there is no restriction on the method you select (e.g. physical, chemical, biochemical, thermal, etc.) Preference will be given, however, to the process that best minimizes waste, produces the most stable product, minimizes the volume of product compared with the waste feed, uses the best process control and product verification techniques.

- 2) Test the resulting waste forms to ensure their stability to meet both LDR under RCRA and DOT requirements. Using a combination of toxicity characteristic leaching procedure (TCLP) as specified in methods 1311 found in SW 846, and freeze/thaw (thermal cycle) testing, as specified in ASTM

Method C-666 (this method uses ASTM C215 to test for fundamental transfer frequency), the products must be shown to meet LDR over a thirty (30) year time period. Preference will be given to the most robust product form, which uncontained, can meet the above requirements.

- 3) Prepare a design package, including a list of any permits that might be required to operate the treatment facility, for full-scale processing. Prepare a processing flowsheet and conceptual design. Include material balance, equipment list, floor plan, scope & cost estimate, and labor requirements for building a processing facility for treating 178,357 gallons of water containing 800,000 pounds of dry solids (e.g. a sludge at 35 wt.% solids). Disposal costs must include costs associated with landfill and transportation.

The next mailing will include additional information such as:

- pond: shape, depth, slope, obstructions and other pertinent information

SLUDGE COMPOSITION AND CONTAMINANTS

Contaminants which have been identified in water and sediments and their concentrations are listed in Tables 3 and 4. A recipe for surrogate composite of the sludge pond will be provided to you at a later date.

TABLE 3
SUMMARY OF POND WATER CHARACTERIZATION DATA

<u>CONTAMINENT</u>	<u>MEAN CONC.</u>
Volatiles (1)	
2-Butanone	76
Methylene chloride	5.6
Inorganics (1)	
Arsenic	3,690
Barium	130
Boron	463,000
Cadmium	490
Calcium	ND
Chromium	3,520
Lead	210
Magnesium	2,790
Mercury	ND
Nickel	2,680
Potassium	55,800
Selenium	1,980
Silver	ND
Sodium	138,000
Miscellaneous (2)	
Alkalinity (Methyl Orange)	60,000
Alkalinity (Phenolphthalein)	29,000
Ammonia	3.7
Chloride	23,000
Cyanide - Total	7.7
Nitrate	62,000
pH	10 (units)
Phosphorus, total (as P)	570
Specific Gravity	1.332
Sulfate (as SO ₄)	17,000
TDS	460,000
TOC	1,400
TSS	530

ND = Not Detected

(1) = units are in micrograms per liter unless where indicated

(2) = units are in milligrams per liter unless where indicated

TABLE 4
SUMMARY OF POND SEDIMENTS CHARACTERIZATION DATA

<u>CONTAMINENT</u>	<u>MEAN CONC.*</u>
Volatiles (3)	
1,1,2-Trichloro-1,2,2-trifluoroethane	10.2
2-Butanone	110
Benzene	10.5
Tetrachlorethane (PCE)	22.2
Trichlorethene (TCE)	3.9
Semi-Volatiles (3)	
Pyrene	286
Miscellaneous (4)	
Cyanide-Total	72 mg/kg
Moisture - Gravimetric	44.0 %
Ph	10.4 Units
TOC	7,700 mg/kg
Chloride	770
Nitrate	10,000
Sulfate	970
TDS	21,000
Inorganics (5)	
Arsenic	28
Barium	31
Boron	612
Cadmium	164
Chromium	618
Lead	19.4
Magnesium	3,370
Mercury	0.9
Nickel	52.3
Potassium	78,100
Selenium	ND
Silver	54.1
Sodium	157,600

ND = Not Detected

(3)= units are in micrograms per kilogram unless where indicated

(4)= units are in milligrams per liter unless where indicated

(5)= units are in milligrams per kilogram unless where indicated