DOE/AL/63805--T2-App.

WASTE-MANAGEMENT EDUCATION & RESEARCH CONSORTIUM

(WERC)

MASTER

ANNUAL PROGRESS REPORT, 1992-1993
APPENDICES
FEBRUARY 15, 1993

Administrative Office: New Mexico State University, Box 30001, Department WERC
Las Cruces, New Mexico 88003-0001

DOE/AL/63805--T2-App.

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APPENDIX A

REQUIREMENTS FOR UNDERGRADUATE LEVEL

WERC
UNDERGRADUATE MINOR PROGRAM AT NMSU/NMIMT

Basic Requirements:

1. All requirements for a Bachelor's Degree as set by the Department of registration.

2. A minimum of 18 credit-hours of courses from:

   a. The Department Environmental Management Minor List,

   b. The "Undergraduate Minor" list, and

   c. The "Off-Campus Course" list or courses from the ITV offerings.

3. The 18 credit-hours include:

   a. 6 credit-hours from the "Undergraduate Minor" list outside of the major undergraduate field.

   b. 6 credit-hours of environmental management courses from outside the student's home university through the WERC ITV Program or on a student exchange basis.

   c. 2 credit-hours of Environmental Management Seminar.

The above is a general guideline; there are slight variations in each institution.

APPENDIX A

WERC
UNDERGRADUATE MINOR PROGRAM AT UNM

To obtain a "WERC Certificate" in waste management studies as part of a bachelor's level program, a student at UNM must complete a program which includes:

1. All requirements for BS/BA in major field.

2. A minimum of 17 credit-hours in waste management courses, passed with a grade of C- or better, from the "WERC List" which are acceptable to the major department. At least two of these credit-hours will be in seminar courses in Hazardous Waste.*

3. A minimum of 6 credit-hours of courses in waste management courses outside of the major field for the BS/BA.

4. A minimum of 6 credit-hours in waste management courses from NMSU and/or NMIMT. They will normally be taken by television, but could be done in person on an exchange basis.

5. Courses taken to meet requirements 3 and 4 count toward the total of 17 credit-hours for requirement 2.

* Seminars: Fall and Spring, 1-credit each semester. (CHNE 499, sometimes cross-listed with other departments) Seminar in Waste Management. A survey of practice and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research. May be repeated for a maximum of three credits, since content varies from semester to semester.

Students must apply for WERC Certificates to the UNM WERC education coordinator, Dean Kauffman, College of Engineering, at least one full semester before completing their programs. The WERC Education Committee will have final review authority on all applications.

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF COURSES FULFILLING THE REQUIREMENTS
OF THE ENVIRONMENTAL MANAGEMENT MINOR

NEW MEXICO STATE UNIVERSITY

Undergraduate Minor

Engineering Design		
A EN 459	Design of Water Wells/Pumping Systems	3 cr.
A EN 475	Soil and Water Conservation	3 cr.
A EN 476	Conservation Engineering	1 cr.
CH E 475	Biochemical Engineering I	3 cr.
CH E 476	Biochemical Engineering II	3 cr.
CH E 478	Special Methods in Industrial Microbiology	3 cr.
CH E 486	Industrial Waste Treatment Systems	3 cr.
CH E 492	Nuclear Chemical Engineering	3 cr.
C E 356	Fundamentals of Environmental Engineering	3 cr.
C E 455	Solid and Hazardous Waste System Design	3 cr.
C E 456	Environmental Engineering Design	3 cr.
M E 475	Power Plant Engineering	3 cr.
M E 496	Kinematics and Dynamics of Robots	3 cr.
Engineering Science		
C E 256	Environmental Science	3 cr.

APPENDIX A (continued)

C E 355	Technology and the Global Environment	3 cr.
C E 462	Sampling and Analysis of Environmental Contaminants	3 cr.
C E 483	Surface Water Hydrology	3 cr.
G EN 451/ GEOL 451	Subsurface Geotechnical Investigation	3 cr.
G EN 452 GEOL 452	Geohydrology	3 cr.
G EN 453	Geotechnical Site Evaluation	3 cr.
M E 468	Compressible Flow	3 cr.
M E 492	Nuclear Engineering	3 cr.

Basic Science

BIOL 301	Principles of Ecology	3 cr.
BIOL 403/ GEOG 403	Ecology of Deserts	3 cr.
BIOL 419	Ecology of Microorganisms	3 cr.
BIOL 461	Human Ecology	3 cr.
CHEM 485	Nuclear and Radiochemistry	3 cr.
GEOG 357	Climatology	3 cr.
GEOG 458	Hydrometeorology	3 cr.
GEOG 470	Environmental Pollution	3 cr.
GEOL 295	Environmental Geology	3 cr.
GEOL 474	Ground Water Geology	3 cr.
HL S 470	Epidemiology	3 cr.

APPENDIX A (continued)

PHYS 485	Physics of the Atmosphere	3 cr.
PSY 316	Environmental Psychology	3 cr.
SOIL 424/ CHEM 424/ GEOL 424	Soil Chemistry	3 cr.
SOIL 476 BIOL 476	Soil Microbiology	3 cr.
SOIL 477/ GEOG 477	Soil-Water Relations	3 cr.
SOIL 479	Environmental Soil Chemistry	3 cr.
TOX 461	Toxicology I	3 cr.
WLSC 458	Ecology of Inland Waters	3 cr.

Environmental Policy

AG E 337/ ECON 337	Natural Resource Economics	3 cr.
AG E 437/ ECON 437	Resource Economics for Engineers and Planners	3 cr.
AG E 497/ ECON 497	Water Resources Economics	3 cr.
B A 322	Water and Mineral Law	3 cr.
PLAN 275	Environmental/Water Management	3 cr.
ECON 463	Cost-Benefit Analysis	3 cr.
GOVT 442	The Regulatory Process	3 cr.
IE 411	Industrial Safety	3 cr.
PLAN 351	Environmental Planning	1-3 cr.
PLAN 465	Public Land Analysis	3 cr.
PLAN 475	Transportation Planning	3 cr.
WLSC 310	Management of Endangered Species	3 cr.

WLSC 437	Wildlife Damage Control	3 cr.
WLSC 447	Wildlife Law, Policy, and Administration	3 cr.

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF COURSES FULFILLING THE REQUIREMENTS
OF THE ENVIRONMENTAL MANAGEMENT MINOR

University of New Mexico

Undergraduate Minor

BIO 451	Microbial Ecology	3 cr.
BIO 402	Topics/Bioremediation of Soils and Groundwater	3 cr.
CHEM 462	Environmental Biochemistry	3 cr.
CHNE 231	Radiation Safety Engineering	3 cr.
CHNE 323L	Nuclear Detection and Measurement	3 cr.
CHNE 441	Air Pollution Control	3 cr.
CHNE 466	Nuclear Environmental Safety Analysis	3 cr.
CHNE 499	Indoor Air Pollution	3 cr.
CHNE 313	Colloid Science	3 cr.
CE 431	Intermediate Hydrology	3 cr.
CE 433	Groundwater Engineering	3 cr.
CE 435	Introduction to Water and Wastewater Treatment	3 cr.
CE 436	Biological Wastewater Treatment	3 cr.
CE 437L	Aqueous Environmental Chemistry and Analysis	3 cr.
ECON 342	Environmental Economics	3 cr.
ENGR-N 337	Hydraulics and Hydrology	3 cr.
ENGR-N 338	Air Management and Environment	3 cr.
GEOG 295	Survey of Environmental Issues	3 cr.
GEOG 459	Water Resources Management	3 cr.
GEOL 203	Earth Resources and Man	3 cr.
GEOL 300	Environmental Problems Facing New Mexico	3 cr.
GEOL 333L	Environmental Geology	3 cr.
GEOL 462	Hydrogeology	3 cr.
GEOL 474L	Hydrogeology Laboratory	3 cr.
PHRM 480	General Toxicology	3 cr.
PHRM 481	General Toxicology II	3 cr.
PHRM 485	Biochemical Toxicology	3 cr.
PHRM 487	Pollution Toxicology	3 cr.
PS 376	Natural Resources Policy	3 cr.
PS 475	Environmental Politics	3 cr.
SOC 305	Man, Nature and Society	3 cr.

Also other courses as approved by the Associate Dean of Engineering

APPENDIX A (continued)

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF COURSES FULFILLING THE REQUIREMENTS OF THE ENVIRONMENTAL MANAGEMENT MINOR

New Mexico Institute of Mining and Technology

Undergraduate Minor

BIOL 343	Environmental Microbiology	3 cr.
BIOL 344	Introductory Ecology	3 cr.
BIOL 346	Introduction to Environmental Toxicology	3 cr.
CHEM 422	Environmental Chemistry	3 cr.
ENE 201	Introduction to Environmental Science and Engineering	3 cr.
ENE 312	Water and Wastewater Process Design Engineering	3 cr.
ENE 401	Air Pollution Engineering	3 cr.
ENE 411	Solid and Hazardous Waste Engineering	3 cr.
ENE 426	Case Studies in Industrial Environmental Problems	3 cr.
ENE 431	Water Wastewater Systems Hydraulic Design	3 cr.
ENE 4XX	Radiation Protection Engineering	3 cr.
ENE 491	Radioactive Waste Management	3 cr.
ES 481	Health Physics	3 cr.
GEOCH 422	Environmental Geochemistry	3 cr.
GEOL 341	Environmental Geology	3 cr.

APPENDIX A (continued)

HYD 413	Groundwater Hydrology	3 cr.
HYD 466	Geophysical Methods of Water Resource Evaluation	3 cr.
ME 314	Environmental Management of Mining Wastes	3 cr.
ME 415	Design of Hydraulic Structures	3 cr.
PETR 481	Waste Management Issues in Domestic Petroleum	3 cr.
PETR 491	Treatment of Produced Water for Disposal by Reinjection	3 cr.
PETR 4XX	Environmental Aspects of Oilfield Operations: Drilling and Production	3 cr.
MATE 335	Materials Engineering	3 cr.
MATE 454	Energy and the Environment I	3 cr.
MATE 455	Energy and the Environment II	3 cr.

APPENDIX B

REQUIREMENTS FOR GRADUATE LEVEL

WERC
GRADUATE MINOR PROGRAM AT NMSU/NMIMT

To obtain an Environmental Management Minor as part of a graduate level program, a student must complete the following requirements:

1. All requirements for a graduate degree in the major field.

2. A minimum of 8-12 credit-hours of courses from the "Graduate Minor" lists acceptable for graduate credit within the major department. Credit for individual study, thesis, or dissertation may not be used to fulfill this requirement. The credits must include:

   a. A minimum of 3 credit-hours of courses from the home university "Graduate Minor" list, acceptable for graduate credit within the major department, and taken from outside of the major graduate and undergraduate fields.

   b. A minimum of 3 credit-hours acceptable for graduate credit within the major department, offered by partner universities through the WERC Interactive Television Program or on a student exchange basis.

3. Two credit hours of seminar courses in Environmental Management:

   a. 1 credit. Environmental Management Seminar I. A survey of practical and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research.

   b. 1 credit. Environmental Management Seminar II. A survey of practical and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research.

4. Either a dissertation, thesis, or an independent study course approved by the major department, as appropriate for the degree, relating to environmental management.

The above guidelines vary slightly between the academic institutions.

APPENDIX B

WERC
GRADUATE MINOR PROGRAM AT UNM

To obtain a "WERC Certificate" in waste management studies as part of a doctoral or masters level program, a student at UNM must complete a program which includes:

1. All requirements for the graduate degree in the major field.

2. A minimum of 14 credit-hours in waste management courses, passes with grades of B- or better, acceptable for graduate credit. ("Courses," as used here, do not include individual study, thesis or dissertation.) At least two of these credit-hours will be in seminar courses in Hazardous Waste.*

3. A minimum of 6 credit-hours of courses in waste management courses, acceptable for graduate credit, outside of the student's major graduate field and the student's major undergraduate field.

4. A minimum of 3 credit-hours in waste management courses, acceptable for graduate credit, from NMSU and/or NMIMT. These hours count toward the 14 total. They will normally be taken by television, but could be done in person on an exchange basis.

5. Either a dissertation or thesis, as appropriate for the degree, or an individual study course related to waste management.

6. Courses taken to meet requirements 3 and 4 count toward the total of 14 credit-hours for requirement 2; hours taken to meet requirement 5 do not.

* Seminars: Fall and Spring, 1-credit each semester. (CHNE 499, sometimes cross-listed with other departments) Seminar in Waste Management. A survey of practice and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research. May be repeated for maximum of three credits, since content varies from semester to semester.

Students must apply for WERC Certificates to the UNM WERC education coordinator, Dean Kauffman, College of Engineering, at least one full semester before completing their programs. The WERC Education Committee will have final review authority on all applications.

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF COURSES FULFILLING THE REQUIREMENTS
OF THE ENVIRONMENTAL MANAGEMENT MINOR
OFFERED AT NEW MEXICO STATE UNIVERSITY

Graduate Minor

AEEC 503	Welfare and Resource Economics	3 cr.
AEN 459	Design of Water Wells/Pumping Systems	3 cr.
AGE 497	Water Resources Economics	3 cr.
BIOL 476	Soil Microbiology	3 cr.
BIOL 519	Microbial Ecology	3 cr.
CHE 475	Biochemical Engineering I	3 cr.
CHE 476	Biochemical Engineering II	3 cr.
CHE 478	Special Methods in Industrial Microbiology	3 cr.
CHE 486	Industrial Waste Treatment Systems	3 cr.
CHE 492	Nuclear Chemical Engineering	3 cr.
CHE 620	Topics in Reservoir Modeling	3 cr.
CHE 630	Topics in Bioengineering	3 cr.
CHE 670	Topics in Combustion and Emission Control	3 cr.
CHEM 485	Nuclear and Radiochemistry	3 cr.
CE 455	Solid & Hazardous Waste System Design	3 cr.
CE 456	Environmental Engineering Design	3 cr.

APPENDIX B (continued)

CE 462	Sampling & Analysis of Environmental Contaminants	3 cr.
CE 483	Surface Water Hydrology	3 cr.
CE 551	Unit Processes/Operations of Water Treatment	4 cr.
CE 552	Unit Processes/Operations of Wastewater Treatment	4 cr.
CE 553	Chemical Theories of Environmental Engineering	3 cr.
CE 554	Microbiological Theories of Environmental Engineering	3 cr.
CE 555	Natural Water and Pollution Control	3 cr.
CE 581	Ground Water Hydrology	3 cr.
CE 582	Statistical Hydrology	3 cr.
ECON 690	Economics of Risk, Uncertainty & Information	3 cr.
GEN 451	Subsurface Geotechnical Investigation	3 cr.
GEN 452	Geohydrology	3 cr.
GEN 453	Geotechnical Site Evaluation	3 cr.
GEOL 474	Groundwater Geology	3 cr.
GEOL 560	Geochemistry of Aqueous Systems	3 cr.
GEOG 458	Hydrometeorology	3 cr.
GEOG 470	Environmental Pollution	3 cr.
GOVT 531	Public Program Evaluation	3 cr.
GOVT 544	Public Policy Analysis	3 cr.
IE 537	Large Scale Systems Engineering	3 cr.
ME 504	Combustion	3 cr.

APPENDIX B (continued)

PHYS 485	Physics of the Atmosphere	3 cr.
PLAN 475	Transportation Planning	3 cr.
SOIL 477	Soil-Water Relationship	3 cr.
SOIL 479	Environmental Soil Chemistry	3 cr.
SOIL 540	Advanced Soil Microbiology	3 cr.
SOIL 551	Advanced Soil Chemistry	3 cr.
SOIL 552	Soil Physics	4 cr.
TOX 461	Toxicology I	3 cr.
TOX 523	Environmental Toxicology	3 cr.
WLSC 458	Ecology of Inland Waters	3 cr.

APPENDIX B (continued)

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF CURRENT LIST OF EXISTING COURSES DIRECTLY RELATED TO WASTE MANAGEMENT & ENVIRONMENTAL RESTORATION OFFERED AT NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

GRADUATE MINOR

BIOL 522	Biology of Aquatic Pollutants	3 cr.
CHEM 532	Atmospheric Chemistry	3 cr.
HYD 504	Hydrogeology	3 cr.
HYD 525	Hydrogeochemistry	3 cr.
HYD 526	Isotope Hydrology	3 cr.
HYD 528	Groundwater Contamination	3 cr.
HYD 535	Applied Groundwater Hydrology	3 cr.
HYD 538	Vadose Zone Hydrology	4 cr.
METE 542	Corrosion and Oxidation	3 cr.
MATH 586	Spacial Variability and Geostatistics	3 cr.
MATH 587	Time Series	3 cr.
MATH 588/HYD 545	Stochastic Methods in Subsurface Hydrology	3 cr.

WASTE-MANAGEMENT EDUCATION AND RESEARCH CONSORTIUM

EXAMPLES OF CURRENT LIST OF EXISTING COURSES DIRECTLY RELATED TO WASTE MANAGEMENT & ENVIRONMENTAL RESTORATION OFFERED AT THE UNIVERSITY OF NEW MEXICO

GRADUATE MINOR

BIO 502	Topics/Bioremediation of Soils and Groundwater	3 cr.
CHEM 462	Environmental Biochemistry	3 cr.
CHNE 466	Nuclear Environmental Safety Analysis	3 cr.
CHNE 499	Indoor Air Pollution	3 cr.
CHNE 515/CE 551	Environmental Law Issues	3 cr.
CHNE 515/CE 551	Natural Resource Law Issues	3 cr.
CHNE 566	Methods of Nuclear Safety and Safeguards	3 cr.
CE 530	Groundwater Modeling	3 cr.
CE 531	Physical-Chemical Water and Wastewater Treatment	3 cr.
CE 532	Advanced Physical-Chemical Water and Wastewater	3 cr.
CE 533	Water Resources Engineering	3 cr.
CE 534	Environmental Engineering Chemistry	3 cr.
CE 538	Intro to Hazardous Waste Management	3 cr.
CE 539	Radioactive Waste Management	3 cr.
CE 551	Problems/Hazardous Waste Risk Assessment	3 cr.
ECON 544	Special Topics in Environmental Economics	3 cr.
GOEG 459	Water Resources Management	3 cr.
GEOL 462	Hydrogeology	3 cr.
GEOL 474L	Hydrogeology Laboratory	3 cr.
GEOL 509	Environmental Geochemistry	3 cr.
GEOL 545	Hazardous Waste Disposal	3 cr.
GEOL 560	Vadose Zone Hydrology	3 cr.
LAW 547	Water Law	3 cr.
LAW 565	Natural Resources Law	3 cr.
LAW 580	Environmental Law	3 cr.
LAW 605	Water Law Problems	3 cr.
PHRM 580	General Toxicology	3 cr.
PHRM 581	General Toxicology II	3 cr.
PHRM 585	Biochemical Toxicology	3 cr.
PHRM 587	Pollution Toxicology	3 cr.

APPENDIX B (continued)

P A 574	Seminar on Environmental Policy and Administration	3 cr.
P A 590	Seminar on Environmental Health Issues	3 cr.
P S 475	Environmental Politics	3 cr.

APPENDIX B (continued)

APPENDIX C

GRADUATE DEGREE IN ENVIRONMENTAL ENGINEERING AT NEW MEXICO STATE UNIVERSITY

The College of Engineering at New Mexico State University offers a new interdisciplinary, graduate degree, Master of Science in Environmental Engineering (M.S. EnvE). Through this new program students will gain expertise in the areas of: air pollution control engineering, water and wastewater engineering, solid and hazardous waste engineering, and environmental and occupational health engineering. The faculty, facilities, and courses are presently available to offer the M.S. EnvE degree. The new degree is designed to broaden the scope of the existing environmental engineering program by incorporating the resources and contributions of the Chemical and Mechanical Engineering departments. The existing program will be restructured to fulfill advanced accreditation requirements of ABET. The M.S. EnvE degree conferred by NMSU will be the only accredited program offered in New Mexico as well as within a 1,500 mile radius of NMSU. This program is still in the approval process

Academic Criteria:

ABET Requirements -
11 credits graduate design beyond B.S. degree
11 credits graduate mathematics, basic science, and engineering science
(Non-Engineers Required to Develop ABET B.S. Background)

Graduate School Requirements - 30 credits minimum (24 coursework, 6 thesis)

Required Courses

CE 455 Solid and Hazardous Waste Systems Design*	3 cr (3 Design)
CE 456 Environmental Engineering Design*	3 cr (3 Design)
CE 551 Unit Proc/Ops of Water Treatment	4 cr (2 Design)
CE 552 Unit Proc-Ops of Wastewater Treatment	4 cr (2 Design)
TOTAL	8 - 14 cr

*NMSU graduates may have completed courses during undergraduate studies

Two of Four Courses

ChE 486 Industrial Waste Treatment Systems	3 cr (2.5 Design)
CE 553 Chemical Theories of Environmental Engineering	3 cr (1 Design)
CE 554 Microbiological Theories of Environmental Engr	3 cr (1 Design)
CE 555 Natural Water and Pollution Control	3 cr (1 Design)
TOTAL	6 cr

APPENDIX C

Thesis Requirements

EnvE 599 Thesis		6 cr (1-3 Design)
	TOTAL	6 cr

Optional Requirements

AEN 459	Design of Water Wells/Pumping Systems	3 cr (3 Design)
AGE 497	Water Resource Economics	3 cr
BIOL 461	Human Ecology	3 cr
BIOL 519	Microbial Ecology	3 cr
ChE 498	Environmental Safety in Chemical Plants	3 cr
CE 462	Sample and Anal. of Environ. Contaminants	3 cr
CE 556	Advanced Waste Management	3 cr (3 Design)
CE 557	Water Resources Development	3 cr
CE 630	Fate and Transp of Environ Contaminants	3 cr
GEN 452	Geohydrology	3 cr
GEOG 470	Environmental Pollution	3 cr
GEOL 474	Ground Water Geology	3 cr
GEOL 560	Geochemistry of Aqueous Systems	3 cr
ME 504	Combustion	3 cr (1 Design)
PHYS 485	Physics of the Atmosphere	3 cr
SOIL 476	Soil Microbiology	3 cr
SOIL 477	Soil Physics	3 cr
SOIL 479	Environmental Soil Chemistry	3 cr
SOIL 540	Advanced Soil Microbiology	3 cr
SOIL 551	Advanced Soil Chemistry	3 cr
SOIL 552	Advanced Soil Physics	3 cr
TOX 461	Toxicology I	3 cr
TOX 523	Environmental Toxicology	3 cr
WLSC 458	Ecology of Inland Waters	3 cr
	TOTAL	4 - 10 CR

University Faculty With Expertise in Environmental Engineering or Related Areas

CAGE

Fernando Cadena
Adrian Hanson
John Hernandez
Ricardo Jacquez
Nirmala Khandan
Tim Ward
Phillip King
Zohrab Samani

Chemical Engineering

Richard Long
Ron Bhada
Stan Holbrook
Stuart Munson-McGee
Michael Cho

APPENDIX C (continued)

Mechanical Engineering
Ian Leslie
Richard Hills
Richard Colbaugh
Phillip Smith

Biology
Leon Lundy
Jeffrey Smith
Jim Botsford
Cecilio Barrera
Joe LaPointe
Charlotte McCarthy
Walt Whitford

Economics
Tom McGuckin

Agronomy and Horticulture
William Lindeman
Tim Jones
Bob McCaslin
Ted Sammis
Curtis Monger

Chemistry
Gary Eiceman
Aravamudan Gopalan
Antonio Lara
Wolfgang Mueller
Gary Rayson
Joseph Wang

Geology
Thomas Giordano

APPENDIX C (continued)

APPENDIX D

NON-DEGREE CERTIFICATE PROGRAM

NON-DEGREE CERTIFICATE PROGRAM REQUIREMENTS FOR NMSU/NMIMT

Individuals who have received a bachelor's and/or graduate degrees in appropriate technical fields may obtain WERC Certificates without formally enrolling in a degree program. Such students will normally enroll in the "Non-Degree" status. Below are general guidelines that vary slightly between the academic institutions.

To obtain a "WERC Certificate" in environmental management studies a student must complete a program which includes:

1. A minimum of 15 credit-hours completed with a cumulative GPA of 3.0 or higher of courses acceptable for graduate credit. The 15 credits must include:

    a. A minimum of 6 credit-hours in environmental management courses from the home university "Graduate Minor" list.

    b. A minimum of 6 credit-hours offered from outside the student's home university through the WERC Interactive Television Program or on a student exchange basis.

    c. A 3-hour independent study course in waste management studying a specific problem of interest to the student and under the supervision of a graduate faculty member.

2. Two credit hours of seminar courses in Environmental Management:

    a. 1 credit. Environmental Management Seminar I. A survey of practical and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research.

    b. 1 credit. Environmental Management Seminar II. A survey of practical and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research.

The WERC Education Committee will have final review authority on all applications.

APPENDIX D

WERC
NON-DFGREE CERTIFICATE PROGRAM AT UNM

Individuals who already have bachelors and/or graduate degrees in appropriate technical fields may obtain WERC Certificates without formally enrolling in an additional degree program. Such students will normally enroll in UNM in "Non-Degree" status.

To obtain a "WERC Certificate" in waste management studies independent of study for a degree at UNM, a student must complete a program which includes:

1. A minimum of 18 credit-hours in waste management courses, completed with grades of B- or better, normally acceptable for graduate credit. At least two of these credit-hours will be in seminar courses in Hazardous Waste.*

2. A minimum of 6 credit-hours of courses in waste management courses, acceptable for graduate credit, outside of the student's major graduate field and the student's major undergraduate field.

3. A minimum of 6 credit-hours in waste management courses, acceptable for graduate credit, from NMSU and/or NMIMT. They will normally be taken by television, but could be done in person on an exchange basis.

4. A 3-hour independent study course in waste management studying a specific problem of interest to the student under the supervision of a faculty member. This requirement may be waived for students working full time in waste management.

5. Courses taken to meet requirements 2, 3 and 4 count toward the total of 18 credit-hours for requirement 1.

*Seminars: Fall and Spring, 1-credit each semester. (CHNE 499, sometimes cross-listed with other departments) Seminar in Waste Management. A survey of practice and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research. May be repeated for a maximum of three credits, since content varies from semester to semester.

Students must apply for WERC Certificates to the UNM WERC education coordinator, Dean Kauffman, College of Engineering, at least one full semester before completing their programs. The WERC Education Committee will have final review authority on all applications.

APPENDIX E

CURRICULUM FOR ASSOCIATE DEGREE PROGRAM IN RADIOACTIVE & HAZARDOUS WASTE MATERIALS

Fall Semester		Credits
CHEM 110	Chemistry in Our Time	4
ENGL 111	Freshman Composition I	4 (3 + 2p)
MATH 115	Intermediate Algebra	3
ET 115*	Intro. To Hazardous Materials	3
PHYS 211	General Physics	3
PHYS 211L	General Physics Lab	1 (3p)
		Total 18

Spring Semester		
COMM 265	Prin. of Human Communication	3
ECON 251	Prin. of Macroeconomics OR	
ECON 252	Prin. of Microeconomics OR	
CS 110	Computer Literacy OR	
	Business Related Course	3
ET 121**	Applied Radiation Technology	3
ET 275	Haz. Mat. Sampling & Analysis	4
PHYS 212	General Physics II	3
PHYS 212L	General Physics II Lab	1 (3p)
		Total 17

*ET 115 is a prerequisite for all advanced hazardous materials courses.
**ET 121 is a prerequisite for all advanced radioactive materials courses.

Fall Semester		
ET 268	Applied Robotics	3
MATH 180	Trigonometry	2
ET 211	Radiation Detection	4 (3 + 2p)
ET 225	Industrial Safety & Hygiene	3
ET 271	Radiation Protection	3
PSY 201	Introduction to Psychology OR	
SOC 101	Introduction to Sociology	3
		Total 18

Spring Semester		
ENGL 203G	Business Writing OR	
ENGL 218	Tech. & Prof. Communication	3
MATH 185	College Algebra	3
ET 215	Haz. Mat. Management	3
ET 298	Rad/Haz Waste Management	3
ET 297	Emergency Response Tech	2
ET 221	Applied Radiation Biology	2
		Total 16

Degree Requirements: Regular Admission status, cumulative GPA of 2.0, total of 69 hours.

APPENDIX E

APPENDIX F

CURRICULUM FOR NCC PROGRAM IN EARTH & ENVIRONMENTAL SCIENCES

The curriculum for the A.S. degree in Earth/Environmental Sciences (EES) is given below. The program is interdisciplinary and technically rigorous, and prepares the student to understand and work with complex environmental problems and issues.

Subject abbreviations are: AGR, agriculture; BIO, Biology; CHM, chemistry; CSC, computer science; ENV, environmental science and technology; GLG, geology; MTH, mathematics; and PHY, physics.

PROGRAM REQUIREMENTS (37 credit hours):

BIO 180	Principles of Biology (+ Lab)	4
CHM 151	General Chemistry I (+ Lab)	5
CHM 152	General Chemistry II (+Lab)	5
ENV 201	Environmental System Science (+Lab)	4
ENV 297	Practicum in Environmental Science (Summer)	3
GLG 101	Introduction to Geology I: Physical (+ Lab)	4
GLG 102	Introduction to Geology II: Historical (+ Lab)	4
MTH 191	Calculus and Analytic Geometry I	4
PHY 121	Engineering Physics I (+ Lab)	4

PROGRAM ELECTIVES (7-8 credit hours):
Students choose at least two of the following, in consultation with advisor; choice depends on planned major after transfer to B.S. program at 4-year college.

AGR 231	Soil Science (+ Lab)	4
AGR 246	Introduction to Range Science	3
BIO 184	Plant Biology (+ Lab)	4
BIO 190	Animal Biology (+ Lab)	4
BIO 205	Microbiology (+ Lab)	4
CHM 235	General Organic Chemistry I (+ Lab)	4
CHM 236	General Organic Chemistry II (+ Lab)	4
MTH 213	Statistics	3
PHY 131	Engineering Physics II (+ Lab)	4

GENERAL EDUCATION REQUIREMENTS (23 credit hours):

Communications (3 courses)	6
Humanities and Fine Arts (1 course)	3
Navajo and Indian Studies (3 courses)	9
Physical Education (1 or 2 courses)	2
Social Science (1 course)	3

TOTAL FOR A.S. DEGREE PROGRAM 69-71 credit hours

APPENDIX F

APPENDIX G

BROCHURE OF 1992 TELECONFERENCE SERIES

ESSENTIAL TRAINING FOR INDUSTRY AND GOVERNMENT

Waste Minimization and Pollution Prevention Videoconference Training Series

BEYOND COMPLIANCE – IT MAKES GOOD BUSINESS SENSE!

DOE IS ACTIVELY PARTICIPATING IN THIS EDUCATIONAL ENHANCEMENT INITIATIVE

LIVE TELEVISION INTERACTIVE TECHNOLOGY TRANSFER VIA SATELLITE

Series Starts March 1992, Broadcast on Wednesdays

This televised training addresses the critical nature of waste minimization in light of the serious ecological problems confronting the country. The series will incorporate the latest technology and research showing practical application for business, industry, and educational facilities nationwide.

All programs place a strong emphasis on environmentally-conscious manufacturing.

What is waste minimization and pollution prevention?

Although it is impossible to have entirely "clean" manufacturing, we can reduce the waste generated from nearly all processes. Much of what we call "waste" is actually an unused by-product that could be further processed or refined and sold as a product. Often toxic waste resulting from manufacturing can be reduced significantly through better process control, or avoided entirely by an alternate process.

Presented by

Waste-management Education and Research Consortium

Composed of

New Mexico State University • University of New Mexico • New Mexico Institute of Mining and Technology • Sandia National Laboratories • Los Alamos National Laboratory • Navajo Community College

in Cooperation with

RIOTECH of New Mexico

APPENDIX G

Videoconference Training Series

A live, interactive satellite series on crucial issues facing business and industry today.

The need for information and technologies in the area of waste minimization is critical and faces a growing public concern. By eliminating the cost of travel and per diem budgets, this videoconference series addresses the issue in a cost-effective manner. The low cost and local availability also means that more people can be trained for the same investment.

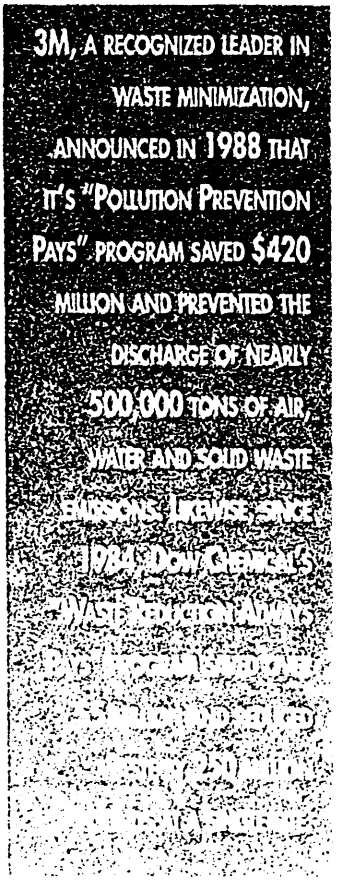
This eight-part series will address hazardous and non-hazardous waste forms. Each program will feature a variety of technical experts, including representatives from universities, national laboratories, and industry.

Every program will include:

- Video demonstrations
- Regulations
- Cost benefits
- Successful applications
- Total Quality Management
- Technology transfer

The Audience: The training is useful to engineers, scientists, technical managers, and supervisors actively working or planning to work on changing processes to implement waste minimization.

Certification: WERC awards certificates of completion to participants. CEUs are also available.



A Technology Transfer Initiative

Waste Minimization and Pollution Prevention Program Description

The audience will have the opportunity to interact with the presenters during the two question/answer segments of each program. All programs air on Wednesday.

Orientation for Facilitators – March 4, 1992, Facilitator Training Meeting

Special program designed to teach facilitators how to use this training series effectively at individual sites.

1. Overview—Why Minimize Waste?—March 25, 1992

Co-Leaders: Joan Woodard, Ph.D., Sandia National Laboratories

Mary Ann Baker, Esq., NM Environment Dept.

- What is waste minimization?
- Beyond compliance—waste minimization makes good business sense from a cost benefit perspective
- Federal regulations (existing and proposed) and State samples
- Determining baselines—how is it done?
- Goal setting/Looking for opportunities
- How waste minimization affects small businesses
- International concerns/Issues

2. Where Do We Start Waste Minimization?—April 22, 1992

Lead Presenter: Jeff Weinrach, Ph.D., Los Alamos National Laboratory

- The need for assessments
  - Establishing base line
  - Up-front planning (technical, organizational, TQM, teams)
- The methods for assessments
  - Mass balance techniques
  - Life cycle (costs, risks, etc.)
- The goals for assessments
  - Waste minimization
  - Cost effectiveness
  - Knowledge of process
- The follow-through to assessments
  - Metrics for success
  - Design of Environmentally Conscious Processes

"YOU'LL DRAW ON AN OUTSTANDING EXPERT POOL FOR TALENT AND, THEREFORE, ARE CERTAINLY MEETING CRITICAL NATIONAL NEEDS IN THESE LEADING EDGE SUBJECTS."

- A QUOTE FROM ONE OF THE INDUSTRY SITES LISTED IN THIS BROCHURE

"YOU HAVE ALREADY REACHED AN IMPRESSIVE AND IMPORTANT AUDIENCE WITH THESE VIDEOCONFERENCES, AND IT IS CLEAR THAT YOU HAVE ONLY BEGUN TO TAP INTO THE WIDE POTENTIAL MARKET."

- A QUOTE FROM ONE OF THE [illegible] LISTED IN THIS BROCHURE

3. How Does Recycling/Reuse/ Reclamation Make Economic Sense? – May 6, 1992

Lead Presenter: John Hernandez, Ph.D., NM State University

- Marketable products as by-products
- How to avoid permitting
- Myths versus facts
- The world view: In-process materials substitutions
- Packaging
- Not changing the front-end processes, changing middle
- Case studies (Siemens, etching)

4. Are the Right Product/ Process Designs Being Addressed? – May 20, 1992

Lead Presenter: Robert V. Fultyn, Sc.D., Digital Equipment Corporation (retired)

- How to get it right from the start
- How to use TQM approaches to lower environmental impact
- Concurrent engineering
- New concepts for product and process design
- Discovering and evaluating alternative materials and methods
- Cost effectiveness of redesign
- Measuring and controlling
- Continuous improvement

5. Solvents and Organic Chemicals – June 17, 1992

Co-Leaders: Barry Granoff, Ph.D., Sandia National Laboratories
Jon Nimitz, Ph.D., University of New Mexico

- Overview and purpose
- Alternative chemicals
- Alternative processes
- Systems and cost/benefit analyses
- Success stories
- Beyond compliance

6. How to Implement Minimization in Metals, Plating, and Electrical Interconnects – September 9, 1992

Lead Presenter: Fred Kear, Ph.D., Siemens Stromberg-Carlson

- Waste minimization opportunities in metallization and soldering
- The regulatory impetus for minimizing waste
- Electroplating waste reduction: process changes and recycling
- Lead legislation and electronic soldering alternatives
- Health-related risks associated with lead use
- Alternate processes/Materials for electronic interconnects

7. How to Minimize "End of Life" Problems – September 30, 1992

Lead Presenter: Larry L. Barton, Ph.D., University of NM

- Before the cradle and beyond the grave
- Liability and federal regulations
- Case studies and success stories
- Lead/acid batteries and other products
- Waste incompatibilities and corrosion

8. Planning and Preparing for the Future—October 21, 1992

Panel of Industry, University, and Government Presenters

- Overview of Case studies, direct applications
- Lessons Learned
- Minimization series summary
- Introduction of the next series: **"The Social & Technological Aspects of Risk"**
- Social and technological issues
- Impact on global environment

About the Lead Presenters

Each program will feature three to six presenters with broad backgrounds—technical, management, technology transfer, and regulations. The presenters are from national laboratories, universities, and industry. With more than forty technical experts involved in this program, we cannot include all biographies, but we would like to introduce you to the individual program leaders:

Mary Ann. R. Baker, Esquire, is an Assistant General Counsel for the New Mexico Environment Department (NMED), concentrating on RCRA/UST regulatory enforcement and litigation, CERCLA negotiations, and advising NMED's management on a wide variety of environmental law issues. In addition, she teaches a course on Hazardous Materials Regulations Applicable in New Mexico at the Santa Fe Community College.

Larry Barton, Ph.D., is a faculty member of the UNM Biology Department, where his laboratory studies the microbial transformation of lead, selenium, and chromium. He has also worked with the Dept. of Biochemistry at the University of Georgia and the School of Health and Hygiene at Johns Hopkins University. His research includes physiological activities of microorganisms, focusing on metabolism of inorganic compounds by bacteria.

Robert V. Fultyn, Sc.D., served as a staff member at Los Alamos National Laboratory for over 17 years, engaged in data analysis and modeling of atmospheric phenomena; computer-based laboratory instrumentation; and administrative data processing techniques. He recently retired from Digital Equipment Corporation, after more than ten years of involvement in the advancement of quality and productivity issues by statistical data analysis.

Barry Granoff, Ph.D., is Manager of the Environmentally Conscious Manufacturing (ECM) Programs at Sandia National Laboratories, where his work focuses on waste minimization and pollution prevention, with an emphasis on precision cleaning and solvent substitutes for chlorofluorocarbons and chlorinated hydrocarbons. Prior to this, he has worked in materials science, process chemistry, and energy conversion. He has been involved in numerous technical programs.

John Hernandez, Ph.D., has been a professor of Civil Engineering at NM State University for the past 25 years, specializing in water quality management. He has served at both the state (New Mexico Department of Public Health) and at the federal level (Deputy Administrator of the U.S. Environmental Protection Agency). He has broad experience in the management of solid and hazardous wastes and in the regulatory structure on which design criteria is based.

Fred Kear is a Staff Process Engineer at Siemens Stromberg-Carlson, involved with manufacturing issues and environmental and OSHA compliance. His memberships include: Siemens USA Environmental Network; U.S. Chamber of Commerce Occupational Health and Safety Council, and the Electronics Industry Ad Hoc Lead Committee. He has authored five engineering texts dealing with process engineering and printed circuit manufacture.

Jon Nimitz, Ph.D., joined the NM Engineering Research Institute as a Senior Scientist after teaching chemistry at the University of New Mexico for several years. His specialties include development, assessment, and review of alternative chemicals and processes to minimize ozone depletion, global warming, and nuclear wastes. He has co-authored over 30 technical reports and papers, plus an organic chemistry laboratory textbook.

Jeff Weinrach, Ph.D. earned his doctorate in physical-inorganic chemistry from the University of Wisconsin-Milwaukee in 1987. He has served as a staff member on the Waste Minimization Team for two years. His major responsibility is overseeing and managing the Los Alamos National Laboratory Waste Minimization Program. During the past two years he has delivered 13 presentations regarding waste minimization and pollution prevention.

Joan Woodard, Ph.D., is Director of Manufacturing and Environmental Research and Development Programs at Sandia National Laboratories. She is responsible for research and development in waste minimization, waste treatment, instrumentation, remediation, and waste management. Her earlier work at Sandia included material characterization, combustion research, and solar thermal systems research.

Ask Some of Our Satisfied Customers About Our Videoconferences

We have a proven track record in producing effective videoconference training for use by government contractors, colleges and universities, and industries. The following customers can provide references about the quality of our programs.

Advanced Sciences Inc.
Aerospace Guidance & Meteorology Center
Air Force Institute of Technology
Allied Signal Aerospace
Argonne National Laboratory
AT&T Bell Laboratories
AT&T Technologies
Auburn University
Barksdale AFB
Beale AFB
Bureau of Land Management
Carlswell AFB
Castle AFB
Columbia Basin College, Hanford
Deere and Company
Digital Equipment Corporation
DOE, Albuquerque Operations Office
Dyess AFB
Eaker AFB
EG&G Rocky Flats
EG&G Mound Applied Technology
Electronic Power Research Institute
Ellsworth AFB
El Paso Natural Gas Co.
Envirco
Fairchild AFB
F E Warren AFB
GE - Canada
GE-Neutron Devices
Grand Forks AFB
Griffiss AFB
Grissom AFB
Harris Corporation
Hewlett Packard
IBM
John Deere Dubuque Works
K I Sawyer AFB
Logistics Command
Loring AFB
Los Alamos National Laboratory
Magnavox Electronic Systems
Martin Marietta
Martin Marietta Energy Systems
Malstrom AFB
March AFB
Mason and Hanger Pantex Plant
Metrum Information Storage
Miller Brewing Company
Minot AFB
Motorola
Muskegon Community College
National Cash Register
National Semiconductor
National Technological University
Naval Research Laboratory
Naval Weapons Support
NCR Corporation
New Mexico Junior College
New Mexico State University
ND University Systems
NM Institute of Mining and Technology
NM Primate Research Lab
Oklahoma State University
Offutt AFB
Pacific Bell
Paducah Community College
Plains Electric Corporation
Pike's Peak Community College
Plattsburgh AFB
Postal Service
Purdue University
Rio Grande Minority Purchasing Council
San Juan College
Sandia Livermore National Lab
Sandia National Laboratories
Savannah River Laboratories
Siemens
Southern Methodist University
State of NM Environment Dept.
Tennessee Eastman Company
UNC
UNI - Chem International
UNM, Occupational Health & Safety
U.S. Army Corps of Engineers
University of Maryland
University of New Mexico
Western New Mexico University
Westinghouse, WIPP Site
Whiteman AFB
Wurtsmith AFB

Registration Information

Registrations received before December 31, 1991 receive a 10% discount. For more information, call toll-free, 1-800-292-7051.

Late Registration/Cancellation: To avoid a late fee, registrations should be received by March 2, 1992. To cancel a registration or request a refund, call Connie Callan at (505) 277-7750. WERC reserves the right to cancel this series if enrollment is insufficient.

Taping Rights: A site automatically receives authorization to tape the broadcasts and use them for in-house training for one month at no additional cost. A site can purchase the permanent rights to the video tapes for double the listed prices.

"THE SERIES PLANNED ON WASTE MINIMIZATION SHOULD BE A TIMELY INFORMATION TOOL. REDUCING WASTE WILL MINIMIZE COST OF PRODUCTION, INCREASE SAFETY AND INCREASE PRODUCTIVITY. THUS, THIS SERIES IS CRITICAL FOR EVERYONE IN INDUSTRY AND BUSINESS."

A QUOTE FROM ONE OF THE INDUSTRY SITES LISTED IN THIS BROCHURE

WHY VIDEOCONFERENCE TRAINING?

Increasingly, budget cuts have reduced the funds available for travel and conferences. Yet employees must keep abreast of new regulations and technology. Videoconferencing instructional television has proven to be the cost-effective training solution for the 1990s.

ABOUT NEW VIDEOCONFERENCING LOCATIONS

The series can be received anywhere in the United States. Most organizations already have the equipment necessary for receiving these instructional television broadcasts. Organizations not having this capability can purchase a satellite dish for a minimum investment, a one-time cost for equipment. If you are interested in locating a satellite dish in your area, we will be happy to help you.

BROADCAST INFORMATION

TECHNICAL: This series is broadcast on C-Band and KU-Band. Facilities with a satellite dish anywhere in the United States can receive this series, providing on-site training for all interested employees.

FACILITATOR TRAINING: A test signal and a site coordinator training program will air on March 4, 1992 from 11:00AM-1:30PM Eastern Standard Time. Participants can check the operation of their equipment and learn how to become an effective site coordinator.

BROADCAST DATES: The Waste Minimization/Pollution Prevention series begins on March 25, 1992 and is broadcast on Wednesdays. The series breaks for two months in the summer, with the final broadcast presented on October 21, 1992.

MATERIALS

A participant's packet containing a full outline of the course with charts and illustrations used by the presenters will be provided to each registered site. The packets are designed to follow along with the presenters. Each site has the right to duplicate the packets for participants. Site coordinators will receive a facilitator's training packet for the entire series.

MARKETING ASSISTANCE

A customized brochure, news release, and advertisements can be developed for each site. A brief promotional tape is also available. Call for details about the cost of camera-ready art or methods for obtaining a copy of the promotional tape.

Broadcast Hours

Eastern	11:30AM - 3:30PM
Central	10:30AM - 2:30PM
Mountain	9:30AM - 1:30PM
Pacific	8:30AM - 12:30PM

(A 30-minute test signal precedes each four-hour program.)
Basic outline of each program in our series shown in Eastern Standard Time:

Agenda Example
(Eastern Time)

CLOCK	DESCRIPTION
11:00AM - 11:30AM	Test Signal, 30 minutes
Section #1	
11:30AM - 11:31AM	Introduction to the Program
11:31AM - 11:35AM	Introduction to the Topic
11:35AM - 12:00PM	First Presentation
12:00PM - 12:25PM	Second Presentation
12:25PM - 12:35PM	Break
Section #2	
12:35PM - 1:00PM	Third Presentation
1:00PM - 1:25PM	Fourth Presentation
1:25PM - 1:35PM	Question and Answer Session
1:35PM - 1:55PM	Lunch
Section #3	
1:55PM - 2:20PM	Fifth Presentation
2:20PM - 2:45PM	Sixth Presentation
Section #4	
2:45PM - 3:00PM	Final Presentation
3:00PM - 3:20PM	Questions and Answers
3:20PM - 3:25PM	Program Wrap-Up
3:25PM - 3:30PM	Introduction to Next Program
3:30PM	Off Air

ORDER FORM

(please check below)

Eight-program series (and Facilitator Program) price (unlimited viewers at one site)

- ❑ Corporate rate ($7000 per site)
- ❑ Government rate ($5900 per site)
- ❑ University rate ($5000 per site)

Per-program price

- ❑ Individual rate at any site ($100 per person, per program)
- ❑ Unlimited attendance at any site ($900 per program)

Taping Rights: A site automatically receives authorization to tape the broadcasts and use them for in-house training for one month at no additional cost. A site can purchase the permanent rights to the video tapes for double the listed prices.

Name _____ Title _____

Address _____ City, State, & Zip _____

Organization _____ Work phone _____

Signature _____ Amount of order _____

Please make your check payable to UNM, Professional Engineering Development/ITV.

If you would like us to bill your organization, please provide your purchase order number:

Return registration form to:

Waste-management Education and Research Consortium
c/o The University of New Mexico, College of Engineering
Farris Engineering Center, Room 151, Albuquerque, NM 87131-1387
or FAX to: (505) 277-7833

Also Available:

"Hazardous/Radioactive Waste Management Training, an 11-program videotape series presented by WERC. A packet of briefing materials accompanies each program on the following topics:

- What Is Waste?
- Risks Associated with Hazardous and Radioactive Wastes
- Transport Processes Related to Wastes
- Waste Form Modification
- Site Characterization
- Sampling and Analysis
- Soil and Groundwater Remediation I: Physical/Chemical Processes
- Soil and Groundwater Remediation II: Biological Processes
- Radiation and Radioactive Materials
- Radioactive and Mixed Wastes Management

Waste Minimization and Series Close

Also Available through WERC: Televised academic courses leading to a certificate in Hazardous Waste Management.

"Total Quality Management, a 7-part videotape training series, produced by the University of New Mexico. Briefing materials accompany each videotaped program.

- Introduction and Implementing TQM in Your Organization
- Organizational Change and Leadership in TQM
- Selecting and Understanding Processes for Improvement in TQM
- Designing Experiments and Gathering Information in TQM
- Analysis and Interpretation of Results in TQM
- Implementing Process Change and Institutionalizing TQM in Your Organization

Videoconferences and live workshops – "Technical Training for Engineers and Managers"

- Total Quality Management (TQM)
- Hazardous Waste Management
- Waste Minimization/Pollution Prevention
- Fuzzy Logic

Call Connie Callan 1-800-292-7051

For more information contact:

Connie Callan

WERC Manager for Continuing Education

Telephone
(505) 277-7750

Toll Free
1-800-292-7051

FAX
(505) 277-7833

A Live and Interactive Satellite Series on a Crucial Topic for the Times Is Now Available:

Waste Minimization and Pollution Prevention

Presented by the Waste-management Education Resource Consortium, in Cooperation with Riotech

The cost-effective training solution for the 1990s:
Videoconferencing Instructional Television

Beyond Compliance–It Makes Good Business Sense!

The University of New Mexico
College of Engineering
Farris Engineering Center, Rm. 151
Albuquerque, NM 87131-1387

APPENDIX H

SITES FOR HAZARDOUS/RADIOACTIVE WASTE MANAGEMENT SERIES

WASTE-MANAGEMENT EDUCATION & RESEARCH CONSORTIUM
Waste Minimization Sites - July 23, 1992

Advanced Micro Devices, I	Austin, TX
Air Force Institute of Technology	Wright Patterson AFB, OH
ALCOA - Pt. Comfort Operation	Pt. Comfort, TX
Allied Signal	Kansas City, MO
Allied Signal	Torrance, CA
Amax Coal Company	Gillette, WY
Columbia Basin College	Pasco, WA
Digital Equipment Corporation	Albuquerque, NM
Eastman Kodak Co.	Rochester, NY
EG&G Idaho INEL	Idaho Falls, ID
EG&G Mound	Miamisburg, OH
EG&G Rocky Flats	Golden, CO
E. I. Dupont	Newark, DE
Envir. Protection Agency, Region 8	Denver, CO
Exxon Research and Development	Baton Rouge, LA
General Electric Company	Utioa, NY
Georgia Institute of Tech.	Atlanta, GA
Hartford Graduate Center	Connecticut
Hewlett Packard	Boise, ID
Hewlett Packard	Camas, WA
Hewlett Packard	Corvallis, OR
Hewlett Packard	Rohnert, CA
Hewlett Packard	Avondale, PA
Honeywell	Fueport, IL
Idaho State University	Pocatello, ID
IBM Corporation	Charlotte, NC
IBM Corporation	Endicott, NY
IBM Corporation	Essex Junction, VT
IBM Corporation	Research Pk, NC
IBM Corporation	Owegon, NY
IBM - Rochester Community College	Rochester, MN
John Deere Dubuque Works	Dubuque, IA
Deere and Company	Noline, IL
Kelly AFB	F/Kelly AFB, TX
Los Alamos National Laboratory	Los Alamos, NM
3M Company	St. Paul, MN
Martin Marietta Astron.	Littleton, CO
Milliken & Company	Spartanburg, SC
*National Center for MNFG. Sciences	Ann Arbor, MI
National Technological University	Ft. Collins, CO

APPENDIX H

Naval Weapons Support Center	Crane, IN
New Mexico Environment Department	Santa Fe, NM
New Mexico State University	Las Cruces, NM
NMSU - Grants	Grants, NM
New Mexico Institute of Mining & Technology	Socorro, NM
Newark Air Force Base	Newark, OH
North Wyoming Community College	Gillette, WY
Ohio University	Ironton, OH
Oklahoma State University	Stillwater, OK
Pantex Plant	Amarillo, TX
Pittsburgh Energy Tech. Center	Pittsburgh, PA
Plains Electric	Grants, NM
Polaroid Corporation	Cambridge, MA
SAIC	Germantown, MD
Sandia National Laboratories	Albuquerque, NM
Siemens Stromberg - Carlson	Albuquerque, NM
Sirkorsky Aircraft	Stratford, CT
*Southeastern Power Administration	Alberton, Georgia
*Southwestern Power Administration	Tulsa, OK
Texas Instrument	Dallas, TX
Thiokol Corporation	Brigham City, UT
Tucumcari Area Vocational School	Tucumcari, NM
University of Maryland	College Park, MD
University of Wisconsin	Kenosha, WI
UW-Eau Claire	Eau Claire, WI
Media Development Center	Eau Claire, WI
UW-Green Bay	Green Bay, WI
Extended Education	La Crosse, WI
AV Services	La Crosse, WI
Office of Outreach Development	Madison, WI
Continuing Education	Oshkosh, WI
Outreach & Extension	Platteville, WI
Continuing Education	River Falls, WI
University Telecommunication	Stevens Point, WI
Continuing Education	Menomonie, WI
Instructional Technology Services	Menomonie, WI
Continuing Education	Superior, WI
Media Services	Superior, WI
Continuing Education & Outreach	Whitewater, WI
Continuing Education	Baraboo, WI
Continuing Education	Menasha, WI
Continuing Education	Richland Center, WI
Continuing Education	Janesville, WI

University of South Carolina	Columbia, SC
US DOE, Albuquerque Field Office	Albuquerque, NM
US DOE, Brookhaven Area Office *	Upton, NY
US DOE, Chicago Field Office	Argonne, IL
US DOE, Idaho Field Office	Idaho Falls, ID
US DOE, Nevada Field Office *	Las Vegas, NE
US DOE, Oakridge Field Office *	Oakridge, TN
US DOE, Pinellas Area Office *	Largo, FL
US DOE, Richland Field Office	Richland, WA
US DOE, San Francisco Field Office *	Oakland, CA
US DOE, Headquarters	Washington, DC
US DOE, Headquarters	Germantown, MD
US Dept. of the Navy	Panama City, FL
*Western Area Power Administration	Bonneville Salt Flats, UT
Western New Mexico University	Silver City, NM
Westinghouse Environmental Mgt. Co. of Ohio	Cincinnati, OH
Westinghouse-Savannah River	Aiken, SC
Westinghouse-WIPP	Carlsbad, NM

TOTAL: 81

KEY: 1) * = Videotapes only
2) Underline Sites = NTU
3) Sites shown in bold were sites for "Hazardous Waste Management" Series.

APPENDIX I

WERC INTERACTIVE TELEVISION COURSES

FALL 1992 INTERACTIVE TELEVISION COURSES

CE 553	Chemical Theories of Environmental Engineering TTH 1:10-2:25 p.m. Instructor: Fernando Cadena Origin: NMSU	3 cr
AGRO 350	Soil, Land Use, and the Environment MW 8:30-9:20 a.m. Lab - Monday 3:30-5:50 p.m. Instructor: Hugh Monger Origin: NMSU	3 cr
CE 555	Natural Water and Pollution Control MW 5:30-6:45 p.m. Instructor: N. Khandan Origin: NMSU	3 cr
ENVE 411	Solid and Hazardous Waste Engineering MWF 1:00-1:50 p.m. Instructor: Clinton Richardson Origin: NMIMT	3 cr
MATE 454	Energy and the Environment TTH 9:30-10:45 a.m. Instructor: Osman Inal Origin: NMIMT	3 cr
CHNE 515/ CE551	Legal Issues in Environmental Engineering T 7:00-9:30 p.m. Instructor: Gordon Veneble & Denise Glore Origin: UNM	3 cr
CHNE 515	Elements of Waste Minimization M 7:00-9:30 p.m. Instructors: Barry Granoff and Jeff Weinrach Origin: UNM	3 cr
ENGR-N 337	Hydraulics and Hydrology MWF 8:00-8:50 a.m. Instructor: Carl E. Morris Origin: UNM	3 cr

APPENDIX I

SPRING 1993 INTERACTIVE TELEVISION COURSES

TOX 523	Environmental Toxicology TTH 5:15-6:30 p.m. Instructor: W. Mueller Origin: NMSU	3 cr
SOIL 476	Soil Microbiology MWF 11:30 a.m. - 12:20 p.m. Instructor: W. Lindeman Origin: NMSU	3 cr
CE 630	Fate and Transport of Environmental Contaminants TTH 8:55-10:10 a.m. Instructor: Toorman Origin: NMSU	3 cr
CE 539	Radioactive Waste Management MW 5:30-6:45 p.m. Instructor: G. Pierce Origin: UNM	3 cr
CE 551	Natural Resource Legal Issues T 7:00-9:30 p.m. Instructor: G. Venable Origin: UNM	3 cr
CE 584	Transportation of Hazardous Materials MW 7:30-8:45 a.m. Instructor: J. Brogan Origin: UNM	3 cr
ES 481	Introduction to Health Physics MW 9:00-10:15 a.m. Instructor: M. Wasiolek Origin: NMIMT	3 cr
PETR 491	Waste Management Issues in Domestic Petroleum TH 7:00-8:30 p.m. Instructor: R. Bretz Origin: NMIMT	2 cr
HYD 535	Applied Ground Water Hydrology F 8:30-10:20 a.m. Instructor: TBA Origin: NMIMT	3 cr

APPENDIX J

WERC RESEARCH SEMINAR SERIES BROCHURES

The Waste-management Education and Research Consortium(WERC) is funded by the United States Department of Energy. WERC is composed of New Mexico universities and national laboratories organized to provide technology training and education in waste management and environmental restoration. The institutions participating in this program are New Mexico State University, the University of New Mexico, New Mexico Institute of Mining and Technology, Navajo Community College, Sandia National Laboratories, and Los Alamos National Laboratory.

One of WERC's primary objectives has been to offer interactive satellite television courses related to waste management and environmental restoration. For the Fall 1992 Semester a total of eight courses ranging from Legal Issues in Environmental Engineering to Natural Water and Pollution Control have been selected for you to choose from. The courses offered over the satellite can be received anywhere. The courses offered over Technet can only be received at Los Alamos, UNM, Sandia, NMIMT, and NMSU. Tune in next fall for the current issues in environmental and waste management.

Waste-management Education and
Research Consortium
c/o New Mexico State University
Box 30001/Dept. 3805
Las Cruces, NM 88003-0001

Waste-management Education and Research Consortium
(WERC)

SDWA

An Interactive Satellite Seminar on the Safe Drinking Water Act

Interactive Television

October 14, 1992

The U.S. Environmental Protection Agency has recently promulgated Drinking Water regulations under the authority of the Safe Drinking Water Act (SDWA) Amendments of 1986. The number of regulated contaminants has increased to 84 with more expected in the future.

With the implementation of the Lead and Copper Rule, the Phase II SDWA Contaminants Rule, the Total Coliform Rule, and the Surface Water Treatment Rule, all public water supplies have been affected. This seminar is expected to address some of the questions facing large and small public water supplies, municipal and private water suppliers, such as:

- What are the requirements?
- How does a system comply?
- What is the impact of the regulations on water supplies (cost, etc.)?
- How do water suppliers fund the costs associated with compliance?
- What will be regulated in the foreseeable future?

System operators
Public Works Directors
Municipal Administrators
Small Water System Owners
Environmental Engineers
Regulatory Compliance Persons
Consultants
Concerned Citizens

Who Will Participate

EPA Officials
NMED Officials
Private Consultants
Public Water Suppliers

What To Expect From Seminar

- Compliance Information
- Breakdown of Complex Regulatory Requirements
- Funding/Cost Information
- Compilation of Handout Materials
- Opportunity for Written Questions Relevant to SDWA to be Answered

Note: Send written questions by Sept. 28, 1992 to:
WERC c/o New Mexico State Univ.
Box 30001/Dept. 3805
Las Cruces, NM 88003-0001

Satellite Coordinate Information to be announced.

Topics to be Covered

Sampling/Analysis Representative
- How to collect samples
- Chain of custody /forms
- Preservation
- How to select lab
- Certification
- Organics, Metals, Microbiological, Radiological

Consultant Representative
- How to work with consultant
- What to expect
- What assistance available for small systems
- Design/Construction/Operation/ Wellhead protection

Regulatory (State and EPA) -Representative
- Current SDWA Regulations
  - Description
  - Implementation
  - Enforcement
  - How to comply
  - Variance/Waiver procedures
  - Wellhead Protection program
- Future developments

Financial/Planning Representative
- How to operate system on enterprise
- Planning for future development/rehab.
- How to pay for

Representatives of very small to medium sized systems.

Waste management Education and Research Consortium Office, Box 30001/Dept. 3805
Las Cruces, NM 88003 Phone: 1-800-523-5996 Fax: (505) 646-4149

APPENDIX K

SUMMARY OF TECHNOLOGY DEVELOPMENT OF THE THIRD YEAR

CONTINUOUS MONITORING FOR SPILLS AND LEAKS AT WASTE STORAGE FACILITIES CONTAINING MIXED WASTE AND PRIORITY ORGANIC POLLUTANTS

Principal Investigator:

Gary A. Eiceman
New Mexico State University

Co-Principal Investigator:

Suzanne E. Bell
Los Alamos National Laboratory

ABSTRACT

The major goal of the proposed research is to provide a continuous sensing capability for waste storage or disposal sites so that early detection of spills or leaks can preempt a massive spill or leak. The specific objectives necessary to meet this goal are centered on both sensor development and system construction.

Several aspects of ion mobility spectrometry need to be addressed and include:

A. Ionization chemistry: The existing ion source (^{63}Ni) may be viewed widely as an unsatisfactory source associated with federal licensing and compliance (i.e. regular wipe tests). We propose a two prong approach of studying source chemistry with this proven source while searching for non-radioactive alternatives. Regardless of sources, a survey on ionization chemistry for a large number of organic compounds will be directed to revealing the principles of atmospheric pressure ionizations of organic compounds. This will be accomplished with an IMS/tandem mass spectrometer in the PI's laboratory at NMSU.

B. Date Base: A data base built with neural networks will be prepared and evaluated for confidence and reliability. Attempts will be made following the evaluation to determine the suitability of the data base and recognition package with vapor mixtures. Changes in the training of the network will follow and ion-molecule chemistry associated with the processes will be explored by IMS/tandem MS.

C. Drift Tube Design: The CAM is an unsuitable sensor for the uses envisioned here in part because of expense, over design for mil-spec guidelines, and dated technology. A new generation of inexpensive and refined drift tubes is the purpose for this objective. These drift tubes will not be radically new but will incorporate recent advantages in detector electronics, printed ink coatings, and microfabrication methods. The intention is to lower significantly the cost of individual sensors and to allow modular on-site repairs of sub-components.

D. Communications Hardware and Software for a Network: The last objective is to integrate electronically several sensors into a desktop computer and to build the software necessary for the operation of a sensor network.

UNSATURATED FLOW THROUGH TEXTURAL INTERFACES IN ENGINEERED (CAPILLARY) BARRIERS

Principal Investigator:

J. Phillip King
New Mexico State University

Co-Principal Investigator:

Tim Jones
New Mexico State University

Collaborator:

Robert Gonzales
Los Alamos National Laboratory

ABSTRACT

Many techniques have been used for protecting buried hazardous wastes. One of the most widely selected options is to include an engineered barrier at the soil surface directly over the buried waste. Engineered barriers consist of one or more horizontal layers of soil material and gravels constructed to retard the downward movement of drainage water into the waste zone. While many specific barrier designs have been suggested, all engineered barriers rely on the observed phenomenon that the downward flow of water is retarded at a textural interface.

Waste site designs take advantage of this retardation of water flow in two ways. The first is to retard the downward flow of seasonal water pulses and retain this water in the root zone long enough to allow plant uptake to remove the water from the profile. This is particularly advantageous in climates where precipitation occurs in the winter when plants are less active but the water drains out of the root zone before spring and summer transpiration levels are reached. The capillary barrier, if designed properly, can retain the winter precipitation within the root zone long enough for the increased transpiration which occurs in the spring and summer to withdraw this water. The water is removed on an annual basis and therefore the process can be repeated every year and the barrier can function indefinitely. The second feature of most barrier designs is to pitch the gravel layer like a roof so that any excess water that might accumulate at the interface is shunted laterally away from the waste zone before water levels become high enough to cause significant leakage through the textural interface. Even in the absence of near-saturated conditions, unsaturated Darcian flow may be significant enough to cause problems over long time periods even if the moisture in the fine textured soil does not reach a high enough saturation for breakthrough to occur. This Darcian flow may be quite small by laboratory standards. However, given the long functional life of engineered barriers, it may allow sufficient moisture to penetrate the barrier to cause movement of hazardous waste, and subsequent impairment of water quality and endangerment of human health.

The focus of this research is the flow through the fine-coarse interface in the normal design range of moisture contents for engineered barriers. Through laboratory experiments involving micro-instrumentation at the textural interface, the characteristics of flow without instability and sudden breakthrough will be investigated. The key feature of the flow process to be investigated

will include the potential distribution across the interface before during and after visual breakthrough will be investigated. The key feature of the flow process to be investigated will include the potential distribution across the interface before during and after visual breakthrough of the wetting front. These results will provide data to answer two key questions about the process: 1) Does flow completely stop or is it merely reduced dramatically as predicted by Darcy's Law from the dramatic differences in hydraulic conductivity across the interface; or 2) Is there a critical water potential on the upstream side of the interface when breakthrough occurs. The results will be incorporated into an unsaturated flow model designed specifically to simulate long term flow through barrier systems.

In the first year, one-dimensional flow through a textural interface will be studied and modeled. In the second year of the project, two-dimensional flow will be studied, so that the lateral movement of moisture induced by the sloped upper surface of the engineered barrier can be modeled. The ultimate goal of the project is to provide the physical basis and a working model for the long-term evaluation of existing and proposed engineered barrier designs. This project will result in a validated model that can rigorously evaluate the performance of an engineered barrier design and therefore allow true design of the optimal properties, both textural and hydrologic, of barrier material.

BIODEGRADATION OF BENZENE, PCE AND TEC IN SAND AQUIFER MICROCOSMS UNDER DENITRIFYING, LOW-CARBON CONDITIONS

Principal Investigator:

Geoffrey B. Smith
New Mexico State University

ABSTRACT

Contamination of the United States' groundwater with anthropogenic contaminants is a serious problem, particularly considering the nation's groundwater supplies drinking water to an estimated 56% of the country's households. New Mexico obtains 90% of its drinking water from groundwater sources (Leeden et al., 1990). Two groups of chemicals widespread in occurrence are the chlorinated solvents such as tetra- and trichloroethylene(PCE and TCE) and the aromatic hydrocarbons such as benzene, toluene, ethylbenzene and xylene (BTEX). Of the BTEX compounds, benzene is the most problematic because of its carcinogenicity and its recalcitrance to degradation. Benzene, TCE and PCE are listed as organic contaminants common at United States Department of Energy sites (DOE/ER-0432, 1990). The United States Environmental Protection Agency (EPA) has recently updated the regulatory levels for public water supply contaminants (1991). Among the compounds regulated on this priority pollutant list are PCE, TCE and benzene which have maximum contaminant levels (MCL) set very low because of their acute toxicity, at 0.005 mg per liter (=5 parts per billion, 5 ppb). Typical concentrations of hydrocarbons such as benzene in contaminated aquifer plumes are low, in the range of hundreds of ppb. Considering the low levels at which the EPA regulates contaminants, and the concentrations commonly observed in aquifers, any biodegradation scheme attempting to remediate a contaminated groundwater must consider and exploit microorganisms which are capable of metabolizing low concentrations of contaminants.

Another problem to overcome when considering biodegradation as a method of remediating groundwater is that most contaminated aquifers are oxygen-depleted, and this lack of electron acceptor often becomes the rate-limiting factor for biodegradation. Amending groundwater with an external oxygen supply is not cost-effective because of the very low solubility of oxygen in water. A viable alternative is the addition of nitrate to overcome the electron acceptor limitation since nitrate is much more water soluble and is cheaper than oxygen. Considering these in situ constraints to aquifer biodegradation, research on the conditions and organisms which can tolerate and grow under the low nutrient, anaerobic conditions found in natural aquifers is needed.

Biodegradation of groundwater contaminants by indigenous or introduced microorganisms remains a cost-effective and potentially the most complete clean-up technology, particularly where contaminants are too dilute to be treated by conventional technologies. Experiments outlined below center on aquifer microcosms consisting of glass columns containing aquifer sands which will be placed under anaerobiosis and continuous liquid flow. The aquifer sands will be exposed to either mixtures of benzene, PCE and TCE, or mixtures of PCE and TCE. All contaminant concentrations will be kept at realistic levels, that is below 1 part per million,

ppm. DNA gene probes will be used to monitor changes in the gene pool of the aquifer columns, using techniques developed during the principle investigator's post-doctoral training (Smith and Tiedje, 1991). Information from this work should first indicate whether benzene, PCE and TCE can be metabolized under anaerobic (denitrifying) conditions and indicate what are the constraints limiting the biodegradation. Secondly, gene probe analysis of the microbial community DNA extracted from the aquifer columns can reveal changes in community structure that occur with time and treatments. The probes will reveal the presence (or absence) of known catabolic genes such as those of the TOL plasmid. It is hoped that one can get a good indication of a system's potential for bioremediation by gaining information on the presence of known biodegradative genes.

Biodegrading organisms isolated from these aquifer microcosms should have more potential for application in bioremediating aquifers because of the low nutrient concentrations typical of groundwater systems under which the microbes will be selected. The column microcosms allow for attachment of microorganisms and biofilm formation on a solid surface. Contaminant compounds in this system will likewise be present in an adsorption equilibrium between the surface and the solution. The equilibrium between sorted and solution concentrations is important in determining the bioavailability of the contaminant, and this equilibrium must be taken into account if results are expected to be applicable at the field remediation level. The experimental design proposed in this project allows for biodegradation to be monitored under these more realistic physical and chemical conditions. Using gene probe techniques to track bacteria in this bench-scale system will identify changes in the microbial gene pool directly, without requiring the bacteria to grow in laboratory media. Gene probe analysis to track particular genes of interest in these aquifer samples will have direct bearing and application on our ability to track biodegradative genes in the environment which will provide information on the potential for *in situ* bioremediation.

OXIDATIVE DEGRADATION/DETOXIFICATION OF SOLID ORGANIC WASTES

Principal Investigator:

Su-Moon Park
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Collaborators:

Wayne H. Smith
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Mark T. Paffett
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Patrick M. Dhooge
Delphi Research, Inc.

ABSTRACTS

The proposed research addresses electrochemical minimization/detoxification of two general categories of organic wastes: relatively nontoxic ploycarbohydrate (cellulose) based wastes including solid biomass and municipal waste sludges, and toxic organic wastes such as poly (chlorinated biphenyls) (PCBs), herbicides, and insecticides. For the carbohydrate-based nontoxic wastes, electrochemical methods of their treatment to produce hydrogen gas at the negative electrode and humic acids at the positive electrode will be explored. For toxic organic wastes, electrochemical methods of detoxifying to produce final products, CO_2 and/or other oxides, will be studied. Large polymeric organic waste including cellulose, biomass, and/or other carbonaceous compounds will produce humic acids as intermediate products; whereas man-made small toxic organic molecules such as PCBs, and pesticides would be oxidized to nontoxic final products, CO_2 and other oxies.

The problem addressed in this proposal, with its successful execution, would benefit local governments as well as residents. The one on toxic wastes is more national and global in that these types of wastes are quickly being accumulated everywhere on our planet.

The method proposed here for the detoxification/minimization of solid organic wastes should be successful from our past experience and track record in the area. The question is more on whether the process would be economical or not. We believe that the process to treat biomass-based wastes should be economical because of its products, i.e., hydrogen gas and humic acids, both of which have high commercial value. While humic acids should benefit farmers mostly in the arid Southwest area, hydrogen gas may be marketed as an energy source or a fine chemical in its pure form. Humic acids can be used as a soil conditioning fertilizer in the Southwest area; for the soil in this area is very alkaline (ph of 8 - 9.5), and thus most minerals are leached out. Humic acids are capable of not only neutralizing alkaline soil, but also retaining minerals by chelating them. The value of expected products should more than counteract the operating cost for the process. The second process of treating man-made toxic organic wastes, which have smaller molecular weights, however, could be marginally economical. Whether or not the latter process would be economical would depend on how

effectively the process can be optimized for hydrogen production at the cathode. Furthermore, toxic wastes and their oxidized compounds such as carbon dioxide, nitrogen oxides, and sulfur oxides are not released into the air; they are trapped in water in their oxidized form. This should be one of the greatest advantages of the proposed process.

The proposed method of detoxifying toxic organic wastes has a number of advantages over direct burning, chemical treatment, or electrochemical treatment in supercritical fluids. Direct bearing of organic wastes introduces a large amount of pollutants such as nitrogen and sulfur oxides as well as the vapor of waste compounds into the air. Chemical treatment are likely to produce another wastes in different forms. Treatment in supercritical fluids requires an operation of the cell under extreme conditions, i.e., at high pressures and temperatures. For these and other reasons, Delphi Research, Inc., Albuquerque is interested in commercialization of the electrochemical process of waste treatment. Finally, we are also responding to the Solicitation for Research Grant Proposals - 1991 Exploratory Research Grants. In the EPA proposal, however, we place an emphasis on fundamental aspects of the process.

IMPROVED ENCAPSULATION OF HAZARDOUS WASTES USING THE TIDE PROCESS

Principal Investigator:

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Co-Principal Investigator:

Stan T. Holbrook
New Mexico State University

Collaborators:

Mike Riddle
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Stephen L. Yarboro
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ABSTRACT

Safe disposal of solid hazardous wastes is one of the biggest problems facing the waste management industry today. These wastes include heavy-metal contaminated incineration by-products, environmental remediation soils, mine tailings, industrial wastes, and radioactive materials. By its very nature, this problem is one faced not only by the entire nation but represents a critical environmental issue throughout the world.

TIDE Inc. has developed a process for encapsulating a wide range of hazardous solid wastes using a mixture of C-grade fly ash, bottom ash, and water. Preliminary testing indicates that the TIDE product's mechanical and thermal properties are excellent in addition to encapsulating the hazardous material. However, this process has yet to be fully developed. The three critical issues that will be addressed in this study are: (1) process optimization, (2) process improvement, and (3) improved encapsulation. The process optimization studies will use a series of statistically designed experiments to determine the conditions under which the "best" encapsulation occurs. Of particular interest is the pozzolanic reaction and how it is effected by process variables such as mixing conditions, maturation time, formulation, pressure, compaction time, etc. The process improvement phase will examine the use of below C-grade ash by the addition of lime or other additive to the coal before burning and/or the use of additives during the TIDE process. The encapsulation process will be further refined and improved for stabilization of hazardous radioactive wastes from LANL.

The primary benefit of this study will be an optimized and improved process for safely and economically encapsulating hazardous wastes. Additional benefits will be the development of a systematic methodology to derive encapsulation formulations for alternate waste materials, the ability to use a wider range of encapsulating ashes including those found in Four Corners region, and provide a more leach-resistant encapsulated product for long-term disposal.

PIPELINE LEAKS DETECTION SYSTEM FOR OIL SPILLS PREVENTION

Principal Investigator:

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Collaborator:

Larry R. Scott
Lynx Petroleum Consultants, Inc.

ABSTRACTS

Presented project addresses the problem of oil spills prevention for environmental protection. The waste generation from pipeline leaks can be prevented by use of the detection and control system for any possible leaks. If such a system is built and operated it can save the expenses for environment restoration and reduce the environmental impact.

Problem of line leaks is becoming more important as the infrastructure is aging. In the first six months of this year 61 percent of production line leaks were attributed to corrosion and approximately 3400 barrels of oil were lost. This number is 55 percent of total oil loss from lines and tanks, so approximately 6200 bbl of oil was spilled. Additionally, it was estimated that spills reported range from 10 to 50 percent of actual leaks.

The result of the research will be the design of pipeline leak detection system. The detection system in case of leak will give an alarm signal. Early detection of the leak will prevent larger scale leaks and spills.

A MICRO-AND MACRO-MECHANICAL INVESTIGATION OF CREEP MECHANISMS FOR THE WIPP ROCK SALT

Principal Investigator:

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Co-Principal Investigator:

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Collaborators:

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ABSTRACTS

The long-term performance of the Waste Isolation Pilot Plant (WIPP) is being evaluated to assess compliance with EPA 40 CFR 191, Subpart B and EPA 40 CFR 268 (RCRA) for both received waste and selected design enhancements (referred to as "engineered alternatives"). One of the primary processes considered in both of these compliance analysis is the creep closure of the surrounding host rock. After disposal of the waste in the WIPP storage rooms, the closure of the repository is expected to occur with the creep process. This creep is in response to the shear gradient that exists between the far-field pressure away from the repository and the pressure inside the repository (which is initially at atmospheric pressure). Complete closure of the repository depends on the outcome of the creep response. Waste-generated gas primarily due to corrosion and degradation may affect this closure history by re-expanding void volumes in the storage rooms. The WIPP performance assessment (PA) couples the processes of creep, brine/gas flow and waste-generated gas in the panel model of CAMCON. A defensible compliance assessment using this panel model needs a satisfactory assessment of the creep effect.

Although the creep phenomenon is understood to play a very important role in natural environmental protection, the micromechanical mechanisms of creep in geological materials are still not clear. Especially during the transition between the secondary and tertiary stages of creep, there is lack of understanding of creep mechanisms, due to the complexity of these materials and limitation of experimental techniques available. As a result, constitutive models used for predicting the creep response are usually based on a phenomenological or an empirical approach. Meanwhile, those nontrivial parameters such as permeability, solubility and brine inflow rate can not be adequately determined because of the lack of knowledge about the creep effects. Thus, from a long-term viewpoint, the safety evaluation of the waste storage system might be inadequate.

The investigation proposed here for the micromechanical mechanisms of creep is based on recent developments in micro-experimental techniques such as Scanning Electron Microscope (SEM), Environmental Scanning Electron Microscope (ESEM), X-Ray Radiography, Laser Holographic Interferometry and Image Analysis (WANG), and new research results in failure prediction, and theoretical and computational aspects of constitutive models for geological materials. The experience of the collaborators in the performance assessment of the WIPP disposal system, creep simulation and other issues associated with environmental protection can provide a necessary link between the basic research and practical applications of this research. The rock salt specimens, relevant data on the room closing rate and previous results on creep modeling, supplied by another collaborator from the WIPP site, could make an immediate contribution to this investigation. By means of micro- and macro-experiments, a general framework of constitutive modeling and corresponding solution procedures can be established to predict the creep response of interest, including the transition between the secondary and tertiary stages of creep. Each model parameter can be identified according to the physical mechanism behind the creep phenomenon, and the relation between the micro-and macro-scales will be verified for engineering analyses. Two of the main performance parameters used to compare the relative merits of each engineered alternative, the gas generation and future inadvertent human intrusion events are in addition directly or indirectly affected by the result of the creep process. The gas generation varies with the fluid pressure that depends on brine inflow, while key factors that control the release of waste elements during human intrusion scenarios include permeability of the waste storage rooms and radionuclide solubility. From a micromechanical point of view, the brine inflow, permeability and solubility are closely related to the internal structure and density change that are direct consequences of the creep damage. Hence, the deeper understanding of the creep mechanisms can provide valuable information for the analyses of the long-term performance of the WIPP disposal system. The cost share funds supplied by Sandia National Laboratories (SNL) to University of New Mexico (UNM) could reduce the cost of this research that also enhances immediately the PA calculations and provides a valuable tool for educating waste management engineers (two of whom will be supported by this proposal).

The long-term objective of this research is to develop a systematic approach for constitutive modeling that is consistent with micromechanics of nonlinear material behaviors such as plasticity, damage and creep. With the use of both macro- and micro-experimental techniques, a simple constitutive model, that captures essential features of material constituents, can be designed based on this approach. The routine applications of failure analyses in the environmental protection can then become feasible with computer resources available.

RISK/BENEFIT ANALYSIS OF THE DISPOSAL OF MIXED WASTE

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Co-Principal Investigator:

Robert D. Busch
University of New Mexico

Leo S. Gomez
Sandia National Laboratory

ABSTRACT

At the present, there is no exclusive policy regulating the disposal of mixed waste. Such a policy could be based on risk analysis of the components of the mixed waste. However, the comparative risks of radioactive versus chemical waste can not be addresses unless the risk (biological and environmental cost) is put on the same basis for each component.

All sectors of the scientific community and the general public will benefit by the methodology of the comparison. The numerous installations which have mixed waste in temporary storage facilities will be able to quantify the risks of each variety of mixed waste and identify possible dispositions. The U. S. government, particularly the Environmental Protection Agency and the Nuclear Regulatory Commission could get together and provide a single unifying regulation governing the disposal of mixed waste. Finally, there will be a technique for the operators of the WIPP site to assess the impact of hazardous materials in the transuranic waste containers.

TYPE-A AND TYPE-B WASTE CONTAINER DESIGN FOR ON-SITE AND OFF-SITE TRANSPORTATION OF RADIOACTIVE WASTE

Principal Investigator:

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University of New Mexico

Co-Principal Investigator:

Frederick P. Ju
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Collaborators:

Ken B. Sorenson
Sandia National Laboratories

Timothy A. Wheeler
Sandia National Laboratories

ABSTRACT

This project proposes the design and implementation of modifications to existing designs of Type-B radioactive waste containers, for the transportation of Contact-Handled (CH) and Remote-Handled (RH) Transuranic (TRU) waste. The modifications proposed in this project will be a complement to the existing TRUPACT II and 72 B shipping containers, and will reflect the state-of-the-art in technological developments toward efficient waste transportation. The reasons for the commencement of this project have been identified, and are presented as answers to the following four critical waste management problems:

1. Large amounts of radioactive waste exist at DOE sites, part of which (LLW) has been designated for on-site permanent storage. Due to the nature of the waste, certified Type-A packages are required. To facilitate safe transportation and minimize the number of on-site shipments, large overpacks are recommended (DOE-AL communication, 1991). The overpacks would have to safely accommodate the various waste packages, they would have to be used at different facilities, and their size would have to provide for minimizing the number of on-site shipments.

2. The waste currently in temporary storage at DOE sites exhibits different activities, thermal loads, and nuclear properties (DOE, 1989). The basic waste packages are generally 30-gal. and 55-gal. DOT Type 17C drums (Berlin & Stanton, 1989), but additional shielding and containment has to be incorporated for waste of higher activity and higher thermal loads. Thus, specific containers are built for each type of waste, requiring separate design, development, and certification (Berlin & Stanton, 1989). No designs as of yet have had the ability to transport more than one kind of waste form.

3. The highest activity waste planned for permanent storage at WIPP is RH-TRU, originating mostly from INEL, LANL, and Hanford (IT Corp. communication, 1991). The majority of the RH-TRU waste is in 55-gal. drums, and the NUPAC 72 B shipping container has been designed for their transportation. However, there are approximately 1200 30-gal. drums of RH-TRU waste in temporary storage at INEL, which will ultimately have to be transported to WIPP. As of yet, no designs have been initiated for the transportation of the RH-TRU 30-gal. drums.

4. The greatest fraction of risks associated with operation of the WIPP repository arises from transportation and handling of the waste (FSEIS, 1990). Furthermore, loading and unloading of the TRUPACT II is performed with overhead cranes - in case of drums slippage or pallet failure, the only containment is the steel drum casing. A hypothetical accident scenario could lead to drum rupture and release of waste during above-ground operations, either at the originator facility or at WIPP; subsequent cleanup efforts and prevention of waste migration would delay the scheduled shipments and increase the public concern about the safety of the WIPP operations.

The four identified critical waste management problems have encouraged research efforts by the University of New Mexico and Sandia National Laboratories towards the design of LLW overpacks and Type-B waste containers, with the goal of enhancing on-site and off-site transportation of various waste forms and activity levels.

The objective of this project is to reduce the risks and costs associated with transportation of radioactive waste. This would be achieved through the design of safe, economic and simple waste containers that would facilitate transportation of all forms of TRU waste to WIPP, and enable efficient transportation of LLW to permanent repositories within DOE sites. The following is a summary of the information and results expected from the suggested container design and modification:

1. Availability of a design for an economical and safe LLW overpack with the potential for immediate use on DOE sites, able to transport large amounts of waste and handle various types of waste packagings.

2. Availability of a design for a Type-B container, based on the existing TRUPACT II model, able to transport both CH-TRU and RH-TRU waste on demand.

3. Availability of guidelines on the optimal design and positioning of doors, locks, and seals for use with waste of high activity and frequent transportation, while eliminating or reducing overhead crane operations.

4. Conclusions as to the feasibility and benefits of using one modular waste container able to safely accommodate waste ranging from CH-TRU to HLW.

5. Experience gained for further cooperation between DOE and UNM under the auspices of WERC, to minimize redundant costs and research and development time associated with waste transportation and WIPP issues.

COGNITIVE MAPPING OF WASTE-RELATED RISKS: A COMPARISON OF EXPERTS AND THE PUBLIC

Principal Investigator:

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Co-Principal Investigator:

Timothy E. Goldsmith
University of New Mexico

ABSTRACT

At all levels, but particularly at local and state levels, the public often has difficulty accepting the assessments and recommendations of the experts regarding solutions to waste management problems. One reason for this difference is that there are major disagreements concerning the risks associated with various waste management alternatives. Past research has indicated that experts base risk assessment largely on the single dimension of expected annual mortality whereas the public assesses the risks multidimensionally. Some of the dimensions of importance to the public include how dreaded a waste-management accident might be and how unknown the consequences are. From such past research it seems likely that experts have a cognitive structure or map that is different from that of the general public and this, at least in part, results in the nonacceptance of the experts' recommendations.

There are a number of ways of constructing cognitive maps to represent a particular domain of interest, in this case waste management. A recently devised scheme called *Pathfinder* has proven itself in a wide variety of domains. Basically *Pathfinder* requires the identification of a number of key terms or concepts (e.g., low-level radioactive waste, high-temperature incineration, underground repository, toxic dump site). A sample of the population of interest, experts or the public, then rates the similarity of all pairs of concepts. *Pathfinder* takes the similarity ratings and constructs a graphical representation of a network where the concepts are the nodes and the links between nodes have weightings that correspond to the similarity of concepts. Procedures are available for comparing the cognitive networks derived by *Pathfinder*. If the cognitive maps for experts and the public are different and can be determined in this manner, a number of important questions could partially be answered.

The proposed research will attempt to determine whether the cognitive maps of experts and the public differ within a domain of waste management. If the maps differ, how do they differ? Does the public include an emotional/affective dimension in their mapping that experts exclude? If so, are there ways of independently constructing affective cognitive maps separately from objective maps? Does exposure to media reporting of waste-management issues change the cognitive maps of the public? If so, how? What means of education are possible if one wishes to inform the public with the intent of changing their cognitive maps to make them more like the experts?

In the first year of funding the specific domain within the waste-management arena will be identified and key terms will be determined. The expert population will be identified and contacts will be made to allow use of sample of these individuals. Procedures will be established for collecting the pair-wise similarity ratings from the experts and the public. Data will be

collected, cognitive maps will be constructed, and comparisons will be made between the samples. These maps will be analyzed to discover the bases for dissimilarities. Assuming that the expected dissimilarities are found, the additional questions posed above will be investigated in subsequent years. External funding agencies both within the waste management arena and outside it should have an interest in supporting this type of research. Basic research issues related to attitude and attitude change are of interest to social and cognitive psychologists. On the more applied side, industries, education and the government are concerned with measuring the content and structure of cognitive maps and how the maps change with various activities such as classroom instruction, informational programs, and even advertising campaigns.

MONITORING WELL LOCATION OPTIMIZATION SYSTEM FOR DEPLOYMENT DECISION AND COMPLIANCE DEMONSTRATION

Principal Investigator:

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University of New Mexico

Collaborators:

Alva M. Parsons
Sandia National Laboratories

Roger G. Cox
Sandia National Laboratories

Paul A. Davis
Sandia National Laboratories

ABSTRACT

This proposal requests funding for extension of a system that provides the optimum well locations for the combined purpose of monitoring for contaminant migration and geohydrologic characterization. The final optimization system will augment a decision support system (DSS) that is under development by the proposed collaborators at the Sandia National Laboratories (SNL). Although the developed system will be generic (non-site specific), it will be tested using available data from WIPP and SNL Mixed Waste Chemical Waste Landfills.

To satisfy the Resource Conservation and Recovery Act (RCRA) ground-water monitoring regulations, a waste site must have a ground-water monitoring system. This system consists of a minimum of one upgradient and three downgradient wells. The waste site must demonstrate that these wells have an acceptable probability of detecting a statistically significant amount of contamination at the water table from the onset site operation to 30 years after the site closure. In addition, other wells are drilled to assess the geohydrology of the region around the waste site. Drilling of these wells can cost in excess of hundreds of thousands of dollars per well. This cost is even higher in arid regions where the water table is several hundred feet below the surface.

To this end, a probabilistic strategy has been proposed which will satisfy the regulations and attempt to minimize subjectivity in evaluating the performance of the monitoring wells. The strategy is based on the determination of the likely ground-water flow paths through both saturated and unsaturated zones and ground water travel times. The technique involves three stages of analysis:

- optimization of monitor well location;
- evaluation of the sampling interval; and
- assessing the monitoring well network performance through time.

The proposed work will add a fourth dimension to this strategy, namely:

- conceptual model development and quantification of associated uncertainties.

The extension of DSS will augment the current projects being developed at SNL. Sandia is currently designing a monitoring well Decision Support System (DSS) to evaluate the most efficient monitoring well locations for the Chemical Waste Landfill. The proposed system will enhance the capabilities of the Sandia DSS by including conceptual model uncertainty quantification as part of the well deployment decision making and compliance demonstration. The following benefits are expected to realize upon successful completion of this project.

1. Capital cost and time reductions: It is anticipated that, through the use of the proposed system, both the capital costs associated with well drilling and the time to obtain regulatory approval for environmental restoration plan to be reduced.

2. Capability Enhancement: The features of Sandia DSS will be extended to include conceptual model uncertainty and geohydrologic characterization requirements.

3. Technology Transfer: Experience gained from this joint effort by SNL and UNM under the auspices of WERC, will be disseminated to the interested parties in at least three modes of communication. First, technical presentations at national and international conference, short courses, and workshops will be offered. Second, in support of WERC education goals, full semester and specialized courses will be developed and offered to all WERC university sites. Finally, the codes that will be developed will be public domain and Sandia will provide support services for its future users.

The Decision Support System, that is currently under development at Sandia, is limited to its Chemical Waste Landfill. The system that is proposed here will augment and benefit from the Sandia effort and expertise. During the course of this project, methods for extending this system to the vast majority of DOE ER sites will also be investigated.

A BASIN-WIDE ANALYSIS OF NORM IN THE OIL AND GAS FIELDS OF SOUTHEASTERN NEW MEXICO

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ABSTRACT

An important issue in waste management is the safe disposal of naturally occurring radioactive material (NORM) present in scales, sludges, and produced waters formed in oil and gas production equipment. Data collected by the New Mexico Oil Conservation Division from oil and gas fields throughout New Mexico show concentrations of radium-226 as high as 6000 picoCuries per liter, some 200 times the New Mexico Water Quality Control Commission's standard for groundwater. Scales and sludges that accumulate in surface equipment may vary from background levels of NORM to elevated levels as high as tens of nanoCuries per gram depending on the radioactivity and chemistry of the geologic formation from which the oil and gas are produced.

The goal of this proposed research is to provide a basin-wide inventory of the occurrence of NORM in the major oil and gas bearing geological formations in the southeastern producing fields of New Mexico. The research will attempt to establish a correlation between subsurface NORM activity levels with those observed on the surface in production equipment.

The proposed research will determine the abundance of NORM in the major oil and gas bearing formations of southeastern New Mexico and show how this can be correlated to NORM buildup in surface production equipment. In the long term this inventory can be extended Statewide to the oil and gas producing formations in northwestern New Mexico. The research will also provide definitive data on the radioactive background before the storage of radio nuclides at localities such as the WIPP Site begins. Thus the mean, the stratigraphic distribution, and the variance of radionuclides concentrated by oil production will be understood before possible background changes occur as the result of waste disposal.

A knowledge of the oil and gas bearing formations that result in high levels of NORM buildup in surface production equipment will allow oil and gas companies to incorporate the necessary waste disposal costs in their overall production costs when drilling for new fields. The initial surveys on NORM buildup show that NORM activity levels depend on geographic location. At some time a statewide and countrywide inventory will be necessary to gain the required understanding of basin development by addressing questions such as the timing of deposition of radioactive shales and sandstones within a basin and why certain basins produce higher NORM buildups than others.

DYNAMIC MODELING FOR DESIGNING TRANSPORTATION PACKAGING COMPONENTS

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ABSTRACT

The development of suitable, economical, safe and well regulated packaging for waste transportation is a key issue in waste management. 'Soft impact limiters' such as Polyurethane Foams and Aluminum Honeycomb are widely used in transportation packages as impact or shock absorbers. Currently, design procedures using these materials are based on empirical formulae which do not adequately account for the different types of prospective packaging components. The different energy absorption mechanisms were studied, to evaluate the effect of dynamic loading rates, confinement and other constraints on the deformation. Based on these experimental observations, engineering models are being developed to assist in the design process using these materials. In addition, constitutive models for cellular materials are being developed to reflect progressive damage during the crushing of cell walls, and the subsequent stiffening caused by the collapse of voids. The models developed, can be used to inspect and evaluate packaging components.

Results of the uniaxial static compression tests were evaluated, considering plastic deformation, buckling and other deformation mechanisms of the cells. It was found that currently available theoretical models do not capture the experimentally observed behavior. This observation reinforces the necessity for experimental results. Under uniaxial compression, the materials exhibit quasi-brittle behavior, and can be understood from fracture mechanics principles. Under confined compression, the materials are mostly insensitive to the confinement pressure. Therefore, a cap model based on the deviatoric stress space was found to provide the best description of the test results.

Under dynamic loading, the specimens exhibit a strain-rate dependence. This dependence is however coupled with the specimen size. The failure mechanisms were found to vary, depending on the material's density and size. These effects can be explained by the collapse of the voids to allow dissipation of internal pressure build-up, during impact loading. Also, the densified foams exhibit characteristics of brittle failure, and the consequent size-effect.

A three-dimensional rate-dependent plasticity model has been developed for rigid polyurethane foams. In this model, the materials is decomposed into the skeleton and the solid matrix from which the material is made. Both of these are then represented by an elastic-plasticity model.

The transverse anisotropy of the material is included by incorporating a shift in the effective stress calculation. The sift, the limit stress for the skeleton, and the hardening parameter for the solid are functions of volumetric strain rate, to account for strain rate effects. For uniaxial compression, the stress strain relation predicted by the model is suitable for numerical calculations in three dimensions, where the stress path is not necessarily one dimensional.

DEVELOPMENT OF PERMEABLE BARRIERS FOR AQUIFER RESTORATION

Principal Investigator:

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Co-Principal Investigator:

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New Mexico State University

James L. Botsford
New Mexico State University

ABSTRACT

With national recognition of the magnitude of ground water contamination problems, there becomes a critical need for more effective methods of addressing them. Current options have a number of constraints including the need for large surface disruptions for long periods of time, management of large volumes of residuals (contaminated soils, treated water, and sludges) from the remediation process, and institutional obstacles associated with permitting and other processes. This study will continue development of a management/treatment alternative consisting of barriers that are permeable to water, but intercept or degrade pollutants and remove them from the ground water.

Two alternatives have been previously investigated: development of combined air stripping and biodegradation barriers for removal of volatile and/or biodegradable constituents, and application of gelling agents that are permeable to water but swell upon exposure to hydrocarbons and bond them inside a relatively inert matrix. This investigation has two components. First, is to operate an air stripping/biodegradation barrier for at least one year to determine its operational characteristics. Performance will be monitored by following removal of specific contaminants, plate counts of heterotrophic bacteria, and impacts on other water quality parameters including coliform bacteria. Previous laboratory and field work has demonstrated excellent removal of aromatic compounds (benzene, toluene, and o-xylene) at very low air-to-liquid flow ratios; these results will be substantiated with field studies. At the conclusion of the study the barrier will be excavated and analyzed for biomass and inorganic precipitates that might result in its plugging.

The study of gelling agents will address two questions: what is the long term stability of the gels with respect to biological degradation, and what is the susceptibility of gelled pollutants to geological degradation. These will be investigated in several ways. First, water will be passed through the gels and the microbial activity of the leachate determined by measuring both numbers and diversity of bacteria present. Next, a direct determination of the biodegradability of the gels will be performed by placing them in respirometric flasks and monitoring microbial activity. Finally, degradation of the immobilized pollutants will be investigated by immobilizing carbon-14 hydrocarbons in candidate gelling agents and monitoring $^{14}CO_2$ evolution.

REMEDIATION OF HAZARDOUS WASTE SITES BY HEAP LEACHING

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Don York
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ABSTRACT

Efforts are being made to devise technologies and treatment systems to remediate heavy metal contaminated soils, on-site without generating significant wastes for off-site disposal. Heap leaching, a technique used extensively in the mining industry, has been investigated by the authors as a method for the remediation of soils contaminated with heavy metals. This has been a three year project which is funded by DOE/WERC. During the first year of this project, laboratory scale column studies were conducted to evaluate the removal of chromium (VI) from four New Mexico soils (sand, sandy loam, and 2 clay) using heap leaching. The column study was conducted on both laboratory spiked soils and soils from a contaminated site at the White Sands Missile Range. The study showed that more than 99 percent of the chromium (IV) can be removed from all four soils using tap water as the leaching agent. The study also showed that the salinity level of the leaching agent, the application rate of the leaching agent and the agglomeration of the soil did not have a significant effect on the removal of chromium from soils. During the second year, batch and column studies were conducted on the removal of lead from contaminated soils. Both laboratory spiked soils and a contaminated soil from a superfund site in New Mexico were used in the study. Before starting the column study, more that a dozen leaching agents were used in the batch study to identify the most effective leaching agent, and 8 lead salts were evaluated for use in contaminating the laboratory spiked soils. The parameters considered in identifying the most effective leaching agent were the rate of removal of the contaminant and the magnitude of dispersion of the soil aggregates by the leaching agent. The dispersion of the soil aggregates by the leaching agent is considered an undesirable factor leading to reduced hydraulic conductivity of the soil and prolonging the remediation process. Among the leaching agents used, Dipotassium EDTA was identified as the most effective leaching agent. Subsequent column studies showed that in excess of 85 percent of the lead can be removed from contaminated soils using a mixture of tap water and EDTA. During the third year, the removal of lead and chromium from contaminated soils will be studied at the field scale. Both laboratory spiked soils and soils from superfund contaminated sites will be evaluated. During the field scale study the techniques for extrapolation of the laboratory parameters to field scale operation will be studied. Other parameters to be evaluated during the third year are: leaching effectiveness and spacial variability of leaching.

TREATMENT OF WATER CONTAMINATED WITH BTX AND HEAVY METALS USING TAILORED ZEOLITES

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Co-Principal Investigator:

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ABSTRACT

Zeolites are natural minerals with significant cation exchange capacity (CEC). The natural cation in zeolites (typically sodium) can be exchanged with organic cations (quaternary amines). The resulting tailored zeolites have physical and chemical properties that are different in nature from the original zeolite. For instance addition of organic tailoring agents at a dose equal to the CEC of the zeolite results in a neutrally-charged solid medium (the zeolite mineral) covered with a monolayer of organic molecules. Neutrally-charged pollutants (in particular the BTEX family) are removed by adsorption on such organically tailored zeolites.

Addition of tailoring agent above the CEC results in charge reversal on the surface of the zeolite. The positive charge induced by the excess tailoring agent may be used to remove anions from solution. Hexavalent chromium, which hydrolyzes in water, exists as an anion in near-neutral solutions. Zeolites tailored with long-chain quaternary amines at doses above their CEC are excellent adsorbents for the removal of this carcinogenic heavy metal from water.

MINIMIZATION AND REMEDIATION OF DOE NUCLEAR WASTE PROBLEMS USING SELECTIVE ACTINIDE CHELATORS

Principal Investigator:

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Collaborator:

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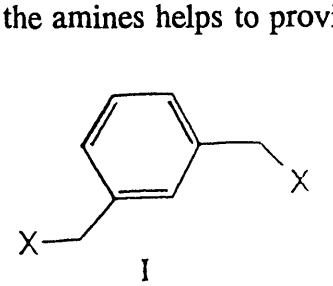
ABSTRACT

The design and synthesis of chelators for the specific binding of actinide ions is both of pharmacological and environmental interest. Since the advent of the Manhattan Project in the early 1940's, radioactive actinides have been discharged in various forms into the world environment. These discharges have occurred as a result of weapons production, medical research and other sources including nuclear power plant by-product. Selective removal of radioactive and highly toxic actinide ions such plutonium(IV) and americium(III) from process waste streams and soils which often contain high concentrations of iron or aluminum presents a formidable challenge.

Hydroxamates and catecholates are known for their ability to strongly complex highly charged metal ions such as plutonium(IV) and iron(III). Therefore, many chelators containing these functionalities have been synthesized and their actinide sequestration properties have been examined. It is generally accepted that octadentate ligands possess the characteristics necessary for selective actinide complexation. The larger size of the actinide ion and its flexible coordination geometry relative to transition metals provides an avenue for differentiation.

As part of a research program for the development of cost-effective organic chelators for practical remediation of actinides, we have recently prepared a new class of tetrahydroxamates that show potential for environmental applications. Two such chelators, I and II, were chosen based on the following considerations. 1) The spacial arrangement of the four hydroxamates meet the requirements of actinide ions. 2) The diamine bridge can be readily varied to optimize actinide selectivity. 3) These chelators are easily prepared from readily available starting materials and can be modified for incorporation into polymeric supports. 4) The presence of the amines helps to provide water solubility for the ligand and its complexes.



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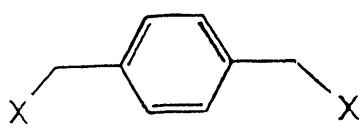

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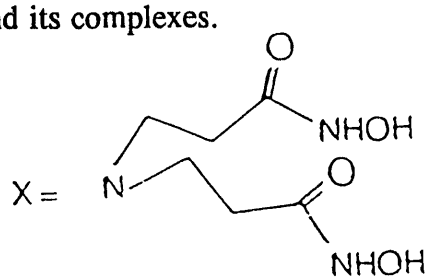

The ligands have been evaluated potentiometrically and spectroscopically to determine their protonation and metal binding constants. For our metal binding studies we chose thorium(IV) as a surrogate for plutonium(IV) and neodymium(III) for americium(III). The substantial depression of the potentiometric titration curves observed for both chelators with thorium,

neodymium and iron is an indication that these metals are strongly complexed even at low pH. A qualitative assessment based upon our studies indicates that these chelators have a larger affinity for the metal ions which have higher charge to radius ratios. Even though neodymium has a substantially smaller charge to radius ratio relative to thorium (IV) and iron(III), it is strongly complexed by both chelators. The similarities of the binding constants indicates no structural bias of either ligand toward neodymium, and the binding constants are comparable to other hydroxamic acid chelators such as desferrioxamine-B. From our data, it is clear that I is more selective for thorium(IV) than iron(III) while II shows no selectivity. The selectivity observed for I could be explained by greater steric interactions between the chelate arms upon complexation of the smaller ferric ion.

Efforts are underway to further improve the binding specificities of this class of chelators through structural modifications. The synthesis of other complex chelators with the correct geometrical arrangement of ligands to allow maximum interaction with actinide ions (using computer modelling studies) is being carried out. Also strategies for incorporation of known and new chelators into insoluble polymeric matrices for downstream concentration of toxic ions will be examined.

APPLICATION OF BIOTECHNOLOGY IN MANAGEMENT OF INDUSTRIAL WASTES CONTAINING TOXIC METALS

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ABSTRACT

The overall goal of this research is to establish a bioremediation process which would be useful for the detoxification of sites containing chromium and lead. We tested several bacteria which displayed rapid transformation of Pb II to Pb°, Cr VI to Cr III as well as tolerance to high concentrations of diverse toxic metals. We identified these bacteria and found that they belonged to the following genera: *Pseudomonas, Enterobacter, Alkaligenes, Corynebacteria, Moraxella* and *Bacillus*. Studies were also conducted with a yeast, *Rhodotorula*, which we isolated from an industrial site containing high concentrations of chromium.

We found that a *Pseudomonas* isolate and the *Moraxella* isolate transformed Pb II at the highest rate. Bacterial cells taken from stationary phase of growth rapidly transformed Pb II when placed in a buffered lead solution and to a very small extent when the bacterial were placed in soil containing lead. From soil and solution studies, it is apparent that the soil containing lead should first be subjected to an extraction treatment. Bacteria can transform lead from various lead-ligand systems. The lead colloids produced from bacterial action have a minimal diameter of 120 nm but may aggregate to diameters of 3600 nm. Due to the high concentration of cellular material associated with the bacterially produced lead colloids, the transformed lead quickly settles out. Bacterial transformation is two step process: initial binding followed by energy-dependent colloid formation.

The bacteria which reduce Cr VI to Cr III also accomplish this with resting cells. About 24 mg/gram of Cr VI are transformed/day/gram of bacteria. Bacteria bind Cr III to the surface of the cell at a rate which is similar to the reduction rate. This reduction and binding is independent on the types of heavy metal cations present in the environment. Additionally, we found that the *Pseudomonas* isolate would overproduce siderophore, ad Fe III binding compound, when grown in elevated concentrations of Cr III. We are exploring the use of this siderophore in detoxification of Cr III sites.

VADOSE ZONE MICROBIOLOGY: BIOMINERALIZATION, CHELATION, AND BIOCONCENTRATION OF MIXED HAZARDOUS WASTE

Principal Investigator:

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Collaborator:

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ABSTRACT

This project was undertaken to determine the potential for microorganisms in the unsaturated (vadose) zone to influence the fate and transport of organic and inorganic pollutants. The majority of research in the relatively new field of subsurface microbiology has been focused on saturated zones, whereas this project is directed towards vadose zone microorganisms. We have selected a limited number of pollutants and limited number of microorganisms for study. Using 15 strains of bacteria isolated from the vadose zone at the Pajarito Plateau in Los Alamos, NM, we have found that the sorption of heavy metals (Cd and Ni) to the surfaces of volcanic tuff collected from the same area is inhibited when microorganisms are present. This finding has important implications for the modeling of metal contaminant transport in the subsurface, particularly at facilities situated in or on volcanic tuff. Microbial metabolites may cause accelerated transport of metals in the subsurface. In studies of toluene-degrading consortium of microorganisms isolated from a contaminated unsaturated subsoil, we have found that matric water potential has a strong effect on the rate of biomineralization of toluene to carbon dioxide. Desiccation decreases mineralization rates; however, measurable biomineralization proceeded even in the most desiccated subsoils. This indicates that organic pollutants such as toluene can be biologically degraded, even under the harsh conditions of the vadose zone. Manipulation of contaminated vadose zones (e.g. by nutrient addition) may stimulate rates of pollutant biodegradation.

A NEW FAST SCANNING ENVIRONMENTAL SEM FOR USE IN WASTE STUDIES

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ABSTRACT

Failures of buried metal pipes and storage tanks caused by microbially induced corrosion have been well documented by many industries including the nuclear power industry, the electrical power industry, and the petroleum processing service industry. The main cause of corrosion of ferrous metals in anaerobic or semianaerobic environments is the activity of sulfate-reducing bacteria (SRB). One proposed mechanism by which SRB influence the electrochemical corrosion process is cathodic depolarization via the hydrogenase enzyme.

The hydrogenase enzymes that are associated with the most corrosive SRB use the molecular hydrogen that forms a protective film on the cathode. The SRB have a highly efficient electron transport system which uses hydrogenase to enzymatically break down the protective hydrogen film. The focus of our research is to establish a rapid, sensitive assay which can be used to measure the in situ oxidation of hydrogen contributing to microbially induced corrosion. We have developed a system which uses tetrazolium salts as electron acceptors and the magnitude of the enzyme activity is quantified using scanning electron microscopy (SEM). We are using two new SEM methods: fast scanning SEM and environmental (or wet) SEM. While oxidized tetrazolium is soluble in water, the reduced tetrazoliums are termed formazans and are not soluble in water but readily crystalize in the reaction mixture. By quantifying either the number of reduced formazan crystals or by measuring the increase in formazan crystal size, a correlation is made between the physical characteristics of the formazan crystal and the enzyme activity.

In our research, we demonstrate the suitability of formazan crystal growth for measuring the amount of enzyme activity. We are currently developing a method to follow formazan crystal formation using the two new types of electron microscopy. The novel use of the fast and wet scanning electron microscopes, currently in development, will enable us to evaluate the in situ activity of the SRB in the biocorrosion process. One goal of our research is to develop a process or product to control corrosion attributed to SRB.

In addition, microfilms of water on rocks which are to become subsurface repositories are of considerable concern. We feel that direct observations of these subsurface specimens after treatment of several different flocculating agents would provide enhanced stability of the bacteria and even the toxic compounds in the aqueous region. In our research we have successfully imaged cells with SEM which have been flocculated by a commercially available EPA-approved agent. We have worked out the conditions necessary to image the cells using SEM. Another goal of our research is to find ways to evaluate cell concentration, pH, and flocculation concentration to get optimum conditions for imaging.

SLURRY-PHASE BIOREMEDIATION OF OILFIELD PRODUCTION PIT SLUDGES

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ABSTRACT

The purpose of this research project has been to develop methods for biologically treating oilfield production pit sludges and produced water to reduce the content of hydrocarbons. Waste pit sludges consist of the high molecular weight fractions of crude oil and they are often also contaminated with various organic and inorganic additives (e.g. de-emulsifiers, corrosion inhibitors, and heavy metals). Produced water is pumped from formations along with crude oil and removed from the oil in a separator. Produced water contains residual hydrocarbons and they are often quite saline.

For the biodegradation of waste pit sludges, we have cultured hydrocarbon-degrading bacteria from oil-contaminated surface soils and from waste oil-produced water mixtures, and we have increased the numbers and activities of these hydrocarbon-degrading bacteria through enrichment culture. We have then tested the capabilities of the cultures to degrade waste oil under various environmental conditions. We have found that addition of water, nutrient amendment, and acid neutralization are essential for enhanced biodegradation. Additions of a surfactant (Tween 80) appears to favor biodegradation of the oil. It was also found that vigorous aeration of the slurry-phase bioreactor increased rates of both volatilization of the lighter fractions of waste oil and degradation of all fractions. Analysis by GC-MS showed that a large proportion of the waste oil consists of unbranched alkanes ranging in size from C13 to C31. Biological treatment of the waste oil was shown to reduce the concentrations of these unbranched alkanes to below detection. We have isolated two hydrocarbon-degrading bacteria in axenic culture and are currently testing them to determine which components of the hydrocarbon mixture are degraded. We have also assessed microbial activity in slurry-phase bioreactors by measuring oxygen consumption with a respirometer. A pilot-scale bioreactor has been designed for testing at the Hobbs Oil and Water Experimental Facility (HOWE).

Studies of hydrocarbon degradation in produced waters have been performed using water samples from several production facilities in New Mexico. A commercial inoculum (Petrobac-S) was used. This culture was chosen because it is adapted to the saline conditions found in the samples. Biotreatment of the produced water samples with this culture resulted in 65 to 90% reduction in the total petroleum hydrocarbon concentration.

BIODEGRADATION OF EXPLOSIVES

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Co-Principal Investigator:

Wolfgang F. Mueller
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Consultant:

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ABSTRACT

Arsenals of the U. S. Government that produce trinitro-toluene (TNT) generate large volumes of highly toxic, nitrobody-containing effluent called "pink water". Pink water, depending on its source, may contain up to several hundred parts per million (ppm or mg/of TNT isomers, 2,4-dinitrotoluene (DNT), and other explosives (e.g. RDX and HMX). DNT is a potent carcinogen for which EPA ambient water quality standards have been established. To date, all conventional treatment technologies permit an escape of toxic pink water components that exceed EPA effluent discharge levels, and the high toxicity of those remaining component levels has made biological wastewater remediation efforts unsuitable. At shooting and bombing ranges as well as blast sites used for weapons development and testing, large areas are contaminated with TNT and other high explosives, probably at fairly shallow depths of penetration below the surface.

Based on preliminary work performed at LANL with tissue-cultured cells of Datura innoxia (Jimson Weed), our experiments have shown that the cells both rapidly remove and metabolize ^{14}C-labeled TNT that had been added to their growth medium. Observations from these experiments may be summarized as follows:

1) Unlike bacterial bioremediation efforts, the added TNT (up to 200 mg/L) is completely removed from the growth medium in less than 24 hours.

2) The radiolabel is internalized by the cells, not adsorbed to the outer surface.

3) Chromatographic analysis shows that during the first 24 hours of contact the TNT is converted into several new compounds that are more polar than TNT.

Studies with suspension cell cultures derived from the wild tomato plant Lycopersicon peruvianum showed that both the uptake and the biotransformation of TNT is not limited to the Datura species, but that it can be achieved by other plants as well. For the subsequent work, both Datura and Lycopersicon cell cultures were used. Isolation and purification of the biotransformation products from cell extracts was achieved by preparative and analytical scale HPLC; the purified metabolites were analyzed by gas chromatography - mass spectrometry after derivatization to enhance volatility. Biotransformation products identified so far include an amino-dinitrotoluene, a diamino-nitrobenzyl alcohol, and a diaminonitrobenzoic acid. This demonstrates that the plant cells use the metabolic pathways of nitroreduction and oxidation of the methyl group in combination. Evidence from total recovery of ^{14}C indicates that part of the TNT added to the cultures is broken down further and potentially mineralized completely.

RECOVERY OF TOXIC HEAVY METALS FROM CONTAMINATED GROUNDWATERS

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Co-Investigator:

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Collaborator:

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ABSTRACT

This proposal specifically addresses Section 2.5.5.2 in the Department of Energy's Applied Research, Development, Demonstration, Testing and Evaluation (RDDT&R) Plan for Environmental Restoration and Waste Management. Section 2.5.5.2 state: "To protect public health and the environment, DOE must provide reduction or elimination of radioactive, heavy metal, and/or inorganic contamination in groundwaters through extraction and *in situ* technologies."

While it may be possible to treat organic contaminants *in situ* by biological or chemical oxidation methods, the *in situ* treatment of metal ions is much more difficult. In many cases the only effective method of treatment will be to pump the waters from the ground and treat them.

In wastewaters, whether industrial, mining, surface leachates or groundwaters, concentration of heavy metal ions which must be treated are relatively low, typically in the 0.1-100 parts per million range. Energy intensive methods, such as distillation, evaporation or reverse osmosis, are not economical for treating these waters. Commercial ion exchange resins, including specialty chelating resins, may be effective in some instances for removing and recovering heavy metals, but if the waters contain a high salt content or contain large amounts of calcium or magnesium ions, the extraction proficiency drops dramatically.

The proposed studies will involve the evaluation of a new, biologically-derived, heavy metal recovery agent (cultured cells from the plant *Datura innoxia*) for the extraction of heavy metals from contaminated groundwaters. This metal recovery agent will be supplied by Dr. Paul Jackson at Los Alamos National Laboratory. Dr. Gary Rayson and his research group at New Mexico State University will evaluate the conditions under which these metal binding agents are most effective and will ascertain which heavy metal ions can be accumulated from water under laboratory conditions. This information will be obtained from both phenominological observations and fundamental investigations of the mechanism(s) responsible for metal binding to the cell material. These mechanisms will be investigated using laser-induced solid-state luminescence and nuclear magnetic resonance spectrometry. These biomaterials will be immobilized to make a product which will be packed in columns and used much as ion exchange resins are now commercially used. Bio-Recovery Inc. of Las Cruces, New Mexico, using information gained from Dr. Rayson's laboratory, will then test these new materials on "real" contaminated groundwaters from Superfund or DOE sites if laboratory studies are sufficiently promising. From this data an economic analysis for commercial treatment will be made.

REFORMING AND GASIFICATION TECHNOLOGY FOR THE DESTRUCTION OF WASTES

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Co-Principal Investigator:

Stan Holbrook
New Mexico State University

Collaborators:

Dale Spall
Los Alamos National Laboratory

Craig Tyner
Sandia National Laboratories

ABSTRACT

The incineration of waste is a disposal strategy that is here to stay. Municipal waste, medical waste, and industrial waste, such as solvents and oils, are all candidates for this method of disposal. The primary problem with incineration is the possibility of discharging potentially harmful by-products of combustion to the environment. These by-products may be either solid or gaseous. The number of possible gaseous compounds is almost limitless-dioxins, furans, and chlorinated benzene are just three of particular interest to the current project. All these compounds contain chlorine. Chlorinated compounds may be present in the original waste, for example polychlorinated biphenyls (PCBs) from transformers or trichloroethylene (TCE) used as a solvent. Of special concern are those compounds, not originally present, that form directly or indirectly as a result of the combustion process. Many examples of de novo formation have been observed. There is a need to understand the processes that lead to the formation of these unwanted and harmful by-products, and a need to develop modified incineration methods based on this understanding.

A joint Mechanical and Chemical Engineering combustion facility has been built to study the gas phase formation of toxic by-products of combustion. The approach taken in this project is to provide a geometrically simple reaction volume that minimizes the data that need to be taken, simplifies data interpretation, and allows existing computer models to be applied. A flat-flame burner is employed to provide a nearly one-dimensional reaction zone. The flat-flame facility has an advantage over other possible burners in that it is free of surfaces that could act as catalysts. This is an important consideration since some evidence is available that the formation of certain toxic compounds is more rapid when surfaced catalyzed. With the flat-flame facility homogeneous gas phase reactions can be investigated. The possibility of adding surfaces in the form of a chimney, particulates, or solid surfaces placed directly in the flow still exists for future studies.

The procedure for the present research is to add our target compounds to a methane or propane flame (both are available). The initial tests will use TCE and benzene, either separately or together. Samples from various points above the flame zone will be analyzed for large molecular weight hydrocarbons and chlorohydrocarbons. For example, chlorobenzene, dioxins, and furans will be quantitatively measured using a GC/Mass Spectrometer. The air/fuel ratio will be varied to assess the effect of this important parameter. In addition, steam will be added to promote dechlorination and the formation of HCl. A comparison of TCE addition alone to

TCE plus benzene will be investigated to determine the importance of ring structures as precursors. Modeling is being facilitated with the CHEMKIN code from Sandia. Preliminary tests have been conducted with propane and trichloroethylene. Fine tuning of the facility is being completed to obtain quantitative results.

ENHANCEMENT OF SOLAR PHOTOCATALYTIC DETOXIFICATION BY ADSORPTION OF PROPHYRINS ONTO TiO_2 AND Al_2O_3 SUBSTRATES

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ABSTRACT

This project addresses the problem of utilizing solar technology for toxic waste disposal on three levels. The immediate (short term) goals are to couple existing solar collector technology, and metalloporphyrin (MP) photoactivity to produce a more efficient system for photodegradation of toxic wastes. These studies have begun with laboratory scale testing of TiO_2 sensitized with MPs already familiar to Ondrias and Shelnutt and rapidly progress to field tests utilizing solar thermal collectors in place at Sandia National Laboratories (SNL).

During the past year significant progress was made in this area. $Sn(IV)Cl_2$ uroporphyrin (SnUroP) adsorbed onto an aqueous suspension of powdered TiO_2 at pH 6 was found to enhance the photodegradation of a model toxin salicylic acid (SA) considerably when only visible light was used. SnUroP adsorbed onto an aqueous suspension of powdered Al_2O_3 at pH 6 was found to be photocatalytically active towards oxidative degradation of SA when illuminated with visible light ($\lambda > 390$nm). No photodegradation of SA is observed in aqueous mixtures with either the porphyrin or the alumina alone. Photodestruction of SA occurs only when porphyrin is immobilized on the alumina surface below pH 8. Irradiation under anaerobic and aerobic conditions shows that oxygen is necessary for the photodegradation reaction to occur on the alumina surface. In other experiments, we have observed photoreduction of $Cr_2O_7^{=}$ to Cr^{+3} by the SnUroP adsorbed onto Al_2O_3 (pH 2). Further, the $Cr_2O_7^{=}$ reduction reaction is catalytic in the presence of SA, which apparently is needed to complete the redox cycle. We are currently investigating the stability and photocatalytic activity of other porphyrins, including ZnUroP and $Sn(IV)Cl_2$ tetrakis (*p*-carboxyphenyl)porphyrin, on both surfaces.

The longer term goals of this project involve the optimization of the photodynamics of the surface/dye systems for greater efficiency and stability. This will require two methodologies: (1) time-resolved optical spectroscopy of isolated dyes and surface/dye systems in order to characterize the mechanisms of MP dyes and their interaction with various surfaces. Such basic knowledge is crucial to the development of a new generation of photocatalysts that will allow these processes to be pursued on a commercial scale. A firm basis for both of these efforts has now been established at UNM and SNL, Albuquerque.

DEVELOPMENT OF CONSTRAINED MOTION CONTROL FOR TELEAUTONOMOUS ROBOT HANDLING OF HAZARDOUS WASTE

Principal Investigator:

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ABSTRACT

During the sorting and repackaging of recovered waste, robotic systems for grasping and manipulating odd-shaped objects of varying sizes will be needed. Also, during the removal of buried waste, there will be items which need "surgical" removal, e.g. grasping by a multifingered dexterous gripper attached to a robot arm. It may not be possible to employ simple parallel-jaw grippers commonly used in current robot systems to grasp such ill-defined objects. Instead, dexterous end-effectors with grasping capabilities similar to human hands may need to be developed. The proposed research is to develop a prototype workcell using a multifingered hand to handle such objects. The proposed system will consist of a robot arm employing a three-fingered dexterous hand, plus a vision system, all controlled by the same computer. The system will be capable of locating and identifying odd-shaped objects, synthesizing fingertip grasp locations on the objects, and grasping and manipulating them. This prototype system will directly address the three areas discussed above, and will serve as an example of state-of-the-art sensing and control technology applied to ER&WM. This dexterous grasping and manipulation technology is somewhat generic, and will serve the needs of a wide variety of applications, beyond those mentioned above.

ADAPTIVE CONTROL OF MANIPULATORS AND TELEROBOTS HANDLING HAZARDOUS WASTE

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ABSTRACT

The objectives of this research project are: (1) To develop a robust high performance adaptive impedance control system for robots possessing kinematic and/or actuator redundancy; (2) To construct an accurate and detailed computer simulation environment for modelling important robotic environmental restoration and waste management (ER & WM) tasks; (3) To begin evaluation of the robot impedance control system's capability to perform ER & WM tasks though both computer simulation and experimentation.

Progress toward achieving the three major research objectives is proceeding ahead of schedule. The theoretical development of the adaptive impedance controller for redundant robotic systems has been completed, and this development has yielded two important results. The first contribution is the derivation of the first reported globally stable direct adaptive impedance controller for general manipulators. This controller provides the excellent performance, efficiency, and robustness properties associated with direct adaptive impedance controllers while ensuring the global stability formerly only provable for indirect adaptive impedance controllers. The second contribution is the development of a unified framework for controlling robotic systems possessing any combination if kinematic and/or actuator redundancy. This result permits the development of redundant robotic systems which possess significantly increased performance capabilities reliability, and fault tolerance compared with conventional robotic systems.

Development of the computer simulation environment for modelling robotic ER & WM operations is on schedule. A general robotic system dynamics simulation environment has been completed. This simulation package incorporates models of all important dynamics subsystems and phenomena; for example, all rigid body, actuator, and transmission dynamics are modelled, and fairly sophisticated models for joint friction and transmission phenomena are included. Additionally, significant progress has been made in constructing computer models of important ER & WM tasks, including radiological swiping of waste containers (e.g., for inspection at WIPP), inspection of cluttered workspaces (e.g., underground waste storage tanks), simple mechanical assembly (as required in automated TRUPACT handling), and robotic deburring for waste minimization (e.g., edge and surface finishing of uranium parts in weapons production). Evaluation of the proposed robot control system is also progressing on schedule, and thusfar has focused on the problem of effectively utilizing the available redundancy. Computer simulation studies have been conducted to examine resolution of both kinematic and actuator redundancy to achieve a wide range of performance objectives, including improved dynamic response, obstacle avoidance, joint limit avoidance, singularity avoidance, increased dexterity, and improved reliability and tolerance to joint failure. Experiments have been initiated at JPL, and

to date have considered the problem of utilizing kinematic redundancy to improve dexterity and avoid workspace obstacles. The research results summarized here have been published at the international level, in the form of journal articles (five), book chapters (one), and conference papers (six), and the interested reader is referred to these publications for additional details.

DEVELOPMENT OF SENSORS FOR WASTE MANAGEMENT APPLICATIONS

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ABSTRACT

The primary goal of our research is the development of sensors that can be applied in the nuclear fuel reprocessing industry or in monitoring the environment surrounding waste disposal sites. A sensor is a measurement system designed to exhibit an experimental response relatable to the quantity of a chemical species or class of chemical species present in a liquid, gaseous, or solid sample. The difference between a sensor and a conventional analytical instrument is that a sensor is generally designed to be small, rugged, portable, and to operate *in situ*. Thus, sensor development will bring the measurement process to the sample, rather than bring the sample to a laboratory. The specific analytes targeted in our program include the uranyl and plutonyl ions, other lanthanide ions, and nitrate ion and nitric acid. The sensors for these analytes must function in the presence of all components of raffinate solutions, particularly high nitric acid concentrations. The sensors for uranyl/plutonyl are based on the fact that these ions selectively form colored complexes with Arsenazo (III) under high acid conditions. The color change due to the complexation when the Arsenazo is immobilized at the end of a fiber optic is sensed spectrophotometrically. A number of other ligands that will potentially form fluorescent compounds with these ligands are also being investigated. One type of nitrate sensor being investigated is based on changes in the spectral properties, particularly changes in fluorescence, of a probe ion. More recently, we have discovered that the nitrate ion Raman band shifts proportionally to the amount of acid present. This latter phenomenon has great potential as a nitrate ion/nitric acid sensor and will be further investigated in the coming year.

STABLE ISOTOPE STUDY OF SOIL-AND GROUND-WATER, WIPP SITE NEW MEXICO: ESTIMATION OF RECHARGE TO THE RUSTLER AQUIFERS

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ABSTRACT

An important issue in waste management is the hydrologic characterization of the natural environment surrounding waste repositories. In the arid southwestern climate this must include characterization of fluid flow in the unsaturated (vadose) zone. It is through the vadose zone that recharge to lower aquifers occurs. The rate of recharge is an important factor in the rate at which contaminants will move away from a storage site. At the WIPP, not only is the rate of fluid flow in the aquifers overlying the repository is uncertain, but many other hydrologic parameters such as recharge and the change in recharge due to climatic changes have not been determined. These parameters are needed as inputs for the performance assessment modeling.

From five sites around WIPP we have collected soil core samples to determine the recharge rate. The core was taken in increments of 5 to 10 cm and immediately sealed in tight jars. In the laboratory the soil water was distilled from the soil and collected for isotopic analysis. The residual soil was leached to determine the amount of chloride. The first technique which we have used to calculate recharge is a mass balance approach based on soil chloride and soil water contents. The resulting recharge rates range from .23 mm/year up to 1.98 mm/year. The relative values of recharge vary with the geomorphology of the sampling. The lowest recharge rate is from the crest of a sand dune, intermediate values for flat areas and the highest rate is from a topographic depression. The accumulation of chloride in the soil column can also be used to determine the age of the water as it infiltrates the vadose zone. In the deepest hole sampled, soil water at 4.5 meters was close to 600 years old.

Recharge will also be calculated using stable isotope techniques. We have finished the oxygen isotope analysis of the soil water but the hydrogen isotopic composition will not be available until next year. The oxygen isotope valves of the water infiltrating through the vadose zone can also be compared with the water in the shallow aquifers. Our steady-state isotopic valves range from $\delta^{18}O$ = -1.4% to -2.9%. These values fall within the range of those shown by Lambert and Harvey to be waters from recent recharge.

LABORATORY VALIDATION OF NEW MATHEMATICAL MODELS OF GROUNDWATER POLLUTION TRANSPORT PHENOMENA

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ABSTRACT

Many hazardous waste sites, oil field produced water pits, petrochemical industry facilities and leaking underground storage tanks involve groundwater contaminated by hydrocarbons, solvents and other non-aqueous phase organic liquids. These organic liquids migrate through the soil and groundwater, leaving behind a residual trapped by capillary forces in the pore matrix. The organic liquid dissolves into the aqueous phase contaminating groundwater supplies, and volatilizes into the air phase. Site characterization and remediation efforts are often based on mathematical models of these multiphase flow and transport processes. The models incorporate porous media continuum concepts and other important assumptions and are often poorly validated by experimental and theoretical work.

The late 1980's there were rapid advances with two non-continuum mathematical modeling approaches for porous media: percolation networks (PN) and cellular automata (CA). These advances provide fundamental theoretical approaches to fluid flow and pollutant transport. From these advances we are gaining a better understanding of behavior, an ability to test many of assumptions incorporated in conventional continuum models, and the insight to improve these conventional tools. However, the new non-continuum approaches are themselves largely unvalidated by experimental work. This project employs etched glass micromodels to experimentally validate PN and CA mathematical models, by making observations at both pore network and pore body scales. The models are validated for selected single and multiphase flow and transport processes, and applied to the study of particular phenomena of interest in aquifer contamination characterization and remediation.

These immediate results will lead to improved continuum level models, to be used for hazardous waste site characterization and remediation. The anticipated improvements in understanding and

capabilities will undoubtedly suggest new remediation design and operation alternatives. The experiments simulating two and three-phase PN models has already pointed out several shortcomings of PN, which are now being addressed. Among these is the importance of wetting phase wedge flows. The CA related experiments have revealed several experimental design flaws which also being addressed. For etched glass micromodels these include sagging pore body 'ceilings', while for large Lucite models there are capillary instabilities due to model imperfections. The CA experiments are currently aimed at validating continuum transport model mixing rules for pore bodies, using colloid particles as tracers.

CONDITIONAL SIMULATION APPLIED TO CONTAMINANT FLOW MODELING

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ABSTRACT

Models for joint conditioning in stochastic flow analysis are presented in this paper. Conditioning of the flow model on both head and transmissivity data are presented for steady state two-dimensional flow.

The model assumes linearization and conditioning is carried out in the spectral domain. A Fast Fourier Transform Spectral approach is used to carry out the simulations and a discussion of that procedure is included. The model developed allows incorporation of measurement errors in addition to the presumed stochastic behavior.

The model was applied to generated fields where the flow equation was solved without linearization using a multi-grid procedure. The effect of conditioning on predictions of travel times are presented and the combined linearized and conditioned models are compared with the non-linearized solution.

To get good agreement of the linearized conditioned model with the non-linear model one needs approximately one point per correlation length. However, travel time variances are considerably reduced even for a modest number of observations.

EVALUATION OF UNSATURATED ZONE CONTAMINANT TRANSPORT MODELS FOR WASTE MANAGEMENT

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ABSTRACT

A simple volume-balance water transport, mixing cell solute transport model was compared to the advection dispersion equation for solute transport and the solution of the Richards' equation for water transport to determine under which conditions the simpler model could be used. When the mixing cell model is parameterized correctly resulting in the proper velocity of water flow through the mixing cell, it calculates solute dispersion identical to the analytical solution of the advection dispersion equation. However, as water increment amounts exceed the cell size, the mixing cell model deviates from the advection dispersion equation and then the process is approximate by assuming piston flow.

The water velocity in the mixing cell model is calculated using an empirical SCS infiltration function. When this equation is parameterized using a finite-difference solution to the Richards' equation then it describes very closely the water velocity and infiltration function predicted by the Richards' equation. Water re-distribution with depth calculated by the Richards' equation after 24 hour is also the same as that calculated by the volume-balance method. If the simple and complex models are not parameterized using equations that interrelate the two methods then the expected results of water and solute transport as predicted by the two models will not be the same. If the two model are parameterized the same results are similar.

EFFICIENT ALGORITHMS FOR MODELING THE WIPP SITE

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ABSTRACT

There are many important physical systems that can be modeled using differential equations with discontinuous coefficients, in particular, porous media flow and heat transfer in composite materials problems. The coefficients in the diffusion term in the partial differential equation for the pressure in a porous-media flow make up the conductivity matrix or tensor. This matrix has large entries when it is easy for the liquid to flow through the material, and has small entries when it is difficult for the liquid to flow through the material. In ground-water modeling and reservoir simulation, this coefficient changes abruptly when the geology that determines the flow changes. The distances over which the changes occur are so small that it is frequently reasonable to model the coefficient as discontinuous. Similar problems occur in heat transfer problems in layered media where the conductivity matrix is discontinuous between materials. If such problems are approximated numerically, then the usual analysis of accuracy fails because of the discontinuous coefficients. The present work provides an alternative analytic analysis of the error for certain critical model problems involving one-dimensional steady-state flow. This analytic technique and numerical experiments are used to compare seven numerical methods, five finite difference methods: Linear Average; Harmonic Average; Geometric Average; Mixed; and Rose; and two finite element methods: Galerkin; and Mixed. The work on higher-dimensional flows is in progress.

Two different models of material interfaces are considered. In the first model, it is assumed that the position of the interface is known with a precision that is significant relative to the grid spacing in the discretization, while in the second, it is assumed that the position of the interface is only known to be some place in a given computational cell. In the first situation, several methods produce the exact analytic answer for the model problem and the error in the methods behaves smoothly with small errors in the position of the interface. In the second situation, most methods produce the same error and thus the simplest methods are the best.

MOBILITY OF RADIOACTIVE COLLOIDAL PARTICLES IN GROUNDWATER

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ABSTRACT

Radiocolloids are a major factor in the rapid migration of radioactive waste in groundwater. At two Los Alamos National Laboratory sites, researchers have shown that groundwater colloidal particles were responsible for the rapid transport of radioactive waste material in groundwater. Similar reports of facilitated plutonium transport by colloids has been reported for several other DOE facilities, e.g., INTEL, NTS, and Maxey Flats. On an international scale, a review of reported field observations, laboratory column studies, and carefully collected field samples provide compelling evidence that colloidal particles enhance both radioactive and toxic waste migration. In this 34 month project, a team of researchers, scientists, and engineers (from UNM, NMSU, LANL, EPA and industry) are addressing the problem of colloid contaminant migration in groundwater. The objective is to understand and predict colloid-contaminant migration through fundamental mathematical models, water sampling, and laboratory experiments. Using this information, the team will develop an effective and scientifically based colloid immobilization strategy. The research is focusing on solving the radiocolloid transport problems at LANL's Mortandad Canyon site.

Results from this study are providing a fundamental understanding and predictive capability of contaminated colloid migration in groundwater. Using this information we are developing an effective and scientifically based colloid immobilization strategy and technology; thus providing DOE a solution to key environmental problem which is very important to New Mexico and to potentially other DOE facilities. To date we have established a state of the art radiocolloid characterization laboratory. Researchers at NMSU have completed preliminary numerical simulations of the groundwater and contaminant transport for Mortandad Canyon.

Findings confirm that unusual and facilitated transport of plutonium and other radionuclides is occurring. Laboratory experiments using natural groundwater colloids from Mortandad Canyon, show that these colloids are easily flocculated and removed from the groundwater using a standard cationic polyelectrolyte. Column studies are used to simulate and test the polyelectrolyte type colloid remediation concept. Column tests using commercial latex microspheres have shown that the polyelectrolyte induced flocculation can be adversely affected by artificially introduced surfactants that are contained in the commercial latex colloid samples. Surfactant free latex colloids will be investigated in the current Phase III of the project.

NUCLEAR WASTE STORAGE VAULT CLOSURE DETERMINATION

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ABSTRACT

Nuclear waste storage vaults, carved from bedded salt, close in on themselves, eventually encapsulating waste placed therein. This process requires an unknown amount of time. Also unknown is the extent to which temperature variations, moisture or faults evident in the walls, will affect the waste barrels or their contents. This is principle among the objections to opening the DOE's Waste Isolation Pilot Project (WIPP) in Carlsbad, NM. Critics cite the recent rockfall events, when slabs of salt rock released suddenly from vault ceilings, as evidence of poor mining practice. Rockfall is part of the waste encapsulation mechanism, which the present research aims to characterize. In particular, a comprehensive mathematical model and computer algorithm is being developed to predict the action of the encapsulating mechanism.

One important difficulty in the larger problem has been the inability to make precise experimental measurements of *whole-field* displacements or strain-rates in existing vaults. Such measurements are needed to guide the thinking of theoreticians as well as to check the predictions of their models. We have employed an experimental mechanics technique, based in coherent optics, called speckle photography. The method is non-invasive and non-intrusive and yields surface displacement information over arbitrarily short gage lengths.

Engineering analysis, coupled with the experimental program, has, to date, provided some answers to the dynamics of the encapsulating mechanism. In summary, we have demonstrated that accurate predictions of salt behavior are possible. We continue our study of the properties of salt formations, the forces that work in them, and the response of salt in the form of flow dynamics. We have used first principles as well as phenomenological relationships to generate a mathematical model of salt deformation. Now, our goal is to 'tune' the model and to develop the appropriate numerical implementation.

CALIBRATION OF NEAR-FIELD STABILITY INSTRUMENTATION AT THE WASTE ISOLATION PILOT PLANT

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ABSTRACT

Time domain reflectometry (TDR) laboratory experiments have been conducted using cylindrical rock salt cores from the WIPP site. The chief objective in applying TDR techniques to rock mechanics is to quantify the type and magnitude of rock mass deformation. Coaxial TDR cables, grouted in rock salt samples subjected to extension loads, were monitored to record changes in reflected voltage signals during rock deformation. Both foam and air dielectric cables were used in 1/2 and 7/8 inch diameters to evaluate cable and signal performance under tension. Cables were crimped to produce local cable faults and thereby reflection (reference) points in order to track cable displacements. Radial and axial extensometers were used to measure circumferential and vertical rock sample strains. LVDT's were used to determine average total displacement of the sample during testing.

An MTS servo-controlled hydraulic testing and data acquisition system was used to control stroke (displacement) during extension tests and capture instrumentation data. Cable deformation data was captured and stored using a Tektronix cable tester and computer serial interface. Reflected wave forms of voltage pulses were digitized and analyzed with regard to changes in characteristic shapes and rock deformations in extension. Evaluation of changes in wave form characteristics shows a good correlation of cable deformation rate to rock mass movement in extension. This was evident from changes in crimp separation distance and to a limited extent, wave form amplitudes. Preliminary analysis for the air dielectric coaxial cables showed that a rock deformation range of 0.07 to 0.15 inches in extension corresponded to a 1% change between two crimp separation distances as detected on the cable tester. At cable failure, a range of 0.03 to 0.05 inch rock deformation per 1% crimp separation was recorded. The air dielectric cables produced consistent results with little or no cable-grout interface slippage.

DEFORMATION MECHANISMS OF WIPP BACKFILL

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ABSTRACT

A fundamental understanding of the deformation mechanisms of backfill is crucial in predicting the long-term creep performance of salt-based radioactive waste repository. It is desirable to have the salt consolidate and become impermeable as rapidly as possible. But, an unacceptably long time is required for dry crushed rock salt to attain the low porosity necessary for the backfill to have the permeability approaching that of the surrounding natural formation. However, natural rock salt always contains some brine (0.1 to 1.0% by weight). This small amount of brine will "weaken" the grain boundary of rock salt and consequently accelerate the consolidation rate under low stress conditions.

Water was found to have a significant influence on the consolidation rate of WIPP crushed rock salt. The results of consolidation tests and SEM (Scanning Electron Microscope) observations show that an optimum value of water content exists (under certain pressure, temperature, consolidation time, gradation, etc) for which the crushed rock salt has the fastest consolidation rate.

Four groups of consolidation tests of WIPP crushed rock salt were conducted under different conditions with water content varying from 0.12% to 5.00%. Two of the four groups, with particle sizes uniformly distributed between the fines (0.075 mm) and an upper limit of 10 mm, were performed using floating ring consolidometers, under pressure and temperature of 1 MPa and 20 °C, 3 MPa and 25 °C, respectively. The other two groups with a 0.15 mm upper limit of particle size were consolidated using a pelletizer, under 20 MPa and 20 °C, 69 MPa and 30 °C, respectively.

The results of the consolidation tests show that water could accelerate the consolidation rate of the crushed rock salt under low stress conditions, if the water content is sufficient. Furthermore, the effect of water is influenced by consolidation pressure, time and particle gradation. High pressure and small particle size increase the optimum value of water content. On the other hand, the optimum value of water content shifts slowly to smaller values as the consolidation time elapses.

From SEM micrographs of the consolidated specimens, it is shown that the water content affects interparticle contact, void and porosity. High pressure and long consolidation time make the grain size increase. Solution transfer, diffusion and recrystalization seem to be important mechanisms contributed to the densification of the crushed rock salt. In addition, TEM (Transmission Electron Microscope) observations show that the crystal structure of wet WIPP crushed rock salt remains unchanged after consolidated, in comparison to the original sample. Finally, a consolidation model of WIPP crushed rock salt is under developed. X-ray techniques and ESEM (Environmental Scanning Electron Microscope) are employed for further research works.

PERFORMANCE OF ROCK REINFORCEMENT SYSTEMS AT ELEVATED TEMPERATURE

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ABSTRACT

The Department of Energy began work on siting, designing, and considering for the operation of geologic repositories for disposal of spent nuclear fuel as far back as the early 1970's. One of the concerns was the effects of heat generated by the high level waste on the repository substructure. The over 200°C temperature, such as that anticipated at the Yucca Mountain Project site, may cause adverse stress changes in the rock mass and also in the rock reinforcing systems. The results of a study performed to estimated the damage zone around an underground opening excavated by the smooth-blasting technique, and also the effects of elevated temperature on the mechanical rock bolting system are reported here. Excavation by blasting is considered here because it may be an easier method but at the same time may cause the most damage. A three dimensional elastic wave propagation code (GDBSWC) was developed by New Mexico Tech for this purpose of determining blast damage. A finite-element code, GEOT2D, which was developed at the University of New Mexico was enhanced to simulate pre-stressing in rock-bolts. It was then used to determine the effectiveness of a mechanical rock bolt installed through this damaged zone and also the undamaged zone. A temperature change of 300°C was also simulated. The damage zone around the underground opening excavated by the smooth-blasting technique was found to be between 0.45 m (1.5 ft) to 2 m (6.5 ft) depending on different firing patterns, blast-hole size and explosives used. Results of the finite element analysis suggested that for a 0.6 m (2 ft) to 1.2 m (4 ft) damage layer thickness, the effective zone of influence of the rock bolt is about 2.5 m (8.2 ft) to 1.75 m (5.75 ft) away from the rock bolt. However, that temperature increase of 300°C was found to more than release the 10,000 lb prestress applied to the rock bolt at the time of installation. At this point the rock bolt became totally ineffective.

NUCLEAR WASTE REPOSITORY VENTILATION SYSTEM STUDIES

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ABSTRACT

The ventilation studies of the Waste Isolation Pilot Plant described in this report were performed by personnel from New Mexico State University in collaboration with Sandia National Laboratories, Los Alamos National Laboratory and Westinghouse Corporation. The following research tasks were performed. High efficiency particulate air filters of the type in use at the Waste Isolation Pilot Plant were loaded with salt aerosol provided from that site. The structural strength of salt loaded high efficiency filters was investigated by subjecting the filters to pressure transients of the types expected from fires, explosions and tornadoes for two humidity levels, high (73%RH) and low (13-14%RH). Filters loaded under the high humidity condition proved to have a greater structural strength than did the filters loaded under the low humidity conditions, when both types were subjected to tornado-like pressure pulses. A filter pre-conditioned with a 100%RH airflow for 4 hours prior to structural testing prove weakest of all. CALAMITY, a transient computer code, was developed at NMSU especially for simulation of the WIPP site ventilation systems for eventual use as part of a model-based control of the ventilation systems. It was shown to very closely predict the steady state operation of the underground portion of the current WIPP ventilation system.

CHARGED AEROSOL SCRUBBER FOR AIR PURIFICATION

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ABSTRACT

The critical waste management problem to be addressed by this project is air pollution caused by industry and automobiles. Acid rain has become not just a local problem, but an international problem. For example, a good deal of Canada's acid rain is generated in the United States. In Europe, where a comparable industrial base is contained within a much smaller land area, air pollution is causing forests to die all over the continent. But air pollution form industrial smoke stacks and automobile exhausts affect the health of people as well as trees, lakes and animals. The problem continues to become worse and solutions are sorely needed.

The purpose of this project is to design and develop a new type of scrubber which would help to solve the air pollution problem. The design, which is based upon a method for creating sub-micron charged liquid aerosol, should result in a highly compact and efficient scrubber.

In 1992, the specific task will be to fabricate and field test two prototype charged aerosol scrubbers.

ASSESSING RISK COSTS OF RAM TRANSPORT: A JOINT PROJECT OF THE UNIVERSITY OF NEW MEXICO AND NEW MEXICO STATE UNIVERSITY

Principal Investigator:

Tom McGuckin
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Co-Principal Investigators:

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Co-Principal Investigators:

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ABSTRACT

A perceived and therefore real cost borne by communities along transportation routes or near disposal sites is the risk of radioactive release. For realistic and legitimate cost estimates, it is crucial that monetary value of reducing the perceived risk on affected individuals be measured. With such monetary measures of changes of perceived risk, the benefits of alternative routes can be directly compared to construction and operating costs. The problem, however, is that the present state of the art for estimating values for non-market goods is inadequate for valuing the risk-cost of nuclear waste. The research in the previous two phases developed a new concept with regard to the quantification (valuation) of the difficult public choices inherent with nuclear waste. The concept consists of two simultaneous but complimentary approaches: (1) a contingent valuation method (CVM) that samples a broad representation of New Mexicans' preferences concerning nuclear waste issues; and (2) an experimental inference procedure (EIP) that has direct monetary incentives for the respondents to accurately reveal preferences.

The complimentary approach of CVM and EIP must be shown to eliminate three major measurement biases in the elisticitation of monetary values; (1) separability bias, (2) the difference between estimates of willingness to pay (WTP) and estimates of willingness to accept (WTA) and (3) incentive bias. These issues are briefly described. The goal of this research, third phase, is to develop credible and professionally accepted methods for valuing risk costs associated with transportation of hazardous materials, in general, and nuclear-related activities in particular. The third phase of this research has the objective of developing the CVM/EIP procedure to the point that it can be demonstrated that the simultaneous approach significantly reduces or eliminates separability, incentive and WTA/WTP biases.

Result 1: Demonstrate that a suitable design of the CVM/EIP procedure can systematically eliminate the three sources of bias encountered in estimating monetary values of nuclear waste transportation. If the CVM/EIP procedure can separate nuclear waste transportation issues from other nuclear or environmental issues, DOE can then specifically weigh the benefits of routes, bypasses and other transportation measures against their respective costs.

Result 2: Demonstrate that willingness to pay measures derived using CVM/EIP can be used to obtain accurate willingness to accept valuation. This will assist DOE in a critical question in negotiations with New Mexico concerning transportation routes; the extent that risk/cost values differs depending on what is assumed about state rights vis-a-vis federal domain.

UNDERSTANDING CHANGE IN PUBLIC PERCEPTIONS OF NUCLEAR WASTE

Principal Investigator:

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Collaborator:

Leo Gomez
Sandia National Laboratories

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Georgia Institute of Technology

ABSTRACT

The current WERC project has collected national base-line data on risk perceptions in the form of a random survey of American households; the second national survey in the series (funded through our existing WERC grant) will be administered in December, 1991. The base-line data have made possible the test of numerous hypotheses about the nature and origin of nuclear risk perceptions; the time series will allow analysis of the factors that lead to change in perceived risks over time. The funding requested here will permit collection of random national samples in June and December of 1992 and 1993, thereby extending the time-series dataset to six samples taken over six-month intervals. Despite the importance of understanding the evolution of popular perceptions of critical policies to manage nuclear wastes, no comparable time-series dataset exists anywhere in the United States.

The fundamental problems addressed by this research are the substantial difficulties encountered in attempts to develop and implement acceptable nuclear waste management policies. As recently described by two eminent scholars of risk perceptions, "officials and experts from DOE and the nuclear industry are profoundly puzzled, frustrated, and disturbed by the public and political opposition that they believe is based on irrationality and ignorance" (Slovic, Layman, and Flynn, 1991). Far too little is understood about the patterns of, and reasons behind, public reactions to federal policies designed to safely manage nuclear wastes. In our ignorance -- and despite the expenditure of many billions of dollars -- our efforts to persuade the public or to override public objections may substantially worsen the problem both now and in the future.

Our proposal is designed to increase our understanding of public perceptions of nuclear risk and of trust in those charged with implementing nuclear waste management policies. In particular, our focus on patterns of change in perceived risk and trust over time is intended to provide a basis for improved risk communication and policy planning in the future.

Several specific aspects of the proposal will generate concrete benefits for those charged with developing and implementing nuclear waste policies. First, we will analyze the characteristics of support and opposition to nuclear waste management policies: how widespread is opposition to these policies? What percentage of those opposed are firmly committed to that opposition, and why? To what degree does opposition represent "spill-over" from other policy concerns, such as opposition to development of nuclear weapons, rather than perceived risks? Second, we will examine in considerable detail to origins of perceived risks of nuclear waste management. Does "knowledge" about radiation and technology influence risk perception"? If so, in what ways? To what degree does perceived risk emanate from the level of trust accorded the primary organizations charged with implementing nuclear waste management policy? To what degree does exposure to the various news media influence perceived risk; do specific kinds of media programming convey specific messages about those risks? Finally -- and most importantly -- we will track changes in each of these areas over time. Is perceived risk (and therefore

opposition to nuclear waste management policies) growing, holding steady, or diminishing over time? Once the time-series is of sufficient length, we will be able to analyze the degree to which perception of risk responds to specific events (e.g., events like Chernobyl or the FBI investigation of the Rocky Flats weapons facility).

Understanding the nature of risk perception will allow the organizations charged with formulation and implementation of nuclear waste policies to assess the political feasibility of prospective nuclear waste management policies before they become committed to those policies; it will permit informed assessment of the degree of support and opposition to existing policies (does vocal opposition represent a small group or is it reflective of the broader population?); it will provide information relevant to educational policies that may affect risk perception; and it will allow planning for nuclear waste management in a manner that accounts for current and evolving public perceptions of the risks of nuclear waste policies.

PUBLIC ATTITUDES TOWARD WIPP

Principal Investigator:

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Collaborators:

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ABSTRACT

Public attitudes towards the handling and management of radioactive and hazardous waste generally range from mildly indifferent to rabid opposition. This proposal hypothesizes that it is possible to modify public opinions towards waste management problems and to reduce opposition by presenting critical facts in an objective and non-biased manner. Identification of these critical facts and development of effective methods of presentation are the keystone of this project. As an example, facts detailing the number of barrels transported to WIPP do not seem to have any influence on attitude towards WIPP. However the discussion of the type and amount of radioactive material in the barrels to be transported to WIPP does appear to affect attitudes.

Results from this study will identify those areas of waste or transportational management which are of most important concern to the public and ways and techniques in which facts dealing with these concerns can be presented to the public and, perhaps just as importantly; ways in which they should not be presented to the public. Our goal is to use short T.V. spot presentations to present the information. Long term goals will be to develop 30 second spot T.V. announcements which could be presented on over the air or cable T.V. to a large population of the state.

APPENDIX L

LIST OF MAJOR PUBLICATIONS RESULTING FROM WERC

WERC GENERATED DOCUMENTS AND PRESENTATIONS 12/17/92

1. Angel, E., "User Interfaces and Tele-robots", Technical University of Graz, Graz, Austria, May, 1991.

2. Angel, E., "User interface Tools for Tele-robotic Systems for Handling Hazardous Waste", AI '91, Frontiers in Innovative Computing for the Nuclear Industry, September 1991.

3. Angel, E., "User Interface Tools for Tele-Robots", Visualization Seminar, Computer Science Department, University of Colorado at Boulder, February, 1992.

4. Bandy, D., Bhada, R., Bickel, J., & Morgan, J. D., "The Achievements of a University-National Laboratory Waste-management Education & Research Consortium", WM'91, Tucson, Arizona, February, 1991.

5. Bhada, R., Jacquez, R., Matthews, L., Morgan, D. J., "A Consortium To Address Multidisciplinary Issues of Waste Management", 1st Encuentro Interamericano Sobre Educacion en Ingenieria, June 28, 1991.

6. Bhada, R., Morgan, J. D., "The Achievements of a University-National Lab Waste-Management Education & Research Consortium (WERC)", Annual Meeting of the AIChE, November 16, 1991.

7. Bhada, R. K., "Centrifugal Film Reactor", AIChE National Meeting, Houston, TX, April 1989.

8. Bhada, R. K., "Waste Education & Research Consortium", New Mexico Environmental Forum, Las Cruces, NM, January, 1990.

9. Bhada, R. K., "Multi Disciplinary Issues of Waste Management", ASEE SW Annual Conference Proceedings, pp. 140-147, March 1990.

10. Bhada, R. K., "Opportunities for Minorities in Waste Management", Navajo Community College Forum, Shiprock, NM, March 1990.

11. Bhada, R. K., "Community Involvement in Environment Education and Technology Transfer", New Mexico City Management Conference, Ruidoso, NM, April 1990.

12. Bhada, R. K., "Progress of the University Consortium", Rio Grande Section of AIChE, Las Cruces, NM, April 1990.

13. Bhada, R. K., "The New Mexico Waste Management Consortium", Weapons Complex Monitor, Phoenix, AZ, April 1990.

14. Bhada, R. K., "Waste Management Problems and Opportunities", New Mexico Hispanic Leadership Program, Las Cruces, NM, April 1990.

15. Bhada, R. K., "Waste Management Education and Research", Rio Grande Section of ASCE, Albuquerque, NM, May 1990.

16. Bhada, R. K., "A Consortium to Address Multidisciplinary Issues of Waste Management", Chemical Engineering Education Journal, pp. 180-183, Fall 1990.

17. Bhada, R. K., "A Multidisciplinary Approach to Education & Research in Environment", AIChE National Meeting, Chicago, IL, p. 246e, November 1990.

18. Bhada, R. K., "Opportunities in Environmental Management", 8th Annual Science, Space & Technology Career Expo, Albuquerque, NM, p. 4, April 1991.

19. Bhada, R. K., "New Mexico's Waste Management Consortium", Rotary Club, Albuquerque, NM, June 1991.

20. Bhada, R. K., "New Mexico's Waste Management Consortium", KBIM TV, Roswell, June 1991.

21. Bhada, R. K., "New Mexico Horizons", KDBC TV, El Paso, TX, June 1991.

22. Bhada, R. K., "Foresight", HBCE/MI Meeting, Jackson, MS, June 1991.

23. Bhada, R., Jacquez, R., Kauffman, D., Morgan, J. D., "Lets Move Towards Multi-Disciplinary, Multi-Organizational Education", American Society for Engineering Education Gulf-Southwest Section Annual Meeting, March 15-17, 1992, Albuquerque, NM.

24. Bhada, R. K., Bickel, J., Bandy, D., Morgan, J. D., "A DOE-University-National Lab Waste-Management Education & Research Consortium (WERC), Status in the Second Year", Environmental Remediation '91, September 8-11, 1991, Pasco, WA.

25. Bhada, R. K., Morgan, J. D. Ghassemi, Abbas, "A National Environmental Design Contest Capstone Course for Universities", Waste Management '92, March 1-5, 1992, The University of Arizona, Tucson, AZ.

26. Bhada, R. K., "The New Mexico Waste Education & Research Consortium (WERC)", Waste Management & Cleanup Conference, Phoenix, AZ, April 17.

27. Brookins, D. G., (accepted), "Use of Eh-pH Diagrams to Address the Problem of Contaminant Migration/Retention in Uranium Mill Tailings Impoundments", Cd, Hg, Pb, Sb, As: Hazardous Waste Society of N.M. annual meeting (March 1991).

28. Brookins, D. G., and Persico, J. L., (accepted), "Behavior of Trace Elements in the Poison Canyon Mine Tailing Site, near Grants, New Mexico", Hazardous Waste Soc. N.M. ann. meeting (March 1991).

29. Burness, H. S., Cummings, Harrison, G. W., "Valuing Environmental Goods: A critical Appraisal of the State of the Art", April 1990, Issues in the Economics and Management of Agricultural Drainage Water.

30. Callan, Connie, "Using Video Conferences for Professional Technical Training & Technology Transfer", 2nd Annual IDLCON, April 23-25, 1992.

31. Callan, Connie, "Using Video Conferences for Professional Technical Training & Technology Transfer", Environmental & Occupational/Public Health Standards Steering Group, Denver, Colorado, July 30-31, 1992.

32. Callan, Connie, "Using Video Conferences for Professional Technical Training & Technology Transfer", Risk Assessment Methodology Workshop, September 28-30, 1992.

33. Callan, Connie, "Using Video Conferences for Professional Technical Training & Technology Transfer", American Society for Training & Development ASTD, Detroit, Michigan, October 14-16, 1992.

34. Callan, Connie, "Using Video Conferences for Professional Technical Training & Technology Transfer", Telecon XII Conference, October 26-28, 1992.

35. Colbaugh, R., & Jamshidi, R., "Robot Manipulator Control for Hazardous Waste Handling Applications", invited paper to special issue on Robots in Unstructured Environments in the Journal of Robotic Systems, Vol. 8, 1991.

36. Colbaugh, R., Seraji, H., & Glass, K., "Adaptive Impedance Control of Redundant Manipulators", Proc. 29th IEEE Conference on Decision and Control, December 5 - 7, 1990, Honolulu, Hawaii.

37. Colbaugh, R., Glass, K., & Hensel, E., "Hierarchical Control of Manipulators Operating in Hazardous and Unstructured Environments", Proc. American Nuclear Society 4th Topical Meeting on Robotics and Remote Systems, February 24-28, 1991, Albuquerque, NM.

38. Colbaugh, R., Glass, K., Hensel, E., "Hierarchical Control of Manipulators Operating in Hazardous and Unstructured Environments", Fourth AND Topical Meeting on Robotics and Remote Systems, pg. 251-257.

39. Colbaugh, R., Glass, K., "On Controlling Robots with Redundancy", Robotics & Computer-Integrated Manufacturing, Vol. 9, No. 2, pp. 00-00, 1992.

40. Colbaugh, R., Glass, K., "On Controlling Robots with Redundancy", 1991 American Control Conference, June 26-28, 1991, Boston, Massachusetts, pg. 2059-2061.

41. Colbaugh, R., Glass, K., Jamshidi, M., "Impedance Control for Hazardous Waste Handling Applications", 30th Conference on Decision and Control, Brighton, England, December 1991, pg. 684-691.

42. Colbaugh, R., Glass, K., Jamshidi, M., "Direct Adaptive Impedance Control of Manipulators", 30th Conference on Decision and Control, Brighton, England, December 1991, pg. 2410-2415.

43. Colbaugh, R., Glass, K., Seraji, H., "An Adaptive Inverse Kinematics Algorithm for Robot Manipulators", International Journal of Modelling & Simulation, Vol. 11, No. 2, 1991, pg. 33-38.

44. Colbaugh, R., Glass, K., "A unified Approach to Controlling Robots with Redundancy", International Journal of Robotics and Automation, Vol. 6, No. 2, 1991, pg. 95-104.

45. Colbaugh, R., Jamshidi, M., "Robot Manipulator Control for Hazardous Waste-Handling Applications", Journal of Robotic Systems 2-9136-Art. 492 Denny 12/5/91, pg. 01-036.

46. Conley, E., Genin, J., "Nuclear Waste Burial Repositories: Analysis and Experiment", Radiological and Mixed Waste, pg. 81-83.

47. Conley, Ed, Genin, J., "Nuclear Waste Vault Closure Analysis", Sixth Annual Hazardous Waste Management Conference, Manhattan, Kansas, May 29-30, 1991.

48. Conley, E., Cloud, G., "Resolution experiments using the white light speckle method", Applied Optics, March 1991, Vol. 30, No. 7, pp. 795-800.

49. Fekete, F. A., Nuttal, H. E., Jain, R., "Production and Partial Characterization of Selenium Colloids", 65th Colloid and Surface Science Symposium, June 17-19, 1991, University of Oklahoma.

50. Fekete, F. A., Barton, L. L., "Effects of iron(III) analogs on growth and pseudobactin synthesis in a chromium-tolerant *Pseudomonas* isolate", Biology of Metals, 1991, pg. 211-216.

51. Fertelli, Y. M., "Colloid Transport in Groundwater Flow Through Saturated and Unsaturated Fractures", Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering, The University of New Mexico, Albuquerque, New Mexico, December 1990.

52. Ghassemi, A., "Mathematical Models and Experimental Studies of Two Phase Flow Correlations Using Differentiation Measurements", American Association for the Advancement of Science (AAAS), Southwestern and Rocky Mountain Division, 68th Annual Meeting, May 17-21, 1992, Tucson, Arizona.

53. Ghassemi, A., Bhada, R. K., Morgan, J. D., "A National Environmental Design Contest" AAAS, Southwestern and Rocky Mountain Division, 68th Annual Meeting, May 17-21, 1992, Tucson, Arizona.

54. Ghassemi, A., Bhada, R. K., Morgan, J. D., "A National Environmental Design Contest - 1992 Focus" American Society of Engineering Educators (ASEE) Annual Meeting, June 21-25, 1992, Toledo Ohio.

55. Ghassemi, A., Bhada, R. K., "An Environmental Design Contest and Capstone Course", 24th Mid-Atlantic Industrial and Hazardous Waste Conference, July 14-17, 1992, Morgantown, West Virginia.

56. Gomez, L., Jenkins-Smith, H., Miller, K., "Changes in Risk Perception Over Time", American Association for Advancement of Science, February 6-11, Chicago, IL.

57. Groffman, A. R., Brookins, D. G., and peterson, S. A., (accepted), "The Removal of Lead, Cadmium, Heavy Metals and Trace Elements from Waste Water Streams using Zeolites, Zeocarb and Other Natural Materials as a Sorption Medium", Hazardous Waste Society N. M. annual meeting (March 1991).

58. Hanson, A. T., Samani, Z., Dwyer, B., Jacquez, R. B., "Heap Leaching as a Solvent Extraction Technique for Remediation of Metal Contaminated Soils", chapter 8, Colloidal, Interface, and Surfactant Phenomena in Subsurface Contaminant Transport and Remediation, American Chemical Society Symposium Series, American Chemical Society (1992).

59. Hunter, Thomas O., "Sharing the Wealth, Consortium combines Laboratory and University Resources", Energy and Environment, a Sandia Technology Bulletin, November 1992, page 6.

60. Jain, R., & Nuttall, H. E., "CTC-Colloid Transport Code & Simulations", Manteo III, Concepts in Manipulating Groundwater Colloids for Environmental Restoration, DOE Sponsored, Manteo, North Carolina, October 15 - 18, 1990.

61. Jacquez, R. B., El-Rayes, H., "Biochemical Control of Sulfide Production in Wastewater Collection Systems", proceedings of the ASCE National Conference on Environmental Engineering, Baltimore, MD, August 1992.

62. Jenkins-Smith, H., Rouse, A., "Subjective Knowledge, Its Origins and Relationship to Perceptions of Risk", American Association for Advancement of Science, February 6-11, Chicago, IL.

63. Jenkins-Smith, H., Smith, W., "Ideology, Culture and Risk Perception", American Association for Advancement of Science, February 6-11, Chicago, IL.

64. Kauffman, D., "A comprehensive Plan for Continuing Education in Hazardous Waste M Management", ACHEMA-91 Meeting, Frankfurt, Germany, Summer 1991.

65. Kirby, J. F., "Remediation of Lead-Contaminated Soils by Heap Leaching", a thesis submitted to the Graduate School in partial fulfillment of the requirements for the degree Master of Science in Civil Engineering, New Mexico State University, Las Cruces, New Mexico, December 1992.

66. Longmire, P. A., Brookins, D. G., Thomson, B. M., and Eller, P. G., 1990, "Hydrogeochemical Investigations at a Uranium Mill Tailings Site, Maybell, Colorado", Geol. Soc. Amer. Abs. w. Programs, v. 21, n. 7, p, A 160. This paper was presented by Brookins at the 1990 annual meeting of the Geological Society of America in Dallas, TX, Oct. 30, 1990.

67. Longmire, P. A., Brookins, D. G., Thomson, B. M., and Eller, P. G., 1990 in press, "Application of Sphagnum Peat for Immobilizing Radioactive and Hazardous Contaminants in the Subsurface", Sci. Basis for Nuc. Waste Management Int. Symposium, Program w. Abstracts, 1990 annual eastern meeting of the Materials Research Society. Presented by Brookins on Nov. 27, 1990 in Boston, MA.

68. Longmire, P. A., Brookins, D. G., Thomson, B. M., and Eller, P. G., "Application of Sphagnum Peat for Immobilizing Radioactive and Hazardous Contaminants in the Subsurface", in Scientific Basis for Nuclear Waste Management XIV (T.A. Abranjo and L. A. Johnson, Eds.), in press.

69. Longmire, P. A., Eller, P. G., Brookins, D. G., and Thomson, B. M., 1991 (in press), "Application of Sphagnum Peat for Immobilizing Radioactive and Hazardous Contaminants in the Subsurface", in Waste Management 91 (Tucson, AZ, International Meeting), Abstracts volume.

70. Longmire, P. A., Brookins, D. G., Eller, P. G., and Thomson, B. M., "Application of Sphagnum Peat for Immobilizing Radioactive and Hazardous Contaminants in the Subsurface", Waste Management 91 Proceedings Volume, accepted for inclusion.

71. Longmire, P. A., Eller, P. G., Brookins, D. G., and Thomson, B. M., 1991 in press, Surface chemistry studies of sphagnum peat: molecular mechanisms for removal of radioactive and hazardous contaminants: Geol. Soc. Amer. Rocky Mtn.-South Central Sectional Meeting (Albuquerque, NM; April 22-24, 1991).

72. Maji, A. K., Donald, S. & Cone, K., "Mechanical Properties of Porous and Cellular Materials" Ed: Gibson, Green, Sieradzki; Mrs Publication (1990), Testing of Impact Limiters for Transportation Cask Design.

73. Maji, A. K., Schreyer, H. L., Associate Members ASCE, and Neilsen, M., "Development of a Constitutive Model for Impact Limiters", Proc. of Engineering Mechanics Conference, Columbus, OH, 1991.

74. Maji, A. K., Satpathi, D., & Schreyer, H. L., "Testing of Materials and Scale Models for Impact Limiters", Proc. of International High Level Radioactive Waste Management Conference, at Las Vegas, Nevada, April 28-May 2, 1991. Organized by ASCE and AND.

75. Maji, A. K., and Sahu, R., "Acoustic Emission Monitoring of Reinforced Concrete", to appear in the proceedings of the SEM Spring Conference, Milwaukee, WI, 1991.

76. Majumder, S., Prairie, M., Ondrias, M., Shelnutt, J., "Photocatalytic Degradation of Aromatic Compounds By Porphyrins Adsorbed Onto Al_2O_3 Using Visible Light".

77. Majumder, S., Prairie, M., Ondrias, M., Shelnutt, J., "Enhancement of Solar Photocatalytic Detoxification by Adsorption of Porphyrins onto TiO_2", Detoxification & Bioconversion Session 1992 ASME International Solar Energy Conference, Lahaina, Maui, Hawaii, April 5-9, 1992.

78. Majumder, S., Ondrias, M., Enhancement of Solar Photocatalytic Detoxification by Adsorption of Porphyrins onto TiO_2", presented by SAM at the Student Competition Section of 36th Annual New Mexico Water Conference, Las Cruces, NM, November 7, 1991.

79. Majumder, S., Shelnutt, J., Prairie, M., Ondrias, M., "Enhancement of Solar Photocatalytic Detoxification by Adsorption of Porphyrins onto TiO_2, presented by SAM at the 1991 Waste Management Conference, San Juan, Puerto Rico, April 1991.

80. Martin, F. D., Bretz, R. E., Bowman, R. S., Kieft, T. L., Cadena, F., "The Hobbs Oil & Water Experimental Facility of the Waste-Management Education & Research Consortium", PETRO-SAFE '92 Conference, January 27-29, 1992, Houston, TX.

81. Martinez, B., Jacquez, R. B., Zachritz, W. H., "Development of a Protocol to Evaluate Volatility and Biodegradability Characteristics of Turpene-Based Solvent Substitutes", proceedings of the ASCE National Conference on Environmental Engineering, Baltimore, MD, August 1992.

82. Munson-McGee, Stuart, "Technology for Waste Encapsulation", Superfund Sludge Characterization & Treatment Workshop in Edison, NJ, June 17-19, 1991.

83. Nuttall, H. E., Jain, R., Triay, I. R., "Colloid Remediation in Groundwater by Polyelectrolyte Capture", 65th Colloid and Surface Science Symposium, June 17-19, 1991, University of Oklahoma.

84. Nuttall, H. E., & Jain, R., "Electrokinetic Model for Colloid Transport in Fractures", American Institute of Chemical Engineers, 1990 Annual Meeting, November 11-16, 1990, Chicago, Illinois, Particulate Processes in Porous Media-II(276).

85. Nuttall, H. E., Long, R., Triay, I., "Radiocolloid Migration in Groundwater", 4th Annual Hazardous Waste Management Conference and Exhibition, March 18-21, 1991, Albuquerque, NM.

86. Nuttall, H. E., Jain, R., & Fertelli, Y., "Radiocolloid Transport in Saturated and Unsaturated Fractures", International High Level Radioactive Waste Management Conference, April 28-May 2, 1991, Ceasars Palace, Las Vegas, Nevada, Sponsored by AND DOE.

87. Nuttall, H. E., and Triay, I., "Removal of Actinides from Waste Water by Flocculation", 4th World Congress of Chemical Engineering, June 16-21, Karlsruhe, FEDERAL REPUBLIC OF GERMANY.

88. Nuttall, H. E., Jain, R., & Triay, I. R., "Colloid Remediation in Groundwater by Polyelectrolyte Capture", 65th Colloid and Surface Science Symposium, June 17 - 19, 1991, The University of Oklahoma.

89. One Ph.D. dissertation in progress; one MS thesis in progress (WERC funded).

90. Pratt, D., Jenkins-Smith, H., "The Role of the Media and Information in Fears of Radiation", American Association for Advancement of Science, February 6-11, Chicago, IL.

91. Rao, Sudeep Motupalli, "Groundwater Colloids: Characterization and The Development of a Remediation Strategy", Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering, The University of New Mexico, Albuquerque, New Mexico, December 1992.

92. Rayson, G., Huei-Yang, D., "Investigation of UO^{2+}_2 Binding Sites on *Datura Innoxia* Using UO^{2+}_2 Luminescence".

93. Rayson, G., Huei-Yang, D., "Characterization of Cd Binding Sites on *Datura Innoxia* Using ^{113}Cd NMR Spectrometry".

94. Rayson, G., Huei-Yang, D., Birnbaum, E., Darnall, D., "Characterization of the Carboxyl Groups on *Datura Innoxia* Using EU(III) Luminescence".

95. Rayson, G., Huei-Yang, D., Birnbaum, E., Darnall, D., Jackson, P., "Investigation of Eu(III) Binding Sites on *Datura Innoxia* using Eu(III) Luminescence".

96. Sharp, R., "Preliminary Development of a Method for Correlating the Hydrogenase Activity of Sulfate-Reducing Bacteria to Rates of Microbiologically Induced Corrosion", Thesis, submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, The University of New Mexico, Albuquerque, NM, December 1991.

97. Sharp, R., Ross, T., Barton, L., "Determination of the Rate of Biocorrosion Via Dehydrogenase Activity", R&D 92, National Research & Development Conference on the Control of Hazardous Materials", February 4-6, 1992, San Francisco, CA.

98. Seraji, H., Colbaugh, R., "Singularity-Robustness and Task-Prioritization in Configuration Control of Redundant Robots", 29th Conference on Decision and Control, Honolulu, Hawaii, December 1990, pg. 3089-3095.

99. Seraji, H., Colbaugh, R., "Improved Configuration Control for Redundant Robots", Journal of Robotic Systems 7(6), 897-928 (1990), pg. 898-928.

100. Triay, I. R., Mitchell, A., Thompson, J., & Nuttall, H. E., "Utilization of a Flocculation Technique to Remediate Waters Contaminated with Actinides", Manteo III, Concepts in Manipulating Groundwater Colloids for Environmental Restoration, DOE Sponsored, Manteo, North Carolina, October 15 - 18, 1990.

101. Townsend, J., "Focus on Haz Mat, APU's - A Hazardous Non-Material", *Industrial Fire World*, August-September 1990.

102. Townsend, J., "Fruit Basket Turnover - Almost", Industrial Fire World, Volume 6, Number 5, pg. 18-19, August/September 1991.

103. Townsend, J. S., "Underground Storage Tanks: Rules & Regulations", Industrial Fire World Exposition, April 16-18, 1991.

104. Townsend, J., "Where There's Smoke There's Fire and Vice Versa", Industrial Fire World, December 1991, pg. 10-11 & 24.

105. Townsend, J., "Arsenic and Old Lace", Industrial Fire World, October/November 1991, pg. 10-11.

106. Townsend, J., "The Peroxide Linkage, A Strained Relationship", Industrial Fire World, January/February 1992, Volume 7, #1.

107. Townsend, J., "Chlorosulfonic Acid, A Russian Puzzle", Industrial Fire World, March/April 1992, Volume 7, #2.

108. Townsend, J., "Hazards Are Where You Find Them - And Sometimes Where You Lease Expect Them", Industrial Fire World, May/June 1992, Volume 7, #3.

109. Townsend, J., "Gaseous Alkyl Amines: Another Case of Something Fishy", Industrial Fire World, July/August 1992, Volume 7, #4.

110. Townsend, J., "The Cyanides: A Fatal Attraction", Industrial Fire World, September/October 1992, Volume 7, #5.

111. Townsend, J., "Orphan Wastes, A Whole New Ballgame", Industrial Fire World, September/October 1992, Volume 7, #5.

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APPENDIX M

TYPES OF EQUIPMENT AT WERC LABORATORIES

TYPES OF EQUIPMENT AT WERC LABORATORIES

Flourometer

Constant Pressure Respirometer

Gas Chromatograph/Mass Spectrometers with Accessories including Purge & Trap Concentrator

High Performance Liquid Chromatograph

Liquid Chromatograph - particle beam/mass spectrometer

Inductively Coupled Argon Plasma (ICAP) Spectrometer

Colloidal Particle Counter/Analyzer

Atomic Absorption Spectrophotometers

Fluorescence Detector

Microwave Digestion System

Evaporation Workstation

Silicon Graphics Computational Machine

Ion Chromatograph System

Carbon-Hydrogen-Nitrogen-Sulphur-Oxygen(CHNSO) Analyzer for GC/MS

Fourier-Transform Infra-Red (FTIR) Spectrophotometer

Gas Chromatograph with Nitrogen-Phosphorous Detector (NPD)

Pulsed Neutron Generator System

Safety Equipment

Extractors

Evaporative Concentrators

Centrifuges

Homogenizer

Crusher

Grinder

Incubator with Shaker

Coliform Water Bath

Deionized Water System

Data Acquisition Systems

Drying Oven

Coaxial Detector

Closed Loop Water Circulating System

Fume Hood

Injector Kit

Auto Sampler

Micro-Centrifuge

Orbital Shaker

High Pressure Pumps

Vibration Free Table

Gross Alpha-Beta Counter

Portable Alpha/Gamma Detectors

TLD System

Gas Adapter

Pressure Controller

Two Stage Pressure Regulator

GOW-MAC Gas Leak Detector

Column Leaching System

Harvard 44 Programmable Syringe Pump

Multi-channel Analyzer

Laser Light Source

High Resolution CCD Camcorder with Video Printer

Still Camera and High Resolution Lens System

Metallurgical Microscope with Camera System

WET-Scanning Electron Microscope Upgrade

Portable Environmental Radiation Monitor

Pocket, Self-reading Dosimeters

Low Background Shield and Pop-Top Cryostat for Germanium Detection System

Supercritical Fluid Extraction System

Trailer Mounted Bioreactor

Van from DOE for HOWE Facility

Radon Gas Monitor

Liquid Scintillation Counter

Continuous Centrifuge

Uranium Fluorescence Analyzer

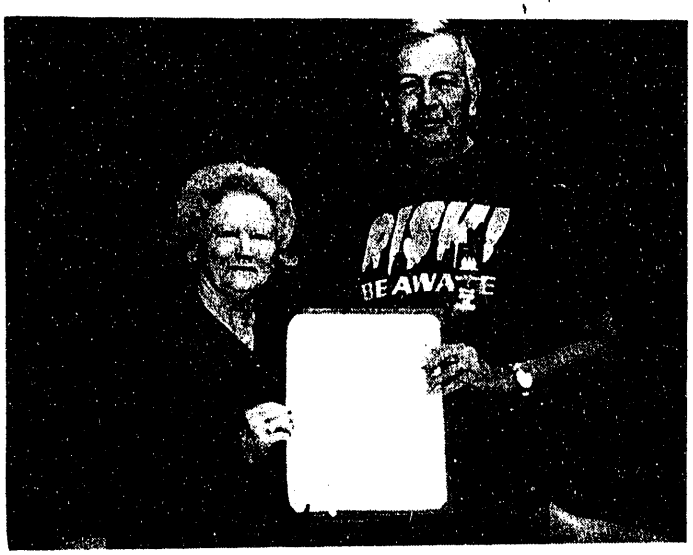
APPENDIX N

WERC NEWSLETTER EXAMPLES

WERCFORCE

Waste-management Education & Research Consortium Newsletter
NMSU * UNM * NMIMT * NCC * Sandia * Los Alamos

December 15, 1992
Volume III, No. 3



First Lady Alice King helps kick off Risk Assessment Week at Albuquerque's Cibola High School.

See story page 6

'ERC CONTINUING EDUCATION SERIES, STUDENTS GAIN NATIONAL HONORS

The WERC Waste Minimization and Pollution Prevention videoconference ries was recognized with a national award by Teleconference Magazine. WERC ɔntinuing Education Coordinator Connie Callan accepted the 1st place award for ERC in the Best Distance Learning Program, 1992 Higher Education Live ogramming category in San Jose, California in October. The eight part series atured professionals from WERC universities and laboratories and professionals ɔm industry and government.

The Waste Minimization and Pollution Prevention Videoconference Series oadcast to 82 sites across the United States and is available on video tape.

WERC students, Kim Dalton, James Markwiese and Karol Holmes received ɔnors in poster competitions at national conferences this year. Dalton is a PhD ndidate in Mechanical Engineering at New Mexico State University (NMSU). ıe received first place for her poster presentation at the Spectrum 92 Nuclear and azardous Waste Management International Meeting in Boise, Idaho in August. ıe American Nuclear Society sponsored conference also gave top honors to the ɔster presentation of James Markwiese. Markwiese is pursuing his MS degree Biology at the University of New Mexico. Karol Holmes, a senior in Chemical ıgineering at NMSU earned top honors at the annual AIChE Annual Conference Miami Beach, Florida in November. Her poster was awarded first place in the ıvironmental group.

"WERC is being recognized throughout the nation for the excellence of our ograms and students," Dave Kauffman, Education Director of WERC said. 'hese honors are a direct result of the collaboration of Consortium members. ıis recognition would not have been possible without the input and cooperation DOE, UNM, NMSU, NM Tech, NCC and LANL and SNL."

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WERC Executive Board

From the Director's Desk....

University research is a boon to teaching. University research is basic to the teaching for our young students and is the prime way that faculty stay informed about the state-of-the-art developments in the field.

If a faculty member teaches a course without staying up with current research, they are probably teaching a course that is eight to ten years out of date; even if a book was published last year, the information contained is several years out of date.

Therefore, to stay at the frontier of technology in such fast moving areas as environmental technology, materials development, new energy development, and new manufacturing processes, a faculty member must be involved in research. In order to perform research, the faculty member must continually keep up with the literature. So, by necessity, that faculty member is up to date in the latest developments and will impart the research results in the courses taught.

Graduate and undergraduate students usually work with faculty so that this knowledge is also imparted directly to the students as they perform work in the laboratory and the field.

The WERC program conducts technology development projects with that very objective in mind. The technology development programs are carefully chosen so they fit in with course work that is required for the degrees and certificates that WERC offers. It would be a crime to turn out students that join our industrial, governmental and professional world who have learned from text books that are ten to twenty years out of date. The research results from the WERC projects clearly show that they not only contribute to technology development of our industry and government, but also contribute heavily to our students who join the professional world. It is for that reason that I am very proud of our research projects.

I hope you will help me spread the word about this important aspect of WERC education. It is important that we communicate with people who do not fully understand the meaning of state-of-the-art research and its importance in the world of teaching.

Some people continue to think that university research is a boondoggle. They are half right in that research is an irreplaceable "boon" to instruction. However, they are very misinformed about the "doggle" aspect.

Ron Bhada,
WERC Director

WERC FOR THE FUTURE

In February, 1990, Secretary James Watkins of the U.S. Department of Energy signed a cooperative agreement or the Waste-management Education and Research Consortium (WERC). The mission of WERC continues to be the evelopment of resources that are required to manage all types of waste through education, technology development nd technology transfer. In April, the "WERC, FOR THE FUTURE CONFERENCE" will be held in one location o illustrate some of the advances which have been made during the Consortium's short history. The 3rd annual VERC Technology Development Conference, The 3rd annual WERC Environmental Design Contest, the WERC ndustrial Affiliate Board, and the WERC Executive Board will participate in this gathering on the campus of NMSU.

Technology Development Conference

The 3rd Annual WERC Technology Development Conference is slated for April 21-23, 1993. The Conference will feature papers from research projects of WERC as well as presentations of research from the Historically Black Colleges & Universities/Minority nstitutions (HBCU/MI), which is also a DOE Education Consortium. Graduate student posters will lso be displayed.

Final selection of papers will be announced on ebruary 8. Topics include Hazardous waste-nanagement; Robotics and waste handling; Public erception of risk; Bioremediation and other emediation technologies; Waste storage; Radioactive vaste-management; Transportation of hazardous & adioactive-waste; Waste Isolation Pilot Plant studies; Thermal destruction of wastes; Groundwater/Surface vater modeling/monitoring; Environmental monitoring nd sensors; Oil and Gas waste-management; and Waste reduction.

Environmental Design Contest

The 3rd annual Environmental Design Contest will eature university teams from the United States and Mexico competing with their design to a stated nvironmental design challenge. This year the challenge was expanded to feature not only nvironmental remediation, but also waste minimization n the manufacturing process of a printed wiring board.

The students will present their proposed solution to a panel of judges from industry, government and academia. The teams will also demonstrate how their bench scale model will effect remediation and minimization.

Last year's contest featured 19 teams from across the United States and one team from Mexico. In the 1992 competition West Virginia received the top overall prize for their design. As a result of their design, West Virginia was awarded a site remediation contract from DOE-Richland.

This year, more than 25 teams have signed up for the contest.

Industrial Affiliate Board

The WERC Industrial Affiliate Board will hold its semi-annual meeting April 22-23.

Industry helps set the educational and research direction of WERC and provides opportunities for the transfer of technological developments and processes which result from WERC research. By using the varied expertise of WERC members, the best and brightest students and the four WERC laboratories, industry can assemble a powerful team to help chart a course through regulations and develop technology to effect industrial environmental solutions.

Affiliate Board members also provide input and expertise for students participating in WERC outreach education for college and pre-college programs, such as the Environmental Design Contest, the WERC Summer Institute, and the SEED program.

Executive Board

The WERC Executive Board will meet April 23 in Corbett Center on the campus of NMSU. The Executive Board sets the strategic direction of WERC and ensures the Consortium is following the mission which was envisioned in the original agreement between the DOE and WERC.

WERC EDUCATION & RESEARCH

WERC WELCOMES FIRST CLASS OF EFP

DOE Assistant Manager of Projects and Energy ɔgrams James Bickel, and NMSU President James :lligan welcomed the first class of the Environmental llows (EFP) Graduate Program in ceremonies in ıgust. The WERC sponsored program trains ofessionals and world leaders in waste management d environmental remediation.

"This new graduate program is a wonderful ɔportunity to unite efforts to help solve some very ɔubling waste problems," U.S. Senator Pete Domenici id. "With the signing of the NAFTA treaty, it has come very important that we work together to watch 'er our environment. The Fellows in this class will ke information back to Mexico about the innovative ıd wide-ranging projects that are being manifested in is exciting program."

Professionals from technological institutes and dustry in Mexico make up the EFP Class. They will ɔmplete course work for a M.S. with an option in 'aste Management starting this Spring semester.

"The WERC program is providing an integrated ɔproach to meet the critical needs for disposal of ızardous, solid and other waste," U.S. Congressman ɔe Skeen said. "Not only does the United States need ghly skilled professionals in this special field, but the ıformation and data which are generated will prove ıvaluable as we address waste problems on the ıternational level."

IACQUEZ TO HEAD ENVIRONMENTAL FELLOWS PROGRAM

Dr. Ricardo B. Jacquez has been selected as the ɔirector of the Environmental Fellows Program.

"Ricardo has been an integral part of the WERC rogram for the last three years serving as the 'echnical Head of Research," said J. Derald Morgan, :EO of WERC. "Through Ricardo's vision and ,uidance the Environmental Fellows Program will become a model for educating emerging world leaders on issues of the environment."

"My vision for this program is to make WERC the international environmental training program of choice through enrollment of emerging national and international leaders who are dealing with environmental issues." Jacquez said.

Jacquez was awarded the 1983 Charles A. Lindbergh Fund Grant. He is also the recipient of the 1983 Society of Hispanic Professional Engineers Jaime Oaxaca Award which was presented in recognition for contributions to advancement of engineering, science, and the Hispanic community.

WERC TECHNOLOGY DEVELOPMENT PROJECTS SELECTED

WERC's technology development program sponsors research projects that identify and propose solutions for waste management and environmental restoration challenges. Projects have been tentatively selected for 1993. Eighty-three proposals were received and 35 of those proposals have been recommended for funding. Proposals were rated by an external panel of experts and recommendations were produced by an internal panel of professionals. Notification letters were sent on December 11 to the researchers. The WERC Executive Board and the DOE will review and give final approval in February, 1993.

Several projects recommended for funding include "Pipeline Leak Detection System for Oil Spills Prevention," Dr. Jerry M. Rajtar, NMIMT in collaboration with Lynx Petroleum Consultants, "Public Opinions and Nuclear Waste Management: Tracking Change Over Time in Public Risk Perceptions," Dr. Hank Jenkins-Smith, UNM in collaboration with SNL and Georgia Tech, and "Nuclear Waste Repository Ventilation System Studies," Dr. Phillip R. Smith, NMSU in collaboration with SNL, LANL and Westinghouse/WIPP.

WERC EDUCATION ASSISTANCE

FELLOWSHIP OFFERS STUDENTS AN OPPORTUNITY

The WERC mission is to provide resources for the aste management problems we face now and will face the future. One question which arises is how to eep the best and the brightest students interested in ursuing a degree in environmental remediation. A uccessful method which has been employed is to rovide fellowships to WERC students.

WERC students in New Mexico are working with esearchers to develop new ways to clean up the nvironment and are getting paid to do so under a nique fellowship offered by WERC universities.

The WERC Fellowship program, available on a ompetitive basis to all students with a declared major, as increased by 52% in the last two years. The rogram has grown from 48 students in the Fall 1990 emester to 73 in the Fall of 1992. The scholarships ange from $250 to $1500 depending on the student's evel of commitment and academic merit. The rogram is sponsored by the U.S. Department of nergy (DOE) as part of their educational effort.

"We have seen a great increase in students wanting o learn about waste management," Ron Bhada, WERC Director said. "Making these fellowships available nsures WERC graduates have hands-on experience in he development of the newest and best technology. The fellowship also makes potential employees more ttractive to industry as a result of their involvement in esearch."

WERC universities include New Mexico State Jniversity (NMSU), The University of New Mexico UNM) and New Mexico Institute of Mining and Technology (NMIMT).

Susan Van Horn, a Chemical Engineering student at NMSU sees the fellowship as a chance to help restore the environment. "The WERC Fellowship makes it possible for me to be involved in finding new ways to make the planet safe and habitable," Van Horn said. "There are answers to environmental problems, you just have to look for them."

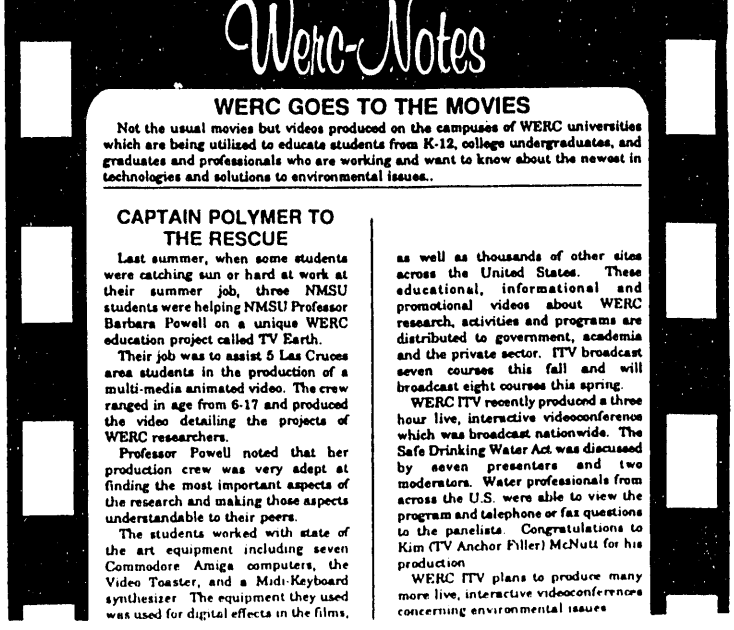
Dr. David Kauffman of WERC, feels students are more aware of environmental issues. "There is no doubt that enrollment in this program has increased because of the public awareness of the environment," Kauffman said. "This program prepares students for the future challenges they will face in remediation of the environment. The WERC fellowship is very competitive and results in the WERC program being able to retain very bright, able students."

WERC-NOTES STUDENT NEWSLETTER

The WERC program has grown tremendously during the last several years. In order to communicate to students who are enrolled in the program, the WERC-NOTES newsletter is being distributed to students in, and students interested in the WERC program.

The monthly publication informs students of opportunities in summer employment, internships, and permanent employment in the environmental field from government and other industries.

It also provides students with information about the history and mission of WERC as well as WERC activities.



Vol. 1, No. 2 November

Werc-Notes

WERC GOES TO THE MOVIES

Not the usual movies but videos produced on the campuses of WERC universities which are being utilized to educate students from K-12, college undergraduates, and graduates and professionals who are working and want to know about the newest in technologies and solutions to environmental issues..

CAPTAIN POLYMER TO THE RESCUE

Last summer, when some students were catching sun or hard at work at their summer job, three NMSU students were helping NMSU Professor Barbara Powell on a unique WERC education project called TV Earth.

Their job was to assist 5 Las Cruces area students in the production of a multi-media animated video. The crew ranged in age from 6-17 and produced the video detailing the projects of WERC researchers.

Professor Powell noted that her production crew was very adept at finding the most important aspects of the research and making those aspects understandable to their peers.

The students worked with state of the art equipment including seven Commodore Amiga computers, the Video Toaster, and a Midi-Keyboard synthesizer. The equipment they used was used for digital effects in the films, as well as thousands of other sites across the United States. These educational, informational and promotional videos about WERC research, activities and programs are distributed to government, academia and the private sector. ITV broadcast seven courses this fall and will broadcast eight courses this spring.

WERC ITV recently produced a three hour live, interactive videoconference which was broadcast nationwide. The Safe Drinking Water Act was discussed by seven presenters and two moderators. Water professionals from across the U.S. were able to view the program and telephone or fax questions to the panelists. Congratulations to Kim (ITV Anchor Filler) McNutt for his production.

WERC ITV plans to produce many more live, interactive videoconferences concerning environmental issues.

WERC CONTINUING EDUCATION

WORKSHOP SCHEDULED

The 2nd annual "Ask the Environmental Experts" kshop will be held in Santa Fe, January 27-29, '3. A comprehensive overview of major issues in te minimization, the workshop is designed for ineers, scientists, technical and regulatory managers, ervisors, technicians and business people. It will sent cutting edge developments in reducing waste erated from manufacturing processes.

Workshop speakers are waste minimization cialists, including Rear Admiral Richard J. mond, Assistant Surgeon General and Deputy istant Administrator, Environmental Protection ncy, known for his leadership in developing the A's indoor radon strategy.

VIDEOCONFERENCE TRAINING SERIES

Two new videoconference training series will be adcast starting in February, 1993. WERC awards tificates of completion to series' participants, and U's are available.

Environmental Risk Management

"Environmental Risk Management" is a seven-gram series on developing workable strategies to dge the gap between technical environmental issues l social concerns. The process of risk management olves conflict resolution and communication within urbulent social, political and regulatory framework.

Radioactive Waste Management

"Radioactive Waste Management" is an eight-gram series covering radioactivity, health physics l the major national programs associated with lioactive waste management and disposal. The series ncludes with a discussion of the newest technologies l international radwaste management programs rently under development.

HIGH SCHOOL RISK AWARENESS

Alice King, First Lady of the State of New Mexico recently helped kick off the Risk Awareness Week at Albuquerque's Cibola High School. The week highlighted risk assessment for high school students. Some of the Cibola High students and professionals from WERC Institutions will be featured in a risk awareness video.

The WERC sponsored 30-minute program on risk awareness will be broadcast on Whittle Educational Network (Ch.1) in April, 1993 to 12,000 high school students and will also be available free on videotape with a shipping/handling charge of $10.

The program will encourage students to understand the role of math and science in exploring personal risk and how to extrapolate from the personal to the environmental.

AWARD RECEPTION

WERC and the University of New Mexico celebrated their first place award from the United States Distance Learning Association at a reception at the Maxwell Museum on the University of New Mexico campus on December 8, 1992 The "Waste Minimization and Pollution Prevention" series was awarded best distance learning program for 1992.

WERC Director Ron Bhada and Dean James Thompson of the UNM College of Engineering made opening remarks. In attendance were representatives from the Governor's Office and from Senators Bingaman and Domenici's Offices, Virginia Ostendorf of the U.S. Distance Learning Association and other honored guests.

"This award is the result of a tremendous amount of work by Connie Callan and her staff," Bhada said.

For More Information on these programs contact Connie Callan, WERC Continuing Education Coordinator at 1-800-292-7051.

WERC CONTINUING EDUCATION

SPRING ITV COURSES OFFERED

Ten environmental courses will be offered by WERC hrough its Instructional Television Program (ITV) for he 1993 Spring Semester.

"These ten courses are excellent examples of the ariety of disciplines required for environmental emediation," WERC Director Ron Bhada said. "The ourses present a wide window of opportunity for tudents and professionals who need to be updated in he newest developments in this fast changing field. his ranks as one of the most comprehensive telecourse fferings WERC-ITV has assembled."

For a list of receive sites in New Mexico and sites cross the nation, call the WERC Force toll free hotline t 1-800-523-5996.

UNM will offer:

* WERC 539 Radioactive Waste Management, G. Pierce, M. & W., 5:30-6:45 p.m.;

* WERC 551 Natural Resource Legal Issues, G. Venable, T., 7:00-9:30 p.m.;

* WERC 584 Transportation of Hazardous Materials, J. Brogan, M. & W., 7:30-845 a.m.

NMSU will offer:

* WERC 523 Environmental Toxicology, W. Mueller, T. & Th., 5:15- 6:30 p.m.;

* WERC 476 Soil Microbiology, W. Lindemann, M. W. & F., 11:30 a.m.-12:20 p.m.;

* WERC 630 Fate and Transport of Environmental Contaminants, A. Toorman, T. & Th., 8:55-10:10 a.m.

NM Tech will offer:

* WERC 481 Introduction to Health Physics, M. Wasiolek, M. & W., 9:00-10:15 a.m.;

* WERC 491 Waste Management Issues i Domestic Petroleum, R. Bretz, Th., 7:00-8:3 p.m.;

* WERC 535 Applied Ground Water Hydrology Instructor TBA, F., 8:30-10:20 a.m. 2-3 fiel trip/lab exercises in Socorro during th semester.

The instructors of these telecourses are recognize experts in their fields and will provide an importan educational experience for students interested i creating environmental solutions," WERC CEO J Derald Morgan said.

PETROLEUM ITV CONFERENCE SLATED FOR SUMMER

WERC ITV will sponsor several conference dealing with specific issues facing the petroleu industry on a national and international basis thi summer. NM Tech Professor Robert Bretz wil moderate a panel of renowned oil and gas expert discussing a variety of topics including exploration drilling, environmental impact, storage and othe relevant issues.

WERC SAFE DRINKING WATER ACT TELECONFERENCE HELD

The WERC sponsored Safe Drinking Water Ac Conference held this past October was well received. Participation by the small to mid-size water syste operators was excellent. Water operators from Ne Mexico, California, Minnesota, Virginia and Uta viewed the 3-hour interactive teleconference.

For more information about WERC ITV contact J Kim McNutt at 1-800-523-5996.

you would like additional information concerning the expertise represented by WERC which includes four ıcational institutions and two national laboratories, please call our Toll-Free Number.

WERC TOLL-FREE NUMBER
1-800-523-5996

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ERC FORCE

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