Kenneth S. Johnson

Editor

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Hazardous-Waste Disposal in Oklahoma—A Symposium

Kenneth S. Johnson
Editor

Proceedings of a symposium held in conjunction with the annual technical meeting of the Oklahoma Academy of Science, November 9, 1989, at Central State University in Edmond, Oklahoma.

Symposium Cosponsors:

Oklahoma Academy of Science
Oklahoma Geological Survey
Oklahoma State Department of Health
Oklahoma Department of Wildlife Conservation
Oklahoma Wildlife Federation

Oklahoma Geological Survey
Charles J. Mankin, *Director*
The University of Oklahoma
Norman, Oklahoma

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Preface

The management and disposal of hazardous wastes is one of the major problems being addressed in Oklahoma and throughout the nation. Oklahoma has taken a number of specific steps to deal with these issues, and the purpose of this symposium was to bring together people knowledgeable about various hazardous-waste activities in the State and discuss the issues in a public forum. This goal was well met, and this symposium-proceedings volume is a further attempt to disseminate information to the concerned public.

In the Spring of 1989, the Oklahoma Geological Survey (OGS) proposed to the Executive Committee of the Oklahoma Academy of Science (OAS) that a one-day symposium on hazardous-waste disposal in Oklahoma be presented under the sponsorship of OAS at the next annual technical meetings, held at Central State University in Edmond. It was proposed that the Geology Section of OAS would organize the session, and that it be held on November 9, 1989, the day before the OAS technical meeting. This was agreed to, and the final program was offered under the cosponsorship of the OAS, OGS, Oklahoma State Department of Health (OSDH), Oklahoma Department of Wildlife Conservation, and Oklahoma Wildlife Federation. All these organizations were instrumental in the success of the symposium.

The success of the program can be measured in part by the number and diversity of attendees. About 275 people attended the symposium, including representatives of industry, government (city, state, and federal), academia (faculty and students), environmental organizations, and the general public.

Special thanks are expressed to the speakers (authors) who contributed to this symposium. Each of them was successful in making a special effort to synthesize years of work and many data into the report. Persons who assisted in the organization and planning of this symposium include Kenneth Johnson and Charles Mankin of the OGS; Kenneth Conway, Paul Buck, and Terry Harrison of the OAS; and Mark Coleman and Damon Wingfield of the OSDH.

KENNETH S. JOHNSON
General Chairman

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Welcoming Address

Kenneth E. Conway
President
Oklahoma Academy of Science
Stillwater, Oklahoma

I welcome you on behalf of the Oklahoma Academy of Science and encourage you to participate in this symposium by questions to speakers and/or informal discussions during the meeting. I hope that we can learn from our speakers how to avoid mistakes that will be harmful to Oklahoma and how best to plan for alternatives.

The Oklahoma Academy of Science was formed in 1909, and we should be celebrating our 80th anniversary during this year. The purpose of the Academy is to stimulate scientific research; to promote fraternal relationships among those engaged in scientific work in Oklahoma; to diffuse among the citizens of the state a knowledge of the various departments of science; and to investigate and make known the material, educational, and other resources of the State.

The Academy has approximately 900 members. Membership is divided into 13 sections (Biological Sciences; Geology, Physical Science; Social Science; Science Education; Geography; Wildlife Conservation; Microbiology; Engineering Sciences; Biochemistry and Biophysics; Electron Microscopy; Mathematics, Computer Science, and Statistics; and Environmental Science), plus a Collegiate Academy of Science for students in colleges and universities, and a Junior Academy of Science for high-school students. This symposium is organized by the Geology Section of the Oklahoma Academy of Science.

We hold at least three meetings a year: a Spring and a Fall Field Meeting, and a Fall Technical Meeting. Field Meetings are held throughout the state and consist of field trips led by scientists and experts in various areas of science. Fall Technical Meetings are held in November at various colleges and universities throughout Oklahoma. This year's Fall Technical Meeting is being held tomorrow, November 10, at Central State University. The Collegiate Academy and the Junior Academy meet during the Fall Technical Meeting.

We invite you to join the Oklahoma Academy of Science. Application blanks will be available during this meeting.

Thank you for your interest in this symposium; I hope that it will generate knowledge about hazardous-waste disposal and provide you with an increased awareness of this problem.

Introduction to Symposium

James W. Bennett
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Hazardous waste is a topic on the public's mind. Basically, people want to know "what is the *risk* associated with a particular hazardous substance." Risk can be quantified in parts per million with the resulting probability of cancer. The questions begin when decisions are made concerning whether the degree of risk is reasonable. Whether a risk is reasonable is usually a value judgment, not a fact, and it often is based on whose ox is being gored. An example: Annually, we kill as many people on this nation's highways as were killed during the entire Vietnam conflict. One risk we accept as reasonable; one shook this country to its very foundations. Reasonable risk could be reduced almost overnight on our highways. How?

1) Outlaw liquor;

2) Reduce speed limits to 50 mph maximum;

3) Double state tax and apply it to highway safety engineering.

Do I hear someone's ox starting to moan? Safety is a value judgment, made by our society. The point is, the issues, including hazardous-waste management, are complicated. They will require a well-planned approach to the decision-making process to arrive at workable solutions. Don't misunderstand me; I believe that environmental quality is the most pressing issue before us today. Decisions made today require a certain amount of lead time for implementation. The time we have left in which these decisions will even matter is ever becoming less.

We are truly at an environmental crossroads. State-of-the-art technology today is the best we can do. Our grandchildren will shake their heads and wonder at our ignorance. But what they need to be proud of is that, in our time, the environmentalists and industry got together and did the best we collectively could. We don't need "shiite environmentalists" demanding zero pollution. We don't need industry with the appearance of Groucho Marx and the philosophy of James Watt. Now is the time to work together for our common future. Let me give some examples of what I'm talking about.

1) Industry needs to take a proactive stance in the community in which they operate. No more "smoke and mirrors" propaganda, but rather, real education programs for a concerned citizenry.

2) Since public health is at the heart of the issue, I believe that the OSDH should expand their education role, and provide lesson guides and information to our teachers and students for classroom use.

3) Environmental issues are complicated. Thus, they require a well-informed citizenry to make rational decisions on issues. I know of no better way to achieve this than improving our overall education system in Oklahoma. Our legislature has our collective future before them now.

4) The days of preaching to the choir must be over. The Board of Directors of the Oklahoma Wildlife Federation must be receptive to the real needs of business and industry. Likewise, the corporate boardroom must include the environment as a cornerstone upon which decisions are made. We must talk to each other. However, if speeches take the place of sound policies, the 1990s will go down as the decade we finally lost the struggle to protect our future.

April 22, 1990, is the 20th anniversary of Earth Day. It will be a major event in Oklahoma and the nation. I suggest that it should be a focal point upon which a new alliance is formed: Industry, the environmental groups, and the government agencies, working together toward meaningful objectives with an even greater long-range goal in mind.

Those of us who live on planet Earth inevitably have a common future. Whatever the outcome of our policies and decisions, our children will harvest the fruit of our labors. It's time to take care of the home we share. Good planets are hard to find.

Hazardous Waste Generated and Disposed of in Oklahoma

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EARLY STUDIES

The first comprehensive study of hazardous-waste generation in Oklahoma was by Dr. Shelly Jean Williamson, who completed her Ph.D. in Environmental Science at the University of Oklahoma (1975). The study was conducted in cooperation with Environmental Health Services of the Oklahoma State Department of Health. All of Oklahoma's 77 counties were surveyed, and generators were classified according to Standard Industrial Classification (SIC) code numbers. Mining and petroleum-refining industries and NPDES dischargers were included in this survey as potential hazardous-waste generators. Hazardous wastes were divided into two major types: (1) "sewered" potentially hazardous wastes generated by the selected manufacturing industries, and (2) "non-sewered" hazardous wastes. The "non-sewered" hazardous wastes included the known quantities of hazardous wastes disposed of at the Criner hazardous-waste site and at industrial injection wells. Where data were lacking or unavailable, hazardous-waste quantification was determined by use of generation factors, effluent volumes, influent volumes of water, and waste-generation factor per employee.

A list of 5,300 industries in Oklahoma was compiled, and a total of 4,632 industries were actually surveyed with help from county sanitarians. More than 50% of the hazardous wastes produced in Oklahoma came from Oklahoma City and Tulsa. During the year May 1974 to April 1975, 11,875 tons of hazardous wastes from Oklahoma and 16,623 tons of hazardous wastes from Texas was disposed of at the Criner, Oklahoma, disposal site. The Texas contribution was approximately 59% of the total. During this same period an estimated 1,838,000 tons of industrial waste was disposed of in injection wells in Oklahoma, of which 1,070 tons (dry-weight basis) was considered hazardous. Approximately 47,500 tons of industrial wastes from outside of Oklahoma was also disposed of in injection wells in Oklahoma during this period. A summary of wastes generated and disposed in Oklahoma during 1974–75 is shown in Table 1 (Williamson, 1975).

CURRENT STUDIES

The most current comprehensive study of hazardous-waste generation and disposal in Oklahoma is the 1989 Hazardous Waste Assurance Plan for Oklahoma (hereafter referred to as *the plan;* Oklahoma State Department of Health, 1989).

This plan contains the following sections:

1) Executive summary;
2) Status of demand (generation, imports, exports) and management capacity;
3) State waste-minimization activities;
4) Projection of hazardous-waste generation and the demand for management capacity;
5) State plans to increase in-state capacity;
6) Limitations.

The plan is mandated by section 109(C)(9) of the Federal Comprehensive Environmental Response

TABLE 1.–SUMMARY OF WASTE QUANTIFICATION

Source	Total annual volume (tons)
Sewered wastes—estimated potential hazardous waste generated from manufacturing sources	146,324
Non-sewered wastes disposed:	
Licensed hazardous-waste site	
Oklahoma sources	11,875
Manufacturing in Oklahoma	6,636
All sources	29,450
Industrial injection wells	
Oklahoma sources	1,840,899
Estimated hazardous	1,070
Manufacturing in Oklahoma	1,838,155
All sources	1,846,136

Compensation and Liability Act (CERCLA), which requires that each state develop a hazardous-waste capacity-assurance plan in order to continue to receive Superfund remedial-action funds. This plan assures that hazardous wastes generated in Oklahoma through the end of 2009 can be properly treated or disposed of by facilities within the State or by capacity provided by other states in EPA Region VI.

The executive summary of the plan (Oklahoma State Department of Health, 1989) states that 610,384 tons of hazardous waste was generated in the State of Oklahoma during the 1987 base year for this report. Wastes exported to other states or countries amounted to 28,257 tons, and 22,019 tons was imported from other states or countries; Oklahoma is therefore a net exporter of hazardous wastes. A net 604,156 tons of hazardous wastes was managed by Oklahoma facilities in 1987. Eighty-two percent of the waste managed was by on-site treatment or disposal facilities; commercial facilities managed 14%, and 4% was managed at captive facilities (Fig. 1). Sixty-four percent of all waste managed in Oklahoma in 1987 was disposed of by onsite deep-well injection facilities, while 5% of the waste was handled by commercial landfill facilities. Imports totaled less than 4% of the net tons of waste managed in Oklahoma, while exports were less than 5% of the hazardous waste generated.

Projections in the plan for the years 1989, 1995, and 2009 are based on the following assumptions (Oklahoma State Department of Health, 1989):

1) Hazardous-waste generation in Oklahoma should parallel economic trends, as described by the earnings projections of the U.S. Department of Commerce.

2) Waste minimization, including source reduction or recycling efforts, is projected according to anticipated generator-initiated trends.

3) The effects of land-disposal restrictions are also reflected in this report, as well as the impact anticipated from managing superfund and other clean-up wastes.

4) Oklahoma has cooperated with all of the states in Region VI in the preparation of this plan and plans to continue to cooperate with these states in the reductions and proper disposal of hazardous wastes.

5) Since Oklahoma is not completely self-sufficient for hazardous wastes generated in-state, it must continue to cooperate with the states in Region VI. A less desirable alternative would be to be forced to accept wastes from all states, including certain northeastern states.

6) The Region VI states can mutually assure capacity for the next 20 years, covering shortfalls in any individual state with the excess capacity of the group.

Table 2 is a summary of 1987 hazardous waste generated in Oklahoma by SARA waste type. This information was compiled from the 1987 Biennial Report. Recurrent generation is attributable from ongoing industrial activity, while one-time generation results from isolated events such as site clean-up or equipment cleaning. In 1987, 610,384 tons of hazardous waste was generated in Oklahoma; inorganic liquids which contain metals accounted for 54% of the total. One-time generation produced 101,194 tons of waste. Contaminated soils accounted for 98% of the one-time waste generation.

Table 3 presents the projected commercial capacity remaining in Oklahoma and the other states in EPA Region VI in 1989, 1995, and 2009. Disposal shortfalls identified in 1987 data have been reduced by a subsequent increase in disposal capacity. However, disposal shortfalls still exist in the categories of metals recovery, incineration, energy recovery, and other treatment. Deep-well injection is the largest single method of treatment/disposal in Oklahoma, accounting for 76.7% of the total capacity in 1989. If deep-well injection is curtailed through new and/or existing regulations, the States of Oklahoma and Texas will need to

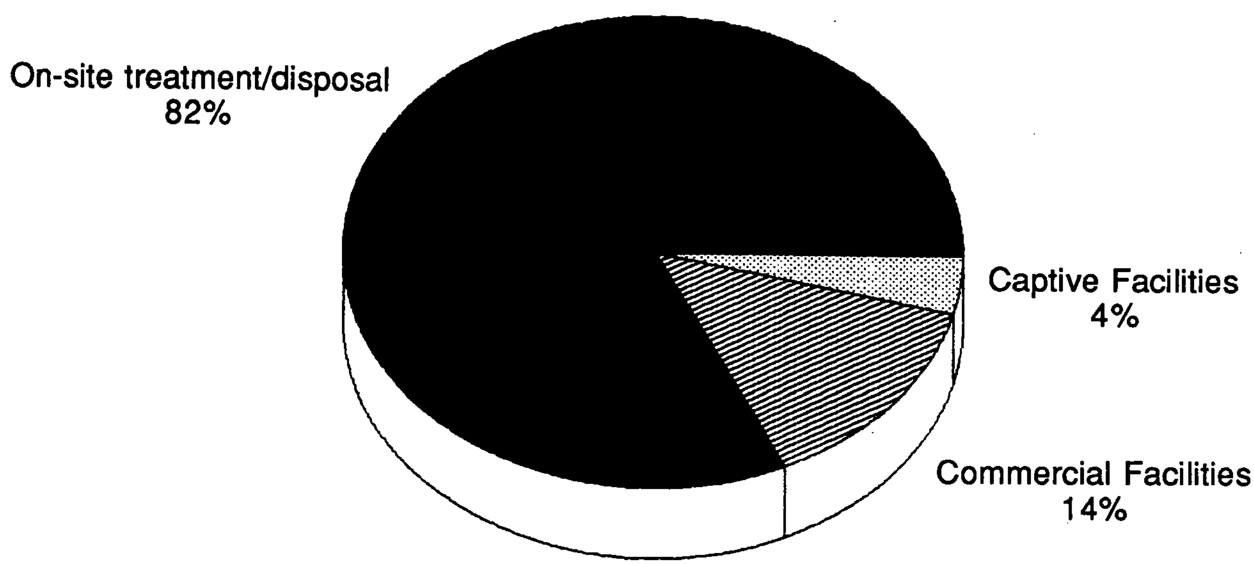

Figure 1. Hazardous waste managed in Oklahoma in 1987.

TABLE 2.—SUMMARY OF IN-STATE GENERATION BY WASTE TYPE IN 1987 FOR THE STATE OF OKLAHOMA (TONS)

Waste type	Recurrent generation	One-time generation	Total generation
1. Contaminated soils	0	99,461	99,461
2. Halogenated solvents	1,876	2	1,878
3. Nonhalogenated solvents	6,924	335	7,259
4. Halogenated organic liquids	1	2	3
5. Nonhalogenated organic liquids	540	33	573
6. Organic liquids, unspecified	5,955	107	6,062
7. Mixed organic/inorganic liquids	5,209	21	5,230
8. Inorganic liquids with organics	878	7	885
9. Inorganic liquids with metals	328,148	21	328,169
10. Inorganic liquids, NEC*	92,916	41	92,957
11. Halogenated organic sludges/solids	160	0	60
12. Nonhalogenated organic sludges/solids	423	21	444
13. Organic sludges/solids, unspecified	8,644	918	9,562
14. Mixed organic/inorganic sludges/solids	2,519	4	2,523
15. Inorganic sludges/solids with metals	54,342	105	54,447
16. Inorganic sludges/solids, NEC*	79	106	185
17. Other wastes, NEC*	576	10	586
Total	509,190	101,194	610,384

*NEC: Not elsewhere classified.

modify projected disposal options for 1995 through 2007. Under existing regulations, Texas is projected to have a shortfall in deep-well injection capacity by 2009 of 2,252,466 tons. Viable options should include increased waste reduction and increased incinerator capacity.

CURRENT INFORMATION SOURCES

The Petroleum Information Waste Generators Report is a very comprehensive and ongoing source of information regarding hazardous-waste generation in Oklahoma (Petroleum Information, 1989). It contains the following format: Business/Plant, EPA Waste No., Hauler, Receiving Site, Amount. This information is published quarterly at a fixed cost for generators, haulers, and treatment-disposal facilities. This information is available for all the states in Region VI, and for most of the other states as well.

The Oklahoma Hazardous Waste Capacity Assurance Plan for Oklahoma is prepared biannually by the Waste Management Service of the Oklahoma State Health Department. This plan is also available for purchase.

CONCLUSIONS

The State of Oklahoma currently has the capacity for hazardous-waste treatment and disposal in cooperation with the other states in Region VI. Although total quantities of hazardous waste being generated are decreasing, certain bans on land disposal are being promulgated by the EPA. This action will encourage recycling and source recovery, as well as alternative treatment methods. Even with new restrictions in place, the 1989 Hazardous Waste Capacity Assurance Plan projects adequate treatment/disposal facilities for hazardous wastes generated in Oklahoma for the next 20 years.

ACKNOWLEDGMENTS

The authors wish to thank the Oklahoma State Department of Health Waste Management Service for invaluable assistance and information in preparation of this paper. Mr. Jack Badgett was particularly helpful in this endeavor. We would also like to thank Mr. Floyd Roupe of Petroleum Information Corp. for information on waste generation in Oklahoma.

REFERENCES CITED

Williamson, S. J., 1975, A comprehensive survey of hazardous waste generation in Oklahoma: University of Oklahoma unpublished Ph.D. dissertation.

Oklahoma State Department of Health, 1989, 1989 hazardous waste capacity assurance plan for Oklahoma: Waste Management Service.

Petroleum Information, 1989, Waste generators report: Oklahoma, First Quarter 1989, EPA Region VI: Oklahoma City.

TABLE 3.—REMAINING COMMERCIAL CAPACITY FOR REGION IV STATES AFTER ACCOUNTING FOR SHORTFALLS IN CAPTIVE AND ON-SITE CAPACITY

SARA management category	Arkansas 1989 remaining capacity	Arkansas 1995 remaining capacity	Arkansas 2009 remaining capacity	Louisiana 1989 remaining capacity	Louisiana 1995 remaining capacity	Louisiana 2009 remaining capacity	New Mexico 1989 remaining capacity	New Mexico 1995 remaining capacity	New Mexico 2009 remaining capacity
1. Metals recovery	(1,343)	(3,784)	(5,108)	47,850	47,135	45,535	0	(16,019)	0
2. Solvents recovery	32,566	32,550	31,167	928,320	963,063	917,479	(901)	(901)	(901)
3. Other recovery	(57)	(66)	(89)	0	0	0	(112)	(65)	(16)
4. Incineration liquids	43,479	55,191	56,179	61,683	156,199	147,184	(617)	(799)	(909)
5. Incin. solids/sludges	7,136	7,783	3,125	21,099	19,114	4,363	(128)	(37,697)	(741)
6. Energy recovery	88,867	88,926	86,937	19,692	17,843	13,710	(7)	(10)	(13)
7. Aq. inorg. treatment	(628)	(722)	(975)	144	144	0	(39)	(63)	(105)
8. Aq. org. treatment	(21)	(27)	(36)	150	150	0	0	0	(134)
9. Other treatment	(282)	(324)	(437)	421,157	417,874	410,534	(24)	(26)	(27)
10. Sludge treatment	(83)	(108)	(146)	2,172	2,125	2,019	0	0	0
11. Stabilization	(11,964)	(15,999)	(21,597)	804,041	803,392	801,941	(9)	(84)	(110)
12. Land treatment	0	0	0	0	0	0	0	0	0
13. Landfill	(44,797)	(41,213)	(55,639)	3,335,824	3,285,438	3,170,028	(5,986)	(4,079)	(27,477)
14. Deep-well injection	(16,168)	(18,593)	(25,101)	1,039,651	1,023,053	985,951	(35)	(35)	(35)
15. Other disposal	0	0	0	0	0	0	0	0	0
Total	96,705	103,614	68,280	6,681,783	6,735,530	6,498,744	(7,858)	(59,778)	(30,468)

SARA management category	Oklahoma 1989 remaining capacity	Oklahoma 1995 remaining capacity	Oklahoma 2009 remaining capacity	Texas 1989 remaining capacity	Texas 1995 remaining capacity	Texas 2009 remaining capacity	Region 6 1989 remaining capacity	Region 6 1995 remaining capacity	Region 6 2009 remaining capacity
1. Metals recovery	(6,316)	(9,994)	(12,848)	97,800	50,000	31,000	137,991	67,338	58,579
2. Solvents recovery	14,458	11,557	6,146	35,000	37,000	21,000	1,009,443	1,043,269	974,891
3. Other recovery	13,475	13,278	12,904	0	0	0	13,306	13,147	12,799
4. Incineration liquids	(1,150)	(3,380)	(4,370)	131,000	126,000	117,000	234,395	333,211	315,084
5. Incin. solids/sludges	(546)	(6,853)	(8,811)	140,600	27,000	9,000	168,161	9,347	6,936
6. Energy recovery	(7,897)	(10,436)	(13,544)	372,000	367,000	355,000	472,655	463,323	442,090
7. Aq. inorg. treatment	63,154	44,511	38,156	206,000	205,000	201,000	268,631	248,870	238,076
8. Aq. org. treatment	60,963	53,394	49,561	389,000	387,000	384,000	450,092	440,517	433,391
9. Other treatment	(8,542)	(14,769)	(21,234)	2,192,000	3,342,000	1,643,000	2,604,309	3,744,755	2,031,836
10. Sludge treatment	36,485	36,359	36,319	7,320,000	7,320,000	7,320,000	7,358,574	7,358,376	7,358,192
11. Stabilization	173,696	154,754	145,032	37,000	43,000	37,000	1,002,764	985,063	962,266
12. Land treatment	0	0	0	0	0	0	0	0	0
13. Landfill	256,607	876,089	453,395	1,532,000	26,505	(2,252,446)	5,073,648	4,142,740	1,287,861
14. Deep-well injection	1,955,848	1,970,833	1,970,833	6,122,000	6,080,000	5,995,000	9,101,296	9,055,258	8,926,648
15. Other disposal	0	0	0	0	0	0	0	0	0
Total	2,550,235	3,115,343	2,651,537	18,574,400	18,010,505	13,860,554	27,895,265	27,905,214	23,048,647

Source: Oklahoma State Department of Health (1989).

History of Oklahoma's Regulatory Responsibility in Hazardous-Waste Disposal

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INTRODUCTION

Waste disposal became nationally focused upon the land due to the Clean Air Act Amendments of 1970 and the Federal Water Pollution Control Act Amendments of 1972. The EPA estimated that approximately two-thirds of the increase in industrial waste resulted directly from that air and water legislation (Epstein and others, 1982, p. 191). "RCRA" was conceived to specifically regulate hazardous waste and to minimize spoiling of the land. The Oklahoma hazardous-waste regulatory program predates RCRA. This paper explores some of the history of both programs. Statutory citations are deferred to the references.

SOLID-WASTE LEGISLATION

As used today, the term "solid waste" encompasses a broad category of waste materials, including municipal refuse and both hazardous and nonhazardous industrial wastes. The solid-waste program began with the passage of the federal Solid Waste Disposal Act of 1965. This law encouraged research and development and encouraged states to develop waste-disposal plans. Authority was split among the Public Health Service, the Department of Health, Education and Welfare, and the Department of the Interior. This law did not specifically mention hazardous waste. There were no enforcement provisions; thus, the federal government was limited to an advisory role. This was typical of most environmental laws, where Congress enlisted support of the states in solving environmental problems (Anderson, 1978, p. 712).

The Solid Waste Disposal Act was amended by the Resource Recovery Act of 1970, but this neither altered the "advisory" philosophy nor mentioned "hazardous waste." The 1970 amendment broadened the research-and-development approach and shifted emphasis from disposal to recovery (U.S., 1976, p. 6338). While the Resource Recovery Act was being considered in committee, President Nixon sent Congress his plan to create the Environmental Protection Agency (EPA). [Reorganization Plan No. 3, July 9, 1970.] The Resource Recovery Act amendments were adopted on October 26, 1970; and on December 2, 1970, Congress created the EPA. [85 Stat. 2086.] The Public Health Service role in solid waste was then transferred to the EPA, divorcing environmental protection from public-health protection at the federal level.

In 1965, only one-third of the states had passed solid-waste-disposal legislation. However, by 1975 all states had such laws (Anderson, 1970, p. 643). Oklahoma's law came on March 17,1970, when Governor Bartlett signed the Oklahoma Solid Waste Management Act. This law was introduced as H.B. 1499, authored by Representative Sanguin and Senator Lane, and gave the State Health Department authority to regulate waste-disposal sites.

The Oklahoma law defined solid waste to include refuse and "industrial wastes and hazardous wastes, including explosives, pathological wastes, chemical wastes, herbicide and pesticide wastes." [Laws 1970, c. 69, Sec. 3.] Today, pathological wastes still remain under the Solid Waste Management Act, as well as industrial wastes which are not classified as hazardous waste. These nonhazardous industrial wastes are also referred to as "other industrial wastes."

The first "hazardous-waste" regulations in Oklahoma were adopted by the State Board of Health on July 1, 1973, as part of the solid-waste rules under the Oklahoma Solid Waste Management Act. The "hazardous-waste" rules comprised a small portion (Section 5) of the original landfill regulations. These sparse hazardous-waste regulations grew out of the permit which had previously been issued to operate the Hardage disposal site near Criner in McClain County.

FEDERAL HAZARDOUS-WASTE LAWS

Federal Resource Conservation and Recovery Act of 1976 (RCRA)

Eleven years and one day after it was passed, Congress amended the Solid Waste Disposal Act with the more comprehensive law for the regulation of hazardous wastes: the Resource Conservation and Recovery Act (RCRA), signed by President Ford on October 21, 1976. Unlike previous environmental laws, RCRA does not merely encourage the states to develop their own programs. Rather, in RCRA, Congress has mandated a federally regulated, minimum approach to hazardous-waste management.Then, where a state program is determined by the EPA to be "substantially equivalent," it is authorized to operate in that state in lieu of the federal program (42 U.S.C. Sec. 6926).

RCRA Legislative History

RCRA began as H.R. 14496. However, RCRA was a product of several years of hearings in the subcommittees on Health and Environment and on Transportation and Commerce before H.R. 14496 was introduced on June 22, 1976 (U.S., 1976, p. 6246), one week after the Oklahoma bill was signed. This bill became consolidated into S. 2150 in the Senate on September 30, 1976, the day before Congress adjourned (for further discussion of the procedure in Congress, see Kovacs and Klucsik, 1977, p. 216–220; and Epstein and others, 1982, p. 189–194).

RCRA was based on the California cradle-to-grave hazardous-waste tracking system (Epstein and others, 1982, p. 349). RCRA is designed to encourage firms to minimize the amount of hazardous waste generated and to minimize land disposal by encouraging process substitution, materials recovery, and properly conducted recycling and conservation (Sec. 6902). Based on the various estimates of waste production, approximately 1 ton, or more, of hazardous waste per person is generated each year in the United States (Hahn, 1988, p. 204).

Interestingly, some of the hazardous-waste management problems cited by Congress in the 1976 Legislative History of RCRA are not defined to be hazardous waste under the RCRA rules of today (PCBs and, unless a characteristic is met, fly ash). Most of the problem sites discussed were in the eastern United States: five sites in Pennsylvania, six in New York, and 12 sites in New Jersey (U.S., 1976, p. 6293).

While considering RCRA, Congress estimated that this country generated 4 billion tons of discarded materials each year, and anticipated an 8% annual increase in volume (U.S., 1976, p. 6240). The House Subcommittee on Transportation and Commerce believed that the volume of solid waste was increasing five times faster than the population (Kovacs and Klucsik, 1977, p. 207). Although 90% of the waste was being disposed of on the land, only 30% of the 18,500 identified solid-waste land-disposal sites were believed to be in compliance with state regulations (Kovacs and Klucsik, 1977, p. 209). Congress was most concerned with the hazardous part of this waste.

Recovery is also a part of RCRA, primarily because it was projected that 50 of the nation's largest cities would run out of landfill capacity by the end of the decade (U.S., 1976, p. 6247). Also, the EPA Solid Waste Disposal Act program did not seem to be causing a broad adoption of resource recovery at the local level (U.S., 1976, p. 6328).

What RCRA is Designed to Do

Subtitle C of RCRA establishes the nation's basic hazardous-waste management system. The OMB invented "interim status" to allow existing facilities to operate while the EPA developed its regulations (Epstein and others, 1982, p. 193). RCRA required the EPA to promulgate rules by April 1978 (42 U.S.C. 6921, 6925). Proposed rules were published in the Federal Register on December 14, 1978. Although the final manifest rules were published in February, it was not until Monday, May 19, 1980, that the EPA published the final package of hazardous-waste regulations. [45 Fed.Reg. 33418; 40 CFR 122 and following; effective November 19, 1980.] Royal Hardage stopped receiving wastes at his disposal site, now known as the Hardage/Criner Superfund site, on November 18, the previous day.

One purpose of RCRA is to implement a "cradle-to-grave" monitoring of the generation, transportation, treatment, and disposal of hazardous wastes. Practically, however, the EPA does not monitor waste manifests; this task is left to the states. Under the initial EPA regulations, only facilities which generated more than 1,000 kg of hazardous waste per month were included. "Small quantity generators" were exempt (40 CFR 261.5, 1984). The 1984 HSWA amendments to RCRA expanded the domain of regulated material to include the wastes of "small quantity generators," generating between 100 kg and 1,000 kg per month (42 U.S.C. 6921).

Of course, RCRA also involves nonhazardous wastes. For nonhazardous waste, RCRA requires the upgrading of open dumps to sanitary landfills (Sec. 405). This is the Subtitle D program. *City of Philadelphia v. New Jersey*, 437 U.S. 617 (1978), held that solid waste is an article of commerce. Section 208 authorized a tire-shredder grant for discarded tire disposal. Congress knew in 1976 that tires tend to "float" to the surface of landfills, disrupting the cover (U.S., 1976, p. 6253). Oklahoma added waste tires to its Solid Waste Management Act in 1989 (the Oklahoma Waste Tire Recycling Act).

What RCRA does not do is address historic problems, such as Love Canal. Hooker [Chemical] bought the canal in 1946, and the New York State Health Department ordered the nearby families to evacuate during the summer of 1978 (Epstein and others, 1982, p. 92). This was the driving force behind Superfund [CERCLA], which President Carter signed on December 11, 1980.

Subsequent Federal Laws

The major amendment to RCRA is known as "HSWA," which is renowned for the "land ban" prohibitions for certain hazardous-waste disposal. HSWA began in 1983 as H.R. 2867, the Hazardous Waste Control and Enforcement Act of 1983 (U.S., 1984, p. 5579). The name "Hazardous and Solid Waste Amendments of 1984" was created in conference committee because the House and the Senate disagreed on the name of the bill (U.S., 1984, p. 5650). It was estimated that RCRA was regulating approximately 40 million metric tons per year of hazardous waste, and Congress was concerned that an equal amount was escaping regulation through various loopholes.

The RCRA standards did not include hazardous wastes burned in boilers (estimated to be 20 million metric tons per year). Also, an estimated 4 million metric tons per year of hazardous waste generated by "small quantity generators" was going into sanitary landfills and into sanitary sewers. Congress was also concerned with waste oil. Approximately 4 million metric tons of waste oil was being burned or disposed of in landfills, and only about 10% was being recycled. HSWA also directed the EPA to write rules on recycling used oil, mostly because of the Times Beach, Missouri, dioxin-contaminated used oil sprayed onto roads (U.S., 1984, p. 5684). Finally, Congress believed that land disposal of hazardous waste was not protecting ground water from contamination. This was exacerbated by the slow RCRA permitting process (U.S., 1984, p. 5578).

On October 10, 1980, President Carter signed a modest reauthorization law which added stiffer penalties to RCRA (Pub.L. 96-482). Two months later, Carter signed Superfund (Pub.L. 96-510). Superfund was reauthorized when, aboard Air Force One, President Reagan signed SARA (Superfund Amendments and Reauthorization Act) on October 17, 1986. SARA replenishes $8.5 billion over five years by taxing petroleum, chemicals, and corporations. SARA also sets cleanup standards and increases public and state participation. In addition to Superfund amendments, SARA also contains the community right-to-know and emergency-planning provisions, in response to the chemical-poisoning disaster in Bhopal, India, on December 3, 1984.

Last, reacting to medical waste being beached on the East Coast, Congress passed the Medical Waste Tracking Act on November 1, 1988. Atlantic Coast and Great Lakes states are included in a "demonstration program."

In summary, RCRA is a broad waste-management law comprising several parts (subtitles). Subtitle C covers hazardous waste; Subtitle D covers nonhazardous solid waste; Subtitle I regulates underground storage tanks [UST] storing petroleum products or any other nonhazardous waste; and Subtitle J contains the demonstration medical-waste tracking program. The EPA is considering RCRA reauthorization legislation for 1990. EPA seems interested in tightening the regulatory programs; and the states seem interested in increasing criminal enforcement, redefining solid waste to be more amenable to enforcement, and increasing authority over waste minimization and recycling.

OKLAHOMA HAZARDOUS-WASTE LAWS

The Oklahoma analog to RCRA, the Controlled Industrial Waste Disposal Act [CIWDA] was H.B. 1811, signed by GovernornBoren on June 15, 1976. It lacked an emergency clause and became effective on September 8, 1976.

Legislative History

H.B. 1811 was authored by Representatives Ted Cowan (R. Tulsa) and Bill Wiseman (R. Tulsa). It was introduced on January 19, 1976. House Speaker Bill Willis doubly assigned the bill to two committees: Environmental Quality, and then to Oil and Gas. The Environmental Quality Committee passed a committee substitute on February 18 which added Bob Funston (D. Broken Arrow) as Senate author. The committee substitute favored the recycling of hazardous waste by only requiring disposal plans for wastes which were to be disposed. The committee substitute also stated that the operator of a hazardous-waste facility would be strictly liable for any damages resulting from the operation of such facility (Section 10). On March 3, 1976, the Oil and Gas Committee passed its substitute with minor technical changes. The bill came up on General Order in the House on March 15, and passed 81-13. Engrossed H.B. 1811 also contained the reciprocity provision from the Solid Waste Management Act (where it had been added the previous year, Laws 1975, c. 351, Sec. 14). This provision was for reciprocity among other states for importing hazardous waste.

The Hardage disposal site near Criner was closed for various periods from March through June. Mr. Hardage was protesting the bill, especially the bond and insurance parts, which raised his disposal costs.

Engrossed H.B. 1811 was assigned to the Senate Public and Mental Health Committee on March 17, 1976. This committee passed a committee substitute on April 15, which primarily added the Senate Minority Floor Leader, Steve Wolf (R. Tulsa), as a coauthor. When the bill came up on General Order on May 19, 1976, Senator Funston amended the bill by changing the name from "hazardous waste" to "controlled industrial waste." It passed the Senate as amended, 32–11. The House declined to accept the Senate amendments, and it was considered in conference. The conferees were Senators Funston, Berrong, and Wolfe, and Representatives Cowan, Dunn, and Wiseman. The conference committee report passed both the Senate (34–11) and the House (90–11) on June 8, 1976, the 89th legislative day. The strict liability section was removed in joint conference, and the term "affected property owner" was defined to mean any person within 1 mile of a proposed new site inside a city or town, and within 2 miles of a proposed new site otherwise (Section 7 of the Bill, 63 O.S.Supp. 1976, Sec. 2757).

Subsequent Oklahoma Laws

In 1978, CIWDA was amended, among other miscellaneous changes, to limit all affected property owners to those residing within 1 mile of a proposed site, regardless of whether the site was to be within city limits. [Laws 1978, c. 260 (May 10, 1978, emergency).] The following year, the only amendment was to provide that at a contruction-permit hearing the Department could hear testimony concerning property values of the affected property owners. [Laws 1979, c. 137.] This language was removed in 1981.

The 10th Circuit Court of Appeals, relying on *City of Philadelphia v. New Jersey*, 437 U.S. 617 (1978), ruled that the Oklahoma reciprocity provision for importing hazardous wastes for disposal was unconstitutional. [*Hardage v. Atkins*, 619 F.2d 871 (10th Cir. 1980).]

The amendments made in 1981 were intended to make the Oklahoma program compatible with RCRA for authorization. [Laws 1981, c. 322.] Also, the 1981 amendments required that the regulations be in reasonable accord with the EPA RCRA rules; added qualified interest groups with standing to call for a hearing on a construction permit; raised the civil and criminal penalties to $10,000.00 per day of violation; and repealed the reciprocity provision which had been struck by the 10th Circuit Court of Appeals. Last, the 1981 amendments recodified CIWDA. CIWDA was originally codified at 63 O.S.Supp. 1976, Sections 2251 and following; and was renumbered to Sections 1-2001 and following by Laws 1981, c. 322, Sec. 18. The purpose of the renumbering was to move CIWDA into the Public Health Code, and thereby subject to the full range of powers available to the State Health Department.

The 1982 amendment simply set out penalties for violation of the Corporation Commission's deleterious-substances provisions. [Laws 1982, c. 248.] More significantly, however, was the passage of the Controlled Industrial Waste Fund Act. This provided a monetary source for dealing with emergencies.

No amendments were made to CIWDA in 1983 and 1984. However, Oklahoma adopted the Central Interstate Low-Level Radioactive Waste Compact in 1983. In 1985, fees for permits and services were authorized. [Laws 1985, c. 113.] This amendment also allowed County Commissioners to review their road-classification plans and to determine whether roads and bridges need upgrading along the route of hazardous-waste transportation to sites proposed in their counties.

In 1986, five separate bills became law. First, the Department of Public Safety was given specific control over hazardous-waste and hazardous-materials motor carriers. [Laws 1986, c. 80.] Financial responsibility requirements were amended. [Laws 1986, c. 140.] Several amendments needed under HSWA were also made. [Laws 1986, c. 180.] The prorating of fees and lower fees for small-quantity generators were provided. [Laws 1986, c. 229.] Incentive for waste reduction and waste recycling was made in the Recycling, Reuse and Ultimate Destruction Incentive Act [RRUDIA]. And finally, a 1-year moratorium was placed on processing permits for controlled industrial waste landfills, surface impoundments, and injection wells, commencing April 11, 1986. [S.J.R. 33.]

In 1987, CIWDA was amended to distinguish on-site and off-site treatment, storage and disposal sites, and prohibited the siting of commercial sites over groundwater resources. Also, the requirement for an emergency-response plan for affected property owners was instituted for new construction-permit applications. [Laws 1987, c. 51.]

1988 added minor corrections for HSWA compatibility, and required objections of affected property owners to the emergency-response plans to be based on minimizing hazards to health and property (this amendment was demanded by the EPA). [Laws 1988, c. 42.] Also, multi-user on-site treatment facilities were authorized for co-owner-generated wastes. [Laws 1988, c. 54.]

Oklahoma Regulations

Section 3 of the original act (now Sec. 1-2003) establishes the Controlled Industrial Waste Management Division. Don Hensch was the first director, and provided the expertise needed for the new regulations. The first CIWDA regulations were adopted by the State Board of Health on June 11, 1977. Since that time, the regulations have been amended 26 times.

In 1980, an ad hoc group, with membership from environmental groups, industry, and the State Health Department, began working on the 1981 amendments to CIWDA, and to the rules, to seek authorization of the Oklahoma program from the EPA. This ad hoc group evolved into the Controlled Industrial Waste Management Council, created in 1981 "to represent the interest of the people of Oklahoma." [63 O.S.Supp. 1981, Sec. 1-2003.1.] The primary function of the Council is to recommend regulations to the State Board of Health. Dr. Kenneth Johnson was the first President of the Council, and was appointed on November 4, 1981, by Governor Nigh. Oklahoma was finally authorized under the federal RCRA program on December 27, 1984. [49 Fed.Reg. 50362.]

In 1985, used oil not destined for recycling was deleted from the list of controlled industrial wastes. On July 9, 1987, the regulations were revised into the present format, which incorporates the EPA regulations by reference, adding rules only where Oklahoma law is more stringent. Then, on October 29, 1987, the exclusionary siting criteria recommended by the Council were adopted as regulations.

In summary, the Oklahoma solid-waste and hazardous-waste laws are comparable to the federal RCRA, and more stringent in some respects. S.B. 153 (1989) will be carried over to the 1990 Oklahoma Legislature. This bill is an attempt to strengthen the Solid Waste Management Act, and it may also serve as a vehicle to provide some needed hazardous-waste authority. Legislative history is such that new solid-waste and hazardous-waste legislation can be expected each year. This legislation should receive supportiv attention.

CONCLUSION

History tells us that politics can react quickly to disasters. For example, Love Canal triggered Superfund; Bhopal prompted SARA Title III; and hypodermic needles on New York beaches induced medical-waste tracking. History also teaches that fast Congressional action tends to shift problems rather than solve them. For example, the air and water legislation of the early 1970s concentrated wastes in the land. HSWA now attempts to ban land disposal of many wastes. Yet, industrial-waste technology has not brought about a significant, timely reduction in the amount of wastes generated. There are now approximately 1,200 Superfund sites, of which only 38 have been cleaned up. [*Daily Oklahoman*, November 8, 1989.] Most of this occurred in the face of a 1965 law intended to encourage the reduction or recycling of wastes. Clearly, Congress can't fool Mother Nature.

Conscientious industries have for more than 10 years been living under the specter of RCRA. Hopefully they will continue. RCRA and HSWA have raised the price of hazardous-waste disposal. Industry, conscientious or not, will search for cheaper methods, including recycling, waste reduction, waste-fuel burning, and illegal disposal. Because there are no ready solutions to the amount of wastes being produced, then "land-ban" may have little impact on the problem—or worse, it may increase the risks. Congress encourages recycling by exempting it from RCRA at the federal level, which has been upheld by the courts. [See *American Mining Congress v. EPA*, 824 F.2d 1177 (D.C.Cir. 1987).] Superfund has taught that hazardous wastes not properly dealt with will continue to burden society. We must eliminate exemptions and take steps to see that such wastes really are properly recycled or disposed of.

CHRONOLOGY OF HAZARDOUS-WASTE EVENTS

Events believed to be significant in shaping the history of Oklahoma's hazardous-waste program are outlined below. Perhaps the time-line perspective will make their importance more apparent.

Dec. 1946	Hooker Chemical purchased Love Canal.
Oct. 20, 1965	Solid Waste Disposal Act enacted (federal).
Jan. 1, 1970	NEPA passed (federal).
Mar. 17, 1970	Oklahoma Solid Waste Management Act enacted.
July 9, 1970	Nixon proposed establishment of the EPA.
Oct. 26, 1970	Resource Recovery Act enacted (federal).
Dec. 2, 1970	EPA created.
Dec. 31, 1970	Clean Air Act amendments (federal).
Sept. 15, 1972	Hardage disposal permit issued (McClain County).
Oct. 18, 1972	Clean Water Act enacted (federal).
July 1, 1973	Oklahoma solid and hazardous waste rules adopted.
July 12, 1975	Hazardous waste reciprocity in Oklahoma.
Jan. 19, 1976	CIWDA introduced (H.B. 1811).
Feb./June 1976	Hardage site closes in protest of H.B. 1811.
June 15, 1976	CIWDA enacted.
June 22, 1976	RCRA introduced in Congress.
Sept. 8, 1976	CIWDA effective.
Oct. 21, 1976	RCRA enacted.
June 11, 1977	CIWDA rules promulgated by State Board of Health.
Apr. 21, 1978	RCRA deadline for EPA to promulgate RCRA rules.
May 10, 1978	CIWDA "affected property owners" within 1 mile.
June 23, 1978	*City of Philadelphia v. New Jersey* (solid waste is commerce).
Aug. 2, 1978	New York ordered Love Canal emergency evacuation.
Apr. 14, 1980	10th Circuit struck Oklahoma reciprocity clause.
May 19, 1980	EPA published the RCRA regulations.
Spring 1980	OSDH began working on RCRA primacy application.
Oct. 10, 1980	RCRA reauthorized (stiffer penalties).
Nov. 18, 1980	Royal Hardage ceased operating Criner site.
Nov. 19, 1980	EPA RCRA regulations became effective.
Dec. 11, 1980	Superfund [CERCLA] enacted.
July 1, 1981	CIWDA amended, renumbered, Council created.
July 24, 1982	Oklahoma UIC primacy (47 Fed.Reg. 27273).
Oct. 11, 1982	Controlled Industrial Waste Fund Act enacted.
May 12, 1983	HSWA introduced in Congress (as H.R. 2867).
Sept. 23, 1983	Central Interstate Low-Level Radioactive Waste Compact.
May 10, 1984	First Superfund amendment introduced (H.R. 5640).
Nov. 8, 1984	HSWA enacted.
Dec. 3, 1984	Methyl isocyanate gas poisoning, Bhopal, India.
Dec. 27, 1984	EPA granted RCRA primacy to Oklahoma.
May 30, 1985	CIWDA amended to add fees and county road plans.
Feb. 7, 1985	Used oil deleted from Oklahoma rules.
Jan. 1, 1986	Sooners became 1985 national football champions.
Apr. 16, 1986	1 year moratorium on hazardous waste permits.
May 1986	RRUDIA enacted to encourage recycling.
Oct. 17, 1986	SARA enacted.
Nov. 1, 1986	Motor Carrier Safety and Hazardous Materials Safety Act effective.
Jan. 1, 1987	RRUDIA effective.
Apr. 29, 1987	CIWDA off-site permits and emergency plans.

July 9, 1987	CIWDA rules revised to incorporate EPA rules.
Oct. 29, 1987	Oklahoma Exclusionary Siting Criteria rules.
Mar. 21, 1988	Multi-user on-site facilities; emergency plans.
Nov. 1, 1988	Medical Waste Tracking Act (federal).
May 8, 1989	Oklahoma Waste Tire Recycling Act enacted.
Nov. 24, 1989	Hardage/Criner Superfund remedy trial began.

REFERENCES

Anderson, R. W., 1978, The Resource Conservation and Recovery Act of 1976: closing the gap: Wisconsin Law Review 637.

Drennan, J. S., 1976, Environmental Law: coping with Oklahoma's Solid Waste Management Act: 29 Oklahoma Law Review 454.

Epstein, S. S.; and others, 1982, Hazardous waste in America: Sierra Club Books, 593 p.

Gorden, W. W., Jr., 1983, The evolution of the Oklahoma Controlled Industrial Waste Disposal Act since 1976: III Oklahoma City Law Review, 397.

Hahn, R. W., 1988, An evaluation of options for reducing hazardous waste: 12 Harvard Environmental Law Review 201.

Kovacs, W. L.; and Klucsik, J. F., 1977, The new federal role in solid waste management: the Resource Conservation and Recovery Act of 1976: 3 Columbia Journal of Environmental Law 205.

Rauch, Barbara, 1977, Oklahoma's Controlled Industrial Waste Disposal Act: 48 Oklahoma Bar Association Journal 2129.

U.S. Code Congr. & Admin. News, 1969, p. 2751 [NEPA].

_____ 1970, p. 5356 [CAA].

_____ 1974, p. 6454 [SDWA].

_____ 1976, p. 6238–6354 [RCRA].

_____ 1980, p. 6119 [CERCLA].

_____ 1984, p. 5576–5702 [HSWA].

_____ 1986, p. 2835 [SARA].

STATUTORY CITATIONS

Central Interstate Low-Level Radioactive Waste Compact, Laws 1983, c. 27; 63 O.S.Supp. 1983, Sections 1-2101 and following.

Clean Air Act Amendments of 1970, Pub.L. 91-604, 84 Stat. 1676, December 31, 1970, 42 U.S.C. Section 7401. This was a major amendment to the original Clean Air Act (which was primarily for research), July 14, 1955, 69 Stat. 322.

Comprehensive Environmental Response, Compensation and Liability Act [CERCLA or Superfund], Pub.L. 96-510, 94 Stat. 2467, 42 U.S.C. 9601, December 11, 1980.

Federal Water Pollution Control Act Amendments of 1972, Pub.L. 92-500, 86 Stat. 816, October 18, 1972; renamed the Clean Water Act, Pub.L. 95-217, 91 Stat. 1567, 33 U.S.C. 1251, December 27, 1977; the Federal Water Pollution Control Act was originally enacted June 30, 1948, c. 758, 62 Stat. 1155.

Hazardous and Solid Waste Amendments [HSWA], Pub.L. 98-616, 98 Stat. 3221, H.R. 2867, November 8, 1984.

Medical Waste Tracking Act of 1988, Pub.L. 100-582, November 1, 1988, 102 Stat. 2958.

National Environmental Policy Act [NEPA], Pub.L. 91-190, Jan. 1, 1970, 83 Stat. 852, 42 U.S.C. 4321.

Oklahoma Controlled Industrial Waste Disposal Act, Laws 1976, c. 251, H.B. 1811, 63 O.S.Supp. 1976, Sections 2751 and following; renumbered to Sec. 1-2001 and following by Laws 1981, c. 322, Sec. 18.

Oklahoma Controlled Industrial Waste Fund Act, Laws 1982, c. 202, 63 O.S.Supp. 1982, Sec. 1-2015 and following.

Oklahoma Motor Carrier Safety and Hazardous Materials Transportation Act, Laws 1986, c. 80; 47 O.S.Supp. 1986, Sec. 230.1 and following.

Oklahoma Recycling, Reuse and Ultimate Destruction Incentive Act [RRUDIA], Oklahoma Laws 1986, c. 164; 68 O.S.Supp. 1986, Sec. 2357.14 and following. Signed May 9, 1976; effective January 1, 1987 (Sec. 8).

Oklahoma Solid Waste Management Act of 1970, Laws 1970, c. 69, H.B. 1499, 63 O.S.Supp. 1970, Sec. 2251 and following.

Oklahoma Waste Tire Recycling Act, Laws 1989, c. 176, 68 O.S.Supp. 1989, Secs. 53001 and following, and 63 O.S.Supp. 1989, Secs. 1-2324 and 1-2325.

Resource Conservation and Recovery Act [RCRA], Pub.L. 94-580, Sec. 2, 90 Stat. 2796, 42 U.S.C. 6901 and following, Oct. 21, 1976.

Resource Recovery Act of 1970, Pub.L. 91-512, Title I, 84 Stat. 1227, October 26, 1970.

Safe Drinking Water Act, Pub.L. 93-523, 88 Stat. 1660, 42 U.S.C. 300f, December 16, 1974. Note: Part C contains the Underground Injection Control [UIC] provisions, 42 U.S.C. 300h.

Solid Waste Disposal Act of 1965, Pub.L. 89-272, Title II, 79 Stat. 997, 42 U.S.C. 3251–3259, October 20, 1965. This was recodified by RCRA to Sections 6901 and following.

Superfund Amendments and Reauthorization Act [SARA], Pub.L. 99- 499, 100 Stat. 1615, October 17, 1986.

Geologic and Hydrologic Siting Criteria for Near-Surface Hazardous-Waste Disposal Facilities

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ABSTRACT.—The Oklahoma Geological Survey has developed several maps and reports for preliminary screening of the State of Oklahoma to identify areas that are generally acceptable or unacceptable for disposal of a wide variety of waste materials. These maps and reports focus on the geologic and hydrogeologic parameters that must be evaluated in the screening process. One map (and report) shows the outcrop distribution of 35 thick shale or clay units that are generally suitable for use as host rocks for surface disposal of wastes. A second map shows the distribution of unconsolidated alluvial and terrace-deposit aquifers, and a third map shows the distribution and hydrologic character of bed-rock aquifers and their recharge areas. The last two maps show the areas in the State where special attention must be exercised in permitting storage or disposal of waste materials that could degrade the quality of ground water. State regulatory agencies and industry are using these maps and reports in preliminary screening of the State to identify potential disposal sites. These maps in no way replace the need for site-specific investigations to prove (or disprove) the adequacy of a site to safely contain waste materials.

INTRODUCTION

In recent years, considerable attention has been focused on the problem of disposal of industrial wastes in Oklahoma. In the past, industrial wastes such as spent acids, caustic solutions, poisons, flammable liquids, explosives, liquids containing heavy-metal ions, and other materials were disposed of without sufficient assurance that they would be permanently isolated from fresh-water resources and the biosphere (the zone of living organisms). To properly regulate current and future industrial-waste disposal, the state legislature passed the Oklahoma Controlled Industrial Waste Disposal Act in 1976, modified in 1978, and the Oklahoma State Department of Health established rules and regulations for carrying out the management and disposal of industrial wastes (Oklahoma State Department of Health, 1979).

To facilitate future selection of near-surface waste-disposal sites, the Oklahoma Geological Survey has prepared several maps and reports (Johnson and Luza, 1980; Johnson, 1983) for preliminary screening of the State to identify areas that are generally acceptable or unacceptable. These are reconnaissance studies only, and they do not establish the ultimate suitability or unsuitability of any particular rock unit or any specific site. Such site-specific suitability can only be established by detailed on-site investigations. Furthermore, these reconnaissance studies address only the disposal of industrial wastes, and do not consider the disposal of radioactive wastes.

The current report summarizes the methodology used in developing the geologic and hydrogeologic parameters important in a regional or statewide screening process, and shows how they have been applied in the State of Oklahoma.

GEOLOGICAL SCREENING

Of primary concern in selecting a rock unit and site for waste disposal is the need for assurance that the waste will be isolated from fresh-water zones and the biosphere for as long as the waste is hazardous to man and his environment. Rock units most favorable for surface disposal of hazardous waste in Oklahoma are impermeable sedimentary rocks, such as shale and clay, that can be excavated and that can prevent loss or migration of wastes from the disposal pit (Fig. 1). Geologic data examined in the screening included all surface geologic maps, as well as most of the literature dealing with mineralogy and physical properties of clays and shales in Oklahoma (Johnson and Luza, 1980).

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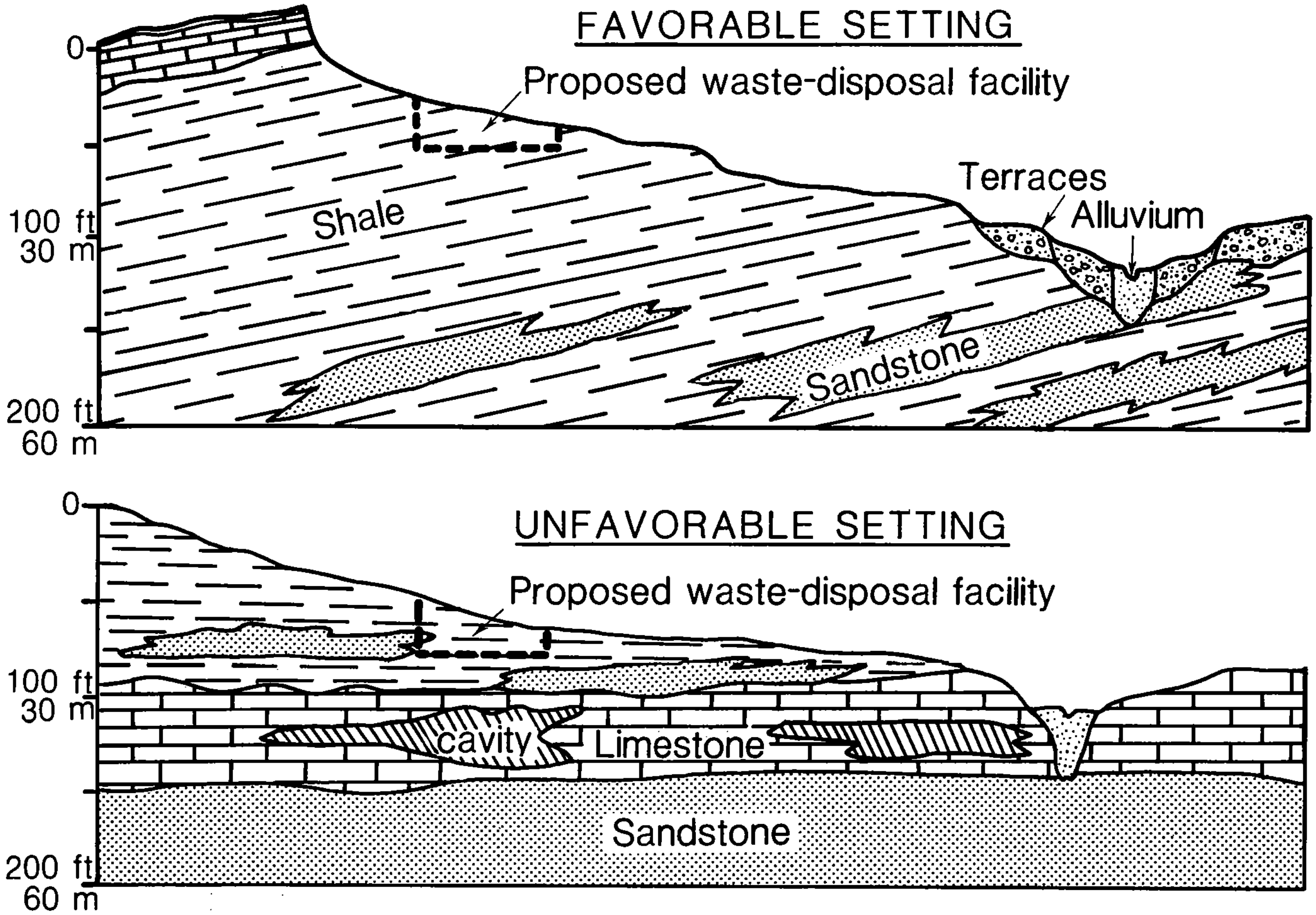


Figure 1. Schematic cross sections showing hydrogeologic settings that generally are favorable (above) or unfavorable (below) for siting a near-surface waste-disposal facility.

Important Geological Characteristics

A reconnaissance-level study consists of evaluating the thickness, structure, and character of potential host rocks, based upon all available data. The character of a potential host rock includes its physical, mineralogic, and lithologic properties. Physical parameters are grain size, permeability, plasticity, and shrink-swell potential, whereas the mineralogic data of chief importance are the identities of the major clay minerals. Lithologic properties used to evaluate bedrock units include the presence or absence of fractures, joints, cavities, caverns, and thin layers or lenses of permeable rock.

In Oklahoma, thick shales and clays are generally the most desirable rock units for geologic containment of industrial wastes at the surface (Fig. 1). Most shales and clays, when wet, have more soil-like than rock-like properties, and they consist chiefly of clay minerals, such as illite, montmorillonite, chlorite, and kaolinite, which generally have the ability to adsorb metal ions, as well as to retard lateral and vertical migration of fluids. It was important to document and reference the more comprehensive and/or detailed studies of clays and shales in Oklahoma, and also to present tables and summary information on the physical, mineralogic, and lithologic properties of the potentially suitable rock units.

Many outcropping geologic units in Oklahoma generally are not well suited for surface disposal of wastes (Fig. 1). Limestone and gypsum are very susceptible to dissolution and commonly are karstic, which makes long-term waste containment unlikely. Granite and metamorphic rocks generally are fractured, which might permit downward and lateral migration of fluids, and many sandstone units have a fairly high porosity and permeability. Alluvium and terrace deposits typically are uncemented, porous, permeable layers of sand, silt, clay, and gravel: such material normally cannot prevent the migration of waste fluids.

Classification of Geologic Units

After evaluating important geological characteristics, Johnson and Luza (1980) classified all the rock units in Oklahoma into three principal zones: Zone 1, generally favorable; Zone 2, less favorable; and Zone 3, least favorable for surface disposal of industrial wastes (Fig. 2).

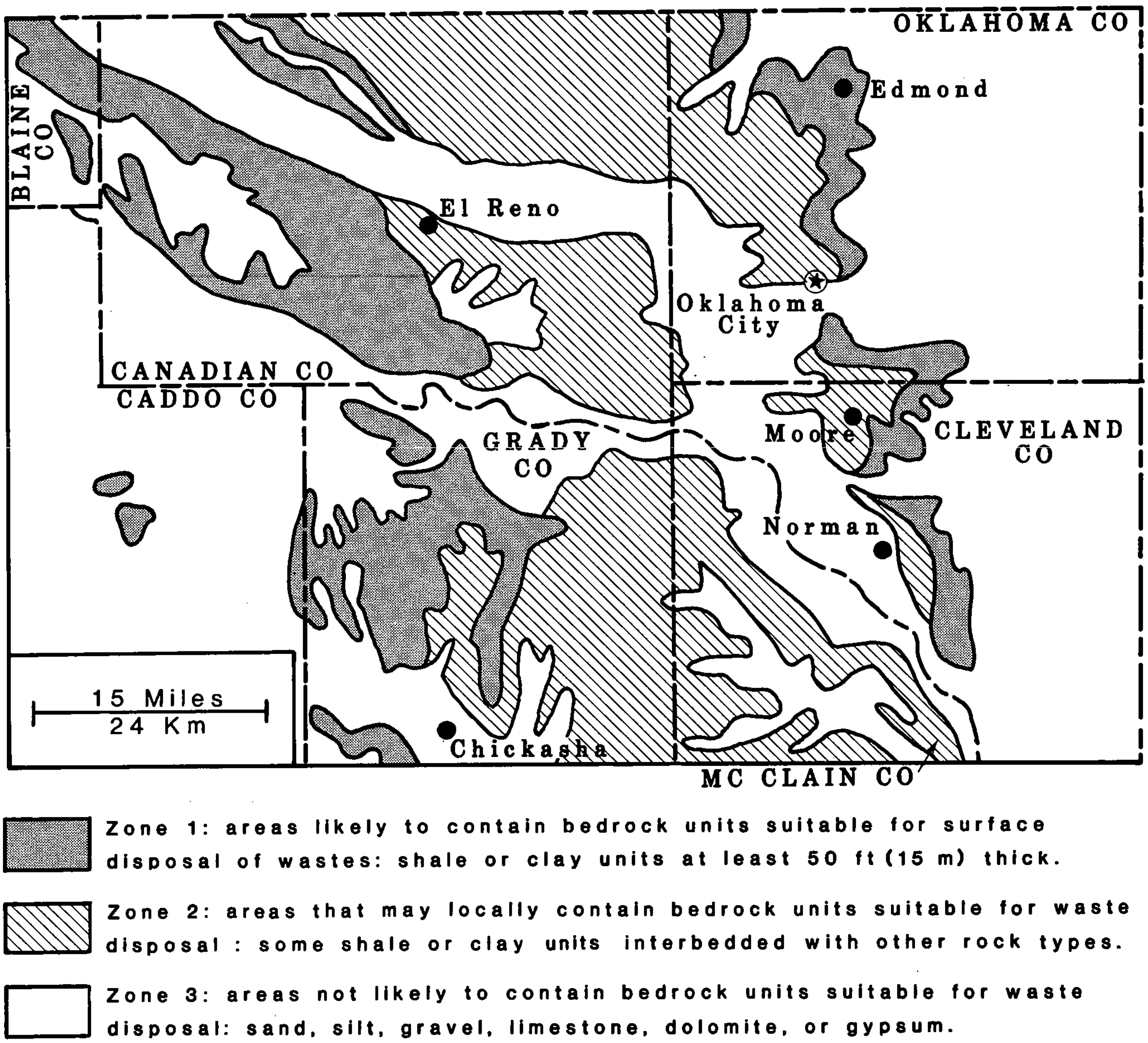


Figure 2. Map of central Oklahoma, showing distribution of bedrock units classified in Zones 1, 2, and 3 (modified from Johnson and Luza, 1980).

The major characteristics of a rock unit classified in Zone 1 are low permeability and sufficient vertical and lateral extent to assure long-term geologic containment of waste. Thick and widespread deposits of shale and clay best fulfill these general requirements in Oklahoma, and Johnson and Luza (1980) arbitrarily selected a minimum thickness of 50 ft as a criterion for identifying the more favorable rock units in the State. Although shales less than 50 ft thick may be suitable locally for waste containment, such shales are too numerous in Oklahoma for characterization in a reconnaissance report and are too thin to be shown adequately on the map prepared by Johnson and Luza (1980) at a scale of 1:750,000.

Zone 1, therefore, consists of bedrock formations composed mainly of shale or clay units at least 50 ft thick, where such shale or clay units crop out or are covered by no more than 10 to 20 ft of soil, alluvium, or other loose material. The shale and/or clay materials in Oklahoma typically have very low permeability coefficients, low to moderate plasticity, and low to moderate shrink-swell potentials. The dominant clay mineral in almost all shales or clays in Oklahoma is illite, and there are lesser and variable amounts of chlorite, kaolinite, montmorillonite, and vermiculite.

Zone 2 embraces areas less likely to contain bedrock units suitable for near-surface disposal of industrial wastes. This zone locally may include outcrops of thick shale or clay, as in Zone 1, but the shales are relatively few and are interbedded with other rocks, such as sandstone, siltstone, and thin layers of limestone. Therefore, additional field studies are needed to determine whether parts of a Zone 2 area may be suitable locally.

Zone 3 areas contain bedrock units least suitable for near-surface disposal of industrial wastes. There is little likelihood that thick shales or clays, such as those in Zone 1, are present in rock units of this category. These geologic units consist mostly of porous and permeable material, such as (1) sand, silt, and gravel in alluvium and terrace deposits; (2) sand, sandstone, and limestone in aquifer-recharge areas; and (3) limestone, dolomite, and gypsum in areas of cavernous or karstic features. Granite and other igneous rocks are included in this zone.

Assignment of each of Oklahoma's bedrock units to one of these three zones is based on previous field studies and on review of published and unpublished geologic reports. Assignment of an area or rock unit to a particular zone does not confirm or reject its suitability for waste containment, as that can be done only through detailed on-site exploration and testing of a prospective site. Furthermore, the assignment does not take into account any special engineering techniques, such as use of clay liners, that might improve long-term containment of waste in a somewhat permeable host.

Statewide distribution of bedrock units according to this threefold zonal classification is presented by Johnson and Luza (1980) on a map at a scale of 1:750,000 (an example of part of this map is shown in Fig. 2). Such a map should be used as a preliminary guide to the geologic suitability of bedrock units as host rocks for near-surface disposal of industrial wastes. Mapped boundaries between zones were compiled from geologic maps referenced by Johnson and Luza (1980), and the user may need to examine those original maps for more detail.

A total of 35 different formations in Oklahoma contain shale or clay units at least 50 ft thick that may be suitable locally for geologic containment of industrial wastes. These Zone 1 units are widely distributed in Oklahoma, and their outcrops aggregate about 7,600 mi² (about 11% of the State); Figure 3 is generalized from the original 1:750,000 map. Johnson and Luza (1980) presented general descriptions of each of the 35 units, but detailed data for specific areas can be obtained through the extensive list of references in their report.

HYDROGEOLOGIC SCREENING

The location and characteristics of ground-water sources are important in judging the suitability of a region or a site for waste disposal. Recharge areas for aquifers should be avoided, to prevent possible contamination of ground-water supplies. Oklahoma's principal aquifers are stream and river deposits (alluvium, terraces, and the Ogallala Formation), limestones, sandstones, and gypsums. Areas not underlain by principal aquifers consist mainly of shales, siltstones, and some sandstones that commonly yield only enough water for household use.

Most reports on the ground-water resources of Oklahoma have been released by the Oklahoma Geological Survey, the Oklahoma Water Resources Board, and the U.S. Geological Survey. Upon review of all hydrologic reports by these and other publishing

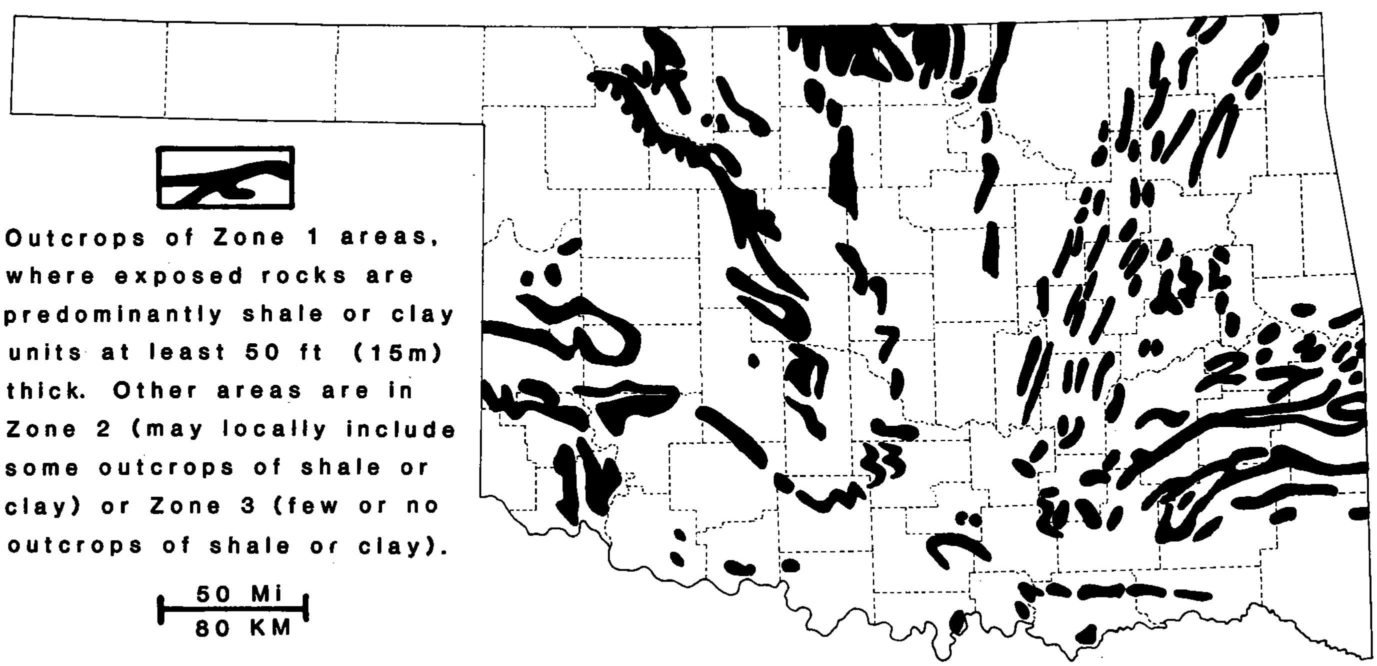


Figure 3. Map of Oklahoma showing areas likely to contain Zone 1 bedrock units generally favorable for near-surface disposal of industrial wastes. Modified from Johnson and Luza (1980).

agencies, two maps were compiled at 1:500,000 to show the principal ground-water resources and recharge areas in Oklahoma (Johnson, 1983): one map shows the bedrock aquifers and recharge areas; the second map shows the unconsolidated alluvium and terrace deposits. Alluvium and terrace deposits are shown on a separate map because they are abundant and would largely mask information on the distribution of bedrock aquifers.

Johnson (1983) compiled a comprehensive bibliography and index map of reports dealing with ground-water resources in Oklahoma.

Bedrock Aquifers and Recharge Areas

Oklahoma's bedrock aquifers are widespread and differ in composition (Fig. 4). Most aquifers are sands or sandstones (Antlers, Cedar Hills, Elk City, Garber–Wellington, Noxie, Ogallala, Oscar, Rush Springs–Marlow, Vamoosa-Ada aquifers); some are mainly limestones or dolomites (Arbuckle–Timbered Hills, Keokuk–Reeds Spring, Roubidoux–Gasconade–Eminence, Simpson–Arbuckle aquifers); one is predominantly gypsum (Blaine aquifer); and one is mainly fractured novaculite and chert (Arkansas Novaculite–Bigfork aquifer). The aquifers range in thickness from 100 ft to several thousand feet. Depths at which fresh ground water can be obtained range from less than 100 ft to more than 1,000 ft.

Aquifer-recharge areas must be identified (Fig. 5) to control waste-disposal activities that could adversely impact ground-water resources. "Recharge areas" are parts of the land surface where surface water (precipitation, surface runoff, streams, rivers, and lakes) enters the subsurface and eventually migrates downward to the zone of saturation in an aquifer. In some areas, bedrock aquifers also may be recharged where the aquifer is overlain by confining strata, such as shales and siltstones, that have low permeabilities and normally prevent or inhibit the movement of ground water. Such recharge may occur where the confining strata contain one or more of the following: (1) continuous or discontinuous layers with higher permeability; (2) joints, fractures, faults, or other structural discontinuities; and (3) boreholes, mine shafts, or other man-made excavations. Any of these natural or artificial features that penetrate the confining strata into the underlying aquifer represent potential local pathways for surface waters to enter the aquifer.

Mapping known or potential recharge areas for

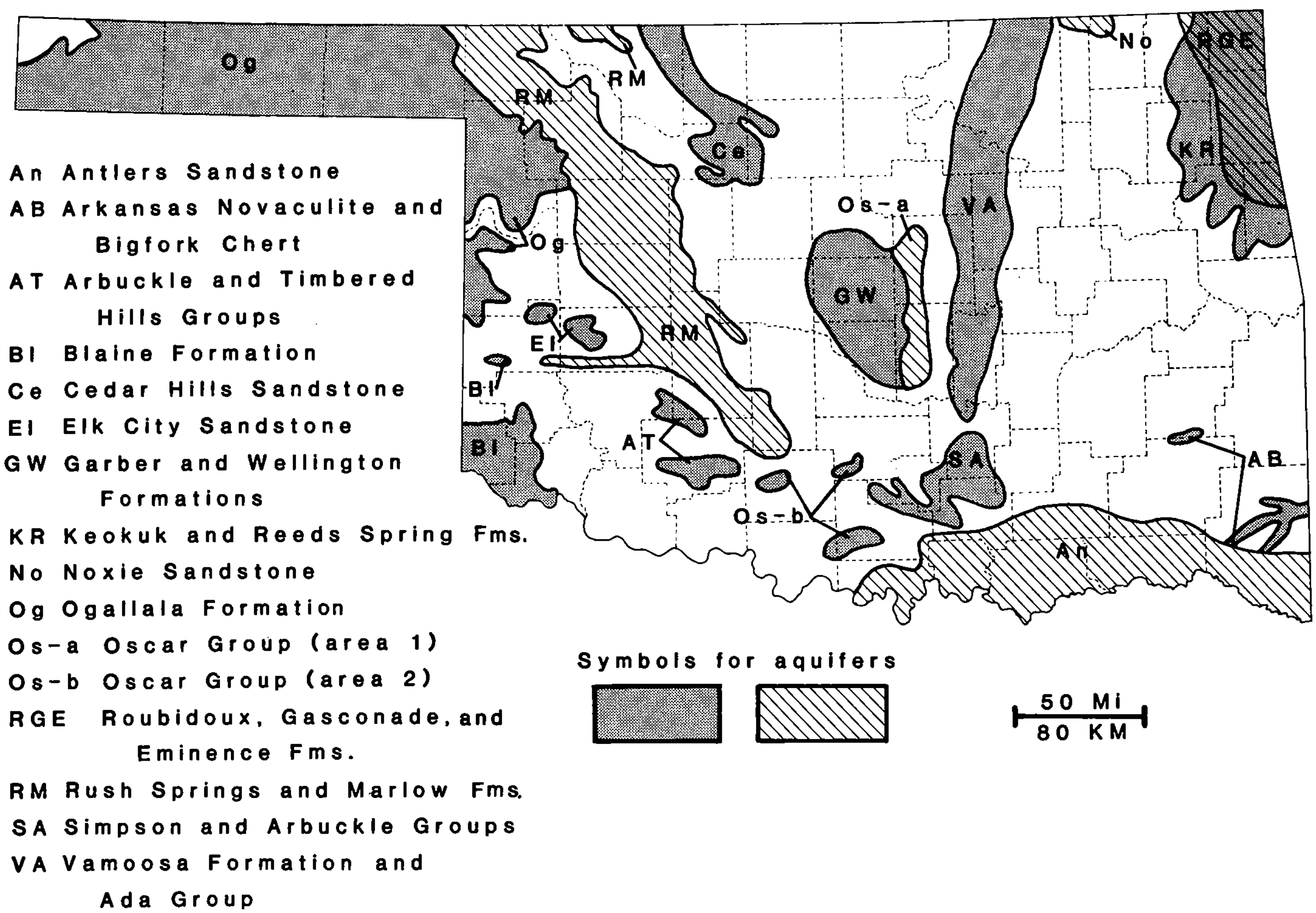


Figure 4. Map showing bedrock aquifers in Oklahoma (modified from Johnson, 1983).

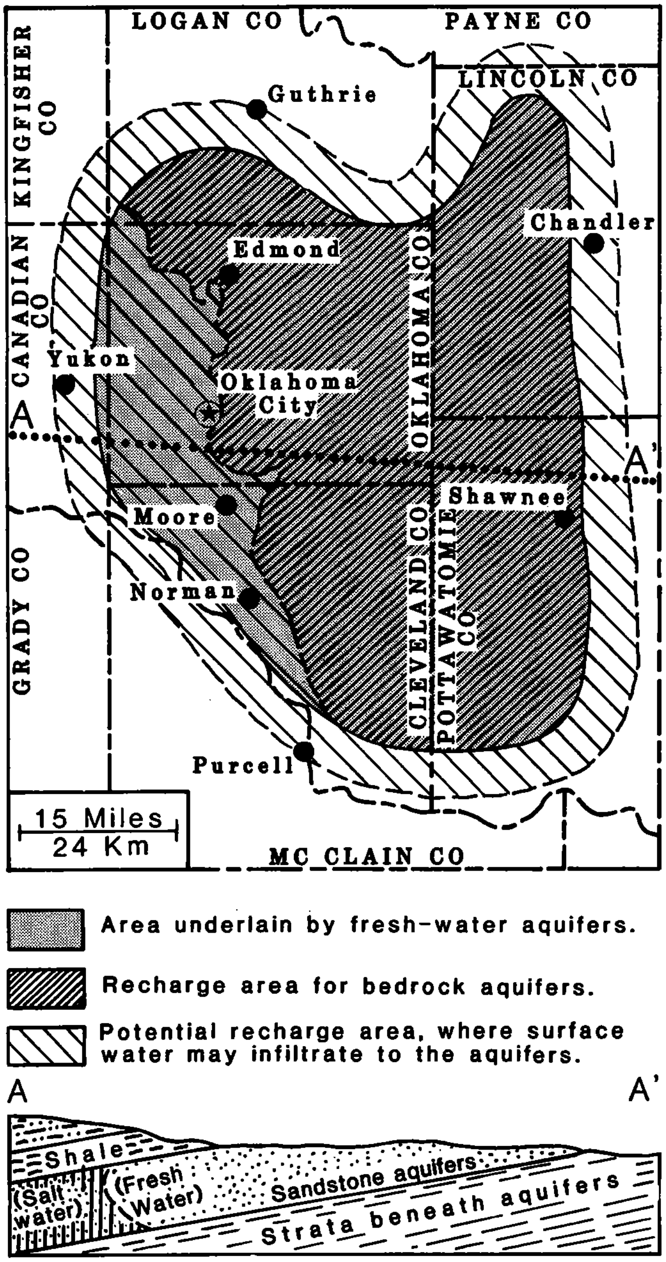


Figure 5. Map showing distribution of the Garber–Wellington and Oscar aquifers and their recharge areas in central Oklahoma (modified from Johnson, 1983).

various bedrock aquifers (Fig. 5) is based upon the surface geology of Oklahoma and the relationship of outcropping rocks to aquifers. On the bedrock-aquifer map, areas characterized as "recharge areas" include: (1) outcrops of the aquifer itself, and (2) outcrops of overlying porous and permeable rocks hydraulically connected with the aquifer. "Potential recharge areas" shown on the map include: (1) areas where an aquifer is overlain by confining strata that may contain natural or artificial pathways that could permit downward movement of surface water to the aquifer, and (2) additional safety zones that generally extend 4 miles beyond the known limits of an aquifer. The safety zones extend an arbitrary, yet conservatively reasonable distance from the aquifers, to protect areas that may have a hydrogeologic impact on the recharge of the aquifer, as well as areas that may overlie unknown, lateral extensions of the aquifer.

Because the known and potential recharge areas are critical to the State's bedrock aquifers, special care must be taken in the utilization of these lands. In particular, special attention must be exercised in storage or disposal of waste materials that contain leachable or liquid contaminants that could degrade the quality of water within or flowing across the potential recharge areas. Even greater care must be exercised to protect the quality of water within or flowing across the known recharge areas.

Bedrock aquifers underlie about 27,000 mi^2 of Oklahoma (about 39% of the State), and an additional 7,000 mi^2 (about 10% of the State) are potential recharge areas: thus, about 49% of the State is underlain by bedrock aquifers and their known or potential recharge areas.

Alluvium and Terrace Deposits

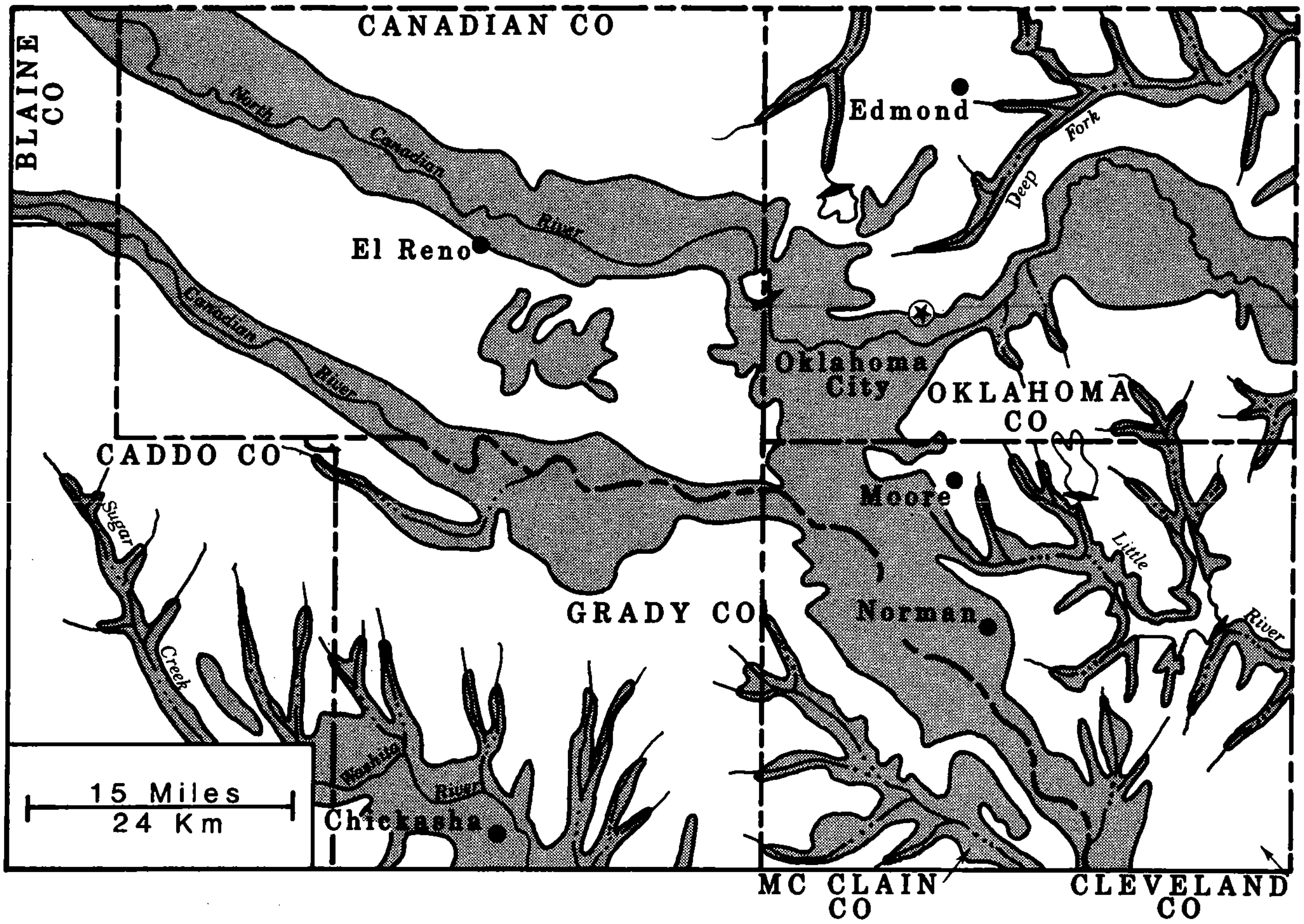
The second hydrologic map in this series (Johnson, 1983) shows the distribution of principal Quaternary alluvium and terrace deposits in Oklahoma. These deposits consist mainly of unconsolidated sand, silt, clay, and gravel laid down by rivers and streams that flow generally to the east and southeast across the State: part of the statewide map is reproduced in Figure 6. In Oklahoma, alluvium and terrace deposits typically are 10 to 50 ft thick, although locally they are nearly 100 ft thick along some of the major rivers.

Many alluvial and terrace deposits contain highly porous and permeable sand and gravel layers, and these deposits typically contain important ground-water resources. Although not all alluvial or terrace deposits contain important ground-water aquifers, such aquifers are common enough that each deposit should be considered a potential water resource until proved otherwise.

Recharge areas for ground-water resources in alluvium and terrace deposits are essentially coextensive with the deposits themselves, because almost all ground water contained in these deposits results from downward percolation of water from the land surface. Surface waters that recharge these deposits include precipitation, surface runoff, and streams and rivers that flow across the unconsolidated material. The other locally significant source of ground water in alluvium and terrace deposits is upward or lateral flow from underlying bedrock formations.

SUMMARY

The Oklahoma Geological Survey has been successful in developing statewide reports and maps showing general suitability of bedrock units for near-surface disposal of industrial wastes, and showing principal ground-water resources and recharge areas. These reports and maps are valuable in setting forth hydro-



Alluvium and terrace deposits. Unconsolidated deposits of sand, silt, clay, and gravel that occur along or adjacent to modern and ancient rivers and streams.

Rivers, intermittent streams, and principal lakes.

Figure 6. Map showing distribution of unconsolidated alluvium and terrace deposits in central Oklahoma (modified from Johnson, 1983).

geological screening characteristics for siting of disposal facilities and in enabling a preliminary screening of large regions of the State to identify potential disposal sites. It must be understood that these reports and maps do not replace the need for site-specific investigations to prove (or disprove) the suitability of a site to safely contain waste materials. At present, the data prepared under this program are being utilized by the Oklahoma State Department of Health in administering their waste-disposal program, and by the Oklahoma Corporation Commission in regulating the storage or disposal of oil-well drilling fluids.

REFERENCES CITED

Johnson, K. S., 1983, Maps showing principal ground-water resources and recharge areas in Oklahoma: Sheet 1—Unconsolidated alluvium and terrace deposits; and Sheet 2—Bedrock aquifers and recharge areas: Oklahoma State Department of Health, scale 1:500,000.

Johnson, K. S.; and Luza, K. V., 1980, Surface disposal of industrial wastes in Oklahoma, *part II in* Johnson, K. S.; and others, Disposal of industrial wastes in Oklahoma: Oklahoma Geological Survey Circular 80, p. 5–48.

Oklahoma State Department of Health, 1979, Rules and regulations for industrial waste management: Oklahoma State Department of Health Bulletin 0525, 81 p.

Aquifer Protection and Contamination Monitoring Related to Waste-Disposal Facilities

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ABSTRACT.—An increasing amount of ground water is used as a freshwater resource every year. Roughly 95% of the world's usable fresh water, not including icecaps and glaciers, comes from ground water. Approximately 50% of all U.S. residents rely on ground water as their primary source of drinking water (Council on Environmental Quality, 1981). Contamination of ground water has gone unnoticed in the past because the ground water around waste-disposal sites was not used for public drinking supplies. As the number of instances of ground-water contamination due to waste disposal activities continues to rise, much attention has been focused on technologies for protecting ground water and measures for contamination monitoring at waste-disposal facilities.

INTRODUCTION

Ground-water contamination can occur by three main mechanisms: (1) natural processes; (2) waste-disposal activities such as solid-waste landfills, hazardous-waste landfills, or deep-well disposal; and (3) spills, leaks, and agricultural activities and other sources unrelated to disposal (Patrick and others, 1983).

Waste-disposal activities with the greatest potential for releasing contaminants to ground water are the land-based activities such as landfills. Landfills can accommodate a broad variety of wastes at a reasonable cost, and they can also accept residues from other waste-treatment methods. This paper will focus on aquifer-protection technologies and ground-water monitoring related to land-based disposal, especially landfills.

AQUIFER PROTECTION

Physical methods of ground-water protection at waste-disposal landfills consist of liners, capping, and surface-water control measures (Canter and Knox, 1987). These measures are all designed to minimize the amount of moisture reaching the waste and/or leaving the waste-disposal site. In order to remove any liquids that do encounter waste materials, leachate detection and collection systems are also utilized. The 1984 Hazardous and Solid Waste Amendments (HSWA) of the Resource Conservation and Recovery Act (RCRA) addressed the issue of liners and leachate collection. It was established that certain landfills and surface impoundments would be required to use "two or more liners and a leachate-collection system above (in the case of landfills) and between such liners." A minimum double-liner system composed of a single flexible-membrane liner (FML) overlying a 3-ft-thick compacted-clay liner was allowed under HSWA, pending issuance of EPA regulations or guidance documents (Richardson and Koerner, 1987).

EPA draft Minimum Technology Guidance (MTG) Documents for liners and leachate-collection systems were made available on December 20, 1984 (U.S. Environmental Protection Agency, 1985a). In the draft guidance document, EPA defines performance requirements for two designs that it feels meet minimum technological requirements for hazardous-waste landfills. The two designs are the synthetic-liner/clay-liner system and the synthetic-top-liner/composite-bottom-liner system. Both designs are shown in Figure 1. A current alternative double-liner system incorporates a composite-FML/clay-liner system in place of the primary and the secondary FML, as shown in Figure 2. However, the primary-leachate-collection system is designed to minimize the depth of leachate on the top of the liner and to effect the removal of liquids. The secondary-leachate-collection system is designed to detect leaks in the top liner and to drain off any liquids, should leakage occur in the primary section.

In addition to the use of double-liner systems, the waste-disposal site is also required to minimize the

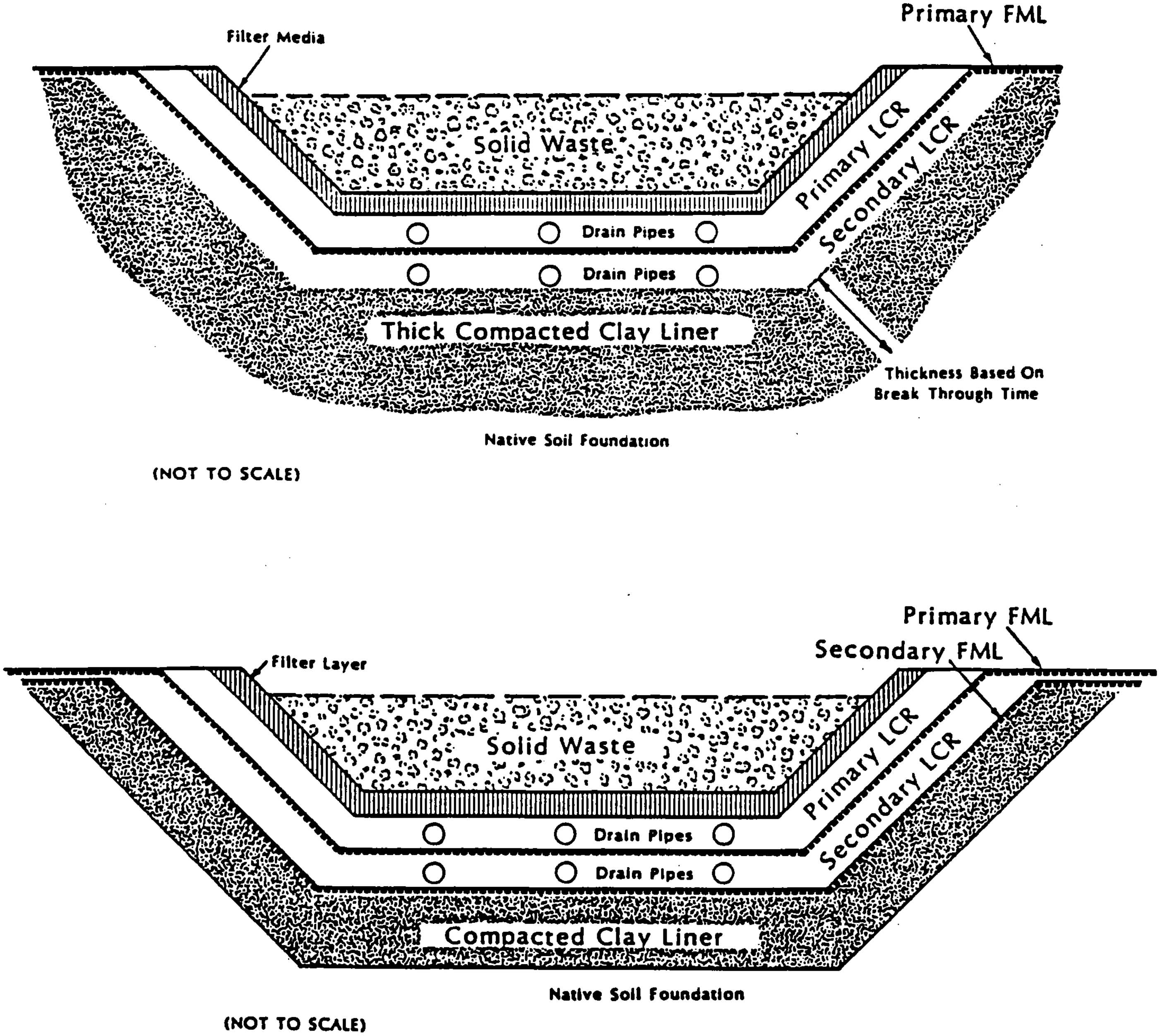

Figure 1. Hazardous-waste landfill liner systems (U.S. Environmental Protection Agency, 1985a).

amount of surface water entering the disposal zone, particularly during the post-closure monitoring period. Figure 3 shows a proposed RCRA guidance final cover and drainage system (Richardson and Koerner, 1987).

In discussing aquifer-protection measures for waste-disposal facilities it is important to delineate the potential shortcomings or deficiencies in the technologies. Discussed below are some of the major issues associated with aquifer-protection measures at hazardous-waste-disposal facilities.

Subtitle C of RCRA mandates that all hazardous-waste landfills must have a liner system capable of preventing migration of liquids from the disposal site for the active life of the waste unit through scheduled closure. In effect, this requirement mandates the use of a synthetic material as the primary liner at hazardous-waste-disposal sites. Thus, containment of contaminants at landfills is attempted with one or more synthetic liners, with or without a compacted-clay liner in parallel. It is now widely recognized that absolute containment at landfills is impossible (Cartwright and others, 1981; Domenico, 1982). Burman and others (1985) examined a large number of hazardous-waste-landfill case studies from the literature and found 27 cases of leakage from 39 sites. Waste escaped in 69% of the cases studied, and the average life of a landfill before a breach of containment occurred was 14 years.

Regardless of waste type, leachate will be formed when the liquid-holding capacity of the landfill is surpassed. Leachate is produced when infiltration from

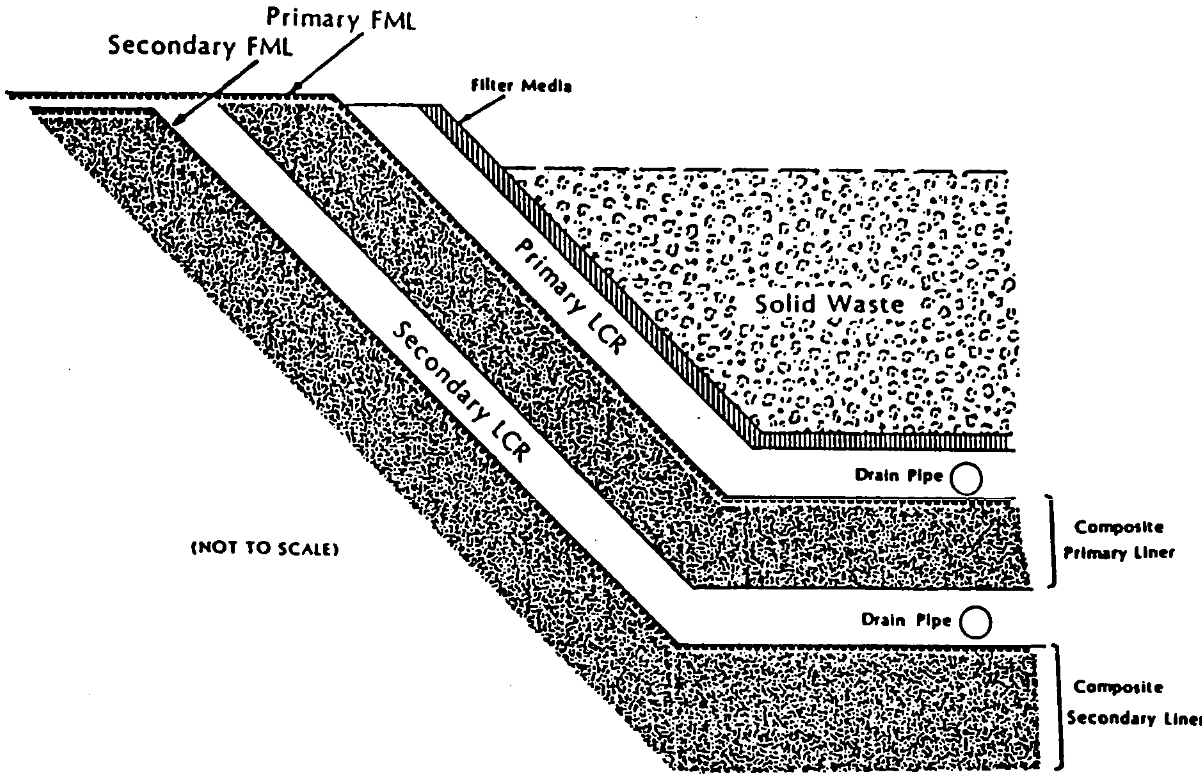

Figure 2. Composite-liner system (U.S. Environmental Protection Agency, 1985a).

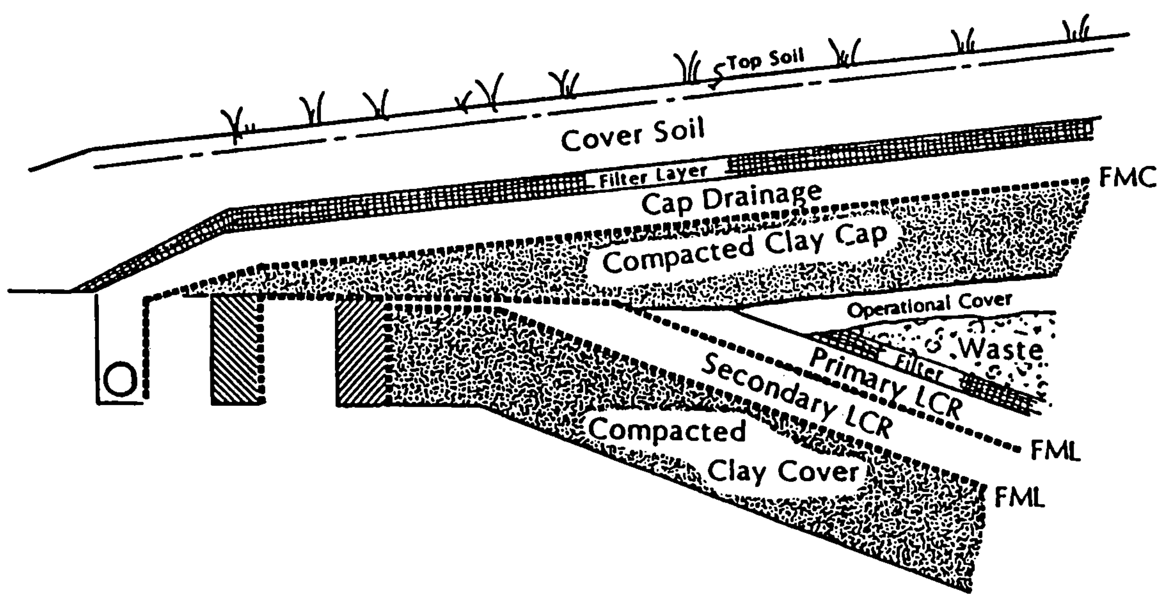

Figure 3. Final cover and drainage system (Richardson and Koerner, 1987).

rainfall, surface drainage, and/or ground water intrusion combine with the inherent moisture content of the waste to exhaust its liquid-holding capacity. The use of leachate-control systems at disposal facilities is designed to maximize the containment and removal of leachate from disposal zones before it can migrate into ground water, or in some cases into surface waters. A major issue associated with leachate collection is the significant volumes of leachate that can be generated. EPA's Office of Solid Waste has estimated that an average land-disposal site, 17 acres in size and with an annual infiltration of 10 in. of water, can generate 4.6 million gallons of leachate per year for 50 to 100 years (Canter and others, 1987).

When a landfill is full and closed, it must be covered with an impermeable clay or synthetic cap accompanied by surface-water drainage measures designed to prevent surface water from entering the disposal zone. RCRA guidelines require the use of a low-permeability layer consisting of at least 2 ft of clay and a 20-mil-thick flexible membrane (U.S. Environmental Protection Agency, 1985b). The design considerations for the cover differ significantly from those for liners. The cover will not be exposed to leachate, but may be breached by erosion or be collapsed due to settlement within the waste material (Richardson and Koerner, 1987; American Institute of Professional Geologists, 1984).

GROUND-WATER MONITORING

The greatest concern with landfill disposal is the possibility of contamination of freshwater aquifers by downward migration of waste constituents from the facility. Monitoring ground-water resources at waste-disposal sites will indicate the occurrence of contamination, so that remedial actions can be undertaken. EPA requires interim-status facilities, which have certain classes of land-disposal units, to have a ground-water-monitoring network capable of evaluating the effects of waste disposal on ground water.

In September 1986, EPA published the RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD), which is mainly directed toward interim-status facilities. The TEGD addresses the topics of (1) site characterization; (2) location and number of ground-water-monitoring wells; (3) design, construction, and development of ground-water-monitoring wells; (4) content and implementation of the sampling and analysis plan; (5) statistical analysis of ground-water-monitoring data; and (6) content and implementation of the assessment plan (U.S. Environmental Protection Agency, 1986).

The basic requirements outlined in the TEGD are to drill a minimum of 1 up-gradient and 3 down-gradient wells, sample the wells for specific parameters on a specific schedule, and statistically compare the up-gradient to the down-gradient data to determine if there was a statistically significant change which would be indicative of ground-water contamination. The ground-water-monitoring program can become complex due to problems associated with location and number of wells, sampling equipment, indicator parameters, and statistical analyses. These issues are discussed below.

Number and Location of Monitoring Wells, Detection

The minimum number of monitoring wells required at RCRA facilities is 4—1 up-gradient and 3 down-gradient wells in the uppermost aquifer beneath the facility. This regulatory minimum number of wells is highly dependent on the characterization of site hydrogeology (U.S. Environmental Protection Agency, 1986).

The purpose of a monitoring well up-gradient from a disposal facility is to provide background ground-water quality from the aquifer monitored by the down-gradient wells. The number of up-gradient wells is highly dependent on the site characterization and the number of the depth-discrete comparisons of water quality with down-gradient wells, as shown in Figure 4. In order to locate up-gradient wells, it is first necessary to identify the ground-water flow direction. Ground-water flow direction may be difficult to determine, as in the following instances (U.S. Environmental Protection Agency, 1986):

1) Waste-management facilities located above aquifers in which the ground-water flow direction changes seasonally;

2) Waste-management facilities located close to a property boundary that is in the up-gradient direction;

3) Waste-management facilities located in areas where nearby surface water can influence ground-water levels;

4) Waste-management facilities located near intermittently or continuously used production wells; and

5) Waste-management facilities located in faulted areas where fault zones may modify flow.

In addition to troubles in determining the location of up-gradient wells, several issues of concern can be noted about the down-gradient or detection monitoring wells. The purpose of down-gradient wells is to detect contaminant movement from the waste-disposal facility. The number and location of the wells are a function of the abundance, extent, and physical/chemical characteristics of the potential contaminant pathways, as well as ground-water flow direction, as shown in Figure 4 (U.S. Environmental Protection Agency, 1986). It is essential that the detection wells be situated such that they intercept any contaminants migrating off-site. In order to determine changes in water quality, the detection wells must also be screened and completed in the same formations as their up-gradient counterparts. This is a feature that cannot always be assured.

Several other deficiencies in the "1 up, 3 down" requirements can also be identified. The requirements do not adequately address the issue of vertical migration or vertical gradients between different formations. The use of spatially and vertically varied monitoring points is not as accurate as the use of spatially varied well nests.

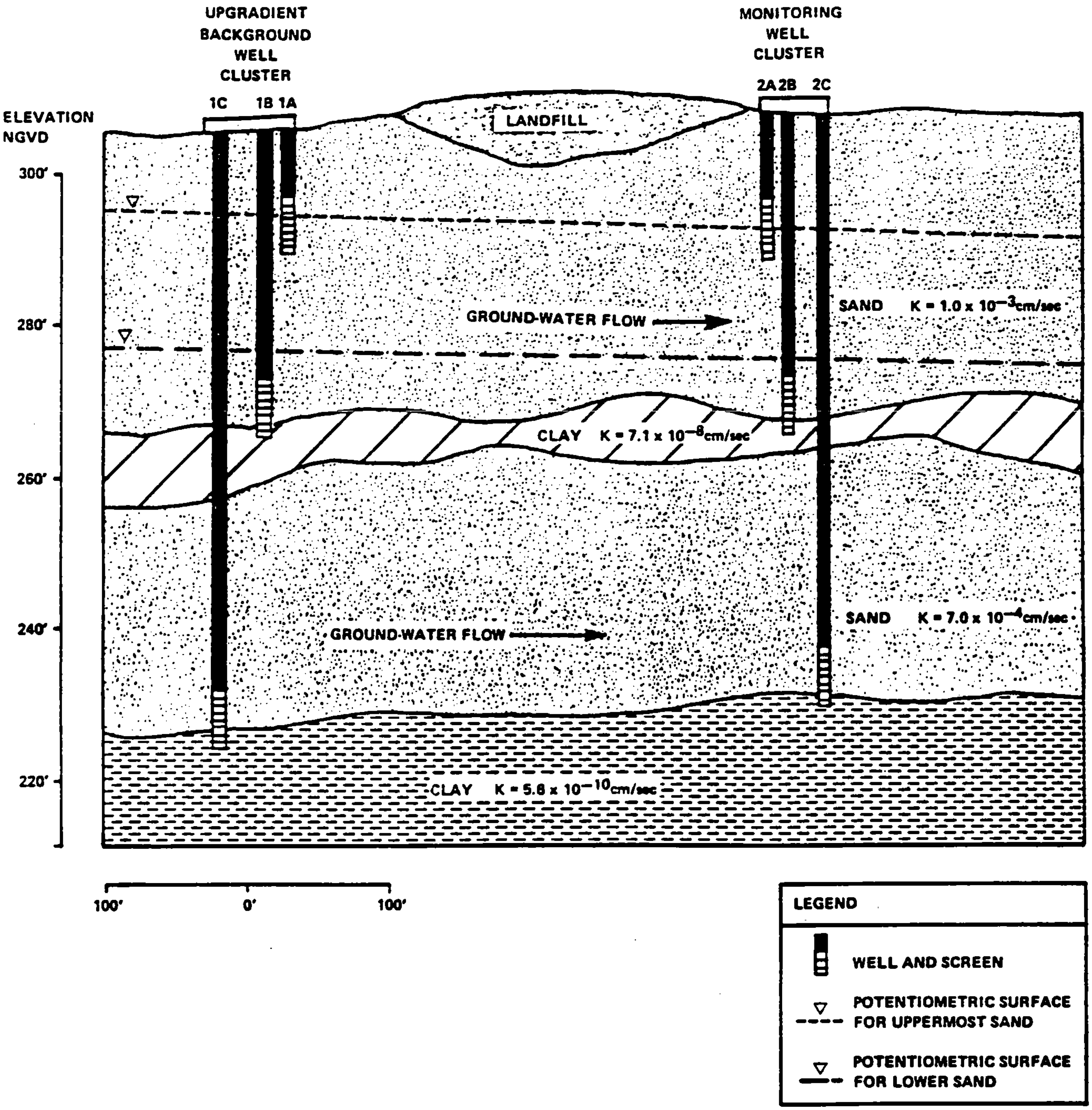

Figure 4. Depth-discrete monitoring wells (U.S. Environmental Protection Agency, 1986).

A basic problem with the ground-water-monitoring requirements is the inherent assumption of hydrogeologic conditions. Simply stated, the status of the subsurface (up-gradient versus down-gradient, vertical migration, etc.) cannot be assessed until the subsurface is accessed. This points to the fact that subsurface characterization becomes a "catch 22" situation, in that information retrieved from a borehole is needed prior to siting and drilling the borehole.

The final issue associated with the ground-water-monitoring requirements is that they represent an "after the fact" approach. In essence, if your monitoring-well network functions properly, you are able to detect a problem with your disposal facility only after it has become a problem.

Monitoring-Well Installation, Purging and Sampling

There is no ideal monitoring-well installation method for all purposes. It is necessary to consider hydrogeologic conditions at the site and parameters to be sampled before deciding which drilling and development method to use. The most widely used drilling methods include air and water/mud rotary methods, cable-tool methods, and auguring. Common development techniques include air-lifting, purging and bailing, and overpumping. It is extremely important that the installation and development of a monitoring well not cause ground-water contamination through alteration of the subsurface conditions.

Prior to sampling a monitoring well, stagnant water in casing storage is purged so that the well contains only water representative of aquifer condition. The amount of purging that is appropriate to obtain a representative ground-water sample has been, and still is, the subject of much controversy (Pennino, 1988).

Sampling equipment used to withdraw ground-water samples must be based on consideration of the parameters to be analyzed. Improper sampling equipment can artificially bias water-quality analyses. The obvious example would be the use of suction lift methods for samples to be analyzed for volatile constituents. EPA has developed a list of acceptable sampling devices.

A final point relative to sampling is the fact that collection of an unbiased sample from a monitoring well is not the end of the potential problems. Once a sample has been collected, the issues associated with preservation, transportation, chain-of-custody, laboratory quality-assurance/quality-control procedures, etc., must all be addressed. Discussion of these issues is beyond the scope of this paper, but it is important to note their potential impact on ground-water-monitoring programs.

Monitoring Parameters

There are no limits to indicator parameter requirements used in ground-water monitoring at hazardous-waste-disposal facilities. Generally, there are two groups of indicator parameters—primary parameters and priority pollutant parameters. Primary parameters include temperature, pH, redox potential, chloride, dissolved oxygen, and specific conductivity. Priority pollutant parameters are outlined in 40 CFR Part 265.92 and include volatiles, base/neutrals, acid extractables, and pesticides.

Statistical Analyses

RCRA interim-status regulations specify that the owners/operators of hazardous-waste facilities use a Student's *t*-test for determination of any statistically significant changes in the quality of ground water at a disposal site. Other *t*-tests that have been recommended include Cochran's Approximation to the Behrens-Fisher *t*-test and the Averaged Replicate *t*-test. The basic idea of these tests is that the mean values of chemical concentrations of samples from wells up-gradient and down-gradient are compared. If there is a statistically significant change in the mean value, it might be indicative of contamination. The TEGD specifies that owners/operators, in addition to these *t*-tests, may perform other *t*-tests as long as the method is explicit and includes (U.S. Environmental Protection Agency, 1986):

1) A clear, understandable explanation of the methodology;

2) Presentation and documentation of all the original data used in the statistical-analysis procedure;

3) Literature-reference citations documenting alternative *t*-test procedures; and

4) A detailed explanation of how data were manipulated and evaluated prior to the statistical analysis, including goodness-of-fit testing, transformations, less-than-detection-limit value manipulations, and power evaluation.

Statistical *t*-tests are based on a number of assumptions, including that the input data approximate a normal distribution and that the data are independent. In other words, sampling of the indicator parameters should be taken randomly, but this is not the case in ground-water sampling procedure as outlined in the RCRA regulations. In addition, the Student *t*-test is based on the assumption that the variances of the two populations from which the two sets of data are obtained must be equal (Canter and others, 1987; U.S. Environmental Protection Agency, 1986).

These assumptions have raised a number of complex issues concerning the use of *t*-tests. The TEGD specifies that owners/operators must submit a goodness-of-fit test to support the non-normality of samples, and use mean and variance estimates from other distributions, such as the log normal, to solve the non-normality of the data. Indeed, the regulations do not allow use of other non-*t*-test statistical procedures (e.g., nonparametric procedures which are less dependent on distributional assumptions) for interim-status facilities (U.S. Environmental Protection Agency, 1986). McNichols and Davis (1988) stated that this is a technically unsound regulation and does not promote statistical procedures for use in ground-water monitoring. They also suggested that many realities surround detection monitoring at hazardous-waste facilities, and these realities must be considered before using any statistical procedures. The realities are listed in Table 1.

MONITORING THE VADOSE ZONE

Currently, monitoring in the vadose zone is required under RCRA only at land-treatment facilities. Canter and others (1987) have identified more than 50 different available vadose-zone monitoring methods, according to the soil characteristics to be monitored. Selecting from these methods, monitoring in the vadose zone could be an early-warning detection of ground-water contamination at landfill disposal facilities.

EPA RESTRICTION ON LAND DISPOSAL

The 1984 amendments to RCRA require EPA to restrict continued land disposal of untreated wastes where such disposal is not protective of human health

TABLE 1.—REALITIES OF GROUND WATER DETECTION MONITORING

Reality #1. The purpose of detection monitoring is to provide an early warning of impending contamination, at relatively low cost to the regulated facility.

Reality #2. So long as monitoring data is subject to random variability, every monitoring decision involves statistical risks that should not be ignored.

Reality #3. A positive finding of suspected contamination in just one monitoring parameter at one well is enough to trigger an entry into compliance monitoring, and any evaluation of false positive rates must take this into account.

Reality #4. On the other hand, a statistical procedure should have a high probability of correctly detecting the presence of even a single contaminant present at just one well; i.e., it should have high power.

Reality #5. Both risk of false positives and power build across time.

Reality #6. Measurements of ground water parameters are subject to several kinds of inherent random variability. Since "statistically significant" means "extreme with respect to inherent random variability," all of this variability must be taken into account.

Reality #7. To be statistically independent, samples must be taken on separate sampling occasions, separated in time.

Reality #8. Measurements of several reasonable monitoring parameters, including those that may eventually be found to be most effective, are often at or below a "detection limit."

Reality #9. The detection limit is itself a statistical concept, which deserves further study for application in this context.

Reality #10. Most common statistical techniques do not adapt well to data with more than a small proportion of "less than detection limit" measurements.

Reality #11. The shapes of the statistical distributions of measurements of monitoring parameters and the actual statistical properties of detection limits are difficult to ascertain with the amounts of data generally available.

Reality #12. When all of the other realities are taken into account, Anderson's law (see preceding) applies.

Reproduced from McNichols and Davis, 1988.

and the environment. The EPA land-disposal-restrictions program is being implemented in five separate rulings which will put an end to untreated waste disposal by May 1990 (Robertson and Shadizadeh, this volume). A survey done by the Environmental and Energy Study Institute (1987) shows that "there is widespread belief that many of the land disposal restrictions will not be implemented by EPA in the time table set out in the law because there will be significant shortfalls in needed waste treatment capacity, source reduction, and recycling." And that "there is general agreement that the land disposal restriction will have to be met through the use of source reduction/recycling and incineration and other existing treatment technologies which will not be available in time and face major regulatory obstacles."

COST OF LAND DISPOSAL

Currently landfills are the cheapest way to dispose of waste. Concern about ground-water protection, finding suitable sites, and complex design and operation requirements under new regulations (Subtitle D Regulation of August 1988), will make landfills much more expensive. In addition, the degree of cost will depend on the level of treatment required under EPA's restrictions on land disposal (Glebs, 1989).

The National Solid Wastes Management Association (Solid Waste Management Newsletter, University of Illinois, 1989) estimated that, under the new requirements, the costs of a landfill with a 100-acre site, a life of 20 years, and a post-closure period of 30 years will be as follows:

$0.2 million	Site characterization
$2.0 million	Preliminary development (including hydrogeologic and geotechnical studies)
$42.0 million	Final development (including liner, leachate-collection systems, leachate management, surface-water controls, final cover construction, and ground-water-monitoring systems)
$7.0 million	Environmental management (including well maintenance and testing, and analysis of ground-water samples)
$13.0 million	Post-closure care (assuming 20 wells and semi-annual testing).

The total cost is estimated to be $64.2 million. From these figures it is obvious that future land-based disposal will become a tremendously expensive alternative.

RECOMMENDATIONS

From the foregoing discussion, a group of broad-based recommendations can be developed regarding aquifer protection and ground-water monitoring at hazardous-waste-disposal facilities. The first recommendation is to minimize land-based disposal. It is imperative that alternative treatment technologies be developed and resource-recovery technologies be utilized to minimize the amount of hazardous wastes ultimately put on or in the ground. By minimizing land-based disposal, the problems associated with aquifer protection and ground-water monitoring can also be minimized.

A second recommendation is to expand the level of sophistication of site-characterization studies. Specifically, the use of tracer tests for delineating the hydrogeology beneath proposed and existing hazardous-waste-disposal facilities should be required. Current approaches to subsurface characterization fall far short in describing the subsurface with any degree of reliability.

A third recommendation is to make expanded use of available geophysical technologies. Geophysics has long been used in the search for oil and gas in order to minimize expensive exploratory-drilling programs. The same principles should be applied to ground water. Although never intended to replace boreholes, piezometers, and monitoring wells, certain geophysical techniques can aid in the proper siting of required monitoring points.

A final recommendation is to expand the requirements for vadose-zone monitoring. Early detection of releases to the subsurface can minimize the time, effort, and costs of remedial actions. The use of ground-water monitoring as a means of facility management is an inefficient and expensive approach. A successful ground-water detection system means an unsuccessful disposal facility. A successful vadose-zone detection system could rescue a failing disposal facility, and also preserve underlying ground-water resources.

REFERENCES CITED

American Institute of Professional Geologists, 1984, Hazardous waste: issues and answers: Mountain West Printing and Publishing, Inc., Denver, 24 p.

Burman, D. R.; Roberts, P. V.; and Mackey, D. M., 1985, Estimating the impact of policy decisions on hazardous waste landfill performance: U.S. Environmental Protection Agency draft report, Washington, D.C.

Canter, L. W.; Knox, R. C.; and Fairchild, D. M., 1987, Ground water quality protection: Lewis Publishers, Inc., Chelsea, Michigan.

Cartwright, K.; Gilkeson, R. H.; and Johnson, T. M., 1981, Geological consideration in hazardous waste disposal: Journal of Hydrology, v. 5, p. 357–369.

Council on Environmental Quality, 1981, Contamination of ground water by toxic organic chemicals: U.S. Government Printing Office, Washington, D.C., 84 p.

Domenico, P. A.; and Palcicuskes, V. V., 1982, Alternative boundaries in solid waste management: Ground Water, v. 20, p. 303–311.

Environmental and Energy Study Institute, 1987, Special report—the national hazardous waste land disposal restrictions: Washington, D.C.

Garner, S., 1988, Making the most of field measurable ground water quality parameters: Ground Water Monitoring Review, v. 8, no. 3, p. 60–66.

Glebs, R. T., 1989, Waste alternative/landfill of the '90s: Subtitle D: how will it affect landfills?: Waste Age, p. 56–84.

Kirschner, F. E.; and Bloomburg, G. L., 1988, Vadose zone monitoring: an early warning system: Ground Water Monitoring Review, v. 8, no. 2, p. 49–50.

Marrin, D. L., 1988, Soil-gas sampling and misinterpretation: Ground Water Monitoring Review, v. 8, no. 2, p. 51–54.

McNichols, R. J.; and Davis, C. B., 1988, Statistical issues and problems in groundwater detection monitoring at hazardous waste facilities: Ground Water Monitoring Review, v. 8, no. 4, p. 135–150.

Oklahoma State Department of Health, 1983, Regulations governing solid waste and sludge management: Oklahoma State Department of Health Bulletin OS24.

Patrick, R.; Ford, E.; and Quarles, J., 1983, Groundwater contamination in the United States [2nd edition]: University of Pennsylvania Press, Philadelphia.

Pennino, J. D., 1988, There's no such thing as a representative groundwater sample: Ground Water Monitoring Review, v. 8, no. 3, p. 4–9.

Richardson, G. N.; and Koerner, R. M., 1987, Geosynthetic design guidance for hazardous waste landfill cells and surface impoundments: U.S. Department of Commerce, National Technical Information Service, EPA/600/2-87/097.

Solid Waste Management Newsletter, 1989: University of Illinois, v. 3, no. 5.

U.S. Environmental Protection Agency, 1985a, Minimum technology guidance on double liner systems for landfills and surface impoundments—design, construction, and operation [2nd version]: EPA/530/SW-84/014, 83 p.

_____ 1985b, Covers for uncontrolled hazardous waste sites: EPA/540/2-85/002.

_____ 1986, RCRA ground-water monitoring technical enforcement guidance document: Office of Waste Programs Enforcement, Office of Solid Waste and Energy Response, OSWER-9950.1.

Impacts and Citizen Concerns of a Hazardous-Waste Disposal Facility

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ABSTRACT.—The Resource Conservation and Recovery Act of 1976 (RCRA) has provided the public with the greatest degree of protection in history. Many problems associated with hazardous-waste disposal were not known when RCRA was enacted. Although several of these problems have been corrected, siting and public participation continue to cause difficulties. RCRA provisions allow a minimal level of contamination and do not address reduction of waste production. The public does not accept this approach, which deals with a problem after it occurs.

Oklahoma has a history of citizen groups opposing commercial hazardous-waste disposal facilities which predates RCRA. Examples of these actions are a USPCI landfill in Creek County in 1975, BFI injection well in Rogers County in 1979, Scipio Farms, Inc. landfill in Pittsburgh County in 1980, and Material Management Corp. landfill in Greer County in 1984. Other examples are the ESI injection well in Washington County in 1984, Southwest Resources Management Corp. injection well in Kay County in 1985, Chief Chemical Co. incinerator in Wagoner County in 1986, and O'Landis Corp. incinerator in Cimarron County in 1988. Citizen opposition is not limited to Oklahoma.

Citizen opposition groups share common characteristics and development. Groups are motivated to form when local citizens become aware of plans to site a facility. The preliminary public notice to issue a draft permit with deadlines for pubic action creates shock and anger. Groups originate in the county of the proposed facility and adjacent counties. They utilize volunteer expertise. Upon learning of the specific role of the Oklahoma State Department of Health (OSDH), the groups develop distrust for the OSDH. Organized citizen groups successfully lobby the State Legislature for their special interests. After their goals are achieved the groups become inactive. Individual knowledgeable citizens continue environmental activities.

The issues that citizen groups want addressed which are not included in permit requirements can be divided into two categories: immediate concerns and value concerns. Immediate concerns are unavoidable contamination, water-supply contamination, site abandonment, transportation, accident response, and property values. Value concerns involve community image, legacy to future generations, elimination or reduction of waste, and risk perceptions.

Public participation in siting commercial hazardous-waste disposal facilities is not a public-relations problem. If citizen involvement starts after the public notice to issue a draft permit, it will be unsuccessful. A plan to implement public involvement would take four steps. The first step would be general public education on hazardous-waste production and disposal. The second step would be a parallel education effort targeted at generators and the public as consumers to minimize hazardous waste by source-reduction techniques. The third step would be a regular forum to exchange information, share problems, and generate ideas. It would be an open dialogue, with participation by citizens, regulatory agencies, industry, and university educators. The fourth step would be to involve citizen experts in regulatory-agency activities and in assisting industry to address concerns during the preliminary stages of siting a disposal facility.

INTRODUCTION

The Resource Conservation and Recovery Act of 1976 (RCRA) placed a major emphasis on strenuous regulation of hazardous waste. RCRA was enacted without comprehensive knowledge by government, industry, or the public of the true complexity and depth of the problems of hazardous-waste disposal. The full dimensions of the problem of inadequate or deplorable waste-disposal practices did not become known until Love Canal in 1978. Then, decades of public apathy immediately became public anxiety. The new RCRA regulations in place were not designed to address extreme existing contamination by historical practices. The locating of new disposal sites was delegated solely to the facility owners/operators. The regulatory role was to grant or disapprove permit applications. RCRA established procedures for public participation to begin after the notice to issue a draft permit (Conservation Foundation, 1983). It became apparent that the purpose of RCRA is to minimize risk and not to eliminate risks to citizens or future generations. RCRA regulations actually provided the greatest degree of protection ever for the public.

This position of knowingly allowing the eventual entry of unknown quantities of hazardous wastes into aquifers, soil, and air—however minimal—has been unacceptable to the public, even when the risks are understood (Williams, 1980). Later in the 1980s, further federal legislation addressed contaminated site clean-up and enacted more restrictive waste-disposal practices. Yet the legacy of problems of siting hazardous-waste disposal facilities has remained with us with the concept of minimizing risk rather than eliminating it. Siting is not a public-relations problem, and it cannot be solved with public-relations solutions. Even a well-informed citizenry that understands and accepts that there are by-products of a technical society will not accept an approach that deals with a problem after it occurs. Citizens feel that the focus of regulation should be on techniques which eliminate hazardous waste rather than facilitate disposal.

HISTORY OF CITIZEN OPPOSITION

There has been a consistent history in Oklahoma of citizen involvement affecting or halting the siting of commercial hazardous waste-disposal facilities that predates the RCRA regulations (Ice, 1989).

1) United States Pollution Control, Inc. Landfill, Creek County, near Slick, 1975. Massive public resistance and objections resulted in suspension of the granted permit (Ice, 1989).

2) Browning-Ferris Industries. Injection well, Catoosa, Rogers County, 1979. Allen West, private citizen, was first to start opposition at the permit stage prior to construction. A public hearing was held, and the company withdrew the application (Texas Water Commission, 1987).

3) Scipio Farms, Inc. Landfill, Pittsburgh County, 1980–81. Public opposition existed, and the Oklahoma State Department of Health (OSDH) rejected the permit on the grounds of site suitability (Ice, 1989).

4) Material Management Corp. Landfill, Mangum, near Haystack Mountain, Greer County, 1984 to present. The facility is opposed by the Haystack Environmental Group. The draft permit was granted in 1985, and public meetings were held. In 1986 a legislative moratorium went into effect. After OSDH determination of the need for a new permit application by the company in August 1989, this case went into the courts (Ice, 1989).

5) Environmental Solutions, Inc. Injection well, Ramona, Washington County, 1984 to present. The facility is opposed by the Toxic Waste Impact Group (TWIG). The notice for the draft permit was issued in November 1984, and a public meeting was held in April 1985. After the construction permit was granted in August 1985, TWIG took the determination to district court. The latest court decision is being appealed by the OSDH in the State Supreme Court (Agnew, 1989).

6) Southwest Resources Management Corp. Injection well, Kay County, 1985–86. This injection well was opposed by Northern Oklahoma Environmental Preservation, Inc. The public meetings held by citizens' groups were well attended. After the 1986 moratorium, the applications were never completed (Muegge, 1989).

7) Chief Chemical Co. Incinerator and additional storage, Wagoner County, 1986 to present. Chief Chemical has been opposed by NOWASTE. The company owner withdrew the application for an incinerator permit, but the permit for storage is still pending. Operator is suing OSDH (Ice, 1989).

8) O'Landis Corp. Cogeneration with incineration, Black Mesa area, Cimarron County, 1988–89. Proposed facility would be located on school lands. No application for permit has been filed. No formally organized local group has appeared, but the Oklahoma Wildlife Federation has been active in a public campaign against the project. The operator has expressed a desire to apply the Keystone Siting Process to this siting proposal (Ice, 1989). The Keystone Siting Process is designed to identify and resolve controversial siting issues outside the established regulatory framework. Developed by a diverse group of people from Texas, the fundamental element is public participation (Texas Water Commission, 1987).

DEVELOPMENT

Strong negative reactions to commercial hazardous-waste disposal sites by local groups has not been restricted to Oklahoma. California (Johnston, 1986), Texas, Illinois, and South Carolina (Breveton, 1980) have been scenes of intense conflict. Characteristically, opposition groups form when local citizens become aware of plans to site a facility. If a community learns of a fully planned facility through a public notice to issue a draft permit published in the local newspaper, they are immediately shocked and angered. The deadlines imposed by the RCRA public-comment period galvanize entrenched public opposition that quickly becomes organized. Those feelings can not be erased by public-relations techniques applied after the notification.

Somewhere in the process, the group learns that the role of the state department of public health is only to rule on the technical merits of the permit as submitted by the operator. They are not required to do any on-site evaluation by qualified experts, nor can they consider any aspects other than technical merits. The citizens feel betrayed again. The expression of loss of faith in the protection of the public by the state health department is the most common statement heard from local citizens groups (Agnew, 1989; Johnston, 1986; Muegge, 1989; O'Mara, 1980; West, 1989). At this point, they feel they have no official voice, and must depend upon themselves alone.

Organized opposition groups are generally restricted to the county of the proposed site and neighboring counties. They are not affiliated with any national groups. Most often these groups rely on the expertise of volunteers to develop their arguments. Occasionally, they will pay for outside consulting.

In Oklahoma, the course of action has been to turn from regulatory agencies to legislative solutions to address the citizen-group concerns. They begin to lobby at the State Legislature. The technique has been effective, and resulted in several pieces of legislation in the past four years. In 1986, the Haystack Environmental Group, the Toxic Waste Impact Group, and Northern Oklahoma Environmental Preservation, Inc., with the support of recognized state environmental groups, successfully passed a one-year moratorium on permitting of off-site controlled-industrial-waste (hazardous) disposal sites (Ice, 1989).

After the goal for organized opposition has been achieved, these local groups become inactive. However, the community involved is now continuously aware of events involving hazardous materials, knowledgeable about government procedures, and much more attentive to environmental issues in general. They raise alarms about other issues and offer their hard-won skills to other citizen groups. Often one or more persons from each group develop second careers participating in environmental issues at all levels. Their knowledge becomes sought by other citizens, groups, and government agencies.

CITIZEN CONCERNS

The issues that local citizen groups want addressed which are not included in permit requirements can be divided into two groups: immediate concerns and value concerns.

Immediate Concerns

1. *Unavoidable contamination.* To what extent would unavoidable incidents cause contamination and what safeguards have been developed for inevitable human error? The public fully understands that accidental discharges will happen, despite the best planning.

2. *Contamination of water supply.* In Oklahoma, this is a pervasive and real fear based on historical experience with earlier oil-field development practices. The general public does not view contamination of a drinking-water source or potential drinking-water source as a "white collar" economic crime. They perceive it as a felony.

3. *Site abandonment.* What happens after the operator is gone? Once again, historical practices and bankruptcy laws have created an atmosphere of distrust. Communities are uncomfortable with the regulatory requirement of 30 years of monitoring. They want a total commitment of responsibility.

4. *Transportation.* Even though the perceived risk of transported hazardous waste may be erroneous, trucking practices since the deregulation of the trucking industry and the condition of many state highways and county roads raise some legitimate questions for citizens. Disposal-facility operators perhaps should plan for control of transportation to their facility. A partial solution might be assessments by the State Highway Department and the Department of Public Safety.

5. *Accident response.* This issue could be addressed by initiating training, providing necessary equipment, and installing safeguards for both facility personnel and local safety officials. Local officials should be involved in the earliest stages of planning.

6. *Property values.* Although concern about property values may seem selfish to an outsider, they are real to a community. Once again, the operator should plan from the beginning to provide a compensatory arrangement, or proof that devaluation will not occur.

A complete discussion of these and 10 other issues can be found in a handbook published by the Conservation Foundation (1983).

Value Concerns

The second list of concerns of citizens may seem more difficult to address, but they are just as important:

1. *Community image.* Regardless of the economic situation in an area, a commercial disposal facility will be viewed as threatening to a community's image. It is considered an insult made by outsiders to the local culture. No one wants to be a garbage dump. Neither do they wish to be designated the recipients of waste from other regions. A local industry that upgrades onsite disposal practices will usually not be seen as threatening.

2. *Legacy to future generations.* One of the greater environmental issues that has arisen in the past two decades is how our misuse of natural resources will impact our children and grandchildren. If a hazardous-waste disposal facility is unable to demonstrate that its function will improve natural resources and decrease degradation, then its operations will be constantly under attack.

3. *Elimination or reduction of waste.* One of the first questions a group will ask is, "Why do we have to have hazardous-waste disposal facilities? Why don't they eliminate hazardous waste?" This is a reasonable question. Because regulatory attitudes established in the 1970s have focused on disposal, the public feels that this does not put enough pressure on generators to actually reduce hazardous waste. Fortunately, we are starting to see a change in this attitude. A full commitment will need legislative support. Commercial hazardous-waste disposal facilities would do well to consider offering source-reduction technology to their customers, as well as disposal.

4. *Risk perception.* Industry, government, and the public have differing views on the acceptance of risk. The public trend toward demanding a risk-free society is unrealistic. Government agencies are so overwhelmed by mandates from the public, industry, and legislative bodies that they tend to use risk assessment as a method for prioritizing work plans and a reason for nonaggressive action in regulatory enforcement.

Industry find themselves in the position of being the ultimate expert on the effects and handling of any hazardous materials. Their very familiarity can lead to an "old news" attitude when they are sharing the information with the public (Thayer, 1989). "Scientists and government and industry representatives often believe the public will understand if they just can get all the facts." John F. Ahearne of the National Research Council said, "Conflicts about risks, however, are often about values, not facts. And when differences in values are involved, even the best risk communication cannot improve the situation. Poor communication, however, can hurt it" (Hanson, 1989). The temptation to simplify risk perception by comparing various types of risks should be avoided. Such an approach only creates distrust.

CONCLUSION

Society as a whole has come to recognize the scope and complexity of dealing with the hazardous-waste by-products of our 20th Century lifestyles. Certain areas of agreement already exist. An approach including the public, industry, and government, which delineates areas of responsibility and leads to solutions, must be created. It should be acknowledged that to start this process with a facility site, announcement is futile.

PLAN FOR PUBLIC INVOLVEMENT

A plan to implement public involvement and responsibility prior to the filing of an application for a draft permit for a hazardous-waste disposal facility would take four steps.

The first step should be a basic education program for the entire state, whether targeted for siting or not. It would include the production of hazardous waste relating to the lifestyle and health of our society, the need for regulated disposal sites after all other measures have been taken, the specific role of regulatory agencies, and consequences of improper handling and illegal dumping. This can be done by a series of press-released stories, media specials, school programs, and town meetings in every county seat. State government and private foundations could lead this education effort.

A second parallel education effort would be targeted at generators and the public as consumers. The emphasis here would be on a mandate to instigate source reduction, reclaiming, and recycling. The regulatory role, the role of the consumer, and complete economic impacts should also be covered. The state government and trade associations should assume responsibility for designing and developing this information effort.

The third step would be establishment of an open, ongoing dialogue among industry, citizens, state agencies, and even university educators. This should be a regular forum, and totally unrelated to any specific siting issue. Participating citizens will have to leave their emotional issues at home. All issues would be explored, and all parties must be willing to openly provide answers without demeaning any questions by the other parties. Besides sharing technical data, raising issues, and exploring solutions, industry and regulatory agencies would benefit from invaluable consulting on potential problems and possible approaches from citizen experts. Universities would be neutral locations for these regularly scheduled dialogues.

The fourth step is public participation, particularly participation by local citizens—not Oklahoma City lobbyists. Public participation has been portrayed as costing money, being time-consuming, and a general hassle. However, when a company begins to consider siting a facility, it would be able to address many of the citizens' pressing concerns before they become flaming issues.

An open attitude on the part of state agencies to involve citizens in planning programs—and even seeking qualified citizen input on permit assessment, even if it is non-binding—would do a great deal to enhance the State's credibility for handling hazardous-waste problems. Those expert lobbying skills developed by citizens could be enlisted to increase staff expertise and strengthen needed enforcement mechanisms.

A public-involvement program would be a step toward addressing citizen concerns and alleviating public opposition to facility siting. Connie Weis O'Mara, in an address on community concerns about hazardous waste to the National Governors' Association 10 years ago, summarized citizen concerns with this statement: "Short-term financial accommodation is simply outweighed by the need to assume to the greatest extent possible that our drinking water supplies and air quality will not be polluted and that we will not suffer from acute or chronic health effects as a result of improper hazardous waste management practices" (O'Mara, 1980).

REFERENCES

Agnew, Shauna, 1989, Private communication: Toxic Waste Impact Group, Ramona, Oklahoma.

Breveton, Barbara, 1980, Siting hazardous waste facilities—a dialogue: LWVEF, Washington, D.C.

Conservation Foundation, 1983, Siting hazardous waste management facilities, a handbook: Washington, D.C.

Hanson, David, 1989, Public's misconceptions act to bar effective risk communication: Chemical and Engineering News, September 25.

Ice, John, 1989, Interview: Public Relations, Oklahoma State Department of Health.

Johnston, Joyce, 1986, Interview: Kern County Valley Action Network, Bakersfield, California.

Muegge, Paul, 1989, Interview: Citizen of Tonkawa, Oklahoma.

O'Mara, C. W., 1980, Community concerns about hazardous waste: National Governor's Association.

Texas Water Commission, 1987, Your community and the Keystone siting process.

Thayer, A. M., 1989, Alar controversy mirrors differences in risk perception: Chemical and Engineering News, August 26.

West, A. D., 1989, Interview: Citizen of Catoosa, Oklahoma.

Williams, T. F., 1980, Waste facility siting—a public dilemma: LWVEF Seminar on Improving Citizen Participation in Waste Facility Siting, Washington, D.C.

Relation of Waste Disposal to Industrial and Economic Development in Oklahoma

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ABSTRACT.—Oklahomans have not been paying the full costs of their waste disposal, because many landfills do not meet current safety standards. As tougher federal regulations go into effect, most landfills face closure in the near future. Incentives to reduce waste or recycle cannot be realized until landfill costs rise. So far, industry has outpaced government in developing disposal alternatives, but the two will need to work together to implement workable solutions if Oklahoma is to avert a crisis in solid-waste and hazardous-waste disposal. Economics will be the prime motivating factor for both.

While the "garbage crisis" of many northeastern and coastal states has not yet hit most communities in Oklahoma, it is rushing toward us in the 1990s like a runaway freight train. New U.S. Environmental Protection Agency landfill regulations due out in December will require inspections and multilayered liners to prevent liquid from contaminating ground water. An estimated 80–85% of Oklahoma's landfills do not have liners and face possible closure when the new regulations are enforced. About 44% of the State's 123 operating landfills have not been upgraded to meet standards already in effect.

This means that Oklahomans have not been paying the full, true costs of solid-waste disposal. The new EPA regulations will only widen the gap between real costs and charged costs. As long as this gap exists, incentives for waste reduction and recycling—two vital alternatives to landfilling all our waste—will be minimal in Oklahoma. What applies to solid wastes also applies to hazardous wastes, but at greatly increased expense.

It is clear that the State and the nation are moving rapidly from an open, voluntary, and largely unregulated era of waste disposal to more-stringent and comprehensive regulations. In Oklahoma, 85% of the businesses have 25 or fewer employees, leaving little capacity for specialists to track and comply with new regulations. Leadership from both the public and private sectors will be necessary to keep solid-waste-disposal and hazardous-waste-disposal regulations comprehensible and workable.

So far in Oklahoma, industry has led the way. A dramatic, strong example is the formation in 1982 of the Oklahoma Beverage Industry Recycling Program (BIRP) by a coalition of soft-drink bottlers, beer wholesalers, glass-container manufacturers, and others who recognized the need for a stronger recycling ethic in the Sooner State. This nonprofit, educational program originally focused on reducing roadside litter by improving recycling opportunities across the State, but now has greatly expanded its mission to apply various types of recycling solutions to most components of the solid-waste stream.

The completely voluntary BIRP program currently includes 55 affiliated recycling facilities which accounted for a $4 million payout for recyclable "trash" in 1988. It is estimated that the positive economic impact of payouts by the entire recycling industry in Oklahoma has grown to more than $100 million annually, and that figure may double by 1992. Not only is the recycling industry providing impressive economic opportunities for individual and commercial recyclers, it is fast becoming a major employer in the State. Among the employees of recycling concerns are scores of handicapped workers.

In addition to recycling, there are several other "Rs" associated with solutions to the disposal of wastes: Reduction, Recovery, Reuse, Refining, and Retooling are but a few. Each "R", however, requires a trio of "Es" to make it feasible: Education, Enterprise, and Economic incentives. The key area is education. Education about wastes and solutions is something that must be strengthened immediately if Oklahoma is to avoid facing the crisis situations now being faced in other parts of the country. It is a burden that should be shared by the public and private sectors, instead of by the private sector alone.

After implementation of comprehensive educational efforts, the disposal cost of wastes must be raised to its true level. Not only will this help avoid an economic shock of disastrous proportions if increases are delayed a few more years, it will spur industry to invest in proven alternatives to landfilling.

The fairest way of spreading the real cost of waste disposal, now being implemented elsewhere in the country, is a measured cost system. In some communities, garbage is weighed and charged by the pound. A few cities sell their own authorized garbage bags, or stickers to put on bags, at a cost representing the full disposal cost of the loaded bag.

Henryetta, Claremore, and Stillwater in Oklahoma currently are experimenting with curbside collection programs of recyclable materials. In many cities in other states, putting designated recyclable items in the same bag with other garbage can result in a fine or suspension of garbage-collection service.

In order to succeed, these and other innovative incentives to reduce and recycle wastes need standards set by the State that allow county or local governments to design and implement the solutions best suited for their population density, geology, accessibility to recycling markets, and industries. What is effective for Edmond could prove to be a costly mistake just 20 mi away in Piedmont, Oklahoma.

This year, the State of Oklahoma has started making waste disposal considerations a priority concern. The final report of the "Oklahoma Recycling and Waste Reduction Project," commissioned by the Oklahoma House of Representatives, is due in the Spring of 1990. Among other things, it is expected to give five prototype communities in the state economic and feasibility models for various recycling and waste-disposal alternatives. When this is combined with state-set goals, standards, and a timetable, Oklahoma should be enviably positioned compared with other states in the region.

Also, in October, the Oklahoma Environmental Concerns Council presented its Environmental Report to the Governor. The report listed 31 clear, concise recommendations dealing specifically with hazardous and solid wastes. Topping the list was a call to implement comprehensive environmental education for students, government officials, and the general public. The report further recommended a $1/ton surcharge on solid-waste disposal to create a multimillion-dollar revolving fund for waste planning, creating improved rural collection systems, transfer stations, recycling projects, yard-waste composting facilities, resource-recovery projects, construction/demolition landfills, and new landfills.

The sooner the populace is charged the true cost of waste disposal, the sooner alternative solutions will be economically attractive and implemented. The positive economics of enlightened waste management will make industry receptive and even more innovative.

As this decade comes to a close, Oklahoma stands on a waste-disposal precipice. In one direction is a landfill about to be closed, a virtual dead end to a well-traveled path. In the other direction is an array of new roads awaiting directional signs. As soon as the State's elected and appointed leaders join hands with the business and industrial leaders who have built these roads, Oklahoma will begin distancing itself from disaster.

Surface Disposal of Hazardous Wastes in Oklahoma

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AN OVERVIEW OF SURFACE DISPOSAL

Introduction

The waste produced by humans has been disposed of on or near the surface of the land for time immemorial. Early civilizations simply dumped their wastes on the land, or into a nearby river, and when the accumulation got to be too bad, the village or group moved on. No thought was given to the concept of "landfilling" of wastes, or proper versus improper disposal practices. That situation survived for centuries, and it is only in the last 100 years or so that serious thought has been given to how solid wastes should be handled, or even what these wastes truly are.

While much can be debated about the proper methods of surface disposal, it was begun and has survived because it serves a very definite need for society—that of handling the innumerable wastes discarded as having no further use or function. This situation exists for both solid wastes—household garbage—as well as for hazardous wastes.

Hazardous wastes are produced by nearly every segment of society. Industry produces these wastes in the manufacture of the goods that we all use and enjoy, but hazardous wastes are also generated by households in everyday activities. The cleaners we use for cleaning our homes, the paints and solvents, and many other items would legally qualify as "hazardous wastes" if they were produced in large enough quantities. It must be remembered that hazardous wastes are not simply an industrial problem, they are a social problem.

For many of these wastes, disposal in a properly designed, properly operated surface-disposal facility is the most practical thing to do. For some wastes, it is the only possible thing to do. Although this situation will be modified in the coming years, it will remain a fact of life for the foreseeable future.

Some Definitions

The term *surface disposal*—or "land disposal," as it is termed by federal law—encompasses a number of different means of waste-handling today. The most obvious of these is the *landfill*. In its most simplified form, a landfill is a designated area for the secure burial of waste. Next are the facilities known as *surface impoundments*—a pit, pond, or other depression where liquids are accumulated for storage or treatment, or disposal. There is also *land treatment*, which is the application of quantities of waste to the surface of the land, measured so that they will either be biodegraded by naturally occurring organisms, or so that any toxic constituents will be bound into the soil matrix. Last, for the purposes of this discussion, are the *waste piles*, which are simply what the name implies. It is these four forms of disposal which I will discuss today. (A fifth form of land disposal is recognized by federal law: liquids disposal through *injection wells*; this subject is discussed by others.)

HISTORY OF THE USE OF LAND DISPOSAL IN OKLAHOMA

Historically, there has been little differentiation between landfills and surface impoundments in Oklahoma or elsewhere. The common practice has been to mix liquids and solids together in a common area for disposal. While surface impoundments have been used for storage of liquid wastes, only in the last decade or so have separate disposal areas been established for solids and liquids.

In any case, up until the early 1970s, hazardous wastes were usually co-disposed with municipal garbage, in sanitary landfills. For the most part, these wastes were handled no differently than the garbage, and consequently there are a number of sanitary landfills that are candidates for clean-up because they are leaching constituents of hazardous wastes into ground or surface waters.

Throughout Oklahoma's history, some individual industries operated their own disposal sites for their own solid-waste products, but most land-disposed wastes went to community-type sanitary landfills. A number of liquid-waste storage impoundments were operated by industries, primarily as part of wastewater-treatment systems for discharge to surface waters. The first commercial facility solely intended for the land disposal of hazardous waste opened in Oklahoma in 1972. This was followed by a number of applications for other facilities, in various parts of the State. In the late 1970s and early 1980s, commercial hazardous-waste handling was seen as an up-and-coming field and received a great deal of attention from entrepreneurs and investors. However, since the Hardage site opened in 1972, only one other facility has been successfully permitted and opened.

Land treatment, on the other hand, has been used in Oklahoma for many years, primarily by the oil industry. This practice was developed for use with oily wastes, and is seen by many as a near-ideal way to handle these materials. Because the procedure was most useful for oil-related wastes, nearly all sites were on or near property owned by refineries.

In essence, the oily waste is applied to the land surface in limited quantities, and then plowed or disked in to mix the waste with the soils. What this accomplished was to expose a large surface area of the waste to the action of natural bacteria in the soil, and the bacteria then digested the organic components of the waste into carbon dioxide, water, and nitrogen compounds. Because of the similarity of this procedure to farming, it is sometimes referred to as "soil farming" or "land farming," and under proper conditions and operating practices, it was thought that large quantities of oily hazardous waste could be handled in this fashion. However, relatively recent changes in the law and rules have reduced the availability of this practice.

CURRENT STATUS OF LAND DISPOSAL IN OKLAHOMA

At the present time, there is only one operating, commercial hazardous-waste land-disposal facility in Oklahoma—the Lone Mountain Facility, owned and operated by USPCI in Major County, near Waynoka. This facility opened for business in 1979, and has been in continuous operation since then.

There is pending before the Oklahoma State Department of Health an application for a second such land-disposal site, known as the Haystack Facility, in Greer County in western Oklahoma. This facility was first proposed in 1984, but has been strongly opposed by local residents, and a final decision on the permit has been delayed by a number of legal, regulatory, and technical issues. When the final decision will be made on whether to issue or deny the permit for this facility is not known.

There has been a general decrease in the number of hazardous-waste surface impoundments in Oklahoma, in response to stricter design and operational standards under revisions to the federal hazardous-waste laws that were made in 1984. Similarly, there has been a decrease in the number of land treatment facilities (part of this decrease is due to a decrease in the number of operating refineries in Oklahoma).

Although the hazardous-waste field is still seen by some as a promising area for entrepreneurs and certain investors, the high costs of entry, as well as the high perceived risks and general public opposition to sites, make it unlikely that there will be any significant increase in land-disposal sites in the foreseeable future.

DESIGN BASIS FOR SURFACE DISPOSAL

Siting Criteria

In considering the installation of a land-disposal unit, there are a number of obvious areas to avoid—active fault zones, for instance, or areas prone to flooding. Geologic and hydrologic exclusion zones have been a part of the hazardous-waste rules for some time. A more recent addition is the exclusion of other areas, for either aesthetic or general environmental reasons. Oklahoma rules now contain exclusion zones for:

1) Ground-water aquifers and their recharge areas;
2) Areas within certain distances of water-supply wells;
3) Areas near any public water-supply reservoir or scenic river; and
4) Locations within 1 mile of schools, nursing homes, hospitals, or public parks.

All of these siting criteria have been put in place to make sure that facilities are not built where there are unusual risks from natural disasters such as earthquakes or flooding, and to give some measure of isolation from the general public and public gathering places.

Design Requirements

After a facility is properly sited, a great deal of attention must be given to its design. For landfills or impoundments, the Hazardous and Solid Waste Amendments of 1984 (HSWA) require that all new units, and all expansions to existing units, meet the so-called Minimum Technology Requirements. MTR specifies that all landfills and impoundments be lined with a minimum of 1 synthetic membrane liner, and 1 composite liner consisting of a synthetic membrane over at least 3 ft of recompacted clay. The liners are separated by a leachate drainage system to detect any leakage in the upper liner. Landfills are also required to have another leachate drainage system above the primary (top) liner, to remove any liquid generated from precipitation. There are extensive Quality Control requirements that must be followed as well.

For land treatment areas, there is a requirement that the applicant first show that the soils are capable of absorbing and attenuating the wastes to be applied, and then perform a very strictly controlled Treatment Demonstration, before a permit can be granted. In addition, one section of HSWA known as the Land Disposal Restrictions, makes the long-term viability of land treatment very questionable, as this section restricts the number of wastes that can be handled through land treatment.

MONITORING

All land disposal units are required to have ground-water-monitoring systems to detect any contamination of the water beneath the unit. This system includes wells both up-gradient and down-gradient of the unit, and periodic sampling for contamination. (Other speakers will discuss this more thoroughly.)

CLOSURE AND POST-CLOSURE, FINANCIAL ASSURANCES

As an essential part of the design, and before a land-disposal unit can be permitted and built, the applicant must specify exactly how the unit will be closed, to ensure that all of the wastes disposed of there will remain in place. This *closure plan* is approved as a part of the permit, and can be implemented at any time. As a part of the closure plan, a reasonable estimate must be made of the costs that will be incurred in the closure of the unit; these costs must be guaranteed in some fashion to ensure that the money is available to properly close the unit, even if the operator should go bankrupt. Last, the owner/operator is required to monitor and maintain the unit for at least 30 years after closure, to make sure that no problems develop.

(Much concern has been expressed by the general public about the ultimate liability for hazardous-waste-disposal facilities. Simplifying the arguments somewhat, there is a very real worry that a landfill operator will open a site, make his money, and then walk away from the site, leaving the public to close and monitor the site, and clean up any problems left behind. While this has happened in the past, changes in both State and federal laws have made this possibility very remote for today's facilities. First, the funding for closure and post-closure activities must be guaranteed by sound financial mechanisms, but, most important, the courts have found that a hazardous-waste-facility owner cannot escape the responsibility for that facility. This liability extends up into parent organizations as well. Consequently, a parent organization cannot shed its responsibility by having its hazardous-waste subsidiary declare bankruptcy and dissolve.)

PERMITTING PROBLEMS AND TIMING

For various reasons, siting and permitting a hazardous-waste facility, especially a commercial land-disposal facility, continues to become more difficult, and more time-consuming. The public has become very concerned about such sites, and in general is very involved in the permitting process. This concern has led to the involvement of politicians at various levels. The end result is that it can take three to five years or more to take a facility from initial concept to final permit; construction can take several more years.

This lengthy process means that a permit applicant must invest several hundred thousand to several million dollars in design and legal costs, just to go through the permit process, and another several million dollars to build a facility, before any waste can be accepted. Intentionally or not, this process will tend to cull the number of applicants, ensuring that only those who are sincere about their intentions and have substantial monetary resources will be able to operate these sites. Additionally, with such an investment, it makes bad business sense to operate the facility poorly, or in such a way as to jeopardize the permit. This should act to provide some degree of assurance to both the government agencies and the general public.

Unfortunately, however, this long permitting process means that it takes a very long time to provide any needed capacity to properly handle the generated wastes.

FUTURE DIRECTIONS FOR SURFACE DISPOSAL

As mentioned earlier, HSWA contains a section known as the Land Disposal Restrictions, or "Land Bans." The purpose of the land bans is to consider the best way to treat or dispose of each waste stream, and then to mandate that the waste be handled in that fashion. The land bans are scheduled to go into effect over several years, the last portion scheduled for May 8, 1990. At that time, all wastes must be treated to meet the standards of the Best Demonstrated Available Technology (BDAT), or the land disposal of that waste is forbidden.

The practical effect of the land bans is to place an increased emphasis on treatment of wastes, rather than simply disposing of them. This treatment will drastically reduce the hazard from the waste prior to disposal, and lessen reliance upon land disposal as much as possible. This will reduce the long-term risks from the disposal of hazardous wastes tremendously.

Other proposals are being made as well, involving the minimization of wastes in general. The proposals range from financial incentives for recycling to mandatory waste-reduction goals, all with the purpose of reducing the need for land disposal. The Oklahoma legislature has already enacted the Oklahoma Controlled Industrial Waste Recycling, Reuse, and Ultimate Destruction Incentive Act, providing tax credits for capital investments for waste recycling and reuse.

Regardless of the progress that has been, or will be, made in the reduction of hazardous wastes, there will always be a need for land disposal of a certain amount of residue of this material. Oklahoma must understand that waste disposal is a problem that may shrink somewhat in size, but will never go away completely. It therefore is in the best interests of the State to see that it has adequate capacity, properly constructed and operated, to handle this waste.

PREDICTIONS FOR THE FUTURE OF HAZARDOUS WASTE LAND DISPOSAL

1. Even though waste minimization will receive more attention in the near future, the growth of industry will probably balance any reductions made in waste generation for the next decade. After that, waste reduction will likely take precedence, and the total amount of "new" wastes will gradually decline.

2. For the next several decades, clean-ups of old waste-disposal sites, under "Superfund" and other corrective-action plans, will generate substantial amounts of "old" hazardous wastes to be re-disposed.

3. Our society will become more and more aware of the environmental consequences of its consumption practices. For instance, the convenience of an automobile is accompanied by the unavoidable generation

of a certain amount of hazardous waste which must be treated and disposed of. Consumption practices will be decided by the individual, and changing those practices will be driven by the convenience to the consumer, and the price of the commodity.

4. Although the disposal of hazardous wastes is of major concern in Oklahoma today, other areas of the country have near-equal concerns about non-hazardous wastes, such as medical wastes and garbage. We can expect this same heightening of awareness and concern in Oklahoma, as the public educates itself on the issues. As a result, many of the institutional restraints that now apply to hazardous-waste facilities—siting, design, operations, etc.—will be applied to solid-waste facilities in the future.

In closing, hazardous wastes may be reduced in Oklahoma, but their safe disposal in or on the land must continue. This requires not only proper behavior on the part of the industry, but also adequate oversight by the government to assure the public that industry is doing the proper job.

Class I Hazardous-Liquid-Waste Disposal Wells in Oklahoma

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AN OVERVIEW OF DEEP-INJECTION WELLS

Deep injection into underground formations is nearly as old as the oil and gas industry. Early in the development of oil fields, producers found use of subsurface geologic formations to dispose of hundreds of thousands of gallons of saltwater produced along with oil and gas. Today, there are more than 38,000 such wells in the nation providing oil and gas operators an inexpensive and environmentally sound disposal technology. Under the Federal Safe Drinking Water Act of 1974 (SDWA), these wells are identified as Class II injection wells.

In addition to those wells, several businesses and industries have adopted the use of deep-well technology to provide low-cost, permanent disposal of liquid industrial waste. The use of this technology is possible because of billions of dollars spent mapping the subsurface geology in oil-producing states. The modern use of deep wells to dispose of hazardous liquid waste is, therefore, confined to oil-producing states where exploration and discovery efforts have uncovered a vast secondary natural resource.

Wells used to dispose of waste below the lowermost underground source of drinking water (USDW) are classified as Class I wells under the Safe Drinking Water Act. According to the Environmental Protection Agency's (EPA) 1989 inventory of active Class I hazardous-waste-disposal wells, they number 245 and are located in 15 oil-producing states. Of the 245 wells, 14 are commercial wells located at 11 facilities. The remaining 231 wells are located at industrial-waste generator sites.

According to *EI Digest* (1989), "Annually, approximately 11 billion gallons of Resource Conservation and Recovery Act waste is injected down deep wells into geologic formations to contain the waste.

"Deep well injection currently ranks as the number one means of waste disposal by volume. Disposal into deep wells accounts for more than three times the volume disposed of in other types of land disposal and more than twenty times the volume of hazardous waste destroyed by incinerators."

Deep wells require six primary considerations to be sited, constructed, and operated safely:

1) A stable geologic setting that offers both receiving and confining formations that are of sufficient aerial extent to ensure long-term use;

2) The absence of faults and vertical fractures, as well as unplugged artificial penetrations, that could serve as points of discharge or allow escape of waste material from the injection zone;

3) The absence of other commercial or natural resources that could be contaminated by the waste materials, such as fresh water or oil and gas;

4) Strict monitoring of the mechanical integrity of the injection well itself, assuring that waste pumped into the well reaches its destination, the receiving formation, and does not migrate vertically;

5) The selection of candidate waste streams that meet strict compatibility requirements; and

6) Established injection pressure restraints that protect the receiving and confining units.

Wells that meet these criteria have operated safely in Oklahoma for nearly 30 years with an absolutely perfect record of protection of the public's health and preservation of the environment.

REGULATORY CONSIDERATIONS FOR MODERN CLASS I INJECTION WELLS

Deep-well-injection facilities are subject to the requirements of at least two separate regulatory systems: the Resource Conservation and Recovery Act (RCRA), and the Safe Drinking Water Act (SDWA). The construction, operation and maintenance of injection wells is regulated by SDWA's Underground Injection Control (UIC) program, which sets requirements on the location, construction, monitoring, and closing procedures at injection facilities. Deep-well-injection facilities that meet these requirements may receive a RCRA permit that regulates only surface operations such as storage. These facilities must also fulfill manifesting, record-keeping, and reporting requirements of the RCRA permit.

The Hazardous- and Solid-Waste Amendments to the Resource Conservation and Recovery Act

Underground-injection facilities are also subject to the land-disposal restrictions set forth in the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act. These restrictions prohibit land disposal of a variety of hazardous wastes. Land disposal is generally considered as land farming and landfilling, but by definition includes deep-well injection.

The HSWA legislation set up a schedule of deadlines by which the Environmental Protection Agency (EPA) was to set treatment standards for various groups of waste. The treatment standards apply to both surface disposal and underground injection. However, the EPA implemented standards for surface disposal before standards for underground injection. The extra time was allowed because of the large volume of waste disposed into deep injection wells, lack of alternative treatment technologies, and limited understanding of deep-well technology (USEPA, 1987).

The National Debate

A National Regulatory Negotiating Committee consisting of industry experts, state UIC program directors, members of the environmental community, and the affected industrial users was chartered, and a national debate began. The result is a comprehensive new awareness of the costs and benefits of deep-well disposal technology. Unlike other land-disposal technologies, deep-well-injection facilities have a number of options regarding future disposal of the banned hazardous wastes:

1) Deep-well operators can treat the hazardous waste to the specifications established under the land-ban regulations; the treated waste can then be disposed into the deep well;

2) Deep-well operators can stop disposing of the waste and send it off-site for treatment and subsequent disposal elsewhere; or

3) Operators can apply for and receive approval of a *no-migration petition.* If the facility receives approval, it may dispose of any hazardous waste without treatment.

No-Migration Petitions

To obtain a no-migration petition, a facility must demonstrate to a *reasonable degree of certainty* that waste injected into the underground formations either will remain there for 10,000 years or that the candidate waste will be transformed into a nonhazardous material because of its interaction with subsurface formations and their interstitial fluids prior to any discharge. A facility can do this in one of two ways:

1) The facility can use flow and transport models to show that injected fluids will not migrate vertically out of the injection zone for 10,000 years; or

2) Geochemical modeling can be used to show that the waste is transformed so that it will become nonhazardous before it reaches the edge of the injection zone.

Modern wells are being sited in areas where one or both of these criteria can be proven. Modern wells can be sited in areas where extensive information about underground formations has been gathered to substantiate the horizontal horizons of injection and confining units, where extensive records of artificial penetrations are available and corrective action can be taken if necessary, and where no ground water or other natural resources are present. In this setting, no-migration petitions can be more easily substantiated. Likewise, for specific waste streams, wells are being sited over geologic formations meeting geochemical-modeling requirements.

Most of Oklahoma's existing Class I hazardous-waste injection wells have, or are submitting, no-migration petitions. A high rate of acceptance is anticipated.

OKLAHOMA'S UNDERGROUND INJECTION CONTROL (UIC) PRIMACY

Oklahoma is a "primacy" state; that is, Oklahoma has sought and received permission from the Federal Environmental Protection Agency to implement a state UIC program in lieu of the federal program. This was accomplished in January 1985, and is the result of a combined effort of the legislative, executive, judicial, and administrative branches of Oklahoma government. This condition in Oklahoma establishes a platform for more public involvement and tighter local control over facilities than might have otherwise been allowed under federal restraints.

The Oklahoma State Department of Health

The Oklahoma State Department of Health (OSDH) is the lead state agency charged with responsibility to regulate UIC hazardous-waste activities in 76 of the 77 counties in Oklahoma. Osage County, a Federal Indian Reservation, is still controlled by the Federal Environmental Protection Agency.

The OSDH is responsible for tracking waste generated in the State, permitting and inspecting disposal facilities, approving generator disposal plans from within and without Oklahoma, and enforcing compliance with environmental laws.

The Controlled Industrial Waste Council

Rules and regulations must be promulgated in order for the administrative branch of government, here the Oklahoma State Department of Health, to carry out the will of the State Legislature. In order to assure that the rules promulgated are in keeping with the will of the elected officials and the people, the Oklahoma Controlled Industrial Waste Council was created as an integral part of the OCIWDA.

The Council holds public hearings to openly discuss suggestions on how rules and regulations should be written. The Council comprises nine citizens representing industry, the waste-management industry, geology, engineering, agriculture, and one member of the general public. The Council meets at least twice annually, holds public meetings to promulgate rules and regulations that are submitted to the State Board of Health for final approval, and may meet more frequently if necessary. The Council assures citizen involvement by inviting participation during rule-making.

The Involvement of Concerned Citizens

Citizens in the State are invited to participate in waste-management decisions on several levels: First, citizens interact with elected officials in both houses of the State Legislature and through lobbying groups. Second, citizens are invited to interact with rule-making activities through the Controlled Industrial Waste Council, which itself is composed of citizens. Third, whenever permit applications of established or new facilities are submitted, citizens are invited to participate through the permit-application review process, public hearings, if requested, and public meetings held prior to the issuance of construction and operation permits.

These multiple levels of citizen involvement are designed to facilitate a free understanding of waste-management problems and solutions. Citizens are openly invited to participate in every aspect of waste-management activities in the State. The State's primacy is based on its equivalency and consistency with the otherwise federal programs promulgated by the Environmental Protection Agency. Therefore, laws passed by the Oklahoma Legislature, and rules, regulations, and guidelines promulgated by the Controlled Industrial Waste Council, adopted by the State Board of Health and administered by the Oklahoma State Department of Health, must be reasonable by federal standards. They may not unreasonably restrict the orderly development of interstate commerce or the development of new physically and technically well-suited waste-management facilities.

The proposals of waste-management-facility developers must adequately meet the requirements of State and federal laws, rules, and regulations prior to the issuance of any construction or operations permits. During permit review and the meetings made possible by the rules and regulations, citizen concerns and objections are identified. These concerns and objections which have a basis in public health or technical and physical suitability must be dealt with by the regulatory and administrative body that will ultimately make the permitting decision, the OSDH.

The Oklahoma State Legislature

The Oklahoma State Legislature has offered Oklahoma developers and concerned citizens a forum in which to air the inevitable dispute over the siting of new waste-management facilities. The legislature has responded by enacting new laws which amend the existing Controlled Industrial Waste Disposal Act of 1976 in several significant ways.

Examples of preventative measures enacted into law include the County Road and Bridges Maintenance Act of 1985, which specifies long-term improvements and maintenance of county roads and bridges to be used by site developers to access a proposed site. This act assures the general public that proposed sites will not be a financial burden on county road and bridge maintenance.

Another example is improvements in the language of the Waste Fund Act. The improved language allows matching funds up to $50,000 for communities that will submit applications for such funds to develop additional fire, police, or emergency-response equipment and plans. The new language gives priority to counties, municipalities, and towns in which off-site disposal facilities are proposed.

A third example is the Groundwater Protection and Good Neighbor Policy Act of 1987. This act strictly prohibits the siting of off-site waste-disposal facilities over principal ground-water resources or recharge areas. The act also includes provisions for accelerated community and property-owner involvement in the potentially affected zone of a facility (within a 1-mile radius of the facility borders).

The Oklahoma Hazardous Materials Transportation Act of 1986 assures citizens that all hazardous materials which are being transported on Oklahoma highways will be transported safely.

CLASS I WELLS IN OKLAHOMA

In 1988, Class I hazardous-waste wells regulated by OSDH numbered only 10 (8 facilities, 10 wells), but accounted for the safe disposal of approximately 632,000,000 gallons of hazardous waste (John Ice, Oklahoma State Department of Health, Waste Management Division, personal communication, October 1988). Using a weight of 8.33 lb/gal for fresh water, that total is more than 5,265,000,000 lb, or 2,632,500 tons of waste materials. This single-year total is 125 times the volume (21,000 tons) of hazardous materials dumped by the Hooker Chemical Co. into Love Canal over a five-year period between 1947 and 1952 (Epstein and others, 1982).

Figure 1 and Table 1 give the names, location by county, and estimated 1988 volumes disposed by existing Class I hazardous-waste wells in Oklahoma. All are operating under the supervision of the Oklahoma State Department of Health.

In addition to these wells, three wells are under construction at two new sites. Two of these wells are at Environmental Solutions, Inc. (Washington County), and the other well is at International Metal Co. (Creek County). Another Class I well operated by the Petrolite Corporation (Osage County) injects hazardous industrial waste (approximately 18 million gal per year). This well operates under the supervision of the U.S. Environmental Protection Agency, which has jurisdiction over waste disposal on Indian Lands in Oklahoma.

Most of the listed and proposed hazardous-waste injection wells are located in northeastern Oklahoma and are completed in the Arbuckle Group (or the Arbuckle and Simpson Groups). The Arbuckle (or the Simpson where present) is immediately overlain by the Woodford Shale and is underlain by granite. This combination of receiving and confining formations has proven itself over the last 30 years an exceptional resource for Oklahoma.

Typical waste streams injected by these facilities in Oklahoma are wastewaters containing solvents, clean-

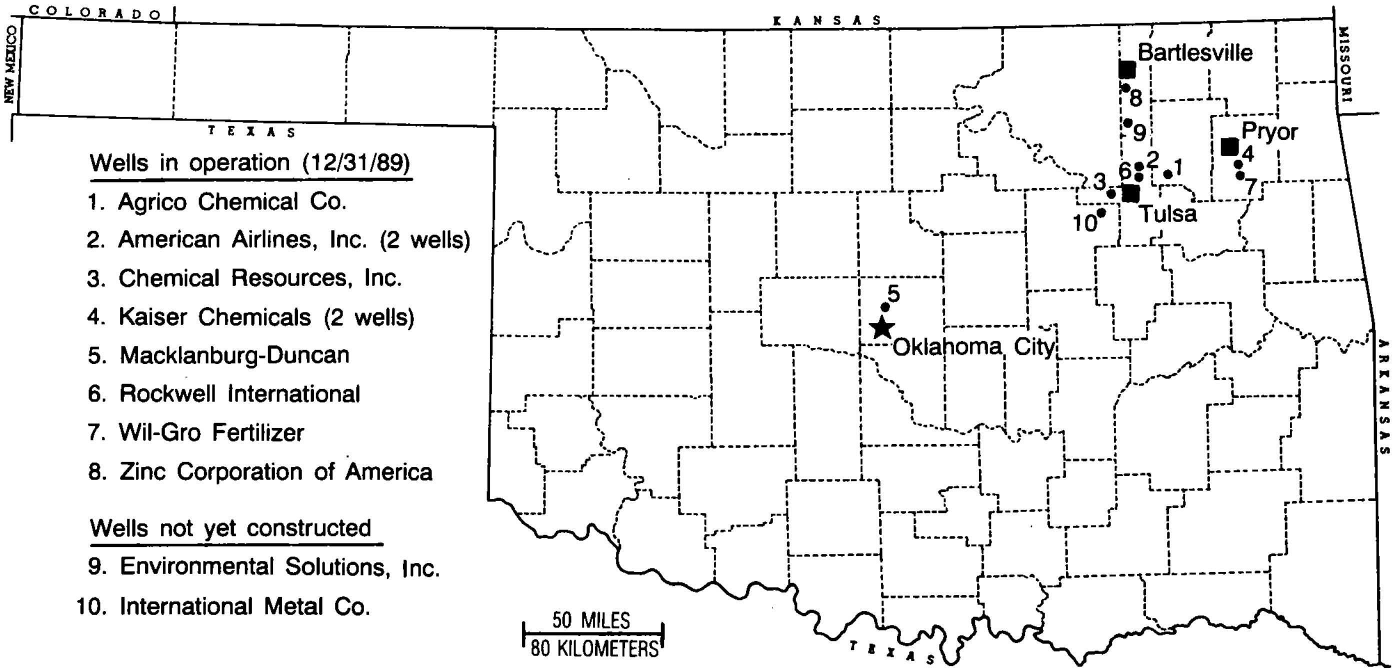

Figure 1. Locations of Class I injection wells regulated by the Oklahoma State Department of Health.

ers, and spent acids; alkaline solutions; rinse water; cooling-tower waters; rainwater runoff contaminated by heavy metals; petroleum-refining wastes; and, acidic pickling solutions used to remove impurities from steel.

Candidate waste for injection wells are typically high-volume aqueous solutions whose water content is 90–98% by volume. These waste streams are ideal candidates for deep-well injection because of the relative high expense of treating the impurities out of the water versus injecting the whole volume into deep wells.

UNIQUE OKLAHOMA RESOURCES

Oklahoma has many unique resources that make it an ideal place for the use of deep-injection-well technology.

First and foremost is Oklahoma's undisputed worldwide leadership in oil and gas technology, the cornerstone of successful deep-injection-well operation. Oklahoma is rich in expertise in all of the oil and gas engineering and construction sciences and is supported by its major universities and colleges across the State. The research and development departments of companies such as Halliburton Service Co., Christiansen Diamond Products, Schlumberger Well Services, Phillips Petroleum Co., and a host of others whose worldwide headquarters are located in Oklahoma lend considerable expertise to deep-well-injection sciences, methods, and techniques.

Noted organizations, such as the Underground Injection Practices Council (UIPC), have chosen Oklahoma for their home. The UIPC is a nationally chartered organization whose members include some of the most distinguished members of the environmental community, the heads of federal and State UIC programs, academia, scientists, and the regulated community.

The UIPC has established itself as "the source for reliable information on underground injection." Today, the UIPC is nationally known as a clearinghouse for information on underground injection, has conducted original research on all classes of wells, and has established a body of knowledge through a series of highly acclaimed international symposia (UIPC, 1989).

The Arbuckle Group, overlain by the Woodford Shale and underlaid by granite, has proven a most successful geologic setting in Oklahoma for subsurface injection of hazardous waste.

Transportation is a dominating factor favoring Oklahoma. Oklahoma is connected to the interstate highway system, has good access to rail, and is the farthest inland state connected to waterways.

Oklahoma is a "primacy" state. It has a well-developed and refined system of laws, rules, regulations, and guidelines which encourage the development of Oklahoma's best-kept secret, its deep-injection-well resource. Many industries could benefit by locating in Oklahoma.

Oklahoma is positioned to use its unique resources to provide a solution to regional liquid-hazardous-waste disposal problems, to clean up yesterday's mess, and to provide national leadership in the development of subsurface resources.

TABLE 1.—1988 ESTIMATED VOLUMES OF HAZARDOUS WASTE DISPOSED AT CLASS I WELLS REGULATED BY OSDH IN OKLAHOMA

Facility name	No. of wells	1988 volume (million gal)
Zinc Corp. of America (Washington County)	1	222
American Airlines (Tulsa County)	2	144
Rockwell International (Tulsa County)	1	18
Agrico Chemical Co. (Rogers County)	1	84
Kaiser (Nipak) (Mayes County)	2	36
Cherokee Nitrogen (Mayes County)	1	54
Chemical Resources, Inc. (Tulsa County)	1	24
Macklanburg Duncan Co. (Oklahoma County)	1	50
8 facilities	10 wells	632 million gal

Source: John Ice, Oklahoma State Department of Health, personal communication, 10/12/88.

CONCLUSION

There are at least 10 remaining reasons why Oklahomans should embrace subsurface deep-well technology and insist on its development:

1) The Compass Industries abandoned landfill near Chandler Park on the Arkansas River in Tulsa, Oklahoma, where surface and ground water is highly contaminated with spent jet fuel, solvents, caustics, bleaches, benzene, and pesticides;

2) The Sand Springs Petrochemical Complex in Sand Springs, Oklahoma, where unlined acid-sludge, solvent, and waste-oil lagoons pose a threat to ground water;

3) The Hardage Landfill near Criner, Oklahoma, where surface and ground water is being threatened by pesticides, solvents, alcohols, acids, and caustic chemicals;

4) The Double Eagle Refinery in Oklahoma City, Oklahoma, where about 2,500 cubic yards of waste oils containing heavy metals are contained in surface impoundments, and four ponds, some unlined, are threatening ground water;

5) The 4th Street Refinery, directly across the street from the Double Eagle site in Oklahoma City, Oklahoma, where unlined oil-sludge pits, contaminated surface waters, and an unknown full extent of other contamination is imminent;

6) Tinker Air Force Base in Midwest City, Oklahoma, where a plume of contamination threatens the Garber–Wellington Formations, which provide water for most of central Oklahoma;

7) The Mosley Road Landfill in Oklahoma City, Oklahoma, which contains about 2 million gal of hazardous liquid waste, including, pesticides, industrial solvents, sludges, and waste chemicals and emulsions;

8) The Oklahoma Refining Co. in Cyril, Oklahoma, where process waste was placed in nearly 100 unlined pits;

9) The Sunray Refinery in Allen, Oklahoma, where unlined pits occupy 40 acres (the pits contain sludge from refinery operations including, copper, lead, and zinc) (Singletary, 1989); and

10) The hundreds of unidentified regional sites that pose a threat to Oklahoma's environmental quality.

The cost of cleanup has emerged as the single greatest barrier to cleaning up old, abandoned sites. Responsible parties cannot be found in many instances, and the taxpayer is ultimately saddled with the cost of cleanup. Class I injection wells that meet strict new standards can provide low-cost disposal of the hundreds of millions of gallons of liquid hazardous waste that pose threats to the health and well-being of Oklahomans at these sites.

The development of new, technically and physically well-suited Class I hazardous-waste injection wells and strict enforcement of environmental laws will assure four things for Oklahoma:

1) Long-term protection of the public health and the environment;

2) A steady regulatory driven market for the physically and technically well-suited successful sites;

3) A most affordable disposal technology for Oklahoma's existing and expanding industries and an attractive waste-management alternative to clean up Oklahoma's abandoned dump sites; and

4) A known cost of disposal that can be relied upon for geologic periods of time.

Unlike yesterday's "who-done-it-mystery" disposal methods, deep wells offer Oklahoma a proven, environmentally sound disposal technology, the cost of which can be relied upon by its users as a one-time expense.

SELECTED REFERENCES

Boraiko, Alan, 1985, Storing up trouble: National Geographic, v. 167, no. 3.

Borlaug, Norman, 1985, Toxic terror (foreword): Jameson Books, Ottawa, Illinois.

EI Digest, 1989, Commercial underground injection facilities: a summary of this option in waste management: EI Digest, September, p. 17–21.

Epstein, Samuel; Brown, Lester; and Pope, Carl, 1982, Hazardous waste in America: Sierra Club Books, San Francisco.

Magnuson, Ed; Nash, Madeline; Stoler, Peter; and Yang, J. E., 1985, A problem that cannot be buried: Time, v. 126, no. 15.

Maurer, Cassandra; Olin, Richard; Andrews, Richard; Lynn, Francis; and Smith, Martin, 1985, Costs and benefits to local governments due to presence of a hazardous waste management facility: Institute for Environmental Studies—University of North Carolina at Chapel Hill.

Oklahoma Controlled Industrial Waste Disposal Act of 1976. Oklahoma Statutes title 63, article 20, section 1-2001, et. seq.

Singletary, Wayne, 1989, State Superfund sites detailed: The Daily Oklahoman, September 24, p. A21.

Underground Injection Practices Council, 1989, A record of achievement in ground water protection: UIPC Press.

U.S. Environmental Protection Agency, 1982, Using compensation and incentives when siting hazardous waste management facilities: July (DOC. SW942).

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, 1987, The hazardous waste system: U.S. Congress, General Accounting Office, E-S4.

Transportation of Hazardous Wastes in Oklahoma

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INTRODUCTION

Hazardous materials as defined by the U.S. Department of Transportation are substances capable of posing an unreasonable risk to health, safety, and property when transported in commerce.

It is estimated that 1.5 billion tons/yr are moved by land, sea and air, while hazardous waste shipments account for 2.5 billion tons. Nearly a half million shipments occur daily. Highway transportation accounts for more than half of all shipments.

The regulations that govern these shipments (Title 49 CFR 100-179 et seq.) are complex and comprehensive. They regulate some 30,000 hazardous materials.

While the vast majority of these materials are transported safely, the potential for a catastrophic event is so great that this has become an area of intense public concern nationwide.

The volumes of materials, the complexity of needed regulations, and the public's concern over their safe transportation indicate a need for uniform enforceable laws. To this end, Oklahoma has adopted these federal regulations without exception for interstate and intrastate carriers (Fig. 1).

HISTORY AND REGULATORY AUTHORITY REGARDING HAZARDOUS-WASTE TRANSPORTATION

The transportation of hazardous waste in Oklahoma is nothing new. These products of industry, manufacturing, and even household applications of various cleaners and compounds have been in transportation on our public roads since the day Oklahomans decided "it's better to transport it far away than to live with it in our front yards." While the transportation is nothing new, enforcement and control of that aspect of hazardous waste is.

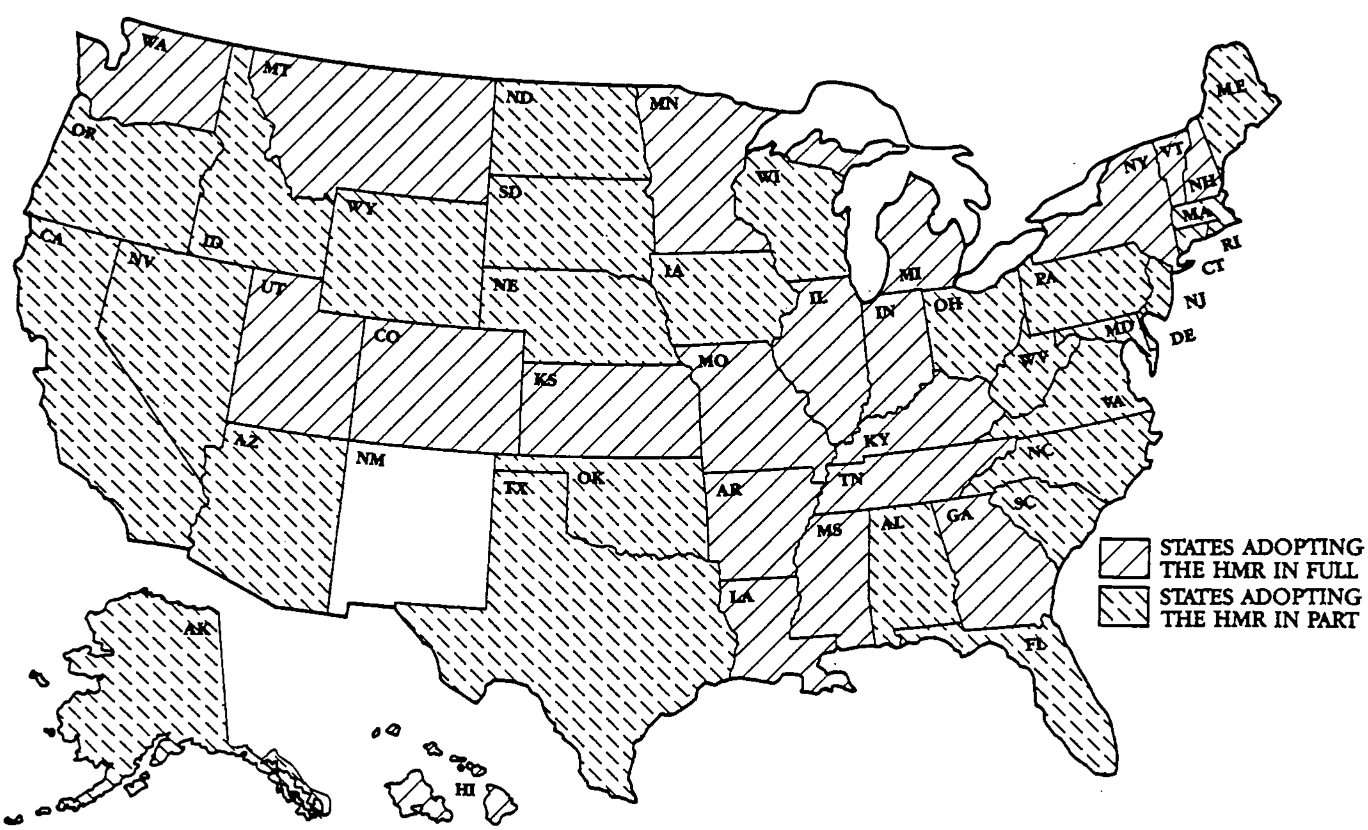


Figure 1. States adopting HMR in full or in part.

Several agencies share responsibility for storage, disposal, and similar facets of the conversion of materials into waste products, but until recently the transportation was only regulated by the Federal Highway Administration's Office of Motor Carrier Safety. This agency, through the authority contained in 49 Code of Federal Regulations Parts 100 through 179, applied jurisdiction only over interstate transportation or certain aspects of intrastate moves (e.g., bulk transportation in tanks over 3,500 gal water capacity). Until recent years, this office consisted of as few as two safety investigators statewide with responsibility for all aspects of motor-carrier safety.

In 1985, an Ad Hoc Interagency Task Force was formed under Governor George Nigh. The task force was charged with studying the transportation of all hazardous materials and recommending methods of reducing the probability of incidents that would lead to personal injury or environmental damage.

The task force identified various shortcomings in the two broad areas of incident response and, even more important, incident prevention. Recommendations included legislation adopting federal hazardous-materials and motor-carrier safety regulations, as well as encouraging participation in the Commercial Vehicle Safety Alliance[1] and the federally funded Motor Carrier Safety Assistance Program[2].

As a result, the Oklahoma Legislature passed the Oklahoma Motor Carrier Safety Act in 1986. Subsequent rules developed by the Department of Public Safety adopted appropriate parts of 49 CFR. The Highway Patrol's Troop S (Size and Weight Enforcement Division) began training and equipping troopers for roadside enforcement of these regulations shortly thereafter.

As the emphasis on vehicle safety and hazardous-materials transportation developed, the need for a specific division charged with enforcement of these intricate regulations emerged. In mid-1989, the Patrol created the Motor Carrier Safety Division (designated Troop SM). Troop SM was to be responsible not only for roadside safety inspections of commercial motor carriers, but also for development of methods of auditing internal records-keeping systems required of motor carriers under the Act. The troop will accomplish approximately 20,000 roadside inspections with 20 troopers in 1990, and begin these audits in early 1991 with five additional inspectors.

[1]The Commercial Vehicle Safety Alliance is an association of state and provincial commercial-motor-carrier safety-enforcement agencies who have formed a union to promote uniform safety and transportation issues. CVSA has grown from four Pacific Northwest states in 1980 to include 49 states and all Canadian provinces.

[2]The Motor Carrier Safety Assistance Program (MCSAP) is a federally funded grant program authorized by Congress in the Surface Transportation Assistance Act of 1982. The purpose of the Act is to reduce the number of commercial-motor-vehicle accidents and hazardous-materials incidents occurring in transportation by authorizing funds to states desiring to participate.

The Department of Public Safety provides enforcement and inspection information to the Oklahoma State Department of Health through a contract executed between the two agencies. This agreement provides information on the transportation of hazardous wastes and determines compliance with DOT and OSDH requirements. These requirements specifically incorporate 49 CFR Subchapter C, Parts 171 through 178 (excluding 174, rail transportation; 175, aircraft transportation; and 176 vessel transportation), as well as OSDH requirements arising under the Controlled Industrial Waste Disposal Act, including applicable U.S. Environmental Protection Agency regulations at 40 CFR Parts 262 and 263.

A secondary purpose of the contract is to conduct inspections of vehicles carrying radioactive materials to determine compliance with those requirements of 49 CFR Part 171. The transportation of spent nuclear fuel or other high-level radioactive wastes being transported by vehicles controlled or operated by the U.S. Government or one of its agencies transporting nuclear weapons or components thereof is specifically excluded from this agreement. However, the Department of Public Safety has been designated as the official contact for the proper notification by generators and contractors of radioactive wastes through Oklahoma in compliance with requirements of Title 10 CFR Part 71. Therefore, the DPS does exercise a certain amount of authority over monitoring of these shipments, regardless of the contract.

VOLUMES AND CATEGORIES OF HAZARDOUS-WASTE SHIPMENTS

Obviously the monitoring and enforcement of safety regulations as regards hazardous wastes is in its infancy in Oklahoma. It would not be possible now to supply accurate figures on the volumes or classifications of the various wastes transported in and through Oklahoma. Currently, no registration or prenotification of these shipments is required for carriers simply transporting wastes through Oklahoma for disposal or recycling in other states. Specific exceptions to this do apply to transporters of certain radioactive wastes and materials, as mentioned.

The State Department of Health does not require registration of transporters who will haul materials destined for disposal or recycling in Oklahoma. Currently, 237 companies have been registered with the Industrial Waste Division of OSDH.

Reports supplied to OSDH indicate the quantities of materials and the EPA classification of each waste as it is disposed of at the two commercial hazardous-waste-disposal sites in Oklahoma[3].

[3]United States Pollution Control Inc. (USPCI) operates the Lone Mountain Surface Disposal Site for solid wastes in Major County near Waynoka. This facility handles more than 35,000 tons of waste annually. Chemical Resources Inc. (CRI) operates an injection well in Tulsa County for the disposal of liquid wastes. CRI reports handling more than 8 million gal of waste annually.

These reports only indicate the materials disposed of in Oklahoma through these two commercial sites, and therefore are no indication of the actual volumes transported through our State.

The Department of Public Safety and the State Department of Health share concerns over reports of illegal dumping, which are sporadic and difficult to detect until the effects are noticed. Cooperation between the Department of Public Safety, Health Department, and the Oklahoma Corporation Commission is aimed at detecting, prosecuting, and preventing such actions.

GENERAL REQUIREMENTS FOR HAZARDOUS-WASTE TRANSPORTERS

Generally, as required in 49 CFR 171.3, no material classified as a hazardous waste may be offered for transportation unless that material is properly classified, packaged, labeled, listed on a proper manifest, and in general condition for transportation. The entire quantity of material shipped must be delivered to the designated facility or subsequent carrier.

The transport vehicle must be properly marked or placarded (if required) and in good mechanical condition for the transportation.

General Definitions

171.8 defines a hazardous waste as any material subject to the Hazardous Waste Manifest Requirements of the U.S. Environmental Protection Agency specified in 40 CFR Part 262. Any material so designated is subject to the specific packaging and transporting requirements contained in the Hazardous Materials Regulations.

Required Manifest

All hazardous-material shipments must be accompanied by a "shipping paper" (Fig. 2) to describe the product transported to emergency responders or others as to the nature and magnitude of any problem that may involve the shipment. With hazardous materials, the basic information described on the paper is formatted, but any general document form is acceptable. However, the form of this paper is prescribed by law for hazardous wastes. 40 CFR 262 specifies the format to be utilized. The description of the product must be followed by the word "waste" if it is not incorporated into the proper name [172.101(c)(10)].

Additional entries required on hazardous-waste shipping papers include a Reportable Quantity notation[4] and shipper's certification declaring the general suitability for transportation of the shipment. 172.205(e)(2) states that this waste manifest must be carried in a location in the transport vehicle that will ensure its accessibility in case of a transportation incident or regulatory inspection.

Proper Packaging

173.24 requires that "each package used for shipping hazardous materials shall be so designed that under conditions normally associated with transportation there shall be no significant release of hazardous materials to the environment." This general packaging requirement covers all hazardous materials; however, 172.101 (hazardous materials table) refers to specific packages that are required for certain materials. Packaging specifications are written to cover everything from cardboard boxes to railroad tank cars (see Fig. 3).

Package Markings

172.300 requires each person who offers a hazardous material for transportation to mark the packages regardless of container type (see Fig. 4). Containers may be specific as to manufacturing requirements (DOT SPEC), or only required to meet general product-integrity standards (not leaking). Containers range from individual drums to cargo-tank shipments. Regardless of type, markings should specify "waste material" in one form or another. Individual packages should also indicate if a reportable quantity (RQ) is present.

Package Labeling

172.400 requires each person who offers a package containing a hazardous material for transportation to label it with labels prescribed for that material (see Fig. 5). Certain packages are exempted from this requirement (e.g., bulk packages, packages of ORM A,B,C,D,E, etc.).

Additional labels may be required to indicate multiple hazard classes or if a specific hazard is associated with a particular commodity (poison inhalation, dangerous when wet, etiological agents, etc.).

Placarding

Placards are generally required on transport vehicles to indicate that hazardous materials or wastes are contained within that shipment (see Fig. 6). Placards are to be so located and visible as to warn of the general hazard represented by that vehicle's contents. The requirement to display placards is dependent upon the hazard class of the material and the amount in the transport vehicle.

172.500 specifies these requirements. Any amount of Class A and B explosives, Poison A, Flammable Solid or Radioactive Yellow III must be placarded. The remaining 12 classifications are required to be placarded only when sufficient amounts of the product are shipped. (Etiological agents and ORMs A,B,C,D,E are exempted from placards.)

[4]"Reportable quantity" (RQ) refers to a certain measurable amount of a hazardous material in a single package that is so noted by its entry in an appendix to the hazardous material table (172.101). A release of this product bearing (RQ) requires notification of the incident as regards environmental damage.

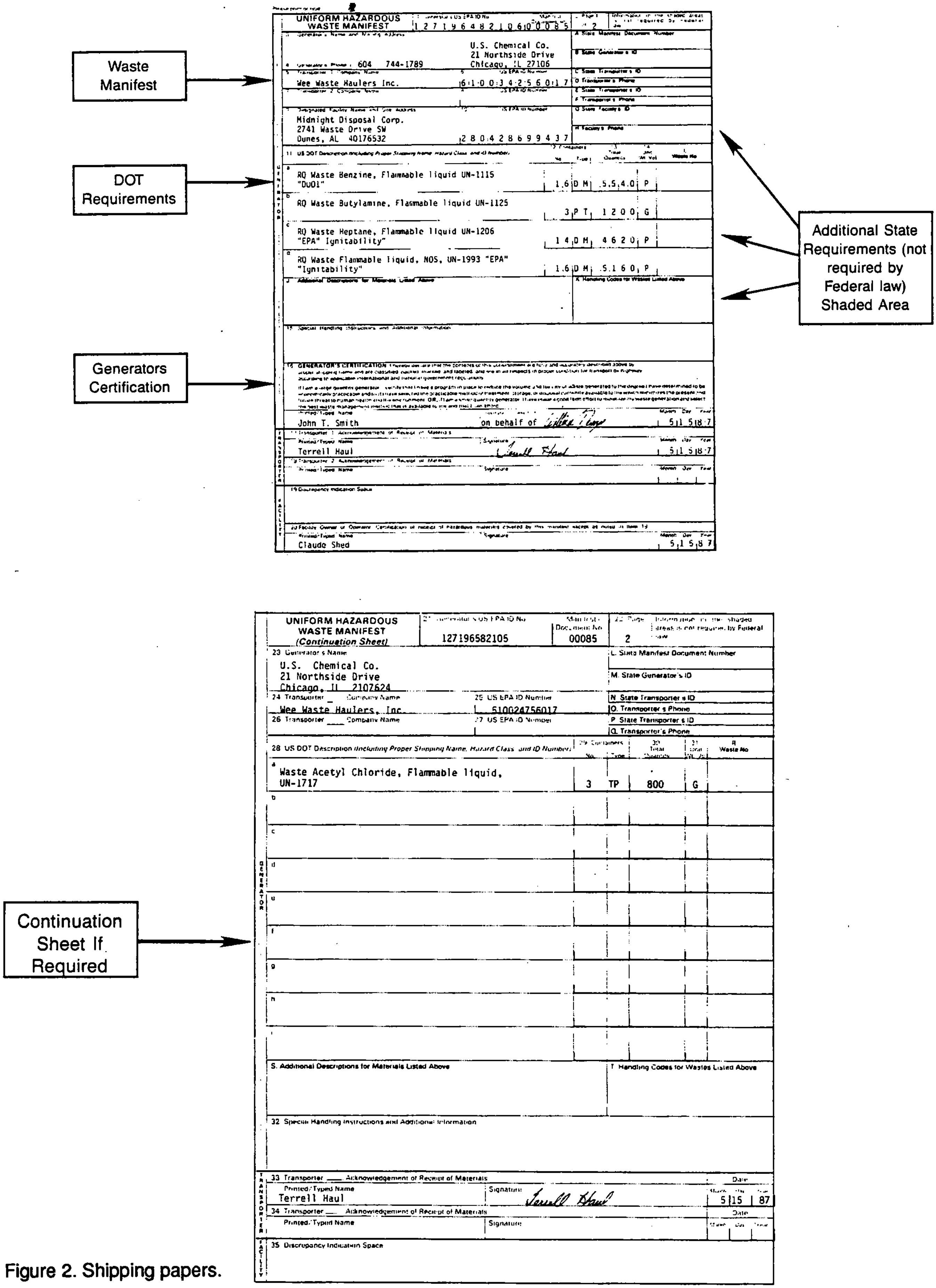


Figure 2. Shipping papers.

Please print or type. *(Form designed for use on elite (12-pitch) typewriter.)* *Form Approved. OMB No. 2050-0039. Expires 9-30-91*

UNIFORM HAZARDOUS WASTE MANIFEST

1. Generator's US EPA ID No. | Manifest Document No. | 2. Page 1 of | Information in the shaded areas is not required by Federal law.

3. Generator's Name and Mailing Address

A. State Manifest Document Number

B. State Generator's ID

4. Generator's Phone ( )

5. Transporter 1 Company Name | 6. US EPA ID Number

C. State Transporter's ID

D. Transporter's Phone

7. Transporter 2 Company Name | 8. US EPA ID Number

E. State Transporter's ID

F. Transporter's Phone

9. Designated Facility Name and Site Address | 10. US EPA ID Number

G. State Facility's ID

H. Facility's Phone

11. US DOT Description *(Including Proper Shipping Name, Hazard Class, and ID Number)*	12. Containers No.	Type	13. Total Quantity	14. Unit Wt/Vol	I. Waste No.
a.					
b.					
c.					
d.					

J. Additional Descriptions for Materials Listed Above

K. Handling Codes for Wastes Listed Above

15. Special Handling Instructions and Additional Information

16. **GENERATOR'S CERTIFICATION:** I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in proper condition for transport by highway according to applicable international and national government regulations.

If I am a large quantity generator, I certify that I have a program in place to reduce the volume and toxicity of waste generated to the degree I have determined to be economically practicable and that I have selected the practicable method of treatment, storage, or disposal currently available to me which minimizes the present and future threat to human health and the environment; OR, if I am a small quantity generator, I have made a good faith effort to minimize my waste generation and select the best waste management method that is available to me and that I can afford.

Printed/Typed Name | Signature | Month Day Year

GENERATOR

17. Transporter 1 Acknowledgement of Receipt of Materials

Printed/Typed Name | Signature | Month Day Year

18. Transporter 2 Acknowledgement of Receipt of Materials

Printed/Typed Name | Signature | Month Day Year

TRANSPORTER

19. Discrepancy Indication Space

20. Facility Owner or Operator: Certification of receipt of hazardous materials covered by this manifest except as noted in Item 19.

Printed/Typed Name | Signature | Month Day Year

FACILITY

EPA Form 8700-22 (Rev. 9-88) Previous editions are obsolete.

Figure 2. *Continued.*

Please print or type (Form designed for use on elite (12-pitch) typewriter) Form Approved. OMB No 2050-0039 Expires 9-30-91

UNIFORM HAZARDOUS WASTE MANIFEST *(Continuation Sheet)*	21. Generator's US EPA ID No.	Manifest Document No.	22. Page	Information in the shaded areas is not required by Federal law.

23. Generator's Name	L. State Manifest Document Number
	M. State Generator's ID
24. Transporter ___ Company Name / 25. US EPA ID Number	N. State Transporter's ID
	O. Transporter's Phone
26. Transporter ___ Company Name / 27. US EPA ID Number	P. State Transporter's ID
	Q. Transporter's Phone

GENERATOR

28. US DOT Description *(Including Proper Shipping Name, Hazard Class, and ID Number)*	29. Containers No.	Type	30 Total Quantity	31 Unit Wt/Vol	R. Waste No.
a.					
b.					
c.					
d.					
e.					
f.					
g.					
h.					
i.					

S. Additional Descriptions for Materials Listed Above	T. Handling Codes for Wastes Listed Above

32. Special Handling Instructions and Additional Information

TRANSPORTER

33. Transporter ___ Acknowledgement of Receipt of Materials		Date
Printed/Typed Name	Signature	Month Day Year
34. Transporter ___ Acknowledgement of Receipt of Materials		Date
Printed/Typed Name	Signature	Month Day Year

FACILITY

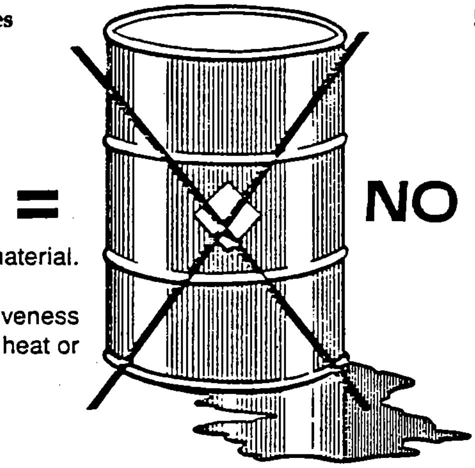
35. Discrepancy Indication Space

EPA Form 8700-22A (Rev. 9-88) Previous edition is obsolete.

Figure 2. *Continued.*

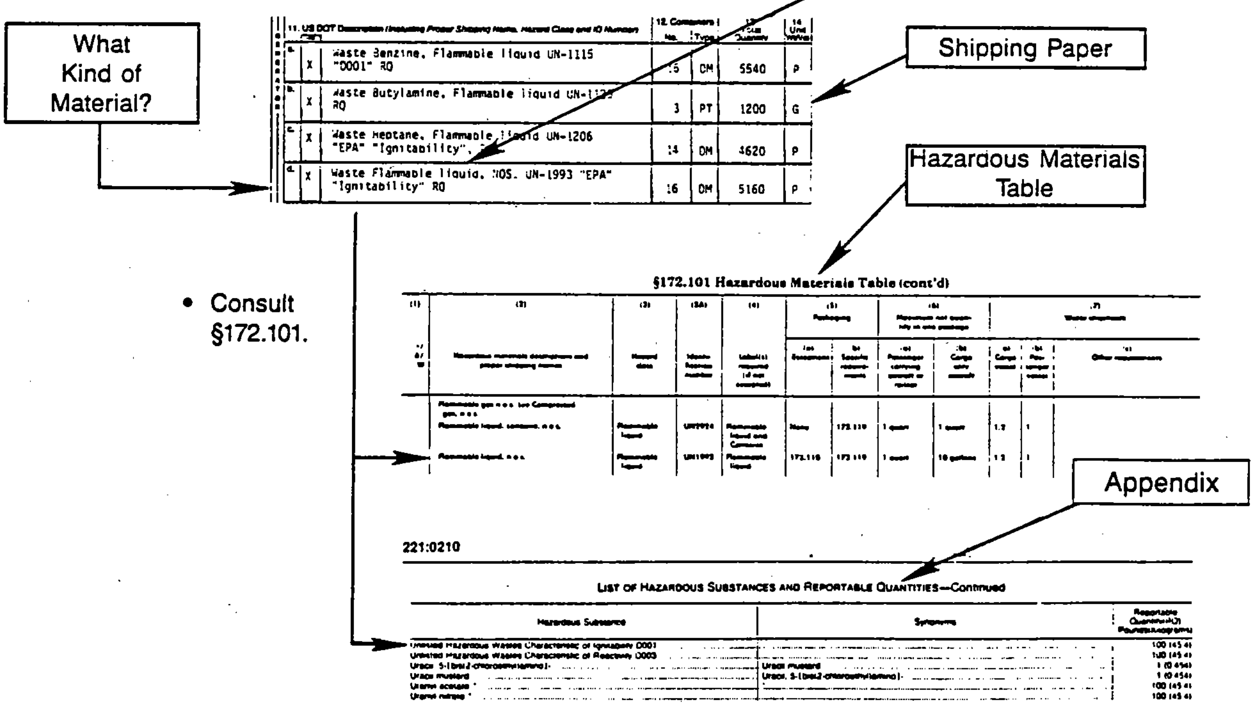
General Requirements (§173.24)

- Strong tight containment.
- Contents must be compatible with the packaging material.
- No significant release of contents.
- No mixture of materials that may reduce the effectiveness of the packaging through spontaneous increase of heat or pressure or through an explosion.



Specific Requirements (See §172.101 for applicable material and packaging requirements)

- Determine proper shipping name of material.



- Consult §172.101.

- Consult §172.101 — APPENDIX — list of hazardous substances and reportable quantities. **NOTE** that Flammable Liquid N.O.S. UN1993 is a hazardous substance and will require additional description on the Uniform Waste Manifest.

Exceptions

- Small Quantity: small quantities of flammable liquids, flammable solids, oxidizers, organic peroxides, corrosive material, Poison B, ORM A, B, C, and Radioactive Materials that also meet the definition of one or more of these hazard classes are not subject to the requirements of this subchapter if: certain quantitive limitations and packaging requirements are met. (§173.4)

- Limited Quantity: when specified as such in a section applicable to a particular material with the exception of Poison B materials, means the maximum amount of a hazardous material for which there is a specific labeling and packaging exception. (§171.8)

  Poison B materials can be limited quantities. They do not require specification packaging but they require labels.

Figure 3. Packaging.

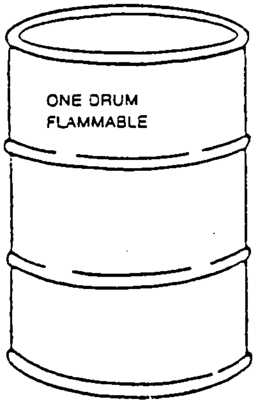
General Requirements (§172.301)

- Proper shipping name.
- Identification number.
- Inhalation Hazard §172.301(a) if required, and
- Consignee's or consignor's name and address (§172.306).

Note: The name and address is not required when the package is:
a. Not transferred from one motor carrier to another.
b. Part of a full load from one consignor to one consignee, or
c. A portable tank.

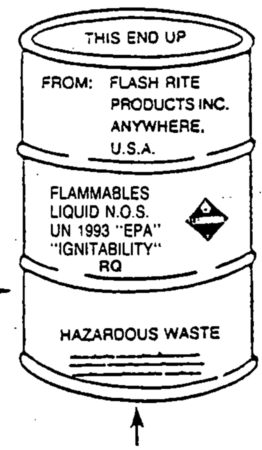
11 US DOT Description (Including Proper Shipping Name, Hazard Class and ID Number)	12 Containers No.	Type	13 Total Quantity	14 Unit Wt/Vol	Waste No.
a. waste Benzine, Flammable liquid UN-1115 "D001" RQ	16	[illegible]	5540	P	
b. waste Butylamine, Flammable liquid UN-1125 RQ	3	[illegible]	1200	G	[illegible]
c. waste Heptane, Flammable liquid UN-1206 "EPA" "Ignitability", RQ	14	DM	[illegible]	P	[illegible]
d. waste Flammable liquid, NOS, UN-1993 "EPA" "Ignitability" RQ	16	DM	5160	P	[illegible]

INCORRECT



- Compare proper shipping name and the identification number on the shipping paper to the markings on the package.
- The word "waste" is not required to preceed the Proper Shipping Name if the package bears the EPA marking specified in 40 CFR 262.32 [§172.301 (a)(1)]

CORRECT



Note: Hazardous waste in containers of 110 gallons or less must be marked in accordance with EPA requirements 40 CFR 262.32

Specific Requirements

- Liquid hazardous material (§172.312) - must have "THIS SIDE UP" or "THIS END UP" orientation markings and may have orientation arrows when the package has inner containers filled with a liquid. This requirement does not apply to limited quantities of flammable liquids under certain conditions [see §172.312(d) and (e)].
- Hazardous substances (§172.324) - if the proper shipping name for a mixture or solution that is a hazardous substance does not identify the constituents making it a hazardous substance, the name or names of such hazardous substance constituents as shown in the Appendix to §172.101 must be marked in parentheses in association with the proper shipping name on each packaging having a capacity of 110 gallons or less. This requirement also applies when descriptions from the Optional Table in §172.102 are used.

  Those packages with a capacity of 110 gallons or less which contain waste streams or waste which exhibit EPA designated characteristics of ignitibility, corrosivity, reactivity, or EP toxicity, must be marked in parentheses in association with the proper shipping

Note: For hazardous materials in hazard classes for which placards are not required, identification numbers may be displayed on a plain white square-on-point configuration having the same outside dimensions as those prescribed for placards (See Step 5). An identification number displayed as authorized by this provision is not considered a placard. This configuration is utilized to meet the marking requirement of ORM-E Materials in containers of more than 110 gallons (portable tanks and cargo tanks). Orange panels may also be used. [§172.336(b)]

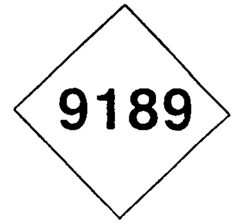


Figure 4. Marking.

General Requirements (§172.400)

- Packages containing a hazardous material must bear the label(s) specified in Column 4 of Hazardous Materials Table. There may be exceptions to labeling under limited quantity provisions.
- Labels are prohibited on packages that do not contain a hazardous material (§172.401).
- Labels must be printed or affixed near the marked proper shipping name (§172.406).
- Multiple labels must be placed next to each other [§172.406(c)].

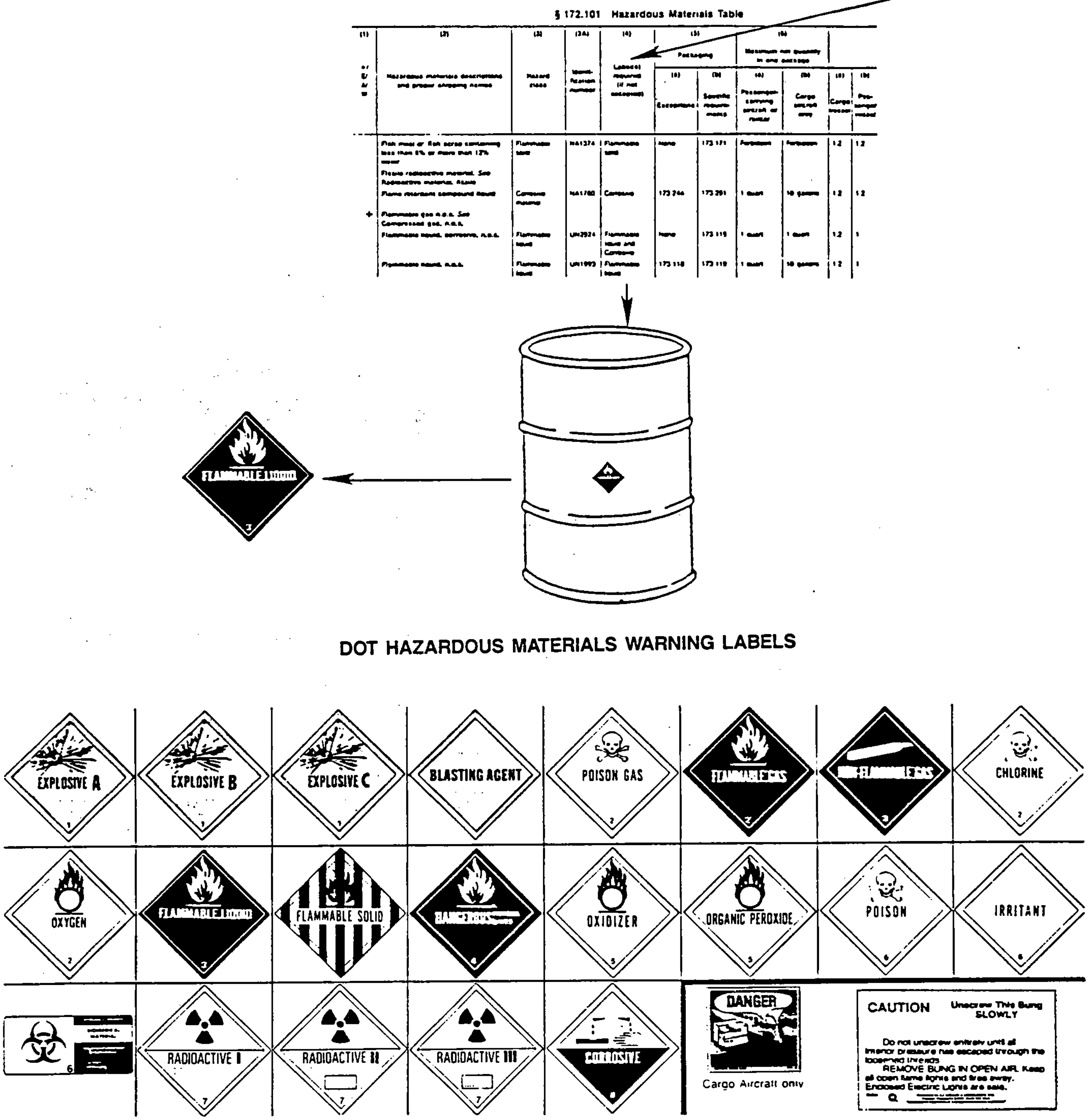


Figure 5. Labeling.

Exceptions (§172.500)

Placarding is not required for:

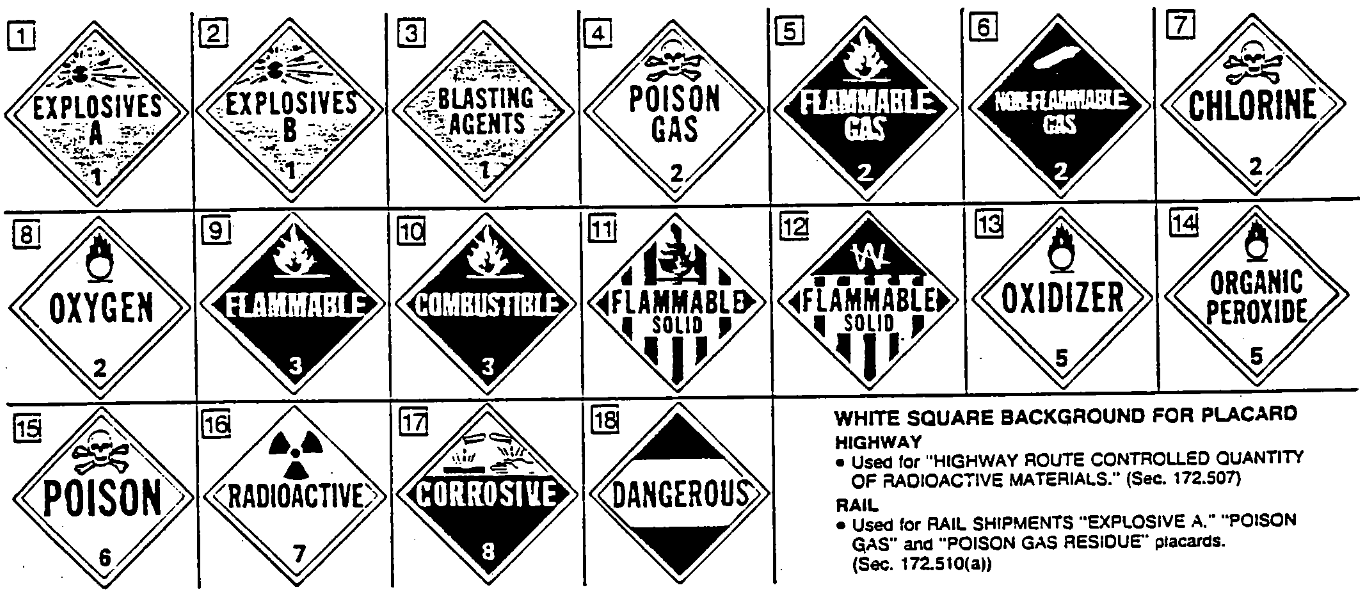
- Etiologic agents.
- ORM — A, B, C, D, or E.
- Limited quantities of hazardous materials that are properly identified on the shipping papers.
- Less than 1000 pounds gross weight of all materials listed in Table 2 of §172.504. (Except Poison Inhalation Hazard Material) [§172.504(c)].

Placard Requirements

- Placards are selected based on the hazard present and the quantity on the transport vehicle.
- Each motor vehicle containing any quantity of a hazardous material listed in Table 1 of §172.504 must be placarded as required in that table

DOMESTIC PLACARDING

Illustration numbers in each square refer to Tables 1 and 2 below.



WHITE SQUARE BACKGROUND FOR PLACARD

HIGHWAY

- Used for "HIGHWAY ROUTE CONTROLLED QUANTITY OF RADIOACTIVE MATERIALS." (Sec. 172.507)

RAIL

- Used for RAIL SHIPMENTS "EXPLOSIVE A," "POISON GAS" and "POISON GAS RESIDUE" placards. (Sec. 172.510(a))

Guidelines

(CFR, Title 49, Transportation, Parts 100-177)

- Placard any transport vehicle, freight container, or rail car containing any quantity of material listed in Table 1.
- Materials which are shipped in portable tanks, cargo tanks, or tank cars must be placarded when they contain any quantity of Table 1 and/or Table 2 material.
- Motor vehicles or freight containers containing packages which are subject to the "Poison-Inhalation Hazard" shipping paper description of Section 172.203(k)(4), must be placarded POISON in addition to the placards required by Section 172.504 (see Section 172.505).
- When the gross weight of all hazardous material covered in TABLE 2 is less than 1000 pounds, no placard is required on a transport vehicle or freight container.
- Placard freight containers 640 cubic feet or more containing any quantity of hazardous material classes listed in TABLES 1 and/or 2 when offered for transportation by air or water (see Section 172.512(a)). Under 640 cubic feet see Section 172.512(b).

TABLE 1

Hazard Classes	No.
Class A explosives	1
Class B explosives	2
Poison A	4
Flammable solid (DANGEROUS WHEN WET label only)	12
Radioactive material (YELLOW III label)	16
Radioactive material:	
Uranium hexafluoride fissile (Containing more than 1.0% U^{235})	16 & 17
Uranium hexafluoride, low-specific activity (Containing 1.0% or less U^{235})	16 & 17

Note: For details on the use of Tables 1 and 2, see Sec. 172.504 (see footnotes at bottom of tables.)

TABLE 2

Hazard Classes	No.
Class C explosives	18
Blasting agent	3
Nonflammable gas	6
Nonflammable gas (Chlorine)	7
Nonflammable gas (Fluorine)	15
Nonflammable gas (Oxygen, cryogenic liquid)	8
Flammable gas	5
Combustible liquid	10
Flammable liquid	9
Flammable solid	11
Oxidizer	13
Organic peroxide	14
Poison B	15
Corrosive material	17
Irritating material	18

Figure 6. Placarding.

ENFORCEMENT AND PENALTIES ASSOCIATED WITH HAZARDOUS WASTES

As referenced earlier, the Oklahoma Motor Carrier Safety and Hazardous Materials Transportation Act (Title 47 O.S. 230.1) authorized the Department of Public Safety to adopt federal regulations to govern the transportation of hazardous materials. The statute vests sole authority for the enforcement of the act with the Department of Public Safety. The Department, through internal policy, has designated the Motor Carrier Safety Division (Troop SM) of the Highway Patrol to enforce the Act.

Primary enforcement is accomplished by roadside inspection. Troopers routinely stop and inspect commercial vehicles to determine the nature of the shipment, and therefore the appropriate compliance with the regulations.

Troopers have the authority to declare a vehicle "out of service" and prohibit its movement until certain conditions have been satisfied (e.g., critical safety items, proper hazardous-materials papers, placards, etc.). Violations that are less critical are simply noted on an inspection form and forwarded to the DPS.

Violations of the act are civil (non-criminal), and penalties may be assessed against shippers, carriers, agents, or employer of parties responsible for the shipment.

By statute, the penalties can range from $100 for certain record-keeping violations to $1,000 for each offense that could constitute a substantial health or safety violation.

The Superfund Program in Oklahoma

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Waste Management Service
Oklahoma State Department of Health
Oklahoma City, Oklahoma

INTRODUCTION

Congress passed the first national comprehensive hazardous-waste-management law, the Resource Conservation and Recovery Act (RCRA), in 1976. This created a regulatory system that governed the storage, transportation, treatment, and disposal of hazardous waste. As this program was implemented, it became apparent that RCRA did not provide a mechanism to cure historical hazardous-waste-management errors such as the uncontrolled dumps at New York's Love Canal or Kentucky's Valley of the Drums.

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA), or Superfund, emerged from Congress in 1980, creating a large-scale national program to identify and clean-up sites contaminated from our previous hazardous-waste-management mistakes. This effort is known as Superfund because CERCLA established a national revolving fund to pay for remedial action at facilities whose owners were no longer available or financially solvent. CERCLA was subsequently amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. The Superfund is financed largely through a tax on chemical feedstocks used to manufacture chemical products whose constituents are likely to become hazardous waste.

While the site clean-up efforts of Superfund have received the most popular attention, the liability concepts pioneered in this statute have actually resulted in a much more dramatic and far-reaching impact. CERCLA established that any person or company who has any responsibility for hazardous waste—be it generation, transportation, treatment, or disposal—is ultimately liable for any environmental problems created by that waste. In Superfund terminology, anyone with liability is called a "potentially responsible party" (PRP). Moreover, the law creates strict joint/several liability, meaning that any PRP is liable for all problems at a Superfund site regardless of the individual contribution to the total problem. This broad concept of liability, which had no precedent in the American legal system, has profoundly impacted the operations of all organizations involved in hazardous-waste management; indeed, it has become the driving force in every aspect of managing any type of waste, either hazardous or non-hazardous.

The liability provisions of CERCLA directed the U.S. Environmental Protection Agency (EPA) to create a legal enforcement system that seeks to compel potentially responsible parties to undertake Superfund clean-up actions. If the government must pursue remedial actions at Superfund sites, the EPA is charged with recovering from PRPs the Superfund money expended. The law provides an incentive to encourage PRPs to participate. EPA is authorized to seek damages calculated at the rate of three times the government's actual clean-up costs. This penalty notwithstanding, the transaction costs associated with federal governmental action are so great that it may be significantly cheaper for a PRP to undertake a private action. This has resulted in the active cooperation of most PRPs at Oklahoma Superfund sites.

THE SUPERFUND PROCESS

The National Contingency Plan (NCP) establishes the basic procedures and processes for the operation of the Superfund program. Through the NCP, EPA has defined a process of identifying, evaluating, and remediating problem hazardous-waste sites that are outside the scope of the RCRA regulation. EPA operates this system through a series of contracts with the states and private contractors. The Oklahoma State Department of Health (OSDH) is the State agency responsible for working with EPA to achieve the program objectives in Oklahoma.

The following is a brief description of each basic step in the current Superfund process. Table 1 presents a summary of all the steps.

Site Discovery

Potential Superfund sites are identified through citizen complaints, systematic investigations of old or abandoned industrial sites, and through the routine operation of other State environmental-health programs. Any site which receives EPA attention is automatically added to CERCLIS, a national inventory of sites addressed by the Superfund program. No site is ever removed from this inventory, even if it is determined not to contain any environmental problems. In Oklahoma the majority of sites on the CERCLIS inventory have been investigated by either the OSDH or EPA

Table 1.—The Superfund Process

Site Discovery
Preliminary Assessment
Site Inspection
Hazard Ranking System
National Priorities List
Remedial Investigation/Feasibility Study and Endangerment Assessment
Record of Decision
Remedial Design
Remedial Action
Operation and Maintenance
Site Delisting

contractors and found to pose no environmental-health threat. Therefore, the gross number of sites on the CERCLIS inventory does not provide an accurate measurement of the scope of historical hazardous-waste-management problems in the state.

Preliminary Assessment

The preliminary assessment (PA) is a cursory investigation of a site. The primary purpose is to attempt to determine if any environmental problems exist that can be addressed by the Superfund Program. Information is obtained on surrounding land uses, groundwater uses, surface-water uses, geology, and surface topography in the vicinity of the site. A PA does not usually include sample collection, but a visual site reconnaissance is generally performed. A preliminary Hazard-Ranking System (HRS) score is estimated, based on the information available at this stage. If a site appears to have any potential to score high enough to qualify for the National Priorities List (NPL), usually a recommendation is made that the site be evaluated in the next step in the Superfund process.

Site Inspection

A screening site inspection (SSI) utilizes a minimal regime of sampling to determine if problems exist at a site. The sampling is typically planned to help identify the potential for human exposure to environmental-health problems through air releases, drinking-water contamination, or direct contact. As with the PA, a preliminary HRS score is calculated with the increased data available at the SSI stage. If the data indicate that a site has enough potential to qualify for the NPL, then either a formal HRS package is prepared, or a listing site inspection (LSI) may be performed.

The SSI may not provide sufficient data for sites that are very complex. The LSI is an action taken to strengthen data at sites that appear to be very strong candidates for the NPL. Some of the activities involved in an LSI, such as monitoring well installation, are intended to provide the basis for remedial-investigation activities that usually occur after NPL listing.

Hazard-Ranking System

The Hazard-Ranking System (HRS) is a model designed to utilize the environmental-sampling data gathered through the site inspections to evaluate which sites are national priorities for Superfund clean-up. The model assesses the potential for a site to adversely affect public health. Critical features of the model focus on the quantity of wastes at a site, the proximity of wastes to sources of underground drinking water and intakes for drinking water systems supplied by surface sources, and the potential for people to be exposed to air releases or directly to the waste. The model assigns a score which is a numerical representation of the relative national significance of the public-health threat posed by a site. The original HRS is currently being revised according to the requirements of SARA. At this point, it is unknown how the revised HRS will actually affect the number of sites that are added to the NPL in the future.

National Priorities List

The HRS score is used to determine which sites are added to the National Priorities List (NPL). This is the inventory of sites where the environmental problems are of sufficient national importance to merit the use of the federal Superfund to correct them. Currently any site which earns an HRS score of 28.5 or above is added to the NPL. A site must be on the NPL in order for the federal Superfund clean-up process to move forward.

Remedial Investigation/Feasibility Study and Endangerment Assessment

The Remedial Investigation (RI) is designed to gather the environmental data necessary to define the nature and extent of problems at a site. The data also form the basis for the Feasibility Study (FS), which examines the various options for remedial action. The environmental data are also used to assess the public-health impacts of a site in an Endangerment Assessment.

Record of Decision

The Record of Decision (ROD) memorializes EPA's selection of a remedy. The ROD is adopted through a formal set of procedures that incorporate the views and opinions of the state, the PRPs, and the public. The completion of the ROD is necessary before any additional site action, on behalf of either the government or PRPs, can take place.

Remedial Design

The Remedial Design (RD) is a phase of detailed design work necessary to implement the remedy selected in the ROD. The end product of the RD is a system of construction plans that will direct field work.

Remedial Action

The Remedial Action (RA) is the construction process to achieve the remedy for problems at the site. Many RA's include complex ground- and surface-water clean-up projects that may last several years.

Operation and Maintenance

As the RA is culminated, plans are prepared for long-term operation and maintenance (O&M) of the construction project. If PRPs perform the clean-up, they will also assume responsibility for long term O&M. The states are required to assure O&M for projects financed by the Superfund. O&M may include activities ranging from continued environmental sampling, repairing erosion and performing other maintenance, to mowing the grass.

Site Delisting

Sites which have been thoroughly remediated and pose no public-health threat may be removed from NPL. Given the long-term nature of most complex Superfund clean-ups, very few sites will be delisted in the near future.

Public Participation

A Community Relations Plan is an integral element of the process at every NPL site. This plan outlines the mechanisms that will be used to help the public gain knowledge about the site and Superfund actions, and incorporate local concerns in the selection of a remedy. Typical activities include public meetings, newsletters, press releases, and individual communications between government officials and citizens. The Oklahoma State Department of Health welcomes and encourages public inquiry, review, and comment during any phase of a Superfund project.

Community groups with a special interest in a particular Superfund site may apply for and receive Technical Assistance Grants from EPA. These grants allow local citizens access to their own technical advisors, who can monitor Superfund actions on their behalf. This will help citizens better understand the technical issues and facilitate their meaningful input in the process of selecting and implementing a remedy.

The Role of the State

Contrary to most other national environmental programs, the Superfund law does not provide for delegation of the program responsibilities to the states. State agencies, then, serve as the local liaisons to EPA, providing advice and carrying out specific technical tasks.

The state officials are usually more familiar than their EPA counterparts with the technical details of each Superfund site, as well as the concerns and desires of local residents. For that reason, it is common for the states to assume the responsibility of managing the technical work at a site. However, all decision-making is reserved for EPA.

Oklahoma has no independent statutory authority or effort that parallels the federal Superfund program. All Health Department staff devoted to these projects are funded exclusively to perform the technical tasks involved in Superfund studies. This is a significant deficiency in two respects. First, it has been established that State sponsored and PRP conducted clean-up projects are much cheaper than federal Superfund actions. This is primarily due to the high transaction costs associated with the elaborate procedures required by the federal program. Second, any site that is examined for Superfund by EPA and is found to contain problems that are not of sufficient magnitude to invoke the national program are referred by EPA to the states for appropriate action. Oklahoma has no mechanism to remediate these sites or to fund enforcement or oversight activities with PRPs.

OKLAHOMA SUPERFUND SITES

Compass Industries Landfill

This 46-acre site is located in Tulsa, near the Arkansas River. Originally a limestone quarry, it was later used for a landfill from 1964 until 1976. During the 1970s and early 1980s, several underground fires occurred at the site. The site was listed on the NPL in 1983, and the OSDH conducted the RI/FS.

The remedy selected was to properly close the old landfill by placing a cap on the site. This will prevent rainwater infiltration, protect against igniting underground fires, and prevent contaminated-surface-water runoff. The remedial design of the cap has been completed by OSDH, and the PRPs are currently pursuing construction. The cap will consist of three layers: a gas transmission layer, a clay and polyethylene membrane barrier, and a drainage layer to collect any infiltrating water. Soil and vegetative cover will be placed over the cap. The cap should eliminate the generation of leachate. However, if any leachate is discovered after the construction of the cap, it will be monitored and treated if necessary. The cap is now under construction, with an estimated completion date of June 1991. The total estimated cost for the construction is $12 million.

Double Eagle Refinery

This site is located in Oklahoma City, near the intersection of Northeast 4th Street and Martin Luther King Boulevard. It was proposed for the NPL in 1988. From

1929 through 1980, a used-oil refinery operated on the site. The primary wastes at the site include asphaltic acid sludges, lead, and other heavy metals. There are several acid-sludge impoundments on the site, and it is located in the alluvium of the North Canadian River. A RI/FS is scheduled to begin in 1990. OSDH will be the lead agency.

Fourth Street Abandoned Refinery

This 38-acre site was proposed for the NPL in 1988, and is located to the east and almost adjacent to the Double Eagle Refinery. Active refinery operations were conducted on site from about 1940 to 1968. There are several asphaltic acid-sludge pits on the site. Sample analysis has indicated that heavy metals and pesticides may be concerns at this site. A RI/FS for this site will be conducted in 1990. OSDH will be the lead agency.

Hardage Criner

This site is located near Criner, in McClain County. This site operated as a commercial disposal facility for industrial wastes from 1972 to 1980. It covers about 60 acres and consists of several surface impoundments and a drum-burial area. It was proposed for the NPL in 1981. Compounds detected on the site include pesticides, solvents, alcohols, acids, caustics, and heavy metals. EPA has been in litigation with the PRPs since 1986. A RI/FS was conducted by a group of PRPs. Due to technical disagreements between EPA, OSDH, and the PRPs, the Federal District Court in Oklahoma City will select the remedy.

Kerr-McGee Corporation

This site is located just north of Cushing, and it covers approximately 116 acres. Petroleum-refinery operations were conducted on site from 1915 through 1972. From 1962 to 1966, a small portion of the site was licensed for the processing of uranium and thorium. There are a total of five large waste pits on the site, four of which contain asphaltic acid sludges and one which contains both acid sludges and low-level radioactive materials. Kerr-McGee originally sold the site in 1972, but has since reacquired the majority of the property. Under the direction of OSDH, Kerr-McGee has been conducting an investigation of the site and evaluating possible remedial technologies. The site was proposed for the NPL in 1989. EPA is still in the stage of responding to public comments regarding the listing of the site on the NPL. Kerr-McGee has made a commitment to remediate the site whether or not it is actually added to the NPL.

Mosley Road Sanitary Landfill

This site is located in Oklahoma City, and it covers approximately 70 acres. This municipal solid-waste landfill also accepted approximately 2 million gallons of hazardous substances in 1976. Compounds including pesticides, solvents, sludges, and other chemical waste were placed into two unlined pits and subsequently covered with up to 20 ft of municipal solid wastes. The site was proposed for the NPL in 1988. It appears that Waste Management, Inc., the owner of the site, will conduct a RI/FS under federal and state oversight.

Oklahoma Refining Company

This site was proposed for the NPL in 1988, and is a former refinery located in Cyril. It operated from 1920 to 1984, and is approximately 160 acres in size. Process wastes were placed in over 100 impoundments and a landfarm. An on-site monitoring well has been found to contain arsenic, lead, chromium, cobalt, beryllium, nickel, and xylene. Contaminated ground water is believed to be discharging to Gladys Creek, which borders the site. OSDH is currently conducting a RI/FS on this site.

Sand Springs Petrochemical Complex

This site was proposed for the NPL in 1983, and is located in Sand Springs. Several petroleum refineries operated on the site from the early 1900s through 1948, and it was occupied by other industries after the refineries closed. OSDH conducted a RI/FS on the site. It covers approximately 200 acres, and contains asphaltic acid sludges, heavy metals, and chlorinated solvents. The acid sludges are to be solidified/stabilized by the PRPs. The PRPs are performing the Remedial Design/Remedial Construction steps.

Sunray Oil Company Refinery

This 40-acre site is located in Allen. There are four pits containing sludges from refinery operations. Compounds of concern detected in on-site sludges, soils, and ground water are principally heavy metals. The site was proposed to the NPL in 1988. It is still unclear at this point when the EPA will initiate a RI/FS for this site.

Tar Creek

This site is located in Ottawa County, and covers a 40-mi^2 area. It was proposed to the NPL in 1981. This area was extensively mined for lead and zinc. These old mines now serve as conduits for surface-water infiltration to ground water. As these waters flow through the old mines they become acidic and leach heavy metals from surrounding materials. The RI/FS was conducted by the Oklahoma Water Resources Board in 1983 and 1984. A remedy was selected and implemented which consisted of diverting and diking a creek to prevent underground discharge, and plugging abandoned wells to prevent contamination of a deep, high-quality aquifer that is the source of local drinking water. The construction was completed in 1986 and monitoring of the effectiveness of the remedy is currently being conducted.

Tenth Street Dump

This site is only about 4 acres in size and is located on Northeast 10th Street in Oklahoma City. It was proposed to the NPL in 1987. A salvage operation and an automotive junk yard were located on this site, and resulted in contamination of soils with polychlorinated biphenyls (PCBs) and lead. In 1985, removal action was conducted by the EPA, which included removing drummed wastes, placing a clay cap over the site, and fencing the site. EPA is currently conducting a RI/FS. Preliminary indications are that the PCBs are not mobile and do not threaten ground water, surface water, or air. The cap appears to preclude any public-health threat.

Tinker Air Force Base

This aircraft maintenance and rebuilding facility was proposed for the NPL in March 1985. Organic solvents from these activities have contaminated ground water at portions of the base. There are also 6 old landfills, 2 inactive waste pits, and 3 historical radioactive disposal sites.

Under the Installation Restoration Program, the Air Force has assessed the problem and is taking appropriate remedial actions. The RI/FS for Building 3001 is complete. A proposed plan is scheduled to be ready for public comment in early 1990. Interim remedies that have already been implemented include capping one landfill to abate migration of contaminants, and plugging several wells that served as possible conduits for ground-water contamination.

SUPERFUND GOALS AND OBJECTIVES: A STATE PERSPECTIVE ON POLICY

The national demand for a rapid resolution to our hazardous-waste-management problems has resulted in intense public scrutiny and debate over the implementation of the Superfund program. A number of observers have been frustrated over the apparent slow pace of the national clean-up effort, or the propriety of the remedy which was selected at particular Superfund sites. This analysis does not seek to resolve the debate, but simply to present attitudes and opinions common to State officials who struggle to make the Superfund program a success.

EPA Organization

EPA is a large organization consisting of the national headquarters and 10 regional offices. The Agency's work is broadly extended through its widespread use of State agencies and private contractors to directly implement program objectives.

EPA functions almost entirely through a process of the regional offices implementing a series of program guidance directives and formal rules prepared by and promulgated through the headquarters office. The national Superfund program addresses an amazing variety of technical, political, financial, and social issues. It is impossible for the EPA headquarters to rapidly prepare and issue the national directives and rules, and at the same time adequately address the tremendous variety of real-world problems encountered in the program.

Federal statutes authorize national environmental programs for discrete periods of time. CERCLA extended from 1980 to 1985. In late 1985, it became apparent that Congress could not produce legislation authorizing Superfund before the program's expiration date. This situation forced EPA to virtually cease operations in the program. This was a major blow to the bureaucratic functions of the agency and the Superfund program. EPA had developed its management system by late 1983, and the program was beginning to function smoothly in 1984. The lack of timely reauthorization forced EPA to halt contracting and other critical program procedures. The requirements of other federal laws make implementation of these procedures very lengthy and time-consuming. When SARA was passed in 1986, EPA attempted to expedite reactivation of the program, yet the required procedures still took several months to implement. Most EPA officials had to devote their attention and energy to the program management demands rather than the more tangible actions of environmental remediation.

The experience of closing down the program in 1984 also illustrates the role of EPA's Superfund budget in driving agency actions. In spite of the Superfund taxing authority, the magnitude of the national clean-up task has become greater than the resources available. EPA must, therefore, carefully plan and prioritize site actions based on the available Superfund budget. This has resulted in necessary program delays at sites where PRPs are not available to perform the work requiring all the financing to come from the government's office.

When measured against the ideal of rapid and comprehensive site remediation, these forces have helped contribute to the public perception of programmatic lethargy. While it is easy to castigate the bureaucratic process of the Superfund program, this is but one element contributing to the ultimate frustration.

Clean-up Technology

Uncontrolled Superfund sites contain complex and often unknown mixtures of a staggering variety of chemicals. In many cases, the ultimate environmental fate and human-health impact is largely unknown for each individual chemical—much less the synergistic chemical soup that was created by past follies. The process of accurately measuring and assessing the nature and extent of a Superfund problem is technically challenging and time-consuming. In an attempt to appease critics, EPA has made short schedules the predominate driving force in the entire Superfund program. In Oklahoma this emphasis has resulted in artificially segmenting the environmental problems at Superfund sites into "operable units" and in conducting abbreviated environmental-sampling projects that fail to adequately characterize the full range of environmental problems at a site, or to provide the type of data needed to adequately evaluate and design appropriate engineering solutions.

Many Superfund sites contain problems that require the innovative application of new technologies that lack extensive operating histories. This lack of technical foundation and experience has contributed to everyone's inability to rapidly remediate specific Superfund site problems.

As the general technological knowledge base of Superfund remediation grows, so does the demand for trained, experienced employees for all parties in the hazardous-waste-management process. This has created a strong demand for and a high rate of turnover among experienced State and EPA employees, sometimes resulting in delay and program inconsistency.

In addition, Congress has refused to allow a large growth in the number of EPA Superfund employees, forcing the agency to rely heavily on contractors to perform site-specific program functions. This means that the EPA employees have primarily administrative functions, and are essentially removed from the mainstream of technical thought and experience. This dependence upon contractors, along with the high employee turnover, has also impeded the development of a coherent institutional memory that is necessary for the effective operation of such a large public-works program. While certainly not the sole cause of debate, the EPA's lack of an institutional base of technical knowledge and direct employee experience has contributed to the intense dissension among the EPA, states, PRPs, and citizens over specific Superfund-site action decisions.

National Policy Debate

EPA has responded to the widespread criticism of its Superfund performance by making adherence to short project schedules the principal driving force of the program. The Agency is imposing project time schedules which are challenging to achieve, and which do not allow for adequate characterization and assessment of site problems in the remedial investigation phase. This has led EPA to make such errors as assuming that large-volume waste sources are homogeneous, when in reality their constituents have been quite diverse.

EPA has been especially sensitive to criticism about the potential impermanence of certain remedies the agency has used at Superfund sites. Critics are encouraging the agency to prioritize clean-up remedies that destroy or eliminate the hazardous-waste problem. In response, EPA has frequently analyzed remedial options in a generic manner, without detailed regard for the exact nature of the waste. This has encouraged many EPA officials to doggedly pursue remedies such as incineration at sites where the chemical mix of contaminants cannot be safely or efficiently burned, even under controlled conditions. EPA's pursuit of questionable incineration remedies at certain Oklahoma Superfund sites has delayed the actual clean-up process as EPA, the state, the PRPs, and citizens have struggled through the laborious administrative and legal process of selecting a clean-up remedy.

CONCLUSION

Superfund site remedies are complicated geotechnical undertakings that are incredibly expensive programs. Most observers would agree that Superfund resources in both the public and private sectors should be devoted to achieving remedies at the individual Superfund sites. However, EPA has created a system of program administration for Superfund that is segmented and fraught with high transaction costs for both the federal government and PRPs. The tremendous costs associated with the administrative process utilized by EPA is one of the strongest incentives for PRPs to independently correct known problems from historical mismanagement of hazardous waste.

The high degree of public attention afforded the Superfund program has helped create an atmosphere of uncertainty among the many regional EPA officials charged with accomplishing Superfund goals. Federal program management and personnel-evaluation procedures have tended to emphasize each isolated segment of the Superfund program. The federal employees in this system, therefore, have frequently lost sight of the long-term environmental clean-up goals due to the tremendous political and financial-liability impact of each significant decision in the program. This has resulted in a lengthy decision-making process which has selected remedies which have been highly controversial.

The states are in a unique position in the national process to restore the environment. State officials have the local knowledge and technical expertise to more efficiently direct the application of federal resources and to facilitate the extensive PRP action that will be necessary to achieve our national Superfund clean-up goals. Many PRPs are already coming directly to the states with clean-up proposals. The professional evaluation and oversight of these remedies requires a state-program talent base ranging from environmental scientists to attorneys. In Oklahoma, the OSDH Superfund employees are devoted to specific functions on federally funded Superfund projects. Without a separate source of State funding, the OSDH cannot fully pursue clean-up projects that are either premature for or not of sufficient magnitude to merit federal Superfund attention.

An additional obstacle in Oklahoma is the lack of State legal authority that parallels federal Superfund authority. This means that the State has little ability to encourage PRP clean-ups in advance or in lieu of EPA involvement, because there is no reasonable assurance that the clean-up action will limit or satisfy the PRPs federal clean-up liability.

It is widely acknowledged that private PRP clean-up actions are cheaper than direct government projects. The Oklahoma experience has been that the State can execute national environmental objectives more cost effectively than can EPA or its contractors. These forces will affect the debate over Oklahoma environmental clean-up policy, for it is much more cost-effective for the State to directly address its historical hazardous-waste problems now than to wait for EPA to discover them and make them a national priority for action.

REFERENCES CITED

U.S. Congress, Office of Technology Assessment, 1988, Are we cleaning up?/or Superfund case studies—special report: OTA-ITE-362, U.S. Government Printing Office, Washington, D.C.

______ 1989, Coming clean: Superfund problems can be solved: OTA-ITE-433, U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency, 1989, A management review of the Superfund program: 623-682/10263, U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, 1989, An analysis of state Superfund programs: 50 state study: EPA/540/8-89/011, Washington, D.C.

Program for Removal of Chemicals from Schools of Oklahoma

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INTRODUCTION

Schools have had a history of accumulating chemicals. The primary cause of this problem has been the change of science teachers in the schools. A science teacher would have experiments which required certain chemicals. When that science teacher moved, and a new science teacher was employed, the new teacher would often request different chemicals. After a few years, the inventory of unused, unwanted, or unknown chemicals became a serious problem. The quantity of chemicals present in schools is the result of bulk buying to take advantage of better pricing. In some instances, schools received donations of chemicals they could not use and should not have used.

Legislation in the past few years concerning hazardous chemicals in the workplace and the disposal of hazardous chemicals has created a problem not only for industry but also for schools. The problem is especially difficult for public schools because they lack knowledge of the laws, expertise of how to safely store and handle chemicals, and financial resources to properly dispose of unwanted chemicals. Insurance companies, scientific supply companies, and certain govenment agencies have added to the problem, telling schools they should remove certain chemicals or they would lose their insurance coverage, or they would be fined, or they would be sued. Schools reacted to this situation in many ways. Some merely discarded their chemicals, others hired disposal companies to remove the chemicals at a high price, and in some instances schools were able to give their chemicals to colleges.

It was obvious there was need for a coordinated, statewide effort to assist schools in the problem of removing unwanted chemicals. The primary driving force behind this effort was to have the chemicals removed in an environmentally safe and legal manner that was as cost-effective as possible. In a discussion of cost, it must be kept in mind that the best disposal price for removing chemicals is not the only factor to be considered. The "cradle-to-grave" requirement of chemicals dictates that schools use a disposal company that would minimize their future liability.

ESTABLISHING A COMMITTEE TO ADDRESS THE PROBLEM

As a result of inquiries from high-school teachers concerning the removal of chemicals, it was obvious that an organized effort was needed to address the problem. Initial contact was made with the Science Specialist in the State Department of Education to develop a plan to remove chemicals from the schools. It was decided that every state agency which had responsibility concerning hazardous chemicals should be involved in the establishment of the removal plan. Letters were written to contact those state agencies and to schedule a first meeting. The agencies represented were State Department of Education, State Department of Health, State Labor Department, Civil Defense Department, State Fire Marshal, State Department of Public Safety, Regents for Higher Education, and Risk Management Department. In addition, there was a representative from the State Science Teachers Association. The first meeting established that there was a problem concerning chemicals in schools, but the magnitude of the problem was not known. The committee decided that the first order of business was to obtain a list of the schools who wanted assistance in removing chemicals, and to obtain an inventory of the chemicals to be removed. The committee also decided upon a master plan, which consisted of the following four phases: Phase 1: Contacting the schools. Phase 2: Schools submit an inventory of chemicals to be removed. Phase 3: Evaluation of the chemicals for hazards. Phase 4: Removal of chemicals.

Certain state agencies were to be responsible for different phases of the program. The State Department of Education was responsible for contacting the schools. Southwestern Oklahoma State University was responsible for developing a data base of the schools responding and the chemicals submitted. The State Department of Health was responsible for evaluating the hazards of the chemicals. The State Department of Health was also responsible for determining removal procedures. A summary of the results of the various phases follows.

PHASE 1: CONTACTING THE SCHOOLS

Phase 1 consisted of two mailings to the schools. The first mailing was from Southwestern Oklahoma State on September 16, 1989, to every superintendent and to every president of a higher-education institution. This letter contained information that such a removal project was being developed and asked them to return a form if they were interested. There were 642 letters sent to superintendents and 77 letters sent to administrators of higher education. There were 113

(18%) responses from the public school administrators and 30 (33%) responses from higher education administrators.

The second mailing was sent from the State Department of Education on October 10, 1989, to the 642 school districts. Information in this mailing reinforced the fact that a removal project was being developed, and if the schools wanted to participate they should send an inventory of the chemicals to be removed.

The people receiving the second mailing and the number of letters sent are given in Table 1.

The respondents to the mailing from the State Department of Education sent their inventories to Southwestern Oklahoma State University. This information was used to prepare a data base of the participating schools. The data are summarized in Table 2.

From the data in Table 2, 127 (40%) of the schools said they had no chemicals to be removed. Of the schools in this category, there were 83 elementary schools, 9 middle or junior high schools, 14 high schools, and 21 other schools. There apparently was some confusion about the intent as there were 36 inventories of cleaning chemicals and 14 complete inventories. There were 143 (45%) schools which responded by sending an inventory of chemicals to be removed.

PHASE 2: SCHOOLS SUBMIT AN INVENTORY OF CHEMICALS TO BE REMOVED

The inventories received in Phase 1 were used to prepare a data base of the chemicals. This data base consisted of 8,000 entries which represented 850 different chemicals. Compounds ranging from relatively safe chemicals such as sodium chloride, calcium carbonate, and potassium chloride to potentially hazardous chemicals such as sodium cyanide, potassium metal, diethyl ether, carbon disulfide, and sodium peroxide were listed for removal.

Approximately 67 of the chemicals were solids and 33% were liquids.

PHASE 3: EVALUATION OF THE CHEMICALS FOR HAZARDS

A survey of the chemicals submitted indicated a group of chemicals which were considered to be shock-sensitive or of an explosive nature. This list included lithium, sodium, potassium, diethyl ether, carbon disulfide, and 2,4-dinitrophenol. It was decided that these chemicals should be the first removed from the schools.

The list also contained chemicals considered hazardous according to 40 CFR Part 261 Subpart C and D. These chemicals have to be disposed of by a licensed disposal company.

There were a large number of chemicals which did not appear on a regulated list and were not considered to be hazardous. The proper disposal of these chemicals was difficult to evaluate. Many of them could safely be placed in a land-fill or could be flushed with dilution. Others could be neutralized and then flushed. There is no good mechanism for addressing the proper disposal of these "gray area" chemicals. Initially, the idea was presented to provide schools with a list of the chemicals which could be disposed of locally. This list would also contain a safe procedure for handling the chemicals during their disposal. This idea is currently being reviewed because of the liability factor in the event the person involved in the disposal could be hurt.

TABLE 1.—MAILING FROM THE STATE DEPARTMENT OF EDUCATION

Middle, junior high, and high schools	2,434
Superintendents of independent districts	456
County superintendents	70
Private administrators	192
University presidents	44
University chemistry chairmen	44
Elementary principals	916
Dependent Principals	153
Vo-tech superintendents	60
Vo-tech science teachers	60
Private science teachers	192
Total	4,621

TABLE 2.—RESULTS OF STATE DEPARTMENT OF EDUCATION MAILING

Action taken by schools	Number of schools
Sent an inventory of chemicals to be disposed	143
Indicated no chemicals to be disposed	127*
Sent an inventory of cleaning chemicals	36
Sent an inventory of all chemicals	14
Total	320

*Of this number, 83 were elementary schools, 9 were middle or junior high, 14 were high schools, and 21 were others (this list included centers and names which were not obvious as to their type).

PHASE 4: REMOVAL OF CHEMICALS

This part of the project is still in development. Only one aspect of this phase has been accomplished as of this writing, that being the removal of those chemicals considered to be shock-sensitive.

Removal of the shock-sensitive chemicals was a coordinated effort involving the State Department of Education, the State Department of Health, The State Department of Public Safety, and the Oklahoma Military Department, it was labelled Operation Safe School.

The State Department of Education was responsible for corresponding with the schools that had shock-sensitive chemicals and for maintaining lines of communication between the local schools and the bomb squads who were to remove the chemicals. Before the chemicals could be removed, the local school had to select a site on which the chemicals could be detonated, provide a legal description of the site, and name a local person to coordinate the removal of the chemicals from the school. The school also had to sign a release of liability.

The State Department of Health was responsible for evaluating each site submitted by the respective schools. If the necessary requirements, were met a permit was issued for that site to be used for detonation. In addition, a representative from the State Department of Health accompanied each bomb squad as the chemicals were removed.

The Department of Public Safety and the Oklahoma Military Department were responsible for providing bomb squads who removed the chemicals. Removal of the chemicals and their detonation was conducted in an efficient and professional manner, with no incidents in a period of one week. The bomb squads logged a total of 7,000 mi during this operation.

The chemicals removed and their quantities are shown in Table 3.

TABLE 3.—CHEMICALS REMOVED BY OPERATION SAFE SCHOOL

Chemical	Amount
Lithium	1.5 lb
Sodium	42.5 lb
Potassium	6.0 lb
Carbon disulfide	45.0 qt
Diethyl ether	12.0 qt
2,4-dinitrophenol	1.5 lb
Picric acid	1 unit
Perchloric acid	1 unit

As of this writing, a contract between the State of Oklahoma and a hazardous-waste-disposal company is being pursued. It is anticipated that such a contract would be utilized by the schools to remove their unwanted chemicals at a savings to the school. An additional advantage to the school is the lowering of the liability factor. If the local school contracts with a disposal company, they may not take the time to completely check the disposal company to see if they have current violations. The local school would also tend to go with the lowest bid. This could haunt them later if the disposal company were to become involved in clean-up litigation. A contract between the State and a disposal company would tend to minimize these concerns.

One aspect of this project which should be mentioned is the possibility of recycling the chemicals that a school wants to remove. Many of the chemicals have market value because they are still in their original containers. This possibility is being pursued, but nothing definite has been developed.

SUMMARY

A plan has been developed to assist schools in the removal of their chemicals. The plan was the combined effort of many State agencies. The ultimate goal of removing the chemicals has not been accomplished as of this writing. Even though every school was contacted at least twice, there still seems to be a lack of knowledge, concern, or interest in this effort. As a preventive measure to keep this kind of problem from recurring, a proposal is being considered to establish regional resource centers which would provide chemicals to the schools in that region. These resource centers could also provide other services, such as lab safety, and act as disseminating sites for public concerns about hazardous chemicals in particular and the environment in general.

Closure of Hazardous-Waste Facilities in Oklahoma

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ABSTRACT.—State and federal regulations require that specific standards and procedures be implemented during the closure and post-closure monitoring of units which manage hazardous waste. They ensure that all closures are accomplished according to specific, minimum standards. The applicable regulations for the closure and post-closure monitoring of hazardous-waste units will be reviewed. An overview of the closure of disposal units at two facilities in Oklahoma will be presented. The closure of these units was accomplished in accordance with the regulations.

INTRODUCTION

The Environmental Protection Agency (EPA) has promulgated regulations which dictate specific closure and post-closure procedures and standards for units which manage hazardous wastes. The State of Oklahoma has adopted these regulations by reference. The closure plan for the units must be maintained on-site and detail the closure sequence and schedule. Minimum performance standards must be fulfilled. Financial assurance must be maintained by the owner or operator of a facility to ensure that adequate funds are available to close the unit and provide for post-closure monitoring. The post-closure plan must detail those activities which will occur during the post-closure period. The plans must be approved by the Oklahoma State Department of Health (OSDH), and any closure and post-closure activities must comply with the approved plans.

The closure of surface impoundments and landfill cells at two facilities will be examined. U.S. Pollution Control, Inc. (USPCI) operates the Lone Mountain Facility near Waynoka, Oklahoma. The Lone Mountain Facility is a commercial treatment, storage, and disposal (TSD) facility which accepts a wide range of solid and aqueous wastes from off-site generators. Aqueous wastes had been stored in impoundments at the facility. Three impoundments were closed between 1987 and 1989. The sludge was stabilized in the impoundments. Caps were than constructed above the mounded waste. The facility continues to manage hazardous waste in other units.

The Allied Refinery operated from the late 1930s through 1984. It is located in Stroud, Oklahoma. Five hazardous-waste impoundments and two landfills were in service from 1961 through December 1984. While the refinery was in operation, hazardous wastes designated as D002, K048, K049, and K051 were generated and stored in five surface impoundments. Solid waste from asphalt manufacturing was stored in two adjacent landfill cells. The contents of the impoundments were transferred to a treatment area and stabilized. Two landfill cells were constructed for the disposal of the materials from the existing impoundments and cells. The new cells were constructed at the location of the previous impoundments and cells. The materials from the old impoundments and cells were then transferred to the new landfill cells. Caps were constructed above the compacted waste in the cells. These units were closed between 1985 and 1989. The closures at both facilities were performed in accordance with the applicable regulations, and post-closure monitoring has been implemented.

REGULATORY REQUIREMENTS

The federal regulations dictate the closure and post-closure standards for the closure of both interim status (40 CFR 265, Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities) and fully permitted (40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities) facilities which treat, store, or dispose (TSD) of hazardous waste. A facility operates under the interim 265 standards until a Part B permit is issued for the facility. Subsequent to the issuance of a Part B permit for a facility, the facility operates in accordance with the 264 standards. The state of Oklahoma has adopted these regulations by reference in Rule 210 of the Oklahoma Rules and Regulations for Industrial Waste Management.

The closure regulations require that a written closure plan be maintained at the facility. The plan must include specific items. It must provide a description both of the steps for closing the individual units and of the entire facility. It must provide an estimate of the maximum inventory wastes ever on-site. The procedures for removing or decontaminating all equipment contaminated during closure must be detailed. Other continuing activities, such as ground-water monitoring and leachate collection, must be outlined. An anticipated schedule must provide the time requirements for each step of the closure sequence. The estimated closure dates for both the individual units and the entire facility must be provided. Detailed cost estimates must be developed for the various units. The cost estimates must be substantiated by actual costs and estimates.

The closure of a landfill cell or surface impoundment must ensure that various performance standards are fulfilled. The closure design must provide for long-term minimization of migration of liquids through the closed landfill or impoundment. The completed closure must function with minimum maintenance. The design must promote drainage of runoff and minimize erosion. The design must accommodate anticipated settling of the cap. The cap system must provide a permeability less than or equal to the permeability of the bottom-liner system. In practice, this requires that a synthetic liner in the cap be of the same or greater thickness than the liner in the bottom-liner system. The clay liner in a cap must have a permeability equal to or less than the permeability of the clay in the bottom-liner system.

Financial assurance must be provided for both the closure and post-closure periods. The financial assurance ensures that adequate funds are available for the closure and post-closure care and monitoring of a facility. Examples of acceptable closure mechanisms include a trust fund, a surety bond, a letter of credit, a financial test, and a corporate guarantee. The Lone Mountain Facility utilizes a trust fund with a bank as trustee. Annual contributions are made to the trust fund by the owner or operator of the facility. The trust fund would be utilized to pay for closure of a facility and for monitoring it during the post-closure period if the owner or operator were financially incapable of performing these tasks. The Allied facility utilized a corporate guarantee of a parent corporation. A corporate guarantee requires submission of various information, including the net worth, liabilities, and assets of the parent company. Sufficient financial strength, as evidenced by a financial analysis of the parent corporation, ensures that the parent company of the owner or operator will be financially capable of expending the necessary funds to close and monitor the closed facility.

The owner or operator of a facility must notify the Regional Administrator at EPA 60 days prior to commencement of closure for disposal units, or 45 days prior to commencement of closure for treatment or storage units. Since Oklahoma has primacy over the closure regulations, an owner or operator would notify the Oklahoma State Department of Health (OSDH) instead of the Regional Administrator.

The closure must be completed within 180 days of receiving the final volume of waste, unless the OSDH approves an extension. Such a time limit is very difficult to meet during closure of surface impoundments or landfill cells, since these closures require implementation of numerous, sequential events. The anticipated schedule is often exceeded due to the difficulty of predicting events such as the necessary settlement period for consolidation of the waste materials. Both the Allied and USPCI facilities received extensions to the 180 day requirement.

The closure must be certified by both the owner or operator and an independent registered professional engineer. This certification must indicate that the completed closure complies with specifications in the approved closure plan. It must be submitted to the OSDH within 60 days after completion of the closure of an individual unit. A notation must be recorded on the deed of the property which indicates that land has been used to manage hazardous wastes and its use is restricted by the hazardous-waste regulations. A survey plat which indicates the location of the disposal units and a record of the type, location, and quantity of hazardous wastes must also be submitted to the local zoning authority.

Post-closure monitoring is required for disposal units such as landfills and impoundments; it is not required when all contaminated materials are removed from a unit such as a tank or waste pile. The removal of all contaminated materials is referred to as a "clean closure." Monitoring of a closed disposal unit must continue for 30 years after closure of the unit. The regulations allow extension or shortening of this time if the OSDH determines that this change in the monitoring is acceptable or necessary to protect human health and the environment. It is extremely unlikely that OSDH would shorten the post-closure period for a disposal unit. The post-closure regulations require that a written post-closure plan be maintained at the facility. The plan must include specific items. It must provide a description and frequency of the planned monitoring activities. It describes the necessary maintenance activities to ensure the integrity of the cap and the monitoring equipment. As discussed previously, post-closure financial assurance must be provided. A certification must be submitted both by the owner or operator and by an independent registered professional engineer upon completion of the post-closure monitoring period. This certification must indicate that the completed post-closure monitoring and care comply with specifications in the approved post-closure plan. Post-closure monitoring has been implemented for both facilities.

OVERVIEW OF SPECIFIC CLOSURES

The closures of units at two disposal facilities in Oklahoma serve as examples of implementation of the closure and post-closure regulations. Surface impoundments have been closed at the USPCI Lone Mountain Facility. Surface impoundments and landfill cells have been closed at the Allied Materials Refinery.

The closures were performed under the interim standards of 40 CFR 265, as neither facility had received a Part B permit at the time of the closures. As of January 1990, there have been no closures of disposal facilities in Oklahoma conducted under 40 CFR 264.

Lone Mountain Facility

Three impoundments at the Lone Mountain Facility were closed between November 1987 and March 1989 (U.S. Pollution Control, 1989). These units were closed in compliance with a closure plan which had been approved by the OSDH. The closure consisted of the following steps:

1) Removal of liquids and stabilization, compacting, and mounding of waste in the impoundment;

2) Construction of caps above the mound; and

3) Notation on deed and submission of certification to OSDH.

The initial step required that the liquid contents of the impoundments be removed and treated in the facility wastewater-treatment system, and that the remaining sludges be stabilized in the impoundments. The sludges were mixed with fly ash by a backhoe until sufficient mixing occurred to provide a stabilized mass. The stabilized waste remained in the impoundment for closure. The waste was then compacted and graded to form a mound on a 1.5% to 5% grade to promote drainage off the final cap.

The cap was constructed on top of the mounded waste. Figure 1 details the cap design at the Lone Mountain Facility. In ascending order, the cap consisted of a two-foot clay liner, a high-density-polyethylene (HDPE) liner, a drainage system, a protective soil cover, and 14 in. of graded rock. The clay liner was constructed with a maximum permeability of 1 EE-07 cm/second. The clay was compacted to 95% of the Standard Proctor Density at a moisture content between the optimum moisture content and the optimum moisture content plus 4%. The clay cap was constructed in two steps. Initially, an interim 1-ft clay cap was constructed. After construction of the interim clay cap, the waste material consolidated during the necessary settlement period. After allowing for any settlement, the interim clay cap was scarified and recompacted. Additional clay was emplaced and compacted until the final clay cap was 2 ft thick. The HDPE liner was 60 mils thick.

The drainage layer would remove any liquids which percolated through the soil cover. It consisted of drainage net and non-woven geotextile. The geotextile prevents the soil from clogging the drainage net. The soil cover was 1 ft thick in the drainage ditches on the perimeter of the cap, and 2 ft thick over the remainder of the cap. The soil cover provides physical protection to the HDPE liner and limits frost penetration into the clay liner. The top layer of rock provides erosion control. Typically vegetation would be utilized instead of

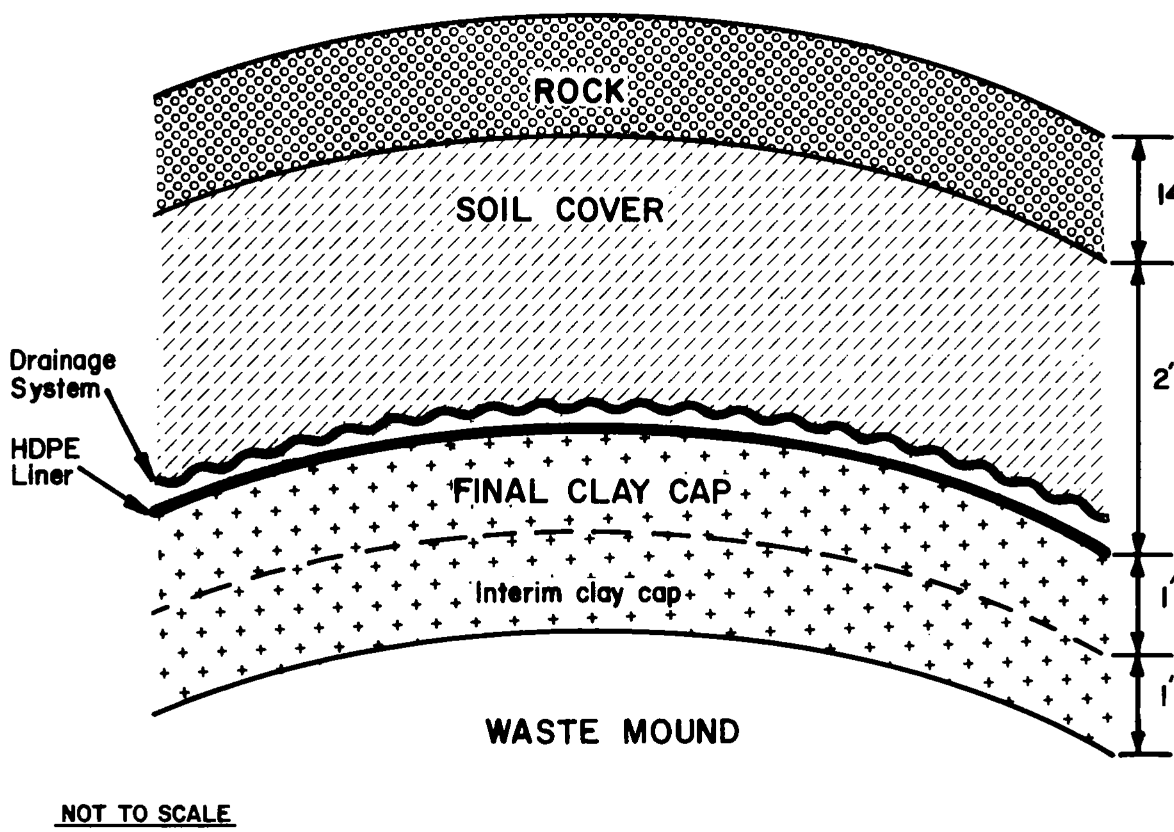

Figure 1. Cap detail for the Lone Mountain Facility.

rock cover; however, adequate vegetation would not be self-supporting in the region. Consequently, a rock cover was utilized. Extensive quality-control procedures were implemented during the construction of these components to ensure that the various components satisfied design specifications.

Upon completion of the closure, the closure was certified by both USPCI and an independent registered professional engineer. The survey plat was filed at the Major County courthouse. The plat indicated the location of each closed impoundment, the restricted future use of each area, and the type and quantity of waste in each closed impoundment. The certification and survey plat were provided to OSDH as part of the closure report which detailed the closure procedures and presented the quality-control data.

Allied Refinery

Five surface impoundments and two landfill cells were closed at the Allied Refinery between 1985 and 1989 (Allied Materials, Inc., 1989). These units were closed in compliance with a closure plan which had been approved by the OSDH. The closure consisted of the following steps:

1) Removal and treatment of the waste material in the impoundments;
2) Construction of new landfill cells;
3) Depositing stabilized waste from the impoundments in the new cells;
4) Transfering waste from the old landfill cells to the new cells;
5) Constructing caps over the mounded waste in the new landfill cells; and
6) Notation on deed, notification to zoning authority, and submission of certification to OSDH.

Whereas the waste was stabilized and disposed of in existing impoundments at the USPCI facility, the material was stabilized in a temporary treatment area and transferred to new cells at the Allied Refinery. The waste was removed from the impoundments and placed in an adjacent treatment area. Cement kiln dust and local soil were mixed thoroughly with the waste, utilizing a Bomag Pulva-Mixer or an equivalent device. The stabilization process both stabilized the waste and raised the pH of the resulting material above 3.0.

The new cells were constructed at the location of the previous impoundments and cells. The contaminated material was removed until no contamination remained. The cells were then constructed with a double-synthetic-liner system above a clay base. The two synthetic liners were 60-mil HDPE liners. Leachate collection and detection systems were installed. The leachate systems consisted of drainage net and gravel-filled trenches containing perforated PVC pipe.

The stabilized waste from the impoundments was deposited and compacted in the newly constructed cells. Each lift of the material was compacted upon placement in the cell with a sheepsfoot compactor. The solid waste was transferred directly from the old landfill cells to the new cells without treatment. Treatment of the solid waste from the old cells was not necessary, since the landfill waste was not acidic, whereas the impoundment waste was acidic.

The cap system was then constructed above the mounded waste. Figure 2 details the cap system at the Allied Refinery. In ascending order, the cap consisted of an HDPE liner, 2 ft of compacted clay, and 6 in. of top soil and vegetation. The synthetic liner was 60 mils thick. The vegetation consisted of Bermuda grass. Extensive quality-control procedures were implemented during the construction of these components to en-

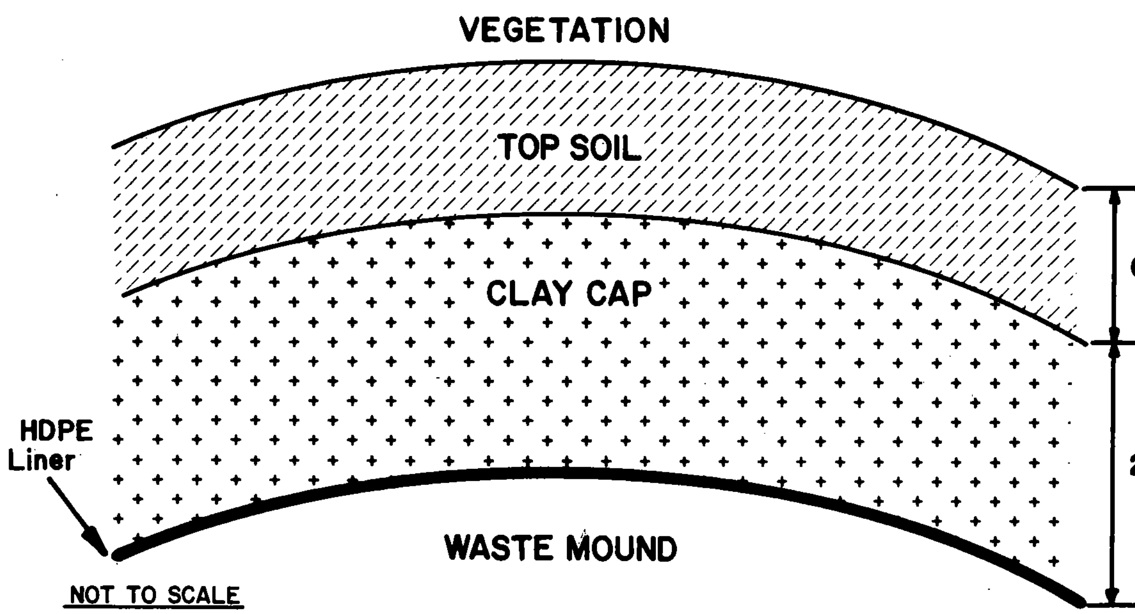

Figure 2. Cap detail for the Allied Refinery.

sure that various components satisfied the design specifications. Additional ground-water-monitoring wells were installed after completion of the cells. The closure was then certified by both Allied and an independent registered professional engineer. The closure report and survey plat were submitted to OSDH. The survey plat for the Allied facility was also filed with the Stroud Planning Commission.

CONCLUSION

Existing regulations require development of comprehensive plans for closure and post-closure monitoring of units which manage hazardous waste. The closure plan details closure procedures, schedules, and costs. The post-closure plan details monitoring and maintenance activities during the 30-year post-closure period. The plans must be approved by Oklahoma State Department of Health (OSDH).

Closure of surface impoundments and landfill cells at two facilities in Oklahoma was accomplished in compliance with closure plans previously approved by the OSDH. The contents of the impoundments were stabilized and transferred to a new landfill cell at the Allied Refinery. The contents of the impoundments were stabilized in-place at the Lone Mountain Facility. The waste was compacted and graded to form a mound in the units. Caps consisting of both clay and synthetic liners were then constructed above the mounded waste. Closure reports were subsequently filed with the OSDH, certifying that the closures had been conducted in accordance with the approved closure plans. Post-closure monitoring has been implemented at both facilities.

REFERENCES CITED

Allied Materials, Inc., 1989, Closure certification for Allied Materials, Inc. at Stroud, Oklahoma: submitted to the Oklahoma State Department of Health, July.

U.S. Pollution Control, Inc., 1989, Cell 1, Cell 2, Cell 3 closure report: submitted to the Oklahoma State Department of Health, May 17.

Alternative Strategies for Managing Hazardous Wastes

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ABSTRACT.—Waste minimization has emerged as one of the principal objectives of federal and state hazardous-waste management policy in recent years. This paper documents recent trends in waste minimization in Oklahoma and assesses the factors that have promoted and constrained waste minimization by the largest generators in the State. A survey of major hazardous-waste generators indicates that economic incentives resulting from federal policies have been the major stimulants to waste minimization in the State, but response to these factors is likely to level off over the next couple of years. Major constraints include costs of capital investments and the costs of acquiring and utilizing technical information. Further progress in waste minimization in Oklahoma will require initiatives to provide additional economic incentives, either by raising the marginal costs of hazardous-waste generation still further, or by reducing the economic constraints to further waste minimization.

INTRODUCTION

Until recently, the primary concerns in hazardous-waste management policy have been with controlling the handling and disposal of hazardous wastes and with remediating problems caused by their improper management. Federal regulations adopted pursuant to the Resource Conservation and Recovery Act (RCRA) of 1976 were principally concerned with such fundamental aspects of controlling hazardous-waste management as requiring use of permitted treatment and disposal facilities and tracking hazardous-waste shipments with a manifest system. The focus of state and federal policy began to shift to a different level of concern with enactment of the federal Hazardous and Solid Waste Amendments (HSWA) in 1984, and several earlier initiatives in such states as California and New York. These policy initiatives introduced the goal of waste minimization and were the foundation for the concepts of integrated waste management and a hierarchy of waste-management alternatives.

This paper reports the status of waste-minimization activity in the State of Oklahoma and examines the factors that have promoted and constrained waste minimization and integrated waste management by major generators of hazardous waste over the past four years. It concludes by examining options for promoting further waste minimization in the State. The data presented were analyzed under a contract with the Oklahoma State Department of Health (OSDH) as part of a project to develop the State's Capacity Assurance Plan, as required under the federal Superfund Amendment and Reauthorization Act (SARA) of 1986.

THE HIERARCHY OF INTEGRATED WASTE MANAGEMENT

The problems of hazardous-waste generation and management that are the focus of public concern are primarily what economists call "externalities." These are the costs of damage to public health and the environment that must be borne by people who do not directly benefit from production and consumption of the goods and services that result in the generation of hazardous wastes, including contamination of ground and surface water from improper land disposal of hazardous waste; air pollution from toxic volatile organic compounds emitted from land disposal facilities, waste-treatment facilities, and manufacturing; and injuries suffered by waste-collection personnel from household hazardous wastes disposed with residential trash.

These costs to society are "internalized" when they are fully reflected in the costs of the goods and services that generate hazardous wastes.

Over the last few years, a consensus has emerged among policy-makers concerning the relative risks of alternative strategies for internalizing the externalities of waste generation. A strategy of integrated waste management has been articulated that serves as the foundation for hazardous- and solid-waste policy in the federal government and many states (Municipal Solid Waste Task Force, 1988; National Research Council, 1985). In Oklahoma, this strategy has been recommended by the Oklahoma Environmental Concerns Council (1989, p. 55) in their recent report to the Governor.

The integrated waste-management strategy is based on a hierarchy of waste-management alternatives which progresses from the strategy of perceived lowest risk to that of highest risk. A common version of the waste-management hierarchy is as follows:

1) Source reduction;
2) Recycling;
3) Energy recovery;
4) Treatment;
5) Disposal.

Source reduction involves changes in the activities that produce hazardous waste, so as to "reduce, avoid, or eliminate" waste generation (United States Congress Office of Technology Assessment, 1986, p. 3). Recycling involves direct reuse of a waste product with or without reprocessing. Energy recovery involves the use of a waste as a fuel and thus capturing the energy value of the substance while also reducing its volume. Treatment includes processes that convert a waste to a less hazardous or nonhazardous product, while disposal involves placing residuals from treatment processes in the environment (National Research Council, 1985, p. 11).

The concept of integrated waste management reflects the recognition that virtually all of the elements of the waste-management hierarchy will be required to manage the full complement of wastes generated by society. The goal of waste minimization is to move as far up the waste-management hierarchy as possible in managing any given waste.

RECENT TRENDS IN OKLAHOMA

The total volume of hazardous waste generated in Oklahoma has dropped dramatically over the past five years, as shown in Figure 1. Based on 1985 and 1987 biennial reports filed by in-State generators, total hazardous-waste volumes declined by 39% between 1985 and 1986, from 1.6 million tons to 975,000 tons (DPRA,

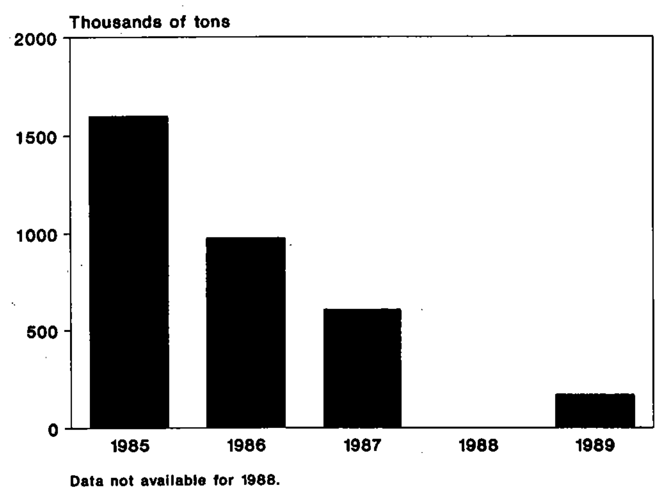

Figure 1. Hazardous-waste generation in Oklahoma, 1985–89.

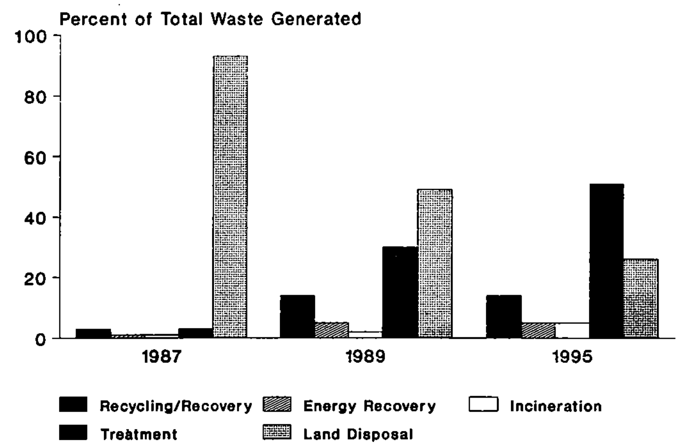

Figure 2. Hazardous-waste management in Oklahoma, 1987–95.

1988,1989). Hazardous-waste volumes decreased an additional 37% between 1986 and 1987, to 610,000 tons (Oklahoma State Department of Health, 1989, p. 5). Values for 1988 are not currently available, but estimated volumes for 1989 represent a further decline of 72% from 1987 to approximately 170,000 tons (Oklahoma State Department of Health, 1989, p. 69). The net decline since 1985 is on the order of 90%.

Figure 2 illustrates the projected shift in hazardous-waste management practices by Oklahoma generators between 1987 and 1995. The graph was generated from data developed by DPRA for the Oklahoma hazardous-waste capacity-assurance plan (Oklahoma State Department of Health, 1989), and from interviews conducted by the author with major hazardous-waste generators in the State. Waste volumes for the five waste-management categories used in Figure 2 were produced by aggregating volumes for the SARA waste-management categories reported in the capacity-assurance plan. Table 1 illustrates how these aggregate waste-management categories were derived.

Data for 1987 were developed by DPRA from the 1987 biennial reports submitted by in-State generators. Data for 1989 and 1995 reflect projected growth in hazardous-waste generation by two-digit Standard Industrial Classification codes and data obtained from the 21 largest generators in the State concerning waste minimization accomplished since 1987 and planned for implementation between 1990 and 1995. DPRA assumed a direct relationship between hazardous-waste generation and constant-dollar earnings in projecting increases in hazardous-waste generation (Oklahoma State Department of Health, 1989, p. 123–125). The 1989 and 1995 projections also reflect assumptions made by DPRA about use of alternative waste-management technologies in response to the Best Demonstrated Available Technology (BDAT) standards published by the federal Environmental Protection Agency (EPA), pursuant to the land-disposal bans enacted under HSWA for specific types of hazardous waste.

TABLE 1.—DERIVATION OF WASTE-MANAGEMENT CATEGORIES

Aggregate waste-management category	SARA waste-management categories
Recycling	Metals recovery Solvents recovery Other recovery
Energy recovery	Energy recovery[a]
Incineration	Incineration—liquids Incineration—sludges/solids
Treatment	Aqueous inorganic treatment Aqueous organic treatment Other treatment Sludge treatment Stabilization
Land Disposal	Land treatment Landfill Deep-well injection

[a]Energy recovery includes fuel blending and direct burning of hazardous waste to capture its energy value.

Data on the 21 generators employed in these projections were collected through interviews conducted by the author in August 1989. These generators were selected from the 25 largest generators in the State, based on hazardous-waste totals reported in the 1987 biennial reports. The other four generators among the top 25 are commercial treatment, storage, disposal, or recycling (TSDR) facilities. The 21 generators interviewed accounted for 96% of all the hazardous-waste generated by in-State sources in 1987. These 21 generators accounted for 98% of all the waste generated in 1987, exclusive of that produced by the four commercial TSDR facilities.

Figure 2 projects a significant decline in the use of land disposal between 1987 and 1995, from 93% of the hazardous waste generated in the state in 1987 to 49% in 1989, and 26% in 1995. Corresponding increases are projected in the use of alternative waste-management technologies, based on the 1986 national survey of TSDR facilities (Oklahoma State Department of Health, 1989, p. 129). As a result, treatment increases from 2.5% in 1987 to 51% in 1995, and incineration increases from less than 1% to 5%. Recycling increases from 3% in 1987 to 14% in 1995. Use of energy recovery is projected to increase from 1% in 1987 to 5% in 1989 and 1995.

An important assumption in making this projection is that use of land treatment and deep-well injection for disposal of hazardous wastes is terminated once the BDAT standards governing these disposal technologies go into effect in 1990 (Oklahoma State Department of Health, 1989, p. 127–128). This projection presumes that no waivers are granted to the land-disposal restrictions governing these practices in response to petitions that may be submitted by operators of land-treatment or deep-well injection facilities. DPRA assumed that if pretreatment of liquid wastes and sludges is required prior to deep-well injection, the treated wastes would more likely be discharged to a surface water body via a publically owned treatment works or a regulated surface-water discharge (Oklahoma State Department of Health, 1989, p. 129).

Waste Minimization: 1986–89

Data from the 21 largest in-State generators provide a more detailed look at the changes reflected in Figures 1 and 2. As shown in Table 2, the waste-management strategies responsible for the most significant reductions in hazardous-waste volumes between 1986 and 1989 were source reduction, off-site recycling, on-site treatment, and off-site energy recovery. It should be noted that the data in Table 2 exclude information from one of the 21 largest generators, Tinker Air Force Base, for which there was no biennial report on file with the OSDH.

Actions by two of the 21 largest generators account for much of the observed change. One generator reduced its total waste production from 898,000 tons in 1986 to 382,000 tons in 1987. This reduction of 516,000 tons exceeds the net decrease in total hazardous-waste generation in the State of 365,000 tons over this time period. This generator was responsible for 99% of the waste reduction attributed to source reduction in Table 2. Substitution of a non-chromium corrosion inhibitor in the generator's cooling system eliminated 308,000 tons of wastewater that had been disposed of by deep-well injection. A pH adjustment within this

TABLE 2.—WASTE MINIMIZATION TRENDS, 1986–89

Waste-management strategy	Number of cases	Volume Reduction (tons)
Source reduction	8	384,386
On-site recycling	4	2,004
Off-site recycling	13	11,296
On-site energy recovery	0	0
Off-site energy recovery	21	2,542
On-site incineration	0	0
Off-site incineration	2	12
On-site treatment	8	8,226
Off-site treatment	5	76

generator's production process eliminated an additional 74,000 tons of corrosive process wastewater which also had been disposed of by deep-well injection. A one-time generation in 1987 by a second generator of some 97,000 tons of bottom sludge from several surface impoundments offset to some extent the impacts of the waste reduction achieved by the first generator, but contributed to the net reduction shown between 1987 and 1989 in Figure 1.

On-Site Recycling

Under the category of on-site recycling, one generator accounted for 96% of the observed reduction (1,929 tons) between 1986 and 1989 by neutralizing a corrosive byproduct and reusing it as a feedstock. Two other generators installed onsite solvent-recovery systems yielding a total reduction of 74 tons.

Off-Site Recycling

Forty-eight percent of the reductions attributable to offsite recycling (5,432 tons) resulted from shipping solvents to off-site recovery facilities. Off-site metals recovery accounted for an additional 40% of the 11,296 tons of reduction shown for this waste management strategy in Table 2.

Off-Site Energy Recovery

The 2,542 tons of volume reduction attributed to off-site energy recovery are the sum of actions affecting 21 different wastes, most of which were solvents or waste oils.

On-Site Treatment

The majority of the reductions accounted for by on-site treatment took place in the petroleum-refining industry. A total of 3,848 tons of reduction (47% of the total) was achieved by one refinery that employed a filter press to dewater oily sludges. Treatment of spent catalysts by another refinery, to adjust the pH to nonhazardous levels, eliminated generation of an additional 4,313 tons.

Waste Minimization, 1990 and Beyond

Waste-minimization trends for 1990 and beyond are summarized in Table 3. These represent the reported activities of the 21 largest generators in the State, including Tinker Air Force Base. Each case is an individual waste stream. The results suggest increasing emphasis on source reduction and continued reliance on on-site treatment and recycling, but no significant increases in the use of energy recovery. In addition, two refineries are planning on-site incinerators for disposal of slop-oil emulsion solids, API separator sludges, and oil–water filtercakes and sludges. Incineration is the BDAT identified by EPA for these waste types (K048,K049,K051). While Table 3 does not identify any planned use of off-site incineration or off-site treatment, these technologies are expected to be used to an increasing extent in response to the BDAT standards promulgated by EPA pursuant to the HSWA land disposal bans. For example, many liquid and sludge wastes are expected to be stabilized prior to land-disposal. These anticipated changes are reflected in the projections depicted in Figure 2.

TABLE 3.—WASTE-MINIMIZATION TRENDS: 1990 AND BEYOND

Waste-management strategy	Number of cases
Source reduction	13
Feedstock substitution	4
Change in product	4
Process change	6
Waste-stream segregation	2
On-site recycling	6
Off-site recycling	2
On-site energy recovery	1
Off-site energy recovery	1
On-site incineration	2
Off-site incineration	0
On-site treatment	10
Off-site treatment	0

Much of the waste-minimization activity identified in Table 3 is attributable to initiatives at Tinker Air Force Base, which is a major aircraft-maintenance facility. Fourteen of the 35 cases (40%) listed in Table 3 are wastes from Tinker. According to a contact at the base (A. Coplin, personal communication, August 1989), the Air Force established a goal of achieving a 10% reduction in hazardous-waste generation each year for the five-year period between 1988 and 1992. This goal is reflected in the large number of waste minimization projects under way at the base, including use of a water-jet knife in place of a highly corrosive silicon rubber solvent; use of carbon dioxide pellet blasting and robotic laser depainters in place of paint-stripping solvents; installation of a chromium-recovery system on one of its electroplating lines; and installation of six different solvent-recovery systems.

Three of the cases of feedstock substitution involve use of nonhazardous substances in place of solvents or solvent-based materials. The four cases of product change involve the scheduled phase-out in production of leaded gasoline over the next several years. All four of the major refineries in the state will be eliminating the generation of leaded tank-bottom sludges (K052) by 1995 as a result of this change.

Four of the cases of on-site treatment will result in the generation of a nonhazardous residual through either ozonation of cyanide wastes or neutralization of corrosive wastes. Five of the on-site treatment cases involve volume reduction, principally through liquids removal. In one other case, a paint stripper will be treated rather than disposed of in a land-disposal facility.

FACTORS AFFECTING WASTE MINIMIZATION

In an effort to ascertain factors that contributed to the decisions of generators to reduce their hazardous wastes, 15 of the 21 large generators surveyed were asked an open-ended question concerning the reasons why their firms had initiated the waste-minimization activities either recently completed or under way. Table 4 presents a frequency tabulation of their responses. The principal motivating factors are clearly economic: immediate cost savings; avoided costs of reducing the volumes of waste requiring more expensive treatment to meet the BDAT standards under the federal land disposal bans; and long-term cost-avoidance by minimizing the risk of incurring liability for the cleanup of abandoned hazardous-waste disposal sites under the federal Superfund program (CERCLA).

Responses to questions included in the federal biennial report forms were also tabulated for 18 of the 21 largest generators concerning constraints to waste minimization. These are presented in Table 5, where a distinction is made among respondents based on firm size measured as total number of employees. Again they reflect a concentration on economics and related concerns such as product quality, but there is also considerable emphasis on technical and information constraints.

Technical limitations can be also viewed as an economic issue. Waste minimization has been characterized by the National Research Council (NRC) as proceeding through three phases (National Research Council, 1985, p. 2). In the first phase, firms take advantage of relatively low-cost, technically simple initiatives, such as improved housekeeping and waste-stream segregation. The second phase is characterized by the NRC as the "development" phase, where generators employ more-sophisticated technologies and generally must make greater capital investments. In the third or "mature" phase, firms begin to confront true technical limits to further waste reduction.

TABLE 4.—FACTORS PROMOTING WASTE MINIMIZATION

Factor	Frequency[a]
Cost savings	60%
Federal land-disposal bans	53%
Long-term liability	47%
Concern with the environment	13%
Worker health and safety	6%
State credit for annual waste-stream fee	6%
Consent decree	6%

[a]$N = 15$; frequency of 6% represents 1 response out of 15.

TABLE 5.—CONSTRAINTS TO WASTE MINIMIZATION BY FIRM SIZE

	Frequencies		
Constraint	<500 employees ($n = 10$)	500 employees ($n = 8$)	All firms ($n = 18$)
Lack of technical information	70%	50%	61%
Inadequate cost savings	50%	63%	56%
Insufficient capital	50%	25%	39%
Lack of a market for recycled waste	50%	25%	39%
Concern with product quality	20%	63%	39%
Technical limitations of production processes	30%	38%	33%
Permitting burdens	40%	25%	33%

There are few purely technical limitations to waste minimization in most firms at this time (Price, 1989, p. 235). Thus, few firms have exceeded the technical limits of the NRC's second phase. The principal limitation to further waste reduction by these generators is what they perceive as *cost-effective* technology, versus the absolute availability of technologies that can achieve further waste reduction. Limited availability of technical information is also an economic phenomenon. The principal constraint is not the absence of such information; rather, it is the cost of obtaining this information. These so-called information costs are mainly the staff time required to locate and analyze the available information. This suggests that many so-called technical limitations are conditioned on the economics of waste management and information acquisition and may, therefore, be changed by altering those economics.

From Table 5 it is evident that smaller firms are more likely to report constraints due to lack of available technical information and insufficient capital. On the other hand, they are less likely to identify concern with product quality as a constraint than are larger firms, and larger firms are slightly more likely to identify technical limitations of production processes as a constraint. In a 1985 survey of hazardous waste generators in New York State, the Rockefeller Institute of Government found that generators with fewer than 500 employees ranked the cost of consultants as a greater constraint to making advances in their waste-management technology (Palmer and others, 1986, p. 58). They found, however, that firms with at least one research and development (R&D) staff person ranked lack of technical information as a more severe constraint than generators without R&D staff.

Taken together, the results of these two inquiries suggest that perceived technical limitations to waste reduction are not limited to the smaller firms, nor is concern with the availability of technical information. It would appear, however, that financial constraints are most significant for the smaller firms.

OPTIONS FOR PROMOTING WASTE MINIMIZATION

Public policies for promoting minimization of hazardous waste can be grouped into three categories: (1) direct regulation, (2) economic incentives, and (3) technical assistance. These options are assessed here in light of the findings from the Oklahoma survey and other empirical studies.

Direct Regulation

Public-policy-makers have generally been reluctant to interfere directly in decisions about manufacturing processes (Blomquist, 1988, p. 828,831,845). Policy-makers have, however, been willing to use reporting requirements as a means of promoting waste minimization. They have also been willing to limit use of hazardous-waste disposal technologies that are ranked lowest on the waste management hierarchy—for example, the federal land-disposal bans.

Under regulations promulgated pursuant to HSWA, hazardous-waste generators are required to sign a certification statement on the uniform hazardous-waste manifest, which states that the generator has a waste-minimization program in effect, and that they have selected the economically practicable method of waste treatment or disposal that minimizes present and future threat to human health and the environment (Freeman, 1989, p. 1). Generators are also required to document their waste-minimization programs in their biennial reports which are filed with the EPA or authorized state. The effectiveness of these reporting requirements is open to debate. None of the 21 largest Oklahoma generators that were interviewed mentioned these as a factor that contributed to their decisions to initiate waste minimization.

The interviews of large generators in Oklahoma suggest that the federal land-disposal bans have been a major factor in prompting these generators to initiate waste-minimization activities by increasing the costs of permissible waste-management practices. A recent study by the author of the effect of public policies on hazardous-waste management in New York State (Deyle and Bretschneider, in preparation), also suggests that land-disposal restrictions have been a factor in motivating shifts to lower-risk technologies in the waste-management hierarchy, such as incineration and recycling.

Economic Incentives

It is evident that economics is the principal factor driving waste-minimization initiatives, and that economic and technical limitations to waste minimization are interrelated. Public policy initiatives that have a significant effect on the economics of waste minimization can be anticipated to influence waste-management decisions. Several avenues are available for influencing the economics of hazardous-waste management. These include taxing waste generation and disposal, providing tax incentives for waste-minimization investments, and providing financial assistance to generators for waste-minimization initiatives.

Waste-End Taxes

One option for influencing the economics of hazardous-waste management is to impose a tax on the generation or disposal of hazardous waste. These so-called waste-end taxes have been imposed in at least 23 states, primarily to raise revenues for state programs, such as remediation of abandoned hazardous-waste-disposal sites (Anonymous, 1989; Bulanowski and others, 1981, p. 18–19,43–45; United States General Accounting Office, 1984, p. ii; ICF Consulting Associates, 1985, p. 41–44).

Deyle and Bretschneider (in preparation) have found evidence that the waste-end tax in New York may have promoted shifts from land disposal and treatment to incineration and recycling. However, they were unable to demonstrate any clear association between the tax and waste minimization over the period 1983 through 1986. No other studies have been identified that document a significant effect of such taxes on waste-minimization decisions. In many cases this may be due to a relatively low level of taxation that does not significantly influence the marginal cost of hazardous-waste management. In some states the tax rate is as low as $0.35/ton, while in others it is as high as $70/ton.

Tax Concessions

The economics of hazardous-waste minimization can also be affected by state financial-assistance programs. Some states offer tax concessions to generators for investments in waste-minimization technology (Focella, 1989, p. 18; United States Congress Office of Technology Assessment, 1986, p. 59; ICF Consulting Associates, 1985, p. 4–8). These include tax credits, tax exemptions, and accelerated depreciation.

There is some question as to whether tax concessions function as true incentives that actually affect decisions. It has been argued that these serve essentially as subsidies to generators who initiate waste minimization for reasons independent of the tax concessions (S. Betts, personal communication, October 1989; United States Congress Office of Technology Assessment, 1989, p. 326). This appears to have been the case in Oklahoma under the Recycling, Reuse, and Ultimate Destruction Incentive Act.

Direct Financial Assistance to Generators

Other forms of financial assistance include issuance of state loans or state loan guarantees to firms for investments in waste-minimization equipment and state grant programs. Only two states, Connecticut and New York, were reported as offering low-interest loans in a recent study conducted by the National Governors' Association (Focella, 1989, p. 62,76). Some state loan-guarantee programs for pollution-control equipment may also be applicable to capital investments in waste minimization. Little information is available on the effectiveness of these programs. Data from the New York State program suggest that loans are generally utilized only by the larger firms (New York State Environmental Facilities Corporation, 1988, p. 42).

Grant programs have been used as a means of addressing the financial constraints to waste minimization and to contending with perceived technical constraints. Some state grant programs, for example those in California and Minnesota, are used to promote adaptation of existing technologies to new waste-management problems and to developing new waste-management technologies (California Department of Health Services, 1988, p. 15–16; Thompson and McComas, 1987). Other states, such as Connecticut, provide grants that subsidize some of the costs of establishing a waste-minimization program within a firm. Eligible activities include waste audits, personnel training, and feasibility studies (Focella, 1989, p. 18). The matching requirements of these programs can be a barrier to participation by some firms.

Technical Assistance

Aside from grants programs, several states provide a variety of technical-assistance services designed to contend with the costs of accessing and utilizing pertinent technical information. These include technical-information clearinghouses, direct-contact programs, and waste exchanges.

Technical-Information Clearinghouses

A number of states have established technical-information clearinghouses that maintain technical libraries and provide user assistance through such means as telephone hotlines, newsletters, and, more recently, electronic bulletin boards. Several of the clearinghouses have been established at the national level, including one operated by the Governmental Refuse, Collection, and Disposal Association (GRCDA) under contract with EPA, and an electronic bulletin board being developed by EPA (United States Environmental Protection Agency, 1988). No evaluations have been done that permit an assessment of the actual impacts of these programs. The only data available quantify use of these services by generators.

Waste Exchanges

Waste exchanges facilitate the transfer of wastes or surplus materials from one industrial firm to another. Successful transfers achieve waste minimization through recycling or reuse of materials that otherwise would be discarded for disposal. While the majority of wastes handled by these exchanges would qualify as hazardous wastes, nonhazardous industrial wastes are often handled as well. Utilization of a waste exchange by a hazardous-waste generator has been determined to satisfy federal requirements governing waste-minimization efforts (McDaniel, 1989, p. 241).

A number of the waste exchanges do not conduct any regular formal evaluations of their programs, nor do they publish annual reports (E. Jones, personal communication, April 1989; R. McCormick, personal communication, April 1989). Most evaluation data that have been produced only measure activity levels. These have increased dramatically for waste exchanges that have been in operation for several years (L. Cutler, personal communication, April 1989; McDaniel, 1988, p. 14). Actual impacts on the volumes of hazardous waste disposed are difficult to accurately document, since most waste exchanges do not calculate such numbers explicitly. The Southeast Waste Exchange reported transfers of acids, alkalis, other inorganics, solvents, other organics, metals and metal sludges, and oils and waxes totalling 23,225 tons in 1987–88 (McDaniel, 1989, p. 17). If one assumes that all of these materials constitute substances that would be regulated as hazardous wastes, this total represents 20% of the hazardous waste generated in 1985 in the eight states within the region served by the waste exchange, based on 1985 EPA biennial report data (DPRA, 1988, p. IV–2). The Northeast Industrial Waste Exchange reported successful exchanges in 1987 for about 3,103 tons of chemical and metal wastes (Cutler, 1988, p. 9–12). If all of these are assumed to be hazardous wastes, they represent 7% of the hazardous waste generated in 1985 in the 11 states that are primarily encompassed by the exchange.

Direct-Contact Programs

Some states and universities, as well as the EPA, conduct workshops, seminars, and conferences to provide information on waste minimization technology to interested generators. While these formats make more-efficient use of public resources, the Rockefeller Institute survey of New York State generators found that firms were less likely to participate in workshops and seminars that were more than 25 miles from their place of business (Palmer and others, 1986, p. 89–90). The effectiveness of these programs in accomplishing technology transfer is also constrained by the expertise of the participants (Deyle, 1989, p. 101).

More-direct assistance is provided through on-site consultation, including waste-management audit programs, many of which are free or subsidized by state funds. Typically these programs are targeted at small and medium-sized businesses which are perceived to have more limited in-house expertise. On-site technical-assistance programs are widely recognized as the most effective means of promoting hazardous-waste minimization (Deyle, 1989, p. 99–100), but they are also the most resource-intensive.

Oklahoma Initiatives

Oklahoma has no formal technical-assistance program for hazardous-waste generators, and the State does not operate a waste exchange. The OSDH had one staff member who initiated some waste-minimization technical assistance efforts in 1987 and 1988, but the program was discontinued (Oklahoma State Department of Health, 1989, p. 22). An application has been submitted to the EPA by the OSDH for funding a technical-assistance program under the Pollution Prevention Incentive for States grants program.

Oklahoma is listed as an affiliate of the Illinois Industrial Material Exchange Service, but distribution is on an ad hoc basis by members of the OSDH staff (R. F. Rood, personal communication, September 1989). Several of the other waste exchanges include listings or inquiries from Oklahoma firms (E. Jones, personal communication, April 1989; R. McCormick, personal communication, April 1989; M. McDaniel, personal communication, April 1989). The Texas waste exchange plans to promote its services with Oklahoma industries in 1990 (C. Wilson, personal communication, April 1989).

Oklahoma offers two tax incentives for waste minimization: (1) an income-tax credit for capital investments in facilities for recycling, reuse, or ultimate destruction of hazardous waste; and (2) a sales-tax exemption for the purchase of machinery, equipment, fuels, and chemicals used in the process of treating hazardous wastes to reduce their toxicity or volume. No data are available on participation in the sales-tax exemption. A total of three income-tax credits have been granted under the tax-credit program since it went into effect on January 1, 1987: (1) storage and piping systems for a commercial solvent recycling facility (11/87); (2) on-site distillation unit for a generator (3/89); (3) on-site distillation unit for a second generator (5/89). Data are not available on the net reduction in hazardous waste disposal that resulted from installation of these recycling systems. While half of the Oklahoma generators surveyed in this study said they were familiar with the Oklahoma income-tax credit program, only 19% thought the tax credits might make a difference in their firm's assessment of waste-minimization options.

Oklahoma has no tax on hazardous-waste generation and disposal, other than a permit fee system based on the number of regulated hazardous-waste streams a generator has. This system does incorporate a small financial incentive for waste minimization through recycling. A minimum tax of $100 is paid. The annual fee for each additional waste stream is $50. Hazardous wastes that are recycled on-site or at off-site facilities are not subject to the tax beyond the $100 minimum. One of the generators surveyed mentioned this as an incentive for his firm's waste-minimization activities. A tax on hazardous-waste disposal is under consideration for financing the State's Superfund cleanup program.

CONCLUSIONS

Most of the waste minimization that has taken place or is under way in Oklahoma appears to have been initiated in response to economic incentives, most of which are rooted in federal policies—namely, the land disposal bans and CERCLA liability. While substantial reductions in hazardous-waste generation have occurred in the State since 1985, it is likely that response to these economic incentives will have leveled off by 1991 or 1992. Further progress in waste minimization in the State will require initiatives to provide additional economic incentives, either by raising the marginal costs of hazardous-waste generation still further, or by reducing the economic constraints to further waste minimization.

State efforts to contend with the information costs of waste minimization, through technical-assistance programs, may have substantial payoffs. Formal support for waste exchange—for instance, through active involvement in one or more of the existing exchanges—could have some measurable impact on waste reduction. A state technical-information clearinghouse that ties in with one or more of the existing national systems could also help diminish problems generators have encountered in obtaining appropriate technical information. Finally, the State could facilitate exchange of information among generators in the State. In particular, an effort to disseminate information from the innovative waste-minimization projects at Tinker Air Force Base could benefit a number of other industries in the State, including aircraft- and vehicle-maintenance operations, and fabricated-metal-products industries.

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REFERENCES CITED

Anonymous, 1989, Washington State not collecting 1988 hazardous waste tax: Focus, April, p. 4–5.

Blomquist, R. F., 1988, Developing a long-term waste management strategy: Environmental Law, v. 18, p. 815–900.

Bulanowski, G. A.; Lazarus, G. H.; Morandi, L.; and Steeler, J. H., 1981, A survey and analysis of state policy options to encourage alternatives to land disposal of hazardous waste: National Conference of State Legislatures, 61 p.

California Department of Health Services, 1988, California hazardous waste reduction grant program: grant application manual: California Department of Health Services Toxic Substances Control Division, 56 p.

Cutler, L., 1988, An assessment of the effectiveness of the Northeast Industrial Waste Exchange in 1987: Northeast Industrial Waste Exchange, 18 p.

Deyle, R. E., 1989, Regulating and assisting the smaller generator: hazardous waste management in small businesses: Quorum Books, 168 p.

DPRA, 1988, Draft 1985 national biennial report of hazardous waste generators and treatment, storage and disposal facilities regulated under RCRA: U.S. Environmental Protection Agency, Office of Solid Waste.

_____ 1989, Ranking report, unpublished data table (July 19, 1989): Oklahoma State Department of Health, 5 p.

Focella, D., 1989, The role of waste minimization, vol. 1: National Governors' Association Center for Policy Research, 85 p.

Freeman, H. M., 1989, Hazardous waste minimization: a strategy for environmental improvement, *in* Freeman, H. M., Hazardous waste minimization industrial overviews: Air and Waste Management Association, p. 1–4.

ICF Consulting Associates, 1985, Economic incentives for the reduction of hazardous wastes—appendices to the final report: California Department of Health Services, 147 p.

McDaniel, M., 1988, Southeast Waste Exchange annual report 1987–1988: Southeast Waste Exchange, 26 p.

_____ 1989, The role of waste exchange in waste minimization, *in* Proceedings of the 6th National Conference on Hazardous Wastes and Hazardous Materials, April 12–14, 1989: Hazardous Materials Control Research Institute, p. 237–242.

Municipal Solid Waste Task Force, 1988, The solid waste dilemma: an agenda for action, draft report: U.S. Environmental Protection Agency, 70 p.

National Research Council, 1985, Reducing hazardous waste generation: an evaluation and a call for action: National Academy Press, 76 p.

New York State Environmental Facilities Corporation, 1988, IMRA Seventh Annual Report: New York State Environmental Facilities Corporation, 45 p.

Oklahoma Environmental Concerns Council, 1989, Environmental report to the Governor: Oklahoma Environmental Concerns Council, 157 p.

Oklahoma State Department of Health, 1989, 1989 hazardous waste capacity assurance plan for Oklahoma: Oklahoma State Department of Health, Waste Management Service, 139 p.

O'Leary, Rosemary, 1989, Legal liability of smaller generators of hazardous waste, *in* Deyle, R. E., Regulating and assisting the smaller generator: hazardous waste management in small businesses: Quorum Books, 168 p.

Palmer, E.; Deyle, R.; Kohn, J.; Rabideau, A.; and Scrudato, R., 1986, A feasibility study for establishing a New York State research and development center for hazardous waste management: New York State Environmental Facilities Corporation, 107 p.

Price, R. L., 1989, Waste reduction—what is it? how to do it, *in* Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Third International Conference on New Frontiers for Hazardous Waste Management: U.S. Environmental Protection Agency, p. 234–242.

Thompson, F.; and McComas, C., 1987, Technical assistance for hazardous waste reduction: Environmental Science and Technology, v. 21, p. 1154–1158.

U.S. Congress, Office of Technology Assessment, 1986, Serious reduction of hazardous waste summary: Office of Technology Assessment, 254 p.

_____ 1989, Facing America's trash: what next for municipal solid waste?: Office of Technology Assessment, 377 p.

U.S. Environmental Protection Agency, 1988, U.S. EPA waste minimization technical information clearinghouse: electronic bulletin board (E-Board): U.S. Environmental Protection Agency, Office of Solid Waste, 32 p.

U.S. General Accounting Office, 1984, State experiences with taxes on generators or disposers of hazardous waste: U.S. General Accounting Office, 124 p.