United States
Environmental Protection
Agency

Research and Development

Hazardous Waste Engineering Research
Laboratory
Cincinnati OH 45268

EPA/600/S2-85/021 May 1985

EPA

Project Summary

Using Mined Space for Long-Term Retention of Nonradioactive Hazardous Waste

R. B. Stone, K. A. Covell, T. R. Moran, L. W. Weyand, and C. U. Sparkman

A project was undertaken to assess the current status of using mined space for long-term retention of nonradioactive hazardous waste. The full report consists of two volumes. Volume 1 updates studies conducted in 1974, reviews recent literature on the subject, determines the involvement of government agencies, reviews regulatory and permitting requirements, and identifies existing mines for a potential demonstration project. Volume 2 investigates the use of solution-mined salt caverns for storing hazardous wastes. This volume examines the extent of salt deposits in the continental United States, their proximity to the U.S. EPA waste-generating regions, salt chemistry, construction, design, and operation of the solution-mined caverns, environmental considerations, projects proposed by industry, advantages, and needed research.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A national hazardous waste management program was formed with the enactment of the 1976 Resource Conservation and Recovery Act (RCRA) and the Hazardous Waste regulations promulgated by the U.S. Environmental Protection Agency (EPA). The presently accepted methods of hazardous waste disposal are deep-well disposal, engineered landfills, land treatment, and incineration. However, these methods yield a certain amount of untreatable hazardous waste that must be dealt with in an environmentally acceptable manner. Permanent storage of such wastes in underground, mined space appears to provide a technically and economically feasible method for dealing with them. Among the advantages of this method are the following:

1. The waste would be below drinking aquifers in deep mines.
2. Wastes would be isolated from the public and the surface ecology.
3. Security can be readily maintained.
4. Minimum maintenance is required in a sealed mine.
5. The mine could be used as a long-term warehouse if retrievability is desired.

The purpose of this two-volume project was to update the state-of-the-art of using mined space for hazardous waste storage in the United States and to determine the feasibility of conducting a limited demonstration project. Specifically, Volume 1 examines the following subjects: (1) the literature produced on mined storage activities in the past decade, (2) involvement of government agencies, (3) various regulatory and permitting requirements for storing waste in mines, and (4) selection of candidates for a potential demonstration project. Volume 2 investigates the use of solution-mined salt caverns for storing hazardous wastes. Subjects covered in this volume include: (1) the extent of salt deposits in the continental United States and their proximity to waste-generation by EPA regions, (2) salt chemistry, (3) construction, design, and operations of solution-mined caverns, (4) environmental considerations, (5) projects proposed by industry, (6) advantages of solution-mined caverns, and (7) needed research.

Literature Review

The literature review was based on a search to identify past and present research, government activities, development of commercial facilities, and foreign use of underground caverns for storing wastes. Citations were retrieved for literature published since 1974.

Foreign Activities

Recent foreign activities include the Herfa-Neurode facility in the Republic of West Germany. This operation continues to run satisfactorily 13 years after its start-up in 1972. About 270,000 tons of hazardous wastes were placed in the mine in 10 years, and the present annual volume is 35,000 to 40,000 tons. Reuse of stored waste is possible, and more than 1,000 tons have been retrieved by a waste producer and returned to the originator for further use.

India has conducted studies to evaluate the concept of storing hazardous waste in mined space.

United States Activities

Empak, Inc., of Houston, Texas, applied for a state permit to build a hazardous waste facility in solution-mined caverns at the Vinton Salt Dome in southwest Louisiana. However, a state law was subsequently passed forbidding such a project for 2 years. The delay was to allow the state time to evaluate the proposed use.

United Resource Recovery, Inc., of Houston, Texas, has an application pending for a state permit to store hazardous waste in the Boling Salt Dome in Texas. This request has triggered a geological study to evaluate the acceptability of using salt domes in Texas for waste disposal and to recommend guidelines for such storage. Work is being done by the Texas Bureau of Economic Geology.

The University of Minnesota conducted a 1982 study of the subsurface isolation of hazardous wastes. The study was sponsored by the Minnesota Waste Management Board and was oriented to deep geologic disposal in crystalline bedrock within the state. Five sites were selected for further investigation, but the crystalline rock concept was dropped from further consideration because of its high cost.

The PPG Industries, Inc., limestone mine in Barberton, Ohio, was proposed for use as a waste storage facility in 1981-82, but the project was dropped because of economic conditions in the United States.

Research Activities

EPA has sponsored several studies in recent years on encapsulation containerization, and fixation technologies. Data from these projects apply directly to the use of mined space for storage of hazardous wastes.

The American Society for Testing and Materials (ASTM) has been working on a hazardous waste compatibility guide. After acceptable methodology has been developed for mined space storage, the compatibility of waste with a salt environment must be established.

Public Reaction

The public has become increasingly aware of the potential danger of hazardous waste through continuing commentary by the media. This public awareness does not include a concern for the national consequences of failing to develop final treatment and storage methods.

Involvement of Government Agencies

Every phase of a hazardous waste storage facility, from conception to closure, requires the involvement of government agencies at all levels—federal, state, and local. These agencies and the extent of their involvement will vary with location and time as new legislation is passed and programs are implemented. Siting of hazardous waste facilities requires approval from all levels of government and public concern is making approval of permits more difficult to obtain.

Regulatory and Permitting Requirements

A reasonably uniform hazardous waste management program is being conducted throughout the United States as a result of RCRA regulations. These regulations provide that a state agency may be authorized to administer a hazardous waste program in that state in lieu of a federally administered program. Many states have developed and manage their own hazardous waste programs under EPA regulatory guidelines. EPA is administering the programs of those states that have not completed development of their hazardous waste management plans.

Presently neither EPA nor individual states have developed regulations specifically pertaining to hazardous waste storage in mined space. Thus, such facilities will have to be designed, sited, and evaluated through interpreting the intent of existing regulations.

Current Applicable RCRA Permitting Requirements

Permitting of new hazardous waste facilities is regulated by EPA in 40 CFR Section 270. This regulation requires a two-part application for approval of the proposed facilities. Present permitting requirements do not include specific terms related to storage of wastes in mined space but they are comprehensive enough to secure the information for such a permit application.

State Hazardous Waste Permitting Requirements

States authorized by the EPA to administer a hazardous waste program have developed and are using permitting regulations. States without EPA authorization are using EPA regulations.

In general, all authorized states now have regulations and permitting practices that conform to EPA hazardous waste management regulations and administrative criteria. Differences in storage regulations and permitting procedures do not specifically relate to hazardous waste storage in subsurface mines.

The 1976 RCRA does not prescribe requirements for the siting of new hazardous waste management facilities. Present policies consider this task the responsibility of each state.

In the past, several states gave various agencies the permitting authority for hazardous waste facilities. The state then ruled on the permit after analyzing the applications and holding public hearings. However, public opposition to new facilities resulted in very few approved permits; as a result, most states now specify procedures for site selection, provide for public participation, and establish the responsibility of state and local agencies.

Selecting Candidate Mines for a Demonstration Project

The object was to select three candidate mines with good potential for use as a demonstration facility for storing non-radioactive hazardous wastes.

The basic criteria were as follows:

- The preferred candidates were to be salt mines, but other types were not ruled out.
- The mine should have been mined by the room and pillar method.
- Existing engineering, geological, and other information should indicate that the mine is suitable for the purpose.
- An industrial organization must exist that is willing to cooperate in a limited demonstration of the concept.

Additional criteria included the following:

- Hazardous wastes to be stored must be packaged, encapsulated or solidified, nonreactive, dry, noncombustible, and untreatable by current technology or the end product of current treatment technology.
- Limestone mines mined by the room and pillar method were included in this report.

The approach to mine selection consisted of (1) identification of all known salt mines in the United States, (2) a preliminary screening of 30 potential candidate mines to eliminate obviously unsuitable subjects, (3) a geographical screening to match mine locations with EPA Regions in which hazardous wastes are produced, (4) a final subjective screening of the seven remaining mines to determine hydrology, geology, marketing, sociopolitical factors, accessibility, location, previous studies, and owner interest, and (5) visits to the three selected facilities and discussions of the proposed demonstration with the owners/operators.

The three selected salt mines were in Michigan, Ohio, and Texas. The alternative limestone mine was in Ohio. One mine was withdrawn from consideration when the operators indicated that it was not in their best interest to participate. Another mine was rejected because it was the subject of adverse public reaction to a recent attempt to establish a commercial hazardous waste storage facility in the mine. Such recent efforts were considered likely to strengthen public resistance and reduce the probability of obtaining a state permit. The third mine was the highest ranked of the original three candidates, and the owner indicated willingness to participate in the demonstration. In this case, the state has jurisdiction for hazardous waste facility siting, and their regulations are equal to or more stringent than those required by the 1976 RCRA. The proposed demonstration facility must undergo the same permitting procedures as any other hazardous waste facility in the state.

As an alternative limestone mine was ranked numerically at the top of the list and illustrates the possibility of using mines in types of rock other than salt. But because this mine would require an expensive hoisting system to be installed, it was not considered further.

The third salt mine discussed has an operating hoisting system and was equal in rating. Thus, the third mine was selected as the best candidate for a demonstration facility.

Solution-Mined Storage

Solution-mined caverns could provide suitable containment facilities for hazardous wastes and good isolation from the environment. After the waste slurry cavern has been plugged with cement, the plastic nature of the salt under strata pressure will provide an effective seal.

Many large salt deposits in the United States are located near a number of the major hazardous waste generation areas, a factor which would minimize transportation and handling cost.

Basic Requirements for Solution-Mined Storage Caverns

Any solution-mined storage facility must have three characteristics for successful cavern construction:

1. a sufficient thickness of structurally sound salt at a proper depth without excess interbedded insolubles,
2. an adequate supply of raw water for leaching the salt, and
3. an environmentally acceptable and economical means of disposing of the resulting brine.

Salt Dome Leaching Techniques

The basic technique for developing a salt dome cavern is to drill into a salt mass and to pump fresh or low-salinity water into the hole. The salt is then dissolved and carried to the surface as a brine solution. The hole within the exposed salt gradually enlarges and eventually forms a useful cavern.

Bedded Salt Leaching Techniques

The basic principles of leaching are the same in bedded salt as in a salt dome, but bedded salt presents an additional problem because of the thinness of the salt resource and the tendency of large, interbedded shale layers to collapse and damage the leaching casing strings. These bedded salt insolubles tend to fall to the bottom of the cavern as a pile of large rocks rather than as fine sand, as is the case in a salt dome cavern.

Locations of Waste Generators and Salt Deposits

Four EPA Regions (III, IV, V, and VI) produced 78% of the Nation's total hazardous waste in 1980. Regions IV and VI, with 25% and 26% of the total, respectively, both have salt domes that could be used for the emplacement of hazardous waste. Regions III and V, with 11% and 16% respectively, both have bedded salt that could be used. These caverns would be smaller and more numerous than the salt dome caverns, but reduced shipping costs might make them cost-effective if a method for brine disposal can be developed.

Methods for Storing Hazardous Wastes in Solution-Mined Salt Caverns

Several methods exist for storing hazardous wastes in solution-mined caverns. Each is discussed here briefly.

Brine-Balanced Cavern with Brine Discharge During Waste Injection

In a brine-balanced cavern, the product to be stored is injected with a pump, displacing brine up the casing string and over to a brine holding pond. Caverns using this concept have a very long life, because the range of stress on the salt is small. The main advantage of using this method for hazardous wastes is that it permits the use of very large caverns. If the hazardous waste slurry is significantly lighter than saturated brine, the waste can be injected into the top of the cavern, displacing saturated brine up the casing string. If the specific gravity of the waste is close to or greater than that of the saturated brine, the waste slurry must be weighted so that it is significantly heavier than the brine and remains on the bottom of the cavern. The floating brine would then be displaced from the top of the cavern and directed to disposal wells.

Brine contamination is possible with this method.

Gas-Balanced Cavern with Zero Discharge

In a gas-balanced cavern, the brine is displaced by an inert gas and injected into a remote brine disposal well. The cavern is sealed at the minimum design pressure, then liquid and slurry wastes are injected into the cavern until the inert gas reaches the maximum design pressure. Gas balancing permits the use of a smaller cavern than the brine balancing and a larger cavern than the atmospheric method (which is discussed in the following section). Gas balancing eliminates the possibility of brine contamination and the need for a scrubber and flare unless they are needed by the surface plant.

Atmospheric Cavern with Controlled Gas Discharge During Waste Injection

In an atmospheric cavern, the brine is pumped out by a means of a submersible pump and directed to disposal. Chemically compatible liquid and pumpable slurry wastes are then inserted into the cavern. Displaced vapors or gases are collected and either sent through a scrubber or burned in an approved flare.

A cavern exposed to atmospheric pressure would be limited in size to maintain structural integrity. No brine contamination would occur, but a scrubber and flare would be required.

In Situ Solidified Waste Storage

Hazardous wastes can be mixed with a cement or polymer slurry before injection into a cavern to provide permanent solidified storage for liquid and slurry wastes and to reduce risks from earthquakes or inadvertent drilling into a hazardous-waste-filled cavern. Such a cavern would be limited in size to maintain structural integrity during the period it is exposed to atmospheric pressure.

String-of-Pearls-Waste Storage Caverns

The string-of-pearl method consists of constructing a series of caverns, one above the other, from one deep solution well in a salt dome. Each cavern is sealed by the installation of a cement plug in the top neck of the cavern before starting construction of the cavern above it. The brine from the first (bottom) cavern is removed by submersible pump and directed to the remote brine wells. This cavern will remain structurally stable because of its small size and because it is filled with waste quickly, thus reducing the time it is exposed to near-atmospheric pressure. For maximum structural integrity, all the hazardous waste could be mixed with a cement slurry so that the entire cavern would solidify. A small middle cavern (and later a top cavern) can then be constructed.

Environmental, Sociological, and Economic Consideration for Solution-Mined Facilities

A hazardous waste retention facility must protect all aspects of the environment at all times. Solution mining has the potential for meeting this requirement.

A minimum of land surface is required, and many salt domes are relatively free of population and industry.

Site operation should have no adverse effect on water quality, since there is no discharge to surface waters. The clean, saturated brine produced by cavern construction can be injected into deep disposal wells.

Air emission sources are limited to the diesel blanket storage tank and vapors displaced from the caverns. The latter would be chemically scrubbed or burned in an approved flare.

Careful siting of the facility will ensure that no wildlife habitat is disrupted. Major facilities would be located in areas already relatively clear of vegetation. The storage facility should not be located in a wetlands area.

The proposed project should not interfere with oil and gas production or any scenic or other natural resource.

Needed Research

Industry has used solution-mined salt caverns for storage and disposal of certain hazardous wastes for many years, but the practice has been limited to compatible chemicals known to be nonreactive to each other and to the salt. The hazardous waste industry faces a nearly infinite mix of chemicals. When a commercial hazardous waste facility has many clients, the potential for adverse reactions is multiplied many times if their wastes are mixed together for disposal. Thus, more research must be conducted for each combination of waste streams. Research is also needed to determine the compatibility of salt core with anticipated waste streams.

Solidifying waste *in situ* would enhance the use of solution-mined caverns even more. Research is thus needed to develop slurries of salt-saturated hazardous wastes and cement or polymer that will remain fluid during emplacement and remain sufficiently strong, long-lived, and economical when solidified in the cavern. After the waste has been emplaced, a method is also needed for flushing the surface piping and well tubing before solidification occurs.

Preliminary feasibility studies are needed for solution-mined hazardous waste retention facilities using both dome and bedded salt formations. These studies should include the following items

- Conceptual designs.
- Order-of-magnitude cost estimates for facilities in both dome and bedded salt formations
- Evaluations of the waste form—solution, slurry, and/or solidification.
- Viable schemes for handling the most difficult-to-manage wastes (those that remain after all economical means have been used to prevent, reduce, neutralize, or otherwise render them nonhazardous).

The full report was submitted in fulfillment of Contract No. 68-03-3191 by Fenix & Scisson, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

☆U. S. GOVERNMENT PRINTING OFFICE: 1985/559 111/10835

R. B. Stone, K. A. Covell, T. R. Moran, L. W. Weyand, and C. U. Sparkman are with Fenix and Scisson, Inc., Tulsa, OK 74119.
Carlton C. Wiles is the EPA Project Officer (see below).
The complete report consists of two volumes, entitled "Using Mined Space for Long-Term Retention of Nonradioactive Hazardous Waste:"
"Volume I. Conventional Mines," (Order No. PB 85-177 111/AS; Cost: $13.00)
"Volume II. Solution Mined Salt Caverns," (Order No. PB 85-177 129/AS; Cost: $10.00)
The above reports will be available only from: (costs subject to change)
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States Environmental Protection Agency

Center for Environmental Research Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300

0000329 PS

U S ENVIR PROTECTION AGENCY
REGION 5 LIBRARY
230 S DEARBORN STREET
CHICAGO IL 60604