

# High-Integrity Isolation of Industrial Waste in Salt

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## ABSTRACT

*Rock salt deposits underlie large regions of North America. For the most part, the salt formations exist as domed and bedded salt deposits. Many of these salt deposits have been evaluated and characterized for mining, resource storage and radioactive waste isolation. On the basis of salt's favorable physical and chemical characteristics, it is believed that mined cavities in salt can provide an environmentally sound alternative for long-term industrial isolation. Waste isolation in salt cavities may be a viable alternative to disposal by landfills and land treatment. Salt cavity utilization for this purpose warrants careful thought and examination.*

*The favorable characteristics of salt, primarily compressive*

*strength and impermeability, provide structurally stable chambers for waste isolation. Solution mining techniques are established for creating space for the storage of hydrocarbons in salt. The proposition of waste isolation in engineered solution-mined salt cavities requires similar characterization, certification and safeguards. The isolated materials, operational procedures and monitoring requirements are the principle differences. Compatibility of wastes with other wastes must be considered, but hazards can be precluded by pre-testing and avoiding certain mixtures or by segregating incompatible waste streams in separate caverns.*

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## INTRODUCTION

Properly designed and operated mines in salt deposits are considered to have great potential for subsequent operations as industrial waste management facilities. There are a number of reasons for recommending disposal of wastes in salt deposits. First, the physical properties of salt support its use for waste isolation. The properties of salt are well understood, owing to a number of international studies related to its use as a medium for hydrocarbon storage and radioactive waste isolation. Recent tests and existing waste facilities in salt confirm its excellent isolation potential. Second, salt deposits are usually mined at depth, thus providing a natural buffer between the isolated waste and the biosphere. This situation has a positive public relations value for an industry that has high public visibility. Third, salt is easily mined and the cost of waste storage space can be offset by the value of the mined salt. Fourth, in general, salt does not react chemically with most treated waste streams. Fifth, the deep burial of hazardous industrial wastes leaves the surface area available for almost unrestricted use. Conversely, shallow land burial areas must be off-limits to the public, monitored and maintained indefinitely. Sixth, salt deposits are widespread so that disposal facilities could operate within many regions of North America and the world.

The location of salt deposits in the United States fortu-

nately correspond to several industrialized areas (Figure 1). The salt domes of the Gulf Coast region offer an alternative to industrial waste landfills. This area of the USA often has high rainfall, near-surface watertables and frequent flooding due to poor drainage. All of these factors increase the risk of shallow landfill failures. Several companies are currently evaluating the economics and regulatory impacts of placing waste management facilities in salt domes at this time. The Northeast and Great Lakes regions have significant bedded salt deposits underlying highly industrialized and populated areas. These regions often suffer from adverse environmental factors that tend to preclude the development of shallow land disposal facilities for the management of hazardous industrial wastes. The Atomic Energy Commission sponsored a study of these regions' salt deposits for radioactive waste storage (The Geotechnical Corporation, 1958).

The isolation of industrial wastes in salt is under study and is being practiced in several countries today. The storage of resources, especially hydrocarbons, is a well established technology. The transfer of this technology is fairly straightforward. Several countries are currently evaluating the potential for storing radioactive wastes in salt formations; at least one country is currently implementing this disposal concept. Likewise, a few countries are already practicing the disposal of nonradioactive waste in salt.

The arguments against disposal of waste in salt usually

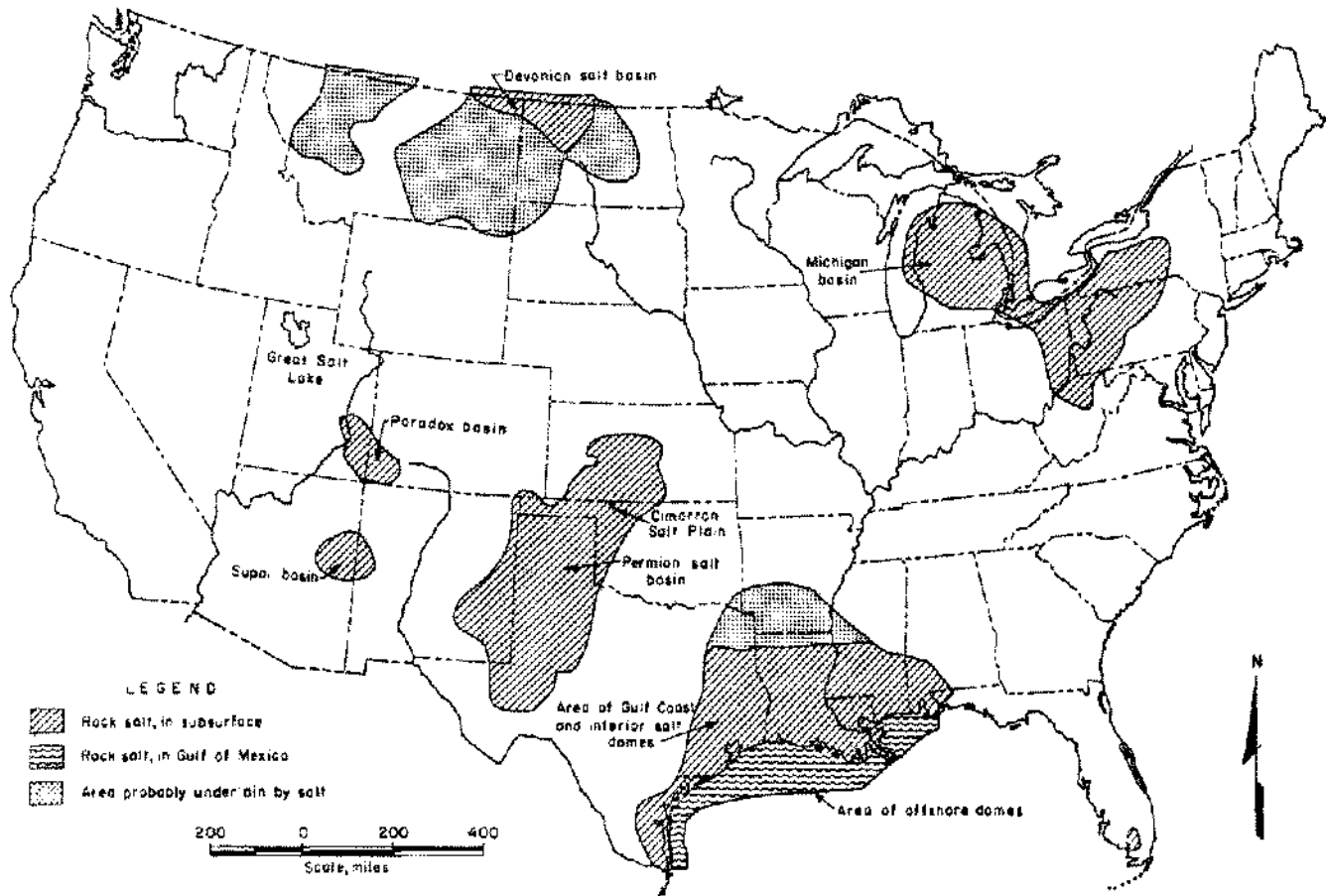


Figure 1. Salt Deposits in the United States

focus around cost. This particular argument is rapidly losing its credence as the life-cycle costs and liability of industrial waste management skyrocket.

#### EVOLUTION OF INDUSTRIAL WASTE MANAGEMENT PRACTICES

The early years of industrial waste disposal in North America left a heritage of environmental damage which industry and the government is still attempting to rectify. These early practices of open dumping in rivers and seepage pits were subsequently replaced by shallow land burial of untreated hazardous wastes. This shallow land burial may or may not have involved engineered barriers to mitigate seepage. Many of the early disposal operations received and buried fluid-filled drums of unsorted hazardous industrial wastes. The drums quickly corroded, rusted or otherwise failed, allowing their contents to damage other drums, seep into the groundwater and react with other dumped waste. Recent regulations proposed by the government environmental agencies preclude the disposal of free-fluid wastes and require the engineered development of secure landfills (Environmental Protection Agency,

1982). The shallow land burial of industrial wastes in secure landfills represents a major step in the right direction; however, to truly appreciate the degree of waste isolation that is possible, we must look to the proposed radioactive waste disposal facilities.

The U.S. Department of Energy (DOE) is involved in a program to evaluate bedded and domed salt deposits to determine their potential for the permanent disposal of intermediate and high-level radioactive wastes. Salt has been found to have the best overall isolation properties, since it has high structural strength, low permeability and will react plastically under confined stress instead of fracturing (Battelle Memorial Institute, 1982).

Another contribution of the DOE and other similar programs is the emphasis placed on the characteristics of the total waste disposal system (U.S. Department of Energy, 1982). The waste isolation system will include: (1) the geologic barriers, (2) the backfill and/or containment vessels, (3) the waste form characteristics, and (4) any added engineered design considerations. Total reliance is not placed on any one part of the system (see Figure 2). This total systems approach should substantially reduce the potential for leaching waste into the biosphere (Karably and Arora,

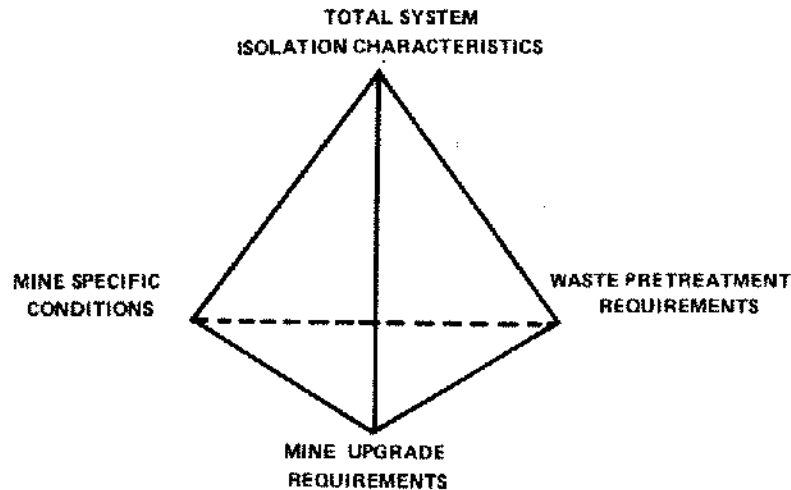


Figure 2. Isolation Variables of a Salt Mine Waste Management Facility

1982). Much of the isolation technology created by the government sponsored radioactive waste management programs is being adopted by the industrial waste management community and its regulators.

#### Salt Properties Research

Numerous studies have been undertaken during the last 30 years to evaluate and characterize the isolation properties of salt. In the United States the DOE has sponsored salt studies related to both the long-term isolation of radioactive wastes and the storage of the Strategic Petroleum Reserve. In recent years, the U.S. Environmental Protection Agency (EPA) has sponsored research into the potential of storing industrial wastes in salt formations.

The studies have determined that salt has excellent characteristics for high-integrity isolation for most radioactive and industrial wastes. The properties most commonly mentioned include:

- widespread distribution
- very low permeability
- plasticity
- high compressive strength
- chemically inert.

#### High-Integrity Isolation of Waste in Salt

The isolation of industrial waste in salt is environmentally and technologically sound. The first U.S. repository for intermediate and high-level radioactive wastes is under construction in southeastern New Mexico. This defense facility is scheduled to start operation in the late 1980s. Other salt areas in Kansas, West Texas, Utah and Mississippi have been or are currently under consideration for high-level radioactive waste repositories (Battelle Memorial Institute, 1982; Boegly, et al., 1961). One of these states will be selected for a test and evaluation facility during

1983. The only active waste disposal operation in the USA using salt as the isolation medium is Hooker Chemical's operation in Muskeegan, Michigan, where the company is storing asbestos in a solution-mined salt cavern.

During the mid to late 1970s, the EPA sponsored several studies related to the emplacement of hazardous industrial wastes in mined openings (Fenix & Scisson, 1975) and the costs associated with this technology (Bechtel Corp.,

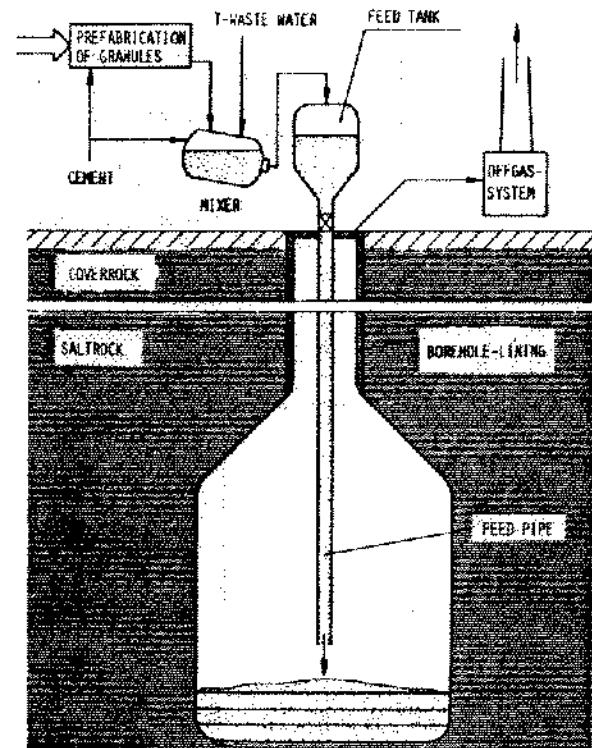


Figure 3. Scheme for the In-Situ Solidification of Radwaste in Salt Caverns

1977). These and subsequent studies on the increasing cost of highly regulated shallow land burial suggest that the future of waste disposal in the USA might be headed toward deep underground isolation in dry mines. The EPA studies concluded that disposal in underground mines was practical and that the life cycle costs could be competitive when using existing mines and efficient waste treatment and transport systems.

The Germans have been storing hazardous chemical wastes in the Kali and Salz A.G. mine at Herfa-Neurade since 1971 (Bechtel Corp., 1977). This room-and-pillar mine is at a depth of about 700 m. It was originally developed to mine potash ore in 1981. Kali and Salz A.G. developed a master plan for the storage/disposal of 700 compounds, which are subdivided into 19 different storage

categories. Most of the storage and disposal is in stacked drums. When a room is filled with drums, it is sealed off with a brick wall. This facility was processing 200 to 300 metric tons per shift, or 36,000 to 38,000 tons during 1976, for a disposal fee of \$53 per metric ton.

**INDUSTRIAL WASTE DISPOSAL USING SOLIDIFICATION TECHNOLOGY**

The disposal of chemical and low-level radioactive industrial wastes in underground mined openings can be a safe and profitable means of isolation. First, by using the appropriate treatment, processing and transport systems, large volumes of bulk waste can be safely emplaced at very reasonable costs. Second, the high-integrity isolation as-

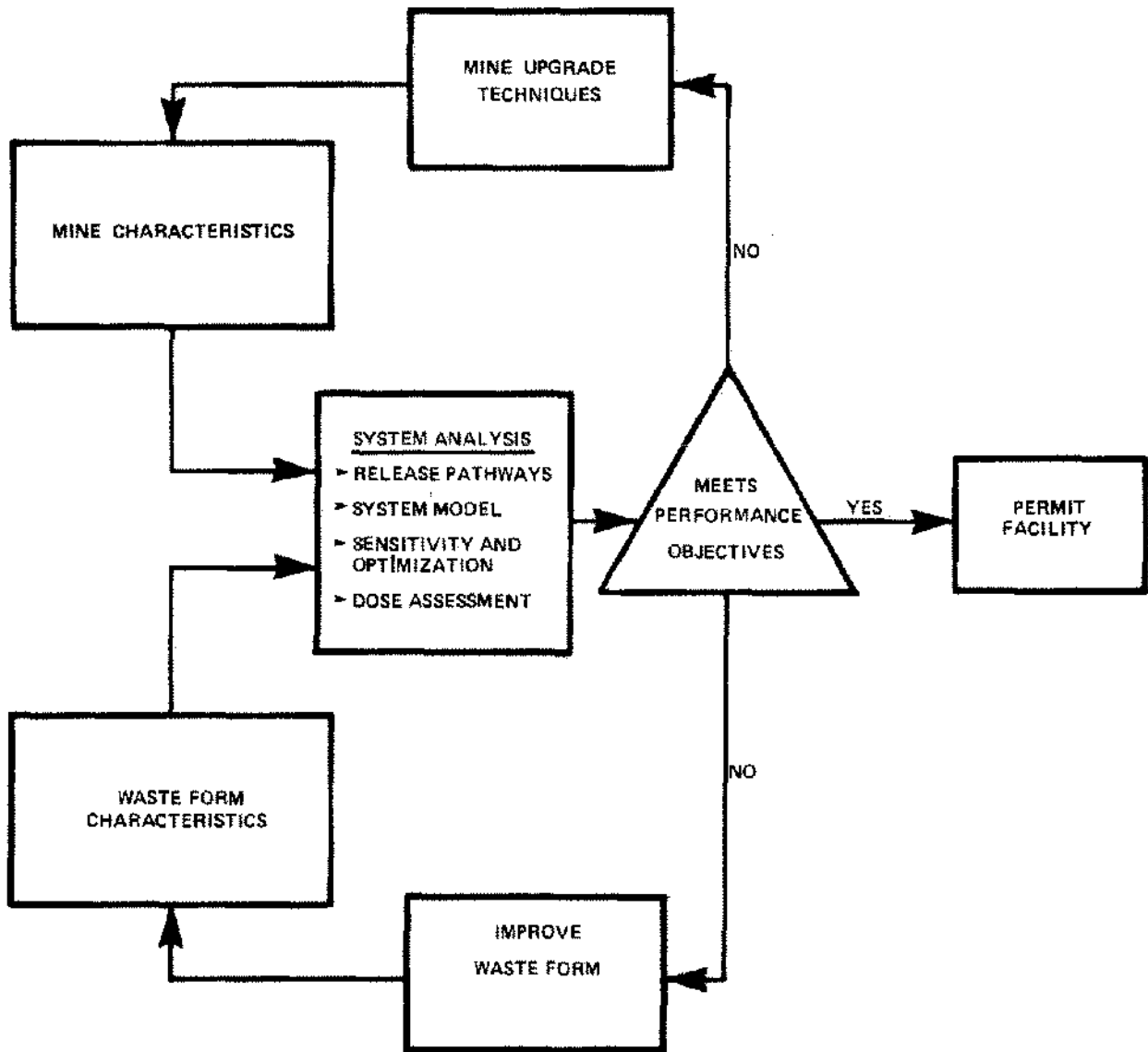


Figure 4. Alternative Means for Meeting Site Performance Objectives

pects of this approach substantially limit the operational and post-closure liability to the operator and should mitigate public opposition.

The most efficient means of handling the waste residue is to combine it with a solidification agent and transport it into cells within a mine or cavity through pipelines (Figure 3). The West Germans have successfully developed and tested the technique for radioactive waste storage in solution-mined cavities (Houmann, et al., 1982; Kraemer and Kroebel, 1982). The cells could be constructed in lifts using 100% of the mined space, thereby reducing the potential for subsidence, groundwater infiltration and leachate migration. Solid non-pumpable objects could be disposed of by placing them in the cell prior to pumping the liquid waste into the lift. When the stabilized waste solidifies the solid objects become part of the impermeable waste rock matrix.

This concept eliminates the requirement of segregated pools, drum storage, solid storage, etc. Bulk solidification would cost approximately \$13.75/bbl (25¢/gal); existing conventionally mined space should cost less than \$0.55/bbl (1¢/gal). The total cost of disposing waste delivered to the site would be approximately \$16.50 to \$19.25/bbl (30¢ to 35¢/gal) in bulk quantities.

#### Facility Isolation Trade-Offs

In the final analysis, some balance must be struck between site suitability and upgrades of the waste-form or mine (Figure 4). A systems analysis will probably determine whether the facility will require upgrading of the

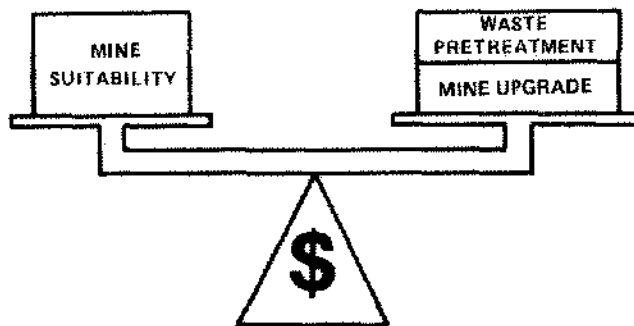


Figure 5. Facility Isolation Trade-Offs

waste-form or mine. The decision on whether to upgrade the waste-form or mine will probably be made by the operator after performing a cost-benefit analysis. It is conceivable that the cost of upgrading the mine or waste-form could dictate a move to an alternative mine (Figure 5).

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