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# Is Hazardous Waste Disposal in Clay Vaults Safe?

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**This discussion questions the safety and adequacy of clay-lined disposal pits for containing the migration of leachates from hazardous wastes into groundwater systems. The authors advocate pretreating all hazardous wastes prior to disposal to detoxify them to the maximum extent possible. Heavy metal wastes should be segregated and immobilized by fixation before burial in a dry form. Approaches are discussed for establishing criteria for monitoring, maintenance, and remedial cleanup to ensure long-term protection of public health and the environment.**

Before the passage of the Resource Conservation and Recovery Act (RCRA) in the late 1970s, there were no regulations in many parts of the country governing the land disposal of hazardous industrial by-products—solid wastes. For the most part, industry disposed of solid wastes in the least expensive way, usually in a manner similar to the disposal of municipal refuse. Most concentrated wastes in a liquid or semisolid state were dumped into pits from which evaporation and seepage took place; some liquid waste was buried in drums. There was also a considerable amount of ocean dumping of hazardous wastes.

Love Canal brought to public attention the inadequacies of such disposal practices. It, and similar waste sites, showed that placing hazardous wastes in the ground could result in contamination of both groundwaters and surface waters in the vicinity of the disposal site. The Resource Conservation and Recovery Act was enacted to provide guidance for, and control of, hazardous waste disposal to reduce public health and environmental hazards associated with future disposal areas. The act included a system for classifying materials (to identify wastes that are hazardous) and described how wastes of given categories could and could not be handled. Although there are problems with the proposed classification system,[1,2] the primary issue discussed in this article is whether permitted disposal methods afford an acceptable degree of public health and environmental protection. Government agencies, such as the US Environmental Protection Agency (USEPA) and state departments of public health and pollution control, are currently attempting to formulate hazardous waste control policies and programs that will strike a balance between the goal of public health protection and the economics of industrial production.

## Current approach

In an effort to eliminate or reduce the migration of hazardous wastes or their leachates from disposal sites, regulatory agencies have begun to specify where and how hazardous wastes can be buried. Because, with few exceptions, the migration of the components in the waste depend on the migration of water, one of the most important properties governing the safe disposal of hazardous waste is the permeability of the strata in which burial pits are located. Geologic strata with an inherent permeability to distilled or tap water of $10^{-7}$ cm/s or less are generally considered suitable for the disposal of many types of hazardous wastes. Strata with permeabilities of more than $10^{-7}$ cm/s are considered limited in their ability to contain hazardous wastes on a long-term basis, especially those with permeabilities of $10^{-5}$ cm/s or greater. There are situations, however, in which geologic strata with permeabilities of $10^{-7}$ cm/s or less contain layers or lenses with higher permeabilities. Such lenses can serve as conduits for the rapid transport of waste components from the disposal site to adjacent lands. Such sites should be considered geologically unsuitable for hazardous waste disposal and should be used only if no other site is available in the general area where the wastes are being generated.

In some parts of the United States, an ill-advised approach is being adopted in which attempts are being made to compensate for the inherently poor or unsuitable geologic characteristics of disposal sites by lining the disposal pit with a few feet of packed clay. From a technical point of view, it is a clay vault in which a

*The hazardous waste leachate evaporation-seepage pond above is located in Missouri. Leaking barrels are located throughout the United States.*

ment is either a detoxification or an immobilization process. Although it is generally accepted that acids and bases should be neutralized before burial in the ground, there appears to be some reluctance to require, for example, the destruction of cyanides and the incineration of organics before burial.

The treatment technology available today does not result in a nontoxic residue. All chemicals are toxic at some concentration, even sodium chloride, if ingested in sufficiently large amounts. The objective of preburial treatment, therefore, is not necessarily to detoxify waste completely, but to remove or immobilize the highly hazardous components of the waste that could migrate from the disposal pit to nearby groundwater systems and be consumed by animals and humans without being readily detected (Figure 2).

There are many highly toxic chemicals that can be present in hazardous wastes at concentrations not readily detectable by methods available today.[9] This leads to situations in which water could be consumed for long periods of time without anyone knowing that it was contaminated with hazardous waste components. Therefore, every effort should be made to detoxify hazardous wastes to the maximum extent possible before burial of the residues.

Of greatest concern are the myriad organic components present in wastes, many of which have unknown toxicity to humans and animals and are difficult to detect with currently available analytical methods. With few exceptions, these chemicals can be destroyed by incineration or by wet oxidation. This approach would not only reduce the toxicity of the residues, but would also greatly reduce the volume of materials that require burial.

Table 1 lists the results of a recent study[10] on the costs of alternative methods of hazardous waste treatment and disposal. The incineration and burial of residues, although somewhat more expensive than landfilling, do not appear to be prohibitively expensive. Therefore, there is little or no justification for not requiring that all potentially toxic organics in wastes be pretreated by incineration, wet oxidation, or other oxidative processes before burial.

The disposal of heavy metal wastes is somewhat more difficult because it is impossible to destroy heavy metals. The approach that must be taken is to segregate and immobilize heavy metals by precipitation, encapsulation, or other means to the maximum extent possible. Processed heavy metals and other inorganic toxic wastes should be buried in a dry form, using a multiple-liner burial pit with an appropriately designed and operated leachate collection system located between the liners. The drying of wastes by mixing them with solids, such as fly ash, or by the evaporation of the liquids does not necessarily immobilize heavy metals.

Some people believe that wastes containing heavy metals should be segregated in separate disposal cells in a clay vault burial system. This procedure would enable the eventual retrieval and processing of the wastes to recover their metal content.

Although there could be some transformation of hazardous chemicals to less harmful forms in a hazardous waste burial pit, it is unlikely that the chemicals would ever be completely detoxified. Without pretreatment, hazardous wastes disposed of by the clay vault

**TABLE 1**
*Costs of alternative methods of hazardous waste disposal*[10]

| Method | Costs* dollars/metric ton |
|---|---|
| Landfill | |
| Drums | 168-240 |
| Bulk | 55-83 |
| Land treatment | 5-24 |
| Incineration | |
| Clean high-Btu liquids | -13-53 |
| Liquids in general | 55-237 |
| Solids and highly toxic wastes | 395-791 |
| Chemical treatment | |
| Acid-base neutralization | 21-92 |
| Cyanide and heavy metals | 66-791 |
| Resource recovery | +66-264 |
| Deep-well injection | |
| Oily wastewater | 16-40 |
| Toxic rinse water | 132-264 |
| Transportation | 0.15/metric ton-mi |

*Based on information supplied by nine of the largest firms that dispose of more than 50 percent of the hazardous wastes in the United States


*A backhoe struggles against the odds to dig a pit in which drummed wastes will be stored while they wait for a cap of clay.*


*Revegetation over the cap of a hazardous waste disposal pit in Missouri cannot disguise the developing erosion that will plague future generations.*

method can pose a greater threat to public health and environmental safety than does the burial of many radioactive wastes with similar toxicity levels. Radioactive substances decay to non-radioactive substances that are typically nonhazardous. However, some common components of nonradioactive waste will never naturally transform to less toxic forms and, thus, will forever remain a potential threat to public health and the environment.

Another difference between hazardous chemical waste disposal and radioactive waste disposal is related to the relative ease of detecting potentially hazardous concentrations of radioactive materials in groundwaters and surface waters, whereas many components of chemical waste at concentrations that can be hazardous to humans are not detectable by today's analytical methods.[9]

Therefore, routine detoxification–fixation of hazardous wastes would provide greater assurance of public health and environmental protection and could, in the long run, save money. Some states, such as California, have adopted this approach.[11-14]

Some people argue that part of the ability of natural geologic strata should be used to attenuate the migration of hazardous materials or otherwise render them harmless. The state of California has recently proposed new regulations governing land disposal of wastes.[15, 16] These regulations would require a minimum of 6 m (20 ft) of natural strata with permeabilities of $10^{-7}$ cm/s or less, determined by tests with leachate, under all hazardous waste disposal pits.

## Hazardous wastes: who generates and who pays?

It is not generally understood that almost all manufactured goods generate concentrated wastes that can be highly hazardous to humans and the environment if not disposed of properly. As long as wastes are not detoxified or fixed prior to disposal, the clay vault method of disposal represents a long-term public health hazard. The barrier may retard the movement of the waste and leachate during the 30-year postclosure monitoring period prescribed by RCRA, but it is likely to fail eventually. The US Congress passed Superfund legislation to provide funds to clean up hazardous waste that has been improperly disposed of in the past, but the clay vault method of disposal virtually ensures that superfunds will always be needed, since this method, in general, does not provide a permanent solution.[17]

Ideally, a hazardous waste disposal site should pose no threat to the health of future generations using the adjacent lands. If this kind of protection cannot be provided, the use of any sites for hazardous waste disposal is tantamount to a form of condemnation of adjacent property through the restriction of future use of groundwaters and surface waters associated with the properties.

Eventually, someone must deal with the adequate disposal of hazardous wastes or with the consequences of inadequate disposal. If the current costs of goods included the costs associated with the adequate disposal of hazardous waste generated as by-products of production, the consumer would obviously pay higher prices for these goods, but consumers would also be taking responsibility for their demands for goods.

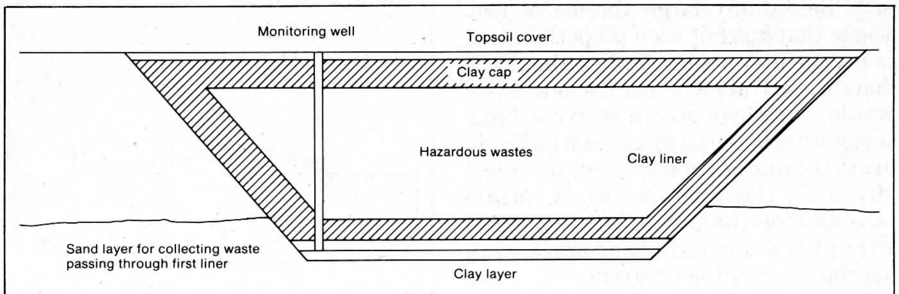


**Figure 1.** Cross-section of a proposed hazardous waste disposal pit to be located in eastern Colorado

## Clay vaults: a case study

An example of the problems associated with using a clay vault system for hazardous waste disposal was recently provided in the state of Colorado. The state department of health negotiated with a private hazardous waste disposal firm on an approach that the department thought would meet state and USEPA regulations for the clay vault method. The site is characterized by geologic strata of sand lenses with permeabilities greater than $10^{-5}$ cm/s. The Colorado health regulations governing hazardous waste disposal sites require an average permeability of the strata in which the disposal pits are to be located of no more than $10^{-7}$ cm/s. To comply with this requirement, the applicant company specified a clay liner that was somewhat thicker than required. The company agreed to placing a groundwater monitoring well in each of the sandy lenses and elsewhere, including in the sump of each disposal pit. The company also agreed to the excavation of any disposal pit that contained leachate and to the reburial of the pit's contents. Superficially, this approach conformed with the current minimum state regulations for hazardous waste disposal sites. However, it fell short of providing for a 1000-year isolation of the wastes from the environment, as specified in the Colorado Board of Health regulations governing hazardous waste disposal sites. (Colorado is one of the few states that have defined "long-term isolation" of hazardous wastes. California recently proposed that hazardous waste sites must provide for the protection of public health and the environment forever.[15])

The basic problem with the Colorado waste disposal site was that all of the safeguards built into it terminate at the end of the postclosure period, i.e., 30 years following formal closure of the site. Since the site was expected to be active for 25 years, and the custody of the site will become the responsibility of the public at the end of postclosure, there will be a 945-year period of public custody. From the end of the postclosure to the year 2982, taxpayers would bear the burden of providing funding for monitoring groundwaters at the site, maintaining the burial pit caps, and remedial measures, if necessary.

There are many problems in obtaining tax funds to enable state and local health departments to carry out their mandated responsibilities for the management of hazardous waste disposal sites. It does not appear that this situation is likely to change in the future, especially if the problems affect "only a few people" in a "remote area."

## Recommended approach

In regard to the disposal of hazardous wastes on land, the approach that would probably provide the greatest protection of public health and the environment would be to require routine detoxification or fixation prior to burial. However, this approach in some cases would be unnecessarily conservative, or expensive, or both. In the 1960s and early 1970s, progress was made toward understanding the aqueous environmental chemistry of contaminants, thereby enabling the selection of disposal sites possessing natural characteristics that would reduce the possibility of environmental contamination. In the mid-1970s, research funding in this area decreased and in the 1980s is virtually nonexistent. This means that a more experimental, empirical approach will prevail than if funding had been continued for fundamental and applied research on the interactions between contaminants and soil and subsurface strata. In light of this situation, the authors recommend the following approach for disposal of hazardous wastes.

**Testing.** First, the geologic strata of a proposed disposal site should be examined for their inherent capacity to prevent migration of hazardous components of waste to adjacent groundwaters and surface waters. Those sites with highly permeable lenses or other unsuitable characteristics should be eliminated from consideration. Only in those areas judged to be geologically acceptable should waste disposal sites be located. Highly hazardous waste components should be detoxified or fixed prior to disposal. All disposal pits should be lined on all sides and on the bottom with a double clay liner. Each liner should consist of at least 1 m (3 ft) of compacted clay with a maximum permeability of $10^{-7}$ cm/s to the type of leachate that would be generated at the site. A collection system should be installed between the liners to collect any leachate that passes through the inner liner.

Several studies[3-8] demonstrate the importance of site-specific evaluation of the clays proposed for use in liners. A liquid, representative of the leachate that could be generated at the site, would be used for the evaluation. If the disposal of free liquids would be allowed at a particular site, representative samples of the dominant types should be evaluated for their potentially adverse effect on the integrity of clay liners. If no free liquids are to be disposed of, e.g., if the free liquids are to be adsorbed on cement kiln dust or fly ash, the fixed (or, more appropriately, dried) waste should be contacted with water over an extended period of time to develop a leachate for evaluation. The common practice of evaluating the permeability of clay liners by using distilled or tap water or a dilute salt solution should not be continued until it is shown that distilled water or another solution properly simulates the permeability of the leachate and liquid wastes that would be placed at a particular site. As more is learned about the interactions of contaminants with packed clays, it will likely be possible to reduce the amount of testing necessary; however, since little is known about the long-term interactions between contaminants and liners, a conservative approach should be taken to ensure, to the maximum extent possible, that disposal at a particular site will not be a threat to public health and the environment in the future. The additional cost to the consumer of such testing, per item that generates the waste, would be trivial. The costs for this testing would also be trivial compared with the costs of exhuming and reburying the wastes at a future time.

This type of testing must be done throughout the active life of the disposal site; clays used for particular disposal pits should be tested against the leachate generated from wastes accepted at the site. Before any large volume of new waste that has not been properly tested is accepted at a site, studies should be done to ascertain whether the new waste would, of its own accord or in combination with other wastes, generate a leachate that could adversely affect the integrity of the clay liner. No permit should be issued for a hazardous waste disposal site until the applicant has completed an appropriate testing program.

A special situation occurs for existing disposal sites that have caused groundwater or surface water contamination. Since many of these sites have become part of urban centers as a result of population growth in the region, there is considerable pressure to stop all hazardous waste disposal at such sites and to move the disposal area to another, more remote location. Although there may be groundwater and surface water contamination from past disposal operations, current disposal at an existing site is normally carried out under the provisions of RCRA; i.e., clay-lined pits are used and a water quality monitoring program is practiced. Under these conditions, the additional disposal now taking place and that which will be taking place during the next few years are not likely to change the degree of hazard that the site currently represents. There is little justification in foregoing investigation of the suitability of the liners and the geologic strata for long-term containment of hazardous wastes in order to develop an alternative site for hazardous waste disposal quickly.

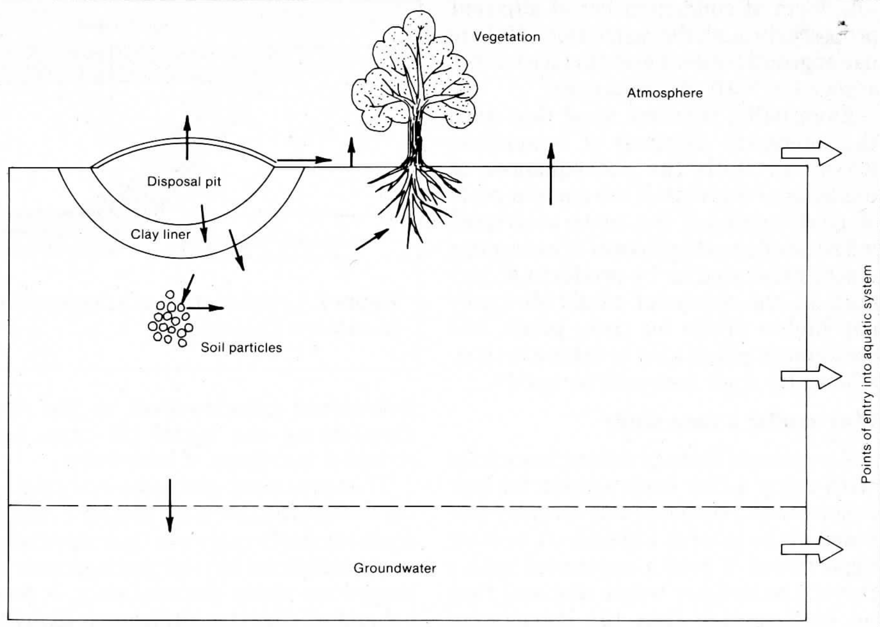


**Figure 2.** General modes of transport of hazardous wastes from the disposal pit to the environment

**Analytical requirements.** An additional aspect of monitoring hazardous waste disposal operations is the analytical methods recommended by the USEPA. For some contaminants, the USEPA-recommended analytical procedures may not be sufficiently sensitive to detect contaminant levels that could be harmful to humans. In November 1980, the USEPA released a set of water quality criteria for toxic chemicals.[18] As part of the development of critical concentrations for some chemicals, a zero threshold model was used to estimate the statistical probability of the occurrence of human cancer that a chemical could cause by being ingested as part of drinking water or food. This approach reduced the estimated critical concentrations of a number of chemicals that are frequent constituents of hazardous wastes and are also present in municipal wastes. Monitoring of groundwaters near hazardous waste or municipal solid waste disposal sites could therefore show that with analytical procedures currently approved by the USEPA, the waters would be judged safe, based on their having nondetectable concentrations of a contaminant. Yet, according to the USEPA water quality criteria, the contaminant could cause a number of incidences of cancer in people who drank the water.[9]

An example of this situation occurs for beryllium. The consumption of a well water having levels of beryllium below the limits of analytical detection could cause more than 1200 additional incidents of cancer in a population of 1 million persons because of the levels of beryllium actually present. Because this situation exists for a large number of contaminants, there is an urgent need for work on improving the sensitivity of the analytical methods used to monitor hazardous waste and municipal solid waste disposal operations.

Also, the USEPA relies heavily on monitoring total organic carbon in groundwaters as an indicator of the presence of a variety of hazardous industrial waste components. Greater use of specific component analysis of nonchlorinated organics should be required.

One means of funding research to develop analytical procedures for measuring hazardous waste components would be to tax all hazardous waste disposal operations and to earmark the funds for research in this area. Improved analytical methods would enable the detection of potentially hazardous concentrations of contaminants in waters near hazardous waste disposal sites or municipal solid waste landfills.

Some of these funds should also be devoted to research for determining the hazard that chemicals in hazardous wastes represent. A tax of a few dollars per ton of hazardous waste would generate a sufficient endowment for a meaningful research program, yet would not significantly add to the total cost of hazardous waste disposal. A recent suggestion was to levy such a tax in proportion to the hazard that the wastes at a particular site represent.[19]

**Monitoring and maintenance endowment.** As part of the siting of a disposal facility and obtaining the initial permits for operation of the site, a funding mechanism to provide for monitoring, maintenance, and remedial programs should be required. The future residents or users of lands adjacent to a hazardous waste disposal site should not have to rely on county commissioners and state legislators to provide funds to protect their health and welfare in view of past disposal practices permitted under RCRA and state and local regulations. It seems appropriate to ensure that a sufficient endowment is available for the monitoring and maintenance of the site forever. This endowment should be sufficient to allow for the complete excavation of the site, if that is deemed necessary, and the proper disposal of the wastes either by detoxification or by burial at a geologically suitable site.

Such an endowment could be accomplished by levying a disposal fee against those industries generating the wastes. If a particular site should prove to retain the wastes over a 500- to 1000-year period, the endowment could be used to help clean up other sites or to fund other projects related to environmental quality. This would pass on an asset rather than a liability to future generations. Further, and most importantly, it would protect the health and welfare of current and future generations.

Some people argue that it is impossible to predict the amount of money necessary at some future time to monitor and maintain, as well as to provide a remedial control program for, a hazardous waste disposal site. Although such a prediction cannot be made with certainty, it can be made with enough reliability to reduce the financial burden imposed by hazardous wastes on future generations. Further, because few new sites permitted under RCRA would likely be active for less than about 20 years, it would be possible to make adjustments in the amount of the user's fee during the active life of the site as knowledge is gained on how to make better estimates of the costs of operating and maintaining disposal sites.

Carden[20] conducted a review of the potential hazard of a proposed hazardous waste disposal site in Georgia. As part of the review, information was presented on the cost of maintaining burial pit caps for an existing site in Kentucky. In this case, it was found that postclosure costs for 200 years would range from $16.2 million at 0 percent inflation to $154 trillion at a 10 percent inflation rate. Based on the amount of money typically set aside for maintenance, this would require the public to pay from 85 to 100 percent of the cost of maintenance, with 0 to 15 percent of these costs paid by the operator of the site. Although the cost of maintaining a disposal site is site-specific, it is evident that the cost is large. Failure to provide proper monitoring, maintenance, and remedial measures at a site means that eventually the health and welfare of the residents and the environment near sites will be jeopardized.

The cost of the presiting testing, monitoring, maintenance, and remedial contingency funds will be passed on to the consumers or taxpayers. If an endowment fund is established early, and if proper preburial treatment and monitoring are carried out, the additional cost for most goods per item should be small compared with the costs and consequences of massive environmental contamination and remedial cleanup efforts. If the additional costs are greater for a particular item, the value of that particular item to society should be evaluated. If it is deemed valuable, manufacturing procedures that would result in less waste and less hazardous waste should be investigated. There would be impetus for establishing a pricing system for disposal that considers not only the volume but also the hazard of the waste.[19] Adoption of such a pricing structure would likely result in industry's developing manufacturing processes or waste pretreatment processes so that less hazardous waste would have to be disposed of by burial in clay vaults.

**Municipal solid wastes.** Until recently, appreciable amounts of hazardous industrial wastes were disposed of in municipal solid waste landfills, typically located in low-lying areas. In many instances, these were wetlands or lands with a shallow water table, which has led to the contamination of the groundwaters. Insufficient attention has been given by regulatory agencies at the state and federal levels to evaluating the hazard that municipal landfills represent. These sites may be just as hazardous as many waste sites now earmarked for Superfund cleanup operations.

The post-RCRA regulations governing the disposal of solid wastes do not give adequate attention to municipal solid waste disposal. Many of the chemicals that cause industrial solid wastes to be classified as hazardous are also present in municipal solid wastes. Although the amounts of these chemicals in municipal solid waste are generally less than in hazardous wastes, their mobility from the disposal site tends to be greater. There is therefore a need to monitor contaminant migration from municipal landfill operations. In addition, new municipal landfill operations should be required to adopt many of the approaches now required for industrial hazardous waste disposal.

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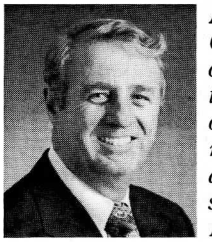


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