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THE MANAGEMENT OF SOIL SYSTEMS FOR THE DISPOSAL OF INDUSTRIAL WASTES

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ABSTRACT

Research continues to provide improved information about the toxicity of materials, their transport in soil, and the kinetics of detoxification that is most useful in evaluating alternative approaches for safely managing industrial wastes. The placement of industrial wastes into soil systems is a satisfactory management approach if the material is nontoxic, if the soil has the capability of detoxifying the material, or if the soil prevents the material from entering the biosphere. Examples from the literature of successful applications of industrial wastes to soil are discussed.

Introduction

The disposal issues associated with industrial waste management become more complex each year with the proliferation of materials and with increased knowledge of the behavior of materials in the environment. In recent years waste management

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issues have been extensively discussed in the public arena (Litchfield et al., 1976; Epstein and Chancy, 1978; Maugh, 1979a and 1979b). The result has been improved legislation to control disposal of materials. This legislation has defined the options available to industry for various classes of materials. The most frequently used options are landfill, incineration, biological treatment in domestic sewage treatment plants, engineered repositories, deep well disposal, or land application.

Improper waste management can have very significant impacts. To vividly demonstrate this statement, I only need to mention the words "Love Canal." The legislative ramifications of past actions of improper waste management are many. "Superfund" is a legislative approach to correct past mistakes where land was improperly used for waste management. Detailed regulations developed as a consequence of the Resource Conservation and Recovery Act of 1976 are an attempt to prevent the improper disposal of materials in the future.

In spite of the occasions where soil systems have been improperly utilized as a waste management agent, soil systems can and should play an important role in management of a limited number of industrial wastes. This article discusses the legislative, economic, and technical factors influencing the selection of soil as an alternative for disposal of industrial wastes.

Legislative

The objective of waste management legislative action is to protect the environment and at the same time to provide guidance so that all companies within an industry must meet the same disposal requirements. Numerous examples of local, state, and federal legislation could be quoted that are available for restricting indiscriminate waste disposal by industry. An extremely important example is the U.S. Resource Conservation and Recovery Act of 1976. This Act is aimed at improving waste management of hazardous wastes. The Act defines hazardous wastes as "a solid waste, or combination of solid wastes which, because of its quantity, concentration, or physical, chemical, or infectious characteristics may:

- cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness, and
- pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed.

Hazardous waste for the purpose of this regulation possesses one of the following characteristics: ignitable, corrosive, reactive, or toxic.

The Act specified acceptable standards for surface impoundments or landfills for hazardous materials. These standards are developed to minimize movement from the disposal site to the groundwater through the use of natural (soil) or artificial barriers (man-made materials) and do not rely on soil properties other than permeability for retarding movement.

The section of the Act discussing landfarming is given in Appendix A. Examples of hazardous wastes that are not generally acceptable for landfarming are ignitable, corrosive, reactive, or mixtures of wastes that are not compatible when mixed. Examples of hazardous wastes that are acceptable are those that can be made less hazardous or non-hazardous by biological degradation or chemical reactions occurring in or on the soil. If an industrial waste is not classed as hazardous, the plant operator may dispose of the waste using less stringent disposal practices than outlined in the Resource Conservation and Recovery Act of 1976.

Economic

In evaluating the alternative options for managing waste, industry will generally select the most cost-effective, all other factors being equal. Costs incurred in disposal are highly site specific (Barrier et al., 1978). The cost-effectiveness of viable options is beyond the scope of this paper but is a critical step in the selection of the disposal method by an industry.

Technical

The factors influencing transport and plant availability of organic and inorganic wastes through soil and their importance have been discussed earlier in this book. The principal factors are soil pH, organic matter content, cation exchange capacity, rainfall patterns, temperature, aeration, time, soil permeability, and material to be disposed of. The interaction of these items and others has been used by Phillips and Nathwani (1977) to provide a tool for determining site suitability for the disposal of industrial wastes.

Soil plays an important role when an industrial waste is placed in either a landfill or placed on the soil using a technique called landfarming. The fate of industrial waste depends on the factors enumerated above. Landfarming reduces the potential for groundwater contamination more than the landfill technique because it reduces the quantity of material available for transport to the groundwater. In both cases the mobility and fate of the waste depends on the properties of the waste in relation to the soil properties enumerated above. Landfarming is particularly effective for wastes that are amenable to biodegradation into plant nutrients, humus, carbon dioxide, water, and innocuous salts. The technique involves three basic steps: application of wastes onto or beneath surface soil, aerating the mixture of wastes and soil to provide conditions conducive for the multiplication of aerobic bacteria, and addition of amendments such as fertilizer to accelerate the decomposition process. Landfill is essentially placing the industrial wastes in trenches and covering them up.

Landfarming has been practiced by industry in areas where land is readily available. Materials that have been landfarmed include petroleum refinery sludges (Phung and Ross, 1979; Huddelston and Meyers, 1979; Overcash and Pal 1979; Raymond, Hudson and Jamison, 1979; Grove, 1978; Knowlton and Rucker, 1979; Huddelston, 1979), pharmaceutical wastes (Swan, 1979; King and Vick, 1978), vegetable wastes (Stephenson and Guo, 1977), dairy products (Pico, 1978; Watson, Peterson and Walker, 1978; Anon, 1980), steel (Dawson, 1980), and chemicals (Rogers and Allen, 1978; Overcash, et al. 1979; Barrier, Faucett, and Henson, 1978).

The petroleum industry has documented its experience with landfarming in the open literature more extensively than most others. Other industries are utilizing landfarming but generally describe the results in reports to regulatory agencies and their company's management. The experience in the petroleum industry over the past 25 years (Grove, 1978; Knowlton and Rucker, 1979; and Huddleston, 1979) has been good. The technique is preferred by the industry for the management of waste sludges and petroleum-containing solutions because of the minimum energy requirement for implementation and operation. The industry has considered and obtained data on decomposition rate, vegetative response, odor, and flammability. Application rates generally range from less than 200 barrels/year/acre to more than 600 barrels/year/acre. The frequency of application of oily wastes varies widely from only one application to a site to multiple applications as frequently as once per week. The decomposition rate is site specific but can be as high as 50% per year. Subsurface samples indicate that if landfarming is operated correctly, neither heavy metals nor oil are very mobile. Trace metal analysis of vegetation growing on oiled areas is generally similar to control locations. Odor is reduced and minimal once the oily waste is blended with the soil. After the wastes are mixed with the soil they are generally not flammable. Modifications of the landfarming technique are under development. Rogers and Allen (1978) discuss the experimental disposal pit for pesticides under investigation by C. V. Hall and his colleagues at Iowa State. The pit prevents the movement of material into the water tables while allowing biodegradation of the material. This approach could be utilized for a variety of mobile biodegradable materials that would otherwise be required to be placed in costly engineered landfills.

Another development, fixation of materials, may result in land application of materials following alteration. Salas (1979) describes the use of chemical fixation and solidification to produce a nontoxic, environmentally safe material that can be used as landfill. Similar techniques have been used with waste from petrochemical, textile, automotive, steel, and chemical industries.

An example from the pulp and paper industry provides a very positive note to close this presentation. Eberhardt, Lewis, Scharp and Barton (1978) describe how a waste material became a product sold for its fertilizer value. To achieve this conversion required (1) extensive engineering developments to convert the waste into a commercially acceptable material, (2) detailed plant nutrient evaluation and testing, and (3) appropriate biological safety tests. The initial condition was a sulfite pulp mill in Pennsylvania landfilling waste-activated sludge from the secondary treatment of plant wastes. This wet, sticky activated sludge was 16 to 18% solids. Trucking this wet material to the landfill caused continuous housecleaning problems at the pickup point, along the road to the site, and at the site. The large amount of water at the landfill aggravated operating conditions by creating odor and leachate problems. Because the sludge had a significant nutrient value, a better solution was sought.

The approach utilized by the Proctor and Gamble Paper Products Company included nutrient analyses, commercial market evaluation, grant-in-aid to the Pennsylvania State University for agronomic testing, and engineering evaluation for product development. The final result is a 13.3 ton/day production rate of a uniformly sized material with uniform nutrient content that is sold as a fertilizer. The heavy metal content of the material is low as would be expected because the waste stream for the treatment plant is essentially from trees. The net cost to the company for a useful commodity is similar to landfill costs.

Conclusions

A number of options are available to industry for disposing of wastes. Landfarming is a viable and useful technique for disposing of a small fraction of industrial wastes. The waste materials best suited for landfarming are either inert or readily biodegradable to nontoxic material. Biodegradation is most effective if the soil system remains aerobic, the soil is not frozen and the pH is greater than 6.5. Hazardous materials should only be landfarmed under very special situations. Instead, they should be placed in repositories consistent with specifications for hazardous wastes outlined in the U.S. Conservation and Recovery Act of 1976. These repositories have low permeability materials to minimize mobility of materials.

Literature Cited

Anon. 1980. Sludge management in food processing: in search of a better whey. Sludge 3: 30-35.

Barrier, J. W., H. L. Faucett, and L. J. Henson. 1978. Economic assessment of FGD sludge disposal alternatives. Journal of the Environmental Engineering Division, Proceedings of the American Society of Civil Engineers 104: 951-965.

Dawson, R. A. 1980. Sludge management in the iron and steel industry: steelmakers eye sludge recycling as more Federal rules approach. Sludge 3: 36-43.

Eberhardt, W. A., J. L. Lewis, R. A. Scharp, and C. A. Barton. 1978. Water Pollution Control Federation Journal 50: 1893-1904.

Epstein, E., and R. L. Chaney. 1978. Land disposal of toxic substances and water-related problems. Water Pollution Control Federation Journal 50: 2037-2042.

Goodwin, R. W., and R. J. Gleason. 1978. Options for treating and disposing of scrubber sludge. Combustion 50: 37-41.

Grove, G. W. 1978. Use land farming for oily waste disposal. Hydrocarbon Processing 57: 138-140.

Huddleston, R. L. 1979. Solid-waste disposal: landfarming. Chemical Engineering 86(5): 119-124.

Huddleston, R. L. and J. D. Meyers. 1979. Treatment of refinery oily wastes by land farming. In Water - 1978. AIChE Symposium Series 75: 327-339.

King, L. D., and R. L. Vick. 1978. Mineralization of nitrogen in fermentation residue from citric acid production. Journal of Environmental Quality 7: 315-318.

Knowlton, H. E., and J. E. Rucker. 1979. Landfarming shows promise for refinery waste disposal. Oil and Gas Journal 77: 108-112.

Litchfield, J. H., J. L. Graham, R. M. Soderquist, J. E. Germain, W. L. Stover, R. A. Morrell, and G. W. Gove. 1976. Industrial wastes. Water Pollution Control 48: 1217-1318.

Maugh, T. H. 1979a. Toxic waste disposal- a growing problem Science 204: 819-823.

Overcash, M. R., H. C. Klose, D. Rock, R. Marshburn, and D. Pal. 1978. Pretreatment land application of textile plant wastes. In Water - 1977. AIChE Symposium Series 75: 163-174.

Overcash, M. R. and D. Pal. 1979. Plant-soil assimilative capacity for oils. In Water - 1978. AIChE Symposium Series 75: 357-361.

Phillips, C. R., J. S. Nathwani, and H. Mooij. 1977. Development of a soil-waste interaction matrix for assessing land disposal of industrial wastes. Water Research 11: 859-868.

Phung, H. T., and D. E. Ross. 1979. Soil incorporation of petroleum wastes. In Water - 1978. AIChE Symposium Series 75: 320-326.

Pico, R. F. 1978. Industrial wastes: dairy wastes. Water Pollution Control Federation Journal 50: 1291-1293.

Raymond, R. L., J. O. Hudson, and V. W. Jamison. 1979. Land application of oil. In Water - 1978. AIChE Symposium Series 75: 340-349.

Rogers, C. J., and R. Allen. 1978. Developing technology for detoxification of pesticides and other hazardous materials. American Chemical Society Symposium Series 73: 100-111.

Salas, R. K. 1979. Disposal of liquid wastes by chemical fixation/solidification: the Chemfix process. Toxic and Hazardous Waste Disposal 1: 321-348.

Santhanam, C. J. R. R. Lunt, S. L. Johnson, C. B. Cooper, P. S. Thayer, and J. W. Jones. 1979. Health and environmental impacts of increased generation of coal ash and FGD sludges. Environmental Health Perspectives 33: 131-157.

Stephenson, J. P., and P. H. M. Guo. 1977. State of the art review of processes for treatment and reuse of potato wastes. Environment Canada and Economic and Technical Review Report EPS 3-WP-77-7.

Swan, R. 1979. Pharmaceutical industry sludge: drug makers face waste management headache. Sludge 2: 21-25.

Watson, K. S., A. E. Peterson, and W. S. Walker. 1978. Effect of whey application on chemical properties of soils and crops. <u>In</u> Water - 1977. AIChE Symposium Series 74: 176-185.

Appendix A

U. S. Resource Conservation and Recovery Act
(43 Fed. Reg. 59013)

Sect. 250.41(46)- Landfarming of a Waste means application of waste onto land and/or incorporation into the surface soil, including the use of such waste as a fertilizer or soil conditioner. Synonyms include land application, land cultivation, land irrigation, land spreading, soilfarming, and soil incorporation.

Sect. 250.45-5-Landfarms

(a) Hazardous waste not amenable to landfarming.

1. Ignitable waste
2. Reactive waste
3. Volatile waste
4. Waste which is incompatible when mixed

[Note: Exceptions are allowed.] (Where exceptions are allowed in these regulations, the burden of proof is on the owner/operator.)

(b) General requirements

1. A landfarm shall be located, designed, constructed, and operated to prevent direct contact between the treated area and navigable water.

2. A landfarm shall be located, designed, constructed, and operated to minimize erosion, landslides, and slumping in the treated area.

3. A landfarm shall be located, designed, constructed, and operated so that the treated area is at least 1.5 meters (5 feet) above the historical highwater table. [Note: exceptions allowed].

4. The treated area of a landfarm shall be at least 150 meters (500 feet) from any functioning public or private water supply or livestock water supply. Note: exceptions allowed if:
(i) No direct contact will occur between the treated area of the landfarm and any functioning public or private water supply or livestock water supply;
(ii) No migration of hazardous constituents from the soil in the treated area of the landfill to any public or private water supply or livestock water supply will occur; and
(iii) A soil monitoring system as specified in Sect. 250.45-5(e) has been installed and is being adequately maintained.

5. A landfarm shall be located on an area that has fine grained soils (i.e., more than half the soil particles are less than 73 microns in size) which are one of the following types, as defined by the Unified Soil Classification System (ASTM Standard D 2487-69): OH-organic clays of medium to high plasticity: CH-inorganic clays of high plasticity, fat clays; MH-inorganic silts, micaceous or diatomaceous fine sandy or silty soils,

elastic silts; CL-inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays; OL-organic silts and organic silt-clays of low plasticity. [Note: exceptions allowed.]

(c) Site preparation

1. Surface slopes of a landfarm shall be less than 5%, to minimize erosion in the treated area by waste or surface runoff, but greater than 0% to prevent the waste or water from ponding or standing for periods that will cause the treated area to become anaerobic. [Note: exceptions allowed.]

2. Caves, wells (other than active monitoring wells) and other direct connections to the subsurface environment within the treated area of a landfarm, or within 30 m (100 ft) thereof, shall be sealed.

3. Soil pH in the zone of incorporation shall be equal to or greater than 6.5 [Note: exceptions allowed.]

(d) Waste application and incorporation

1. Waste application and incorporation practices shall prevent the zone of incorporation from becoming anaerobic.

2. Waste shall not be applied to the soil when it is saturated with water. [Note: exceptions allowed.]

3. Waste shall not be applied to the soil when the soil temperature is less than or equal to 0°C.

4. The pH of the soil-waste mixture in the zone of incorporation shall be equal to or greater than 6.5 and maintained until the time of facility closure. [Note: exceptions allowed.]

5. Supplemental nitrogen and phosphorous added to the soil of the treated area, for the purpose of increasing the rate of waste biodegradation, shall not exceed the rates of application recommended for agricultural purposes by the U. S. Dept. of Agricultural Extension Service.

(e) **Soil monitoring**

1. Background soil conditions shall be determined by taking one soil core per acre in the area to be treated. The depth of the soil core shall be three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater. The bottom one third of the soil core shall be quantitatively analyzed for those constituents known or expected to be in the waste which make it hazardous. At new facilities, soil cores shall be taken and analyzed prior to beginning operation. At existing facilities, background soil cores shall be taken and analyzed within six months after the effective date of these regulations.

2. Soil conditions in the treated area of a landfarm shall be determined by taking one soil core per acre semiannually. The depth of the soil core shall be three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is

greater. The bottom one third of the soil core shall be quantitatively analyzed for the constituents in the waste which make it hazardous. [Note: exceptions allowed.]

3. If soil monitoring shows that the concentration of a hazardous constituent in the bottom one third of the soil core has significantly exceeded the background levels established in accordance with paragraph (e)(1), the owner/operator shall:

(i) Notify the Regional Administrator within seven days;

(ii) Determine, by soil monitoring, the areal extent of vertical contaminant migration in the soil; and

(iii) Discontinue all landfarming in the contaminated area, as determined in (ii), until corrective measures can be taken.

(f) Growth of food-chain crops

Food-chain crops shall not be grown on the treated area of a landfarm.

(g) Closure

1. A landfarm shall be designed and operated so that, by the time of closure, the soil of the treated area(s):

(i) Is returned to its pre-existing condition, as established in paragraph (e)(1) if the facility began operation after promulgation of this requirement (i.e., a new facility).

(ii) Is returned to equivalent pre-existing condition, as determined by soil analysis of similar local soils that have not had hazardous waste applied to them, if the facility began operation prior to the promulgation of this requirement (i.e., an existing facility). Soil analysis of similar local soils shall not be required at existing facilities if background soil data are available and those data establish background conditions for the treated area(s).

2. Soil of the treated area(s) of a new or existing facility that does not comply with paragraph (g)(1)(i) or (ii), respectively, shall be analyzed to determine whether it meets the characteristics of a hazardous waste as defined in Subpart A [43 Fed. Reg. 58954]. In the event the soil is determined to be a hazardous waste, it shall be removed and managed as a hazardous waste in accordance with all applicable requirements of this Part. [Note: exceptions allowed.]