APPENDIX F

BASIC HAZARDOUS WASTE MANAGEMENT TECHNOLOGIES

This appendix provides basic information on the typical characteristics and sizes of hazardous waste management technologies or facilities. This information will assist in understanding the environmental implications of each type of facility, helping to identify general areas appropriate for locating those facilities (based on draft siting criteria) found to be needed in Alameda County.

For each of the six technology groups, the information provided in this section includes:

- o The purpose of the technology (e.g., solvent recovery reclaims solvents from a liquid organic waste stream)
- o The types of wastes to which the technology applies
- o A listing of specific technologies which are considered part of the category (if applicable)
- o How a typical facility would look to an observer
- o A typical facility's annual operating capacity (in tons of hazardous waste per year), truckloads of waste per week, and number of employees (information is provided for large and small facilities)
- o The controls that would be employed at a typical facility to prevent releases of hazardous substances to the environment.

In evaluating the implications of siting these facilities, it is important to understand that these technology groups are often combined. For instance, tank and drum storage will almost always be combined with recycling, treatment, or residual repository facilities. Residual repositories may have solidification capabilities. Recycling facilities typically have treatment units (e.g., incinerators, tank treatment) to manage those materials which cannot be recovered. The size of the facility (i.e., acres of land) may not increase proportionally as different types of waste management units are added to it, because support services and loading and unloading facilities would probably operate for the entire facility. Because the individual descriptions of the technology groups cannot account for all the different ways to combine facility types, each group is described separately.

Table F-1 presents data on typical sizes of onsite and offsite facilities of various kinds. The ability of a non-subsidized entity to profitably operate a commercial offsite facility at the small, medium, and large scales cited in Table F-1 will vary according to market conditions and regulatory requirements. However, it presumably would not be economically feasible for a non-subsidized entity to operate profitably a commercial offsite facility smaller than the smallest units sited in Table F-1.

DRUM STORAGE/TRANSFER

Drum storage and transfer facilities are usually combined. These facilities offer storage services to generators of hazardous wastes and contract with haulers to periodically take the wastes to treatment, recycling, or disposal facilities. Usually, transfer stations serve as a central location for the collection of small quantities of wastes, combining like wastes when the quantities become large enough to be economically shipped to another waste management facility.

Typical drum storage and transfer facilities have a truck loading and unloading area and a series of concrete pads on which 55-gallon drums are stored. Transfer facilities may also have tank storage. The pads and the areas around the tanks contain concrete berms to prevent wastes from migrating from the storage area. All incompatible wastes (e.g., wastes that can react with each other) are stored in separate areas. Facilities are typically equipped with air monitoring and control systems to identify and limit any volatile and particulate emissions.

Facilities may be required by RCRA and the Regional Water Quality Control Board to have a groundwater monitoring system.

A typical transfer station occupies from 1 to 10 acres and has between 2 and 10 employees. Waste flows to and from these facilities range from 10,000 to 40,000 tons annually. This could involve weekly incoming traffic ranging from 6 to 75 (or more) trucks.

AQUEOUS TREATMENT PROCESSES

Many treatment processes can be used for liquid hazardous wastes. These processes fall into three categories: physical, chemical, and biological treatment.

Physical treatment processes either separate the water from the waste stream or prepare it for further treatment. Processes for organic waste streams (e.g., wastewater contaminated with solvents or other organic material) includes distillation, evaporation, steam stripping, gravity settling, flotation centrifugation, reverse osmosis, carbon/resin absorption, and solvent extraction. Physical processes for inorganic wastes (e.g., metals and caustic wastes) include gravity settling, flotation and centrifugation, filtration, and flocculation.

Chemical treatment processes either destroy or reduce the concentration of the waste stream by separating out hazardous constituents. These processes are used to treat organic and inorganic wastes. They include chemical dechlorination, wet air oxidation, chemical oxidation, precipitation, ion exchange, reduction, and neutralization.

TABLE F-1

TYPICAL TREATMENT FACILITY SIZES[a]

Conventional Aqueous Treatment[b]	Size (Tons/Year)
Small Treatment Facility	70,000
Medium Treatment Facility	175,000
Large Treatment Facility	350,000
Stabilization/Solidification[c]	
Small Treatment Facility	50,000
Medium Treatment Facility	125,000
Large Treatment Facility	250,000
Incineration - Rotary Kiln[d]	
Small Treatment Facility	30,000
Medium Treatment Facility	60,000
Large Treatment Facility	100,000
Incineration - Cement Kiln[e]	
Small Treatment Facility	15,000
Medium Treatment Facility	35,000
Large Treatment Facility	85,000
Wet Air Oxidation[f]	
Small Treatment Facility	5,000
Medium Treatment Facility	15,000
Large Treatment Facility	40,000
Residuals Repository[g]	
Small Treatment Facility	75,000
Medium Treatment Facility	170,000
Large Treatment Facility	360,000

NOTES:

a All treatment facilities were sized using the following basic assumptions:

- One gallon of waste weighs 8.34 pounds.
- All facilities will operate 330 days per year.
- All facilities will operate on a 24-hour/day basis.

TABLE F-1 - Page 2

TYPICAL TREATMENT FACILITY SIZES

b Conventional aqueous treatment sizing was based on:

50,000 gpd - small
125,000 gpd - medium
250,000 gpd - large
and rounded up slightly

c Stabilization/Solidification sizing was based on:

150 tpd - small
300 tpd - medium
600 tpd - large
However, these facilities can be tailored to almost any scale.

d Rotary kiln incineration sizing was based on the following additional assumptions:

50 million BTU/hr 1,000 gal/hr = 33,000 TPY - small
110 million BTU/hr 2,200 gal/hr = 72,600 TPY - medium
250 million BTU/hr 5,000 gal/hr = 165,000 TPY - large

e Cement kiln incineration sizing was based on the following additional assumptions:

10,000 BTU/pound or 80,000 BTU/gallon
36 million BTU/hr 470 gal/hr = 15,000 TPY - small
85 million BTU/hr 1,100 gal/hr = 35,000 TPY - medium
206 million BTU/hr 2,700 gal/hr = 85,000 TPY - large

Also note that for cement kilns, typically only forty percent of material burned is hazardous waste liquid.

f Wet air oxidation facility sizing was based on:

3,600 gpd - small
10,800 gpd - medium
28,800 gpd - large

g Residuals repository facility sizing was based on a previously published document entitled, "Residuals Repository - Conceptual Design and Feasibility Study," by C.E. Schubert, Ph.D. (D'Appolonia Waste Management Services) for Southern California Hazardous Waste Management Project, February 1984.

Source:
The Problems and Needs for the Management of Hazardous Wastes in Southern California, Prepared for the Southern California Hazardous Waste Management Project by Louis Berger and Associates, Inc., San Bernardino, January 1985.

Biological treatment processes increase degradation of the hazardous constituent by mixing microbes with the liquid waste stream. These processes are primarily used to treat organic wastes. Biological treatment processes include activated sludge, trickling filter, aerated lagoons, waste stabilization ponds, and anaerobic digestion. Processes with lagoons and ponds will not be permitted to operate after 1992.

Figures F-1 through F-3 illustrate the basic approach used in three kinds of aqueous treatment.

<u>Precipitation: Treatment of Waste Metal Solutions</u>

This common process is used in aqueous waste streams that contain heavy metals. The acidity (pH) of the waste stream is adjusted, usually by the addition of either an acid or caustic (alkalies). Oxidation or reduction of the waste stream may be required before pH adjustment. This causes the metals to form insoluble salts (precipitates) which are subsequently removed from the solution. The byproducts of precipitation are metallic oxide salts in the form of sludges. This process is easy to operate and relatively inexpensive. Precipitation can reduce wastes by 50 to 60 percent. See Figure F-1.

<u>Neutralization</u>

In this process, an aqueous stream (containing no metallic contaminants) with either a high or a low pH is neutralized by the addition of acid or caustic. The potential byproduct of neutralization is an inert salt that usually can be disposed of via Class III disposal. Neutralization can also be used to stabilize inorganic compounds and to reduce the reactivity or corrosivity of the waste. An 85 to 100 percent waste reduction can be achieved by neutralization. See Figure F-2.

<u>Carbon Adsorption: Treatment of Aqueous Organic Wastes</u>

In this process an aqueous stream containing relatively low levels of organic compounds, such as pesticides, are exposed to powdered, activated carbon. The organics are attracted to and captured on the surface of the highly porous carbon and thus removed from the waste stream. When the carbon reaches its capacity to hold organics it can either be replaced or regenerated to its original condition. (Carbon regeneration is costly and only feasible for very large carbon adsorption systems.) The spent carbon can be either disposed in a Class I landfill or incinerated. Carbon adsorption can achieve an 80 to 100 percent reduction of contaminants, depending on the type of organic contaminant. See Figure F-3.

The annual operating capacity of typical aqueous treatment facilities range from 70,000 to 350,000 tons. A small unit may typically cover between 5 to 7 acres, and a larger facility may occupy between 10 and 30 acres. Such facilities may employ between 15 and 40 employees. A facility with an annual capacity of 70,000 tons would have approximately 84 truck (4,000 gallons each) deliveries each week.

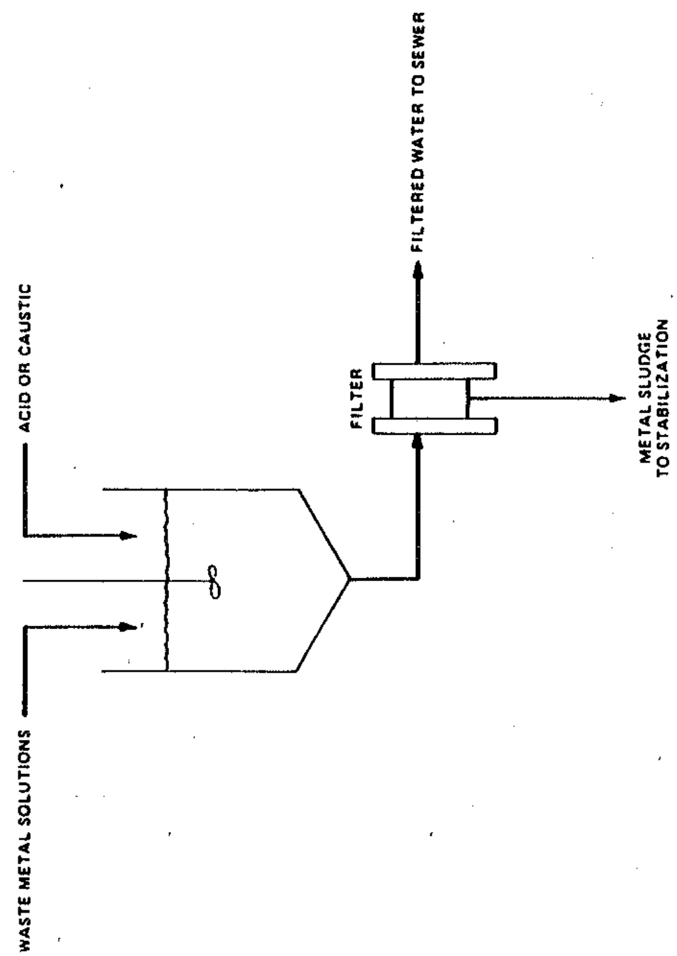

Figure F-1
TREATMENT OF WASTE
METAL SOLUTIONS

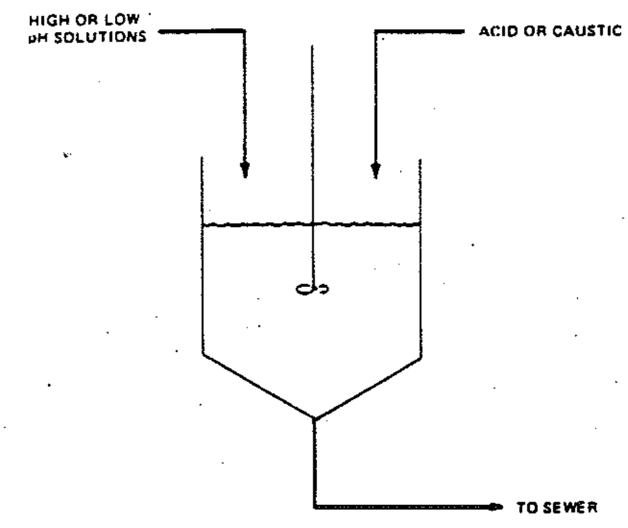

Figure F-2
TREATMENT OF WASTE HIGH OR LOW
pH SOLUTIONS

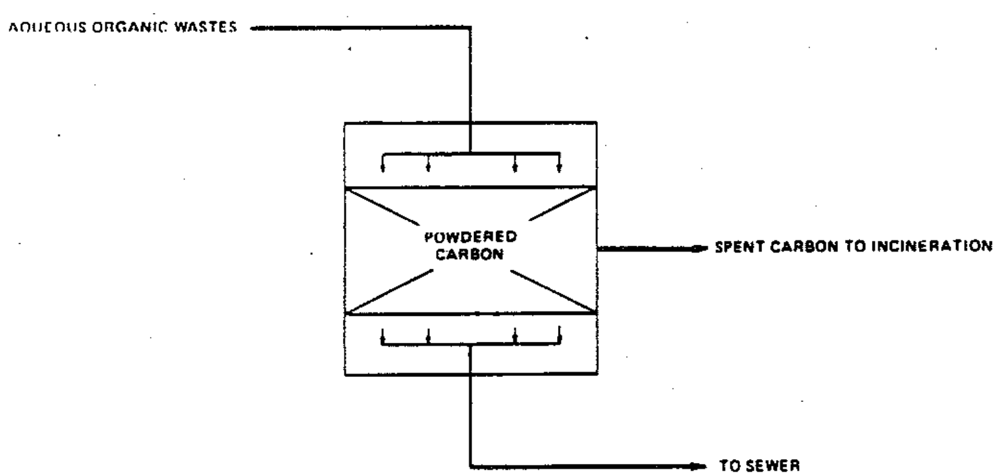

Figure F-3
TREATMENT OF AQUEOUS
ORGANIC WASTES

An aqueous treatment facility consists of holding tanks with containment berms, pipelines, and several groups of other tanks in which the various treatment processes occur. Wastes received by the facility are analyzed and placed in an appropriate tank.

Treated wastewater effluent is discharged either to a sanitary sewer or to an evaporation pond. The sludges formed are sent to an incinerator or to a biological waste converter, or are stabilized for subsequent land disposal.

In most cases, tanks would have roofs to minimize air emissions. Furthermore, the tanks would be surrounded by berms and placed on concrete pads to prevent surface and groundwater releases. Groundwater monitoring may be required.

SOLVENT AND OIL RECYCLING

Several technologies are available for both solvent and oil recycling. These include distillation, solvent extraction, carbon/resin absorption, ultrafiltration, filtration, and reverse osmosis. Each technology separates the solvent or oil from the aqueous solution so that the product can be recovered.

From the surrounding area, a typical solvent or oil recovery facility looks like a small modern petroleum products refinery. The observer would see storage tanks, pipelines, distillation towers, a few industrial buildings, and a warehouse-style building with trucks entering to load and unload materials. Storage tanks are surrounded by berms to contain spills.

Small facilities process between 10,000 to 15,000 tons of materials annually, and occupy from one to three acres of land. Larger facilities can process up to 40,000 tons of hazardous wastes a year and require as much as 10 acres. A large facility may employ up to 60 people.

Vapors from this process are destroyed by incineration or collected on adsorbents. Occasional venting of steam from the distillation equipment may be observed. The residuals from this process are incinerated, extracted from metals, or stabilized prior to land disposal. Wastes remaining after recovery is completed are sent to an aqueous waste treatment facility for further processing. However, not all oil recycling processes produce residual waste.

Process equipment is fitted with seals to prevent emissions. Leaks would be contained by dikes, drains, and basins. Detectors, alarms, and process controls prevent and monitor air emissions and water effluents. Storage tanks and transfer lines have vapor recovery systems. In addition, all such facilities are required to have an emergency response plan and personnel to address accidents (e.g., fires, explosions, spills).

In the distillation process, organic wastes such as oils or solvents are heated in a sealed vessel which causes the material to vaporize. The vapors are then condensed and the oil or solvent is recovered leaving a waste

byproduct known as still bottoms. Still bottoms consist of primarily organic degradation and waste byproducts, and inorganic contaminants, etc. Large commercial processes are designed for high process rates, are very energy efficient, and are usually costly. Small solvent stills are relatively inexpensive, simple to operate, and are not very efficient. Distillation processes usually can achieve, depending upon the waste material to be recovered, a 70 to 80 percent recovery. See Figure F-4.

INCINERATORS

Incinerators burn organic liquid and solid hazardous wastes that cannot be recovered. Incineration of the wastes produces ash that is placed in a residual depository.

This technique can handle large volumes of liquid, gaseous, solid, or slurried wastes. Several types of incinerators can be used for thermal destruction or hazardous wastes. A rotary kiln incinerator is shown in Figure F-5 since it is the least waste specific and most flexible in terms of being able to handle a variety of waste types. Waste handling is a crucial design aspect in incinerator process selection. Other types of incinerators include fixed hearth incineration, liquid injection incineration, rotary and cement kilns, and fluidized bed units. While a fixed-hearth incinerator with liquid injection can be used for an aqueous stream, a rotary kiln unit can also burn solid hazardous wastes.

In a rotary kiln incinerator, solid, gas, or liquid waste organics are injected into a rotating cylinder where thermal destruction occurs by radiant heat transfer from the walls of the kiln to the waste material. The waste byproduct from the incinerator is ash and exhaust gases. Ash typically is composed of silica salts and trace metals. Exhaust gases are typically scrubbed (treated) to remove gaseous contaminants. Rotary kiln incinerators can be used with any combustible waste, and have a high incineration efficiency. Thus for mixed hazardous wastes, it is often the preferred treatment. However, incineration entails substantial capital costs, significant maintenance, and control of gaseous emissions.

Like many other means of treatment, destruction efficiencies for a rotary kiln combustor can be contaminant specific. The best data available show that destruction of most hazardous organic wastes is 99.98 to 99.999+ percent complete. Federal regulations require incinerators to destroy at least 99.99% of the hazardous constituents being burned. The federal government requires that all PCB's and dioxins be destroyed to a level of 99.9999% DRE.

Looking at a typical incinerator facility, an observer may see a tall smoke stack, bermed storage tanks, a truck unloading area, and a few support buildings.

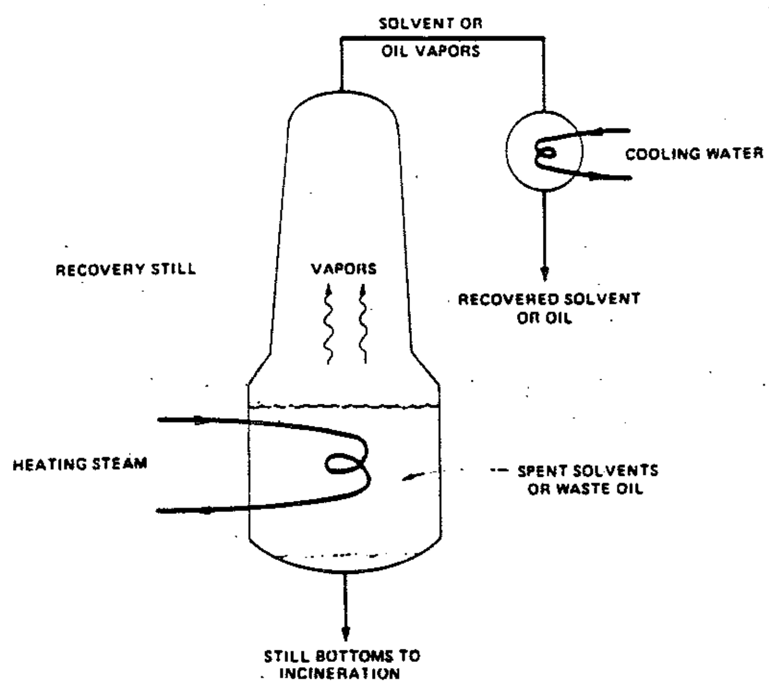

Figure F-4

RECOVERY OF SPENT SOLVENTS AND WASTE OIL

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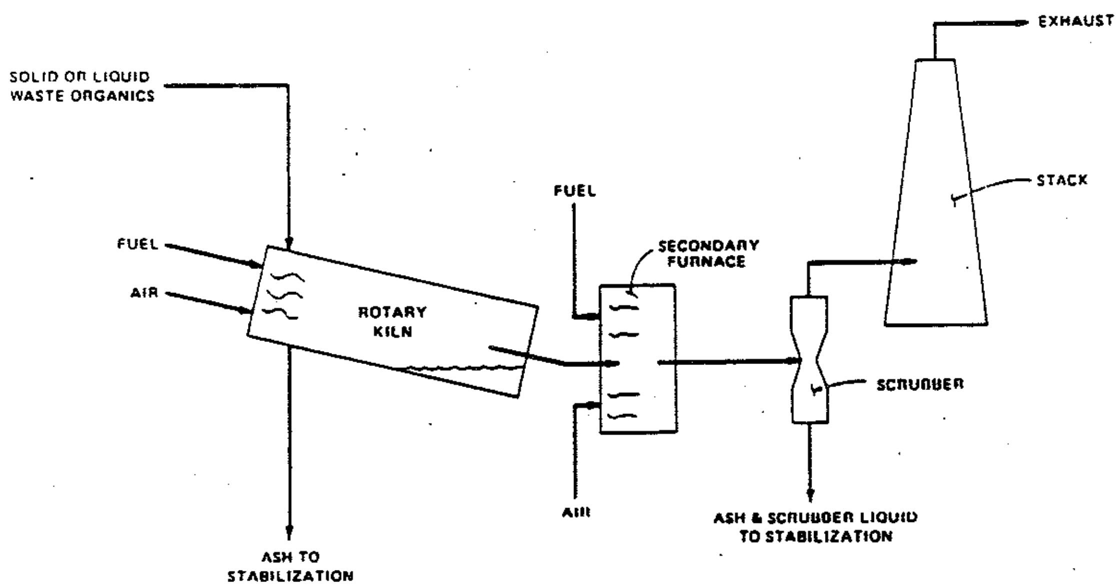

Figure F-5

INCINERATION

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Small rotary kiln incinerators handle about 30,000 tons per year, whereas a large facility could annually burn 100,000 tons of hazardous waste. A large incinerator may require 92 trucks per week. Eight to 12 acres would typically be required for small and large incinerators, respectively. Federal regulations require that the operator monitor waste feed streams, emissions from the stack, and the ash residuals to ensure that operating specifications are continually met. As with all hazardous waste management facilities, containment systems must be adequate to prevent spills from migrating. Incinerators must meet discharge requirements set forth in an air quality permit. In many cases, incinerators are fitted with scrubbers or operate with additives to keep emissions to acceptable levels. Ash residuals exhibiting very low concentration levels and sludge for the air pollution control levels are collected and periodically taken to a residuals repository.

SOLIDIFICATION AND STABILIZATION FACILITIES

Solid and liquid hazardous wastes are solidified or stabilized before being placed in a residuals repository. These wastes will typically be the bottoms from recycling operations or the residues from treatment processes. Contaminated soils may also be stabilized prior to land disposal. Wastes are solidified by applying additives to the material to prevent leaching and chemical reactions. Inorganic sludges can be fixed by adding lime and fly ash. Other wastes can be bound in asphalt or plastic (polymer) coating.

As opposed to the above processes, stabilization adds bulk to the waste stream; approximately 20 to 40 percent in weight and a commensurate increase in volume. See Figure F-6.

Solidification facilities appear to the observer as large industrial buildings with several tall silos attached for storage of dry additives. Solidification facilities can be as small as 1 acre and as large as 10 acres, and employ 5 to 30 people. Stabilization units can be designed to handle a wide range of treatment capacities. Typical offsite facilities might range from 50,000 to 250,000 tons/year of capacity. Similar to other facilities, solidification units have monitoring and containment systems to detect and control releases to the environment.

MOBILE TREATMENT

Increasingly, generators are contracting with mobile (or transportable) treatment firms to treat their hazardous wastes. Mobile treatment is now cost-effective for smaller or periodic generators of hazardous wastes who cannot afford permanent treatment units or offsite disposal/treatment.

Generators use mobile treatment units primarily to treat lower-risk aqueous waste streams (e.g., non-metallic and inorganic metallic liquids). Physical processes that separate water from hazardous constituents, such as filtration and flocculation are the most widely-used techniques. Acid neutralization

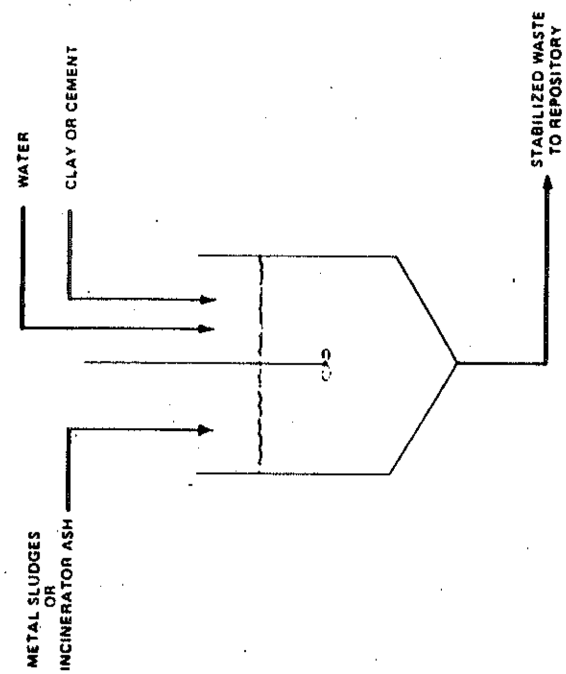

Figure F-6
STABILIZATION

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units are also being increasingly used. In addition, mobile air stripping units are employed to treat contaminated groundwater as it is drawn from withdrawal wells.

Mobile treatment units must meet applicable RCRA requirements. Although they may operate at many different sites, mobile treatment units receive a single permit.

Generators, however, are responsible for properly handling the effluent from these units (e.g., meeting sewer discharge requirements).

New modular incinerators are also becoming available.

RESIDUALS REPOSITORY

A residuals repository is used to dispose the residues of treated wastes from all these processes. Of the five treatment sequences, only neutralization of high or low pH solutions can yield no hazardous residual for a repository. All other waste types and treatment techniques ultimately leave some amount of untreatable hazardous waste.

A residuals repository looks like a modern landfill with several cells in which wastes are placed. Operation of these facilities is subject to several new limitations, however. First, such facilities could only receive solid wastes that have been sufficiently treated. (By 1990, all hazardous wastes in California must be treated to acceptable concentration levels before being placed in a residuals repository facility.) Second, the treated wastes could not contain any free liquids. Third, hazardous organic wastes could not be placed in these units without being solidified.

The intent is also to keep the repository covered (with a plastic sheet or cover) at all times to avoid any penetration of rainfall (and thus avoid any buildup of leachate). The cover or moveable roof would be moved aside during good weather to allow access to the landfill's cells; in inclement weather, only specially covered wet weather disposal cells would be used. See Figure F-7.

These facilities are required to meet all other federal and state residual repository regulations, including double liners, leachate control and monitoring systems, run-on and run-off controls, and groundwater monitoring. Existing state regulations restrict the siting of residual repositories (e.g., they cannot be sited in an area with permeable soils).

A small residuals repository accepts 75,000 tons per year and may occupy 100 acres. A large facility could receive as much as 360,000 tons per year and cover 250 acres. This size of facility could employ as many as 50 people.

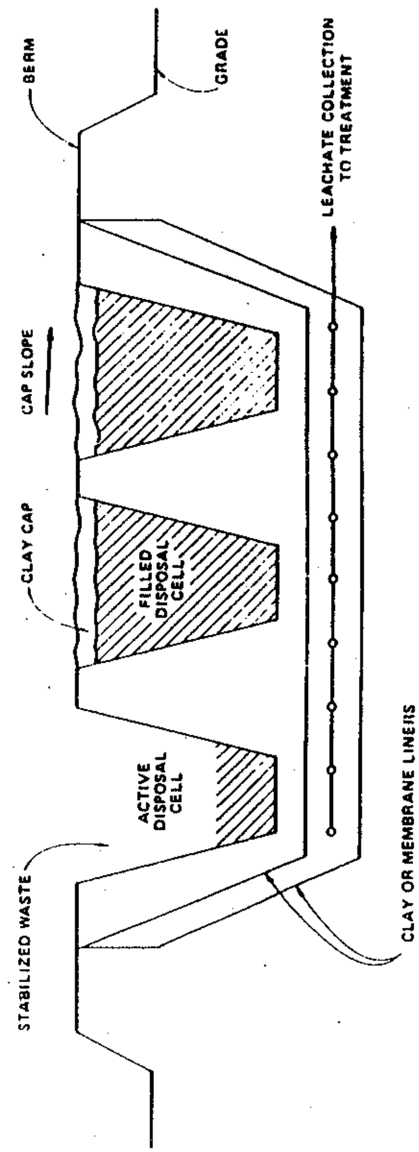

Figure F-7
WASTE REPOSITORY

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BIOLOGICAL TREATMENT

INTRODUCTION

Biological waste treatment is a generic term applied to types of processes which use living microorganisms to decompose organic wastes into either water, carbon dioxide, and simple inorganics, or into simpler organics such as aldehydes and acids. Typically, microorganisms used in a biological process are already present in the incoming waste. In some instances microorganisms which have been developed to attack specific acids are injected into a waste stream. Biological treatment systems must be closely monitored and controlled to ensure that the growth of microorganisms is enhanced. Biological treatment systems must also provide a means for maintaining high concentrations of the microorganism in contact with the wastes.

Because biological systems contain living organisms, they require sufficient nutrients and water to support growth. The systems are affected by many factors including temperature, light and movement, chemical factors, and biotic factors. The organisms tend to thrive in relatively steady state environment in which organic wastes are slowly added to the system. Since biological systems are very sensitive, they are most often used as final stages in a series of physical and chemical pretreatment processes.

Biological treatment systems do not alter or destroy inorganics. In fact, high concentrations of inorganics can severely inhibit decomposition activity. Chemical or physical treatment may be required to condition a waste stream prior to biological treatment.

The five principal types of conventional biological treatment are:

- Activated Sludge
- Trickling Filter
- Aerated Lagoons
- Waste-Stabilization Pond
- Anaerobic Digestion

There are also several innovative treatment systems under development. These systems are designed to enhance the contact between the biological organism and the organic wastes.

Environmental Concerns: Biological treatment processes are considered environmentally beneficial and have few if any negative impacts. Aerobic systems produce no secondary components which are considered pollutants. All of the aerobic systems discussed produce a clarified liquid effluent and a sludge which consists of dead and living organisms and non-biodegradable inorganics and refractory organics. Usually, this sludge must be disposed of in a secure landfill. The risks posed by the sludge depend upon the constituents of the incoming streams. The gas emissions from the biological systems are carbon dioxide and nitrogen and under anaerobic conditions, methane.

ACTIVATED SLUDGE

Process Description: The activated sludge process decomposes organic wastes in water by exposing the water to biological growth. Water is continuously recycled in the system to maintain high concentrations of microorganisms. The process involves an aeration step to provide the oxygen in the waste streams necessary for biological decomposition, followed by a clarifier in which the sludge is separated from the organic free water. A portion of the sludge from the clarifier is recycled back into the aeration tank to maintain high concentrations of microorganisms.

Applications: Activated sludge can be applied to a wide variety of organic waste problems as long as the solids content of the waste stream is less than 1% and the contaminants are primarily organic. The process is not considered acceptable for decomposing halogenated hydrocarbons and other organic chemicals which break down at extremely slow rates. The process can remove some metals in low concentration from waste streams. However, these metals must be in a form and concentration which is non-toxic to the bacteria.

This process is considered to be a well-developed treatment technology. There are at least ten reported uses of activated sludge in industrial waste treatment systems. Activated sludge systems are considered to be environmentally sound because no chemicals are used.

TRICKLING FILTER

Process Description: In the trickling filter process, wastes are allowed to trickle through a bed of rock or synthetic media coated with a slime of microorganic growth. Microorganisms decompose organic matter in the waste stream. Open tanks or towers house the filter, upon which the microorganisms grow, and open tanks clarify the filter effluent. The filter tank or tower uses a rotating spray system for feeding the waste stream to the filter surface.

Applications: Trickling filters are applicable to the same types of wastewaters as other biological treatment systems (wastewater containing up to 1% organic suspended matter). Trickling filters are reported to have successfully handled the following waste constituents: acetaldehyde, acetic acid, acetone, acrolein, alcohols, benzene, butadiene, chlorinated hydrocarbons, cyanides, ephicholorohydrin, formaldehyde, formic acid, ketones, monoethanolamine, propylene dichloride, resins, and rocket fuels. The process can be used in sequence with other biological treatment, but it is not generally efficient enough for use as the sole method of biodegradation.

AERATED LAGOONS

Process Description: Aerated lagoons are based upon the same biological decomposition principle as activated sludge systems. They consist of a large earthen lagoon containing high concentrations of microorganisms. Waste is agitated to increase oxygen content of the waste stream which encourages decomposition. The lagoon step is followed by immersion in concrete tanks where sludge settles out of the waste. The process differs from activated sludge in that sludge is not recycled. Organic decomposition typically takes longer in aerated lagoons.

Applications: Aerated lagoons can be used to treat the same types of aqueous wastewater as activated sludge units. The process has been successfully operated in petrochemical wastewaters, textile wastes, and refinery wastes. The process is not considered appropriate for wastewater with highly variable organic and metal concentration, nor for wastewater with high concentration of solids.

WASTE-STABILIZATION PONDS

Process Description: Waste stabilization ponds are large shallow ponds in which trace levels of organics are decomposed over a long period of time. Aeration is provided only by wind action. In deeper ponds anerobic digestion takes place at deeper levels. Stabilization ponds have been widely used to provide a final polishing of wastewater to insure that effluent standards can be met. They are applicable to wastewaters containing less than 1% concentration of solids and are not suitable for decomposing toxic effluents. The process can be employed only where substantiated land acreage is available and where the climate is suitable. Waste stabilization of industrial wastes is recommended only where the waste has received preliminary treatment to remove most of the organics and virtually all of the inorganics.

ANAEROBIC DIGESTION

Process Description: Anaerobic digestion is a process for decomposing organic matter in closed vessels in the absence of air. This process has traditionally been a supporting process to produce energy for other, sludge producing, biological processes. An anerobic digestive system uses two types of bacteria, acid forming and methane forming. The methane forming bacteria depend upon the acid forming bacteria for their substance. An end product from anaerobic digestion is methane, a combustable gas.

Applications: Anaerobic digestion is considered suitable for only simple organics now typically found in municipal wastewaters. Anaerobic digestion is an integral part of waste treatment systems. The process typically treats sludges containing 5-7% solids content. This sludge is reduced in volume by 40-60%.

Because the methane forming bacteria are highly sensitive to environmental changes, anaerobic systems cannot tolerate acidic wastes. Anaerobic digestive processes are inhibited by many hydrocarbons and are not very effective for most chlorinated hydrocarbons. Consequently, anaerobic digestion is not generally considered as a realistic option for treating hazardous chemical wastes.

INNOVATIVE APPROACHES

In addition to the conventional biological treatment systems discussed in the previous section, there are several innovative approaches to biological treatment in various stages of development. (A compilation of these innovative approaches is contained in a 1979 EPA report entitled Selected Biodegradation Techniques for Treatment and/or Ultimate Disposal of Organic Materials.) These innovative approaches might be categorized as relating to bioreactor design, improved accessories, or operation methods. Among the more prominent innovations now being explored or developed are:

Biological Seeding

Biological seeding is sometimes economically feasible for continuous application to large industrial waste treatment systems. Select microbial cultures have also proven useful, where specialized wastes are being degraded. Special strains of naturally occuring bacteria which have the capability to decompose or digest such materials as aromatic hydrocarbons, fats and greases, and ammonia have been developed. These mutant bacteria can handle several thousand times more material than their precursors. In addition, bacterial cultures have been applied to batch treatment processes where concentrated wastes have been isolated in spill ponds or equilization tanks. One manufacturer of a freeze-dried, biochemical complex indicates that specialized mutant bacteria can be applied with various nutrients to wastes from pulp mills, chemical plants, refineries, petrochemical complexes, and textile plants. A special culture has also been developed that can remove cyanide toxins from coking and chemical plant wastewaters. These bacteria are presently being marketed by several companies within the U.S.

Fluidized-Bed Bioreactor

Fluidized-bed bioreactors provide solid surfaces for microbial growth to develop. This feature enables the system to treat waste solution in which the organics are too dilute to support biological growth. These inert materials within the reactor and which support microbial growth, are not lost through discharge of spent liquors. This system is presently being tested at bench scale.

Deep-Shaft Aeration

This process uses a U-tube aeration chamber below a standard aeration tank to increase the aeration time for aerobic treatment. These systems use less land area than conventional aeration tanks and are presently successfully treating textile, petrochemcial, and pharmaceutical plant wastes. Using a 35-minute resistence time this system is reported to reduce organic levels in incoming waste by a factor of 10.

Pure Oxygen Systems

The use of pure oxygen rather than air as an oxidizing medium can greatly enhance the biological reaction in an aeration system. Although the cost of energy for mechanical oxygen diffusion is greatly reduced compared to conventional air systems, some of these savings are negated by the energy required to produce the pure oxygen supply. Nevertheless, within a range of process scales, savings will outweigh the additional cost of oxygen production hardware and operation. This range of cost-effectiveness is further dictated by the quality and constituents of the waste stream. It is reported that pure oxygen systems produce less sludge than do conventional systems and are much more tolerant of shock loadings of toxics. (Ref. 4, 35, 40, 99, 131)