Chapter 8

Community Wastewater Treatment

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CHAPTER 8

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Introduction

> A decade ago, the small neighborhood sewage treatment plant was generally regarded as a root cause of the American water pollution problem—poorly designed, cheaply constructed, improperly maintained, run by the mayor's brother-in-law and a couple of high school dropouts. So there was a strong trend away from small systems into large centralized facilities 1

Today, however, with a number of new community-based wastewater treatment systems available, centralized conventional treatment methods are only one choice among many. The purpose of this chapter is to introduce the reader to the alternatives that exist for community wastewater treatment and also to provide a more detailed insight into one community's efforts to develop one of these innovative technologies.

The Nation's stake in developing cheaper and more effective treatment methods is potentially enormous: more Federal dollars are being spent for this purpose than for any other nondefense public works program except the Interstate Highway System.[2] Many communities have yet to install treatment facilities that meet the Environmental Protection Agency's (EPA's) effluent standards, and EPA estimates that it will cost as much as $25 billion to complete the construction or upgrading of the needed treatment plants.[3] The General Accounting Office (GAO) has found that the funds required for this investment are not now available and may never be; GAO recommends strongly that lower cost approaches must be pursued.[4]

The range of wastewater treatment systems available to communities must be judged according to the unique needs of each community. For example, the conventional, centralized facilities rely on large trunk sewers to convey wastewater from outlying communities. Suburban expansion often follows these sewer "mains, " a situation which might be either favorable or undesirable depending on the community's growth plans. A community must consider a number of other factors in choosing the most appropriate wastewater treatment system: environmental elements, such as climate, geology, soil, and type of wastewater; socioeconomic factors, like treatment cost and effects on population growth; and the technical characteristics of the treatment system itself. Three levels or stages of wastewater treatment are generally recognized:

- *Primary treatment* removes large particles from raw wastewater through screening and sedimentation. Approximately 60 percent of the suspended solids, and about 35 percent of the 5-day biochemical oxygen demand (BOD5),[5] are removed during primary treatment.
- *Secondary treatment* reduces the concentration of suspended solids and BOD5 still further. EPA defines secondary treatment as "a treatment level meeting effluent limitations for BOD5 and suspended solids of 30 mg/l [each] on a monthly average basis or 85 percent removal of these parameters, whichever is more stringent. "[6]

[1]Clem L. Rastatler, et al., *Municipal Wastewater Treatment: A Citizen's Guide to Facility Planning* (Washington, D. C.: Environmental Protection Agency, January 1979).

[2]Claudia Copeland, "Municipal Pollution Control: The EPA Construction Grants Program, " issue brief No. IB80049 (Washington, D. C.: Library of Congress, Congressional Research Service, Oct. 27, 1980).

[3]*Large Construction Projects to Correct Combined Sewer Overflows Are Too Costly* (CED-80-40) (Washington, D. C.: General Accounting Office, Dec. 28, 1979), vol. 1, p. iii.

[4]Ibid.

[5]BOD5 is a conventional measure of wastewater quality, based on the amount of oxygen required by bacteria to decompose suspended organic waste over a 5-day period. Discharging wastewaters with high BOD5 into surface waters (rivers, lakes) can reduce their oxygen concentration to levels that are harmfully low for aquatic organisms.

[6]Environmental protection Agency, "Intent to Issue Revised Guidance Concerning Review of Advanced Treatment Projects for Construction Grants Program, Request for Comments, " Federal Register, vol. 45, No. 121, June 20, 1980, pp. 41,891.

- *Tertiary or advanced treatment* provides the highest quality of wastewater effluent. It removes nutrients, such as nitrogen and phosphorus, and further reduces BOD5 and suspended solids. EPA defines advanced wastewater treatment as a treatment level "providing for maximum monthly average BOD5 and suspended solids of less than 10 mg/l [each] and/or total nitrogen removal of greater than 50 percent."[7]

In addition to the standard processes described for primary, secondary, and tertiary treatment, chlorine (or in some instances ozone) is sometimes added to treated wastewater to destroy pathogens before discharge.

The Federal Water Pollution Control Act of 1972 mandated that all publicly owned treatment works achieve secondary treatment standards. However, there are still a large number of communities which must build or replace secondary treatment systems.[8] Many communities, especially in arid areas, are also attempting to recover wastewater as a resource, rather than treating it as a burden to be disposed of. Still other communities are concerned with high-quality treatment of wastewaters, in order to avoid such problems as lake eutrophication and ground water contamination. In light of these varying needs, the following discussion identifies a wide range of secondary and advanced treatment alternatives for community wastewater treatment.

[7]Ibid.

[8]Council on Environmental Quality, *Environmental Quality: The Tenth Annual Report of the Council on Environmental Quality* (Washington, D. C.: Executive Office of the President, 1979).

Conventional Wastewater Treatment Systems

The major conventional technologies for secondary treatment use biological processes to treat wastewater. The three most widely used conventional biological treatments are oxidation ponds, activated sludge and trickling filters.

The *oxidation pond* is used in about a third of the existing U.S. secondary treatment facilities. About 90 percent of these ponds service communities of less than 10,000 people.[9] In oxidation ponds, wastes are decomposed by bacteria. Ponds can be aerobic (containing oxygen in water), anaerobic (containing no oxygen), or facultative (aerobic at the top, but anaerobic at the bottom). The type of pond depends in part on the type of wastewater being treated; most ponds now in use are facultative. Oxidation ponds have lower construction costs, require less energy, and are easier to operate and maintain than the other conventional technologies. However, they remove suspended solids poorly, require large land areas, and do not work well in cold weather.[10]

The second conventional biological process, the *trickling filter,* has been in widespread use since 1936.[11] After primary treatment, wastewater is trickled through a bed of rocks or a synthetic medium such as plastic beads; micro-organisms living on the filter medium digest organic wastes. The treated wastewater is then collected by an underdrain and any solids are allowed to settle. This is a simple process that can accommodate a wide variety of wastewaters without difficulty. The system's simplicity is its main advantage: neither operation nor maintenance is difficult. However, if the system is upset, it requires a long time to recover. Other disadvantages of the system include: low tolerance for high concentrations of organic wastes, vulnerability to below-freezing temperatures, odor problems, and limited flexibility and control.

The most commonly used and versatile conventional biological secondary treatment process is the *activated sludge system.*[12] Like oxidation ponds, the activated sludge process relies on bacterial decomposition. However, unlike the pond system, the bacterial culture is aerated and agitated to en-

[9]*Environmental Pollution Control Alternatives: Municipal Wastewater* (Washington, D. C.: Environmental Protection Agency, November 1979) (hereafter "EPA 1979").

[10]Ibid.; and *Innovative and Alternative Assessment Manual* (Washington, D. C.: Environmental Protection Agency, 1980) (hereafter "EPA 1980").

[11]EPA 1980.

[12]Ibid.

sure that the wastewater and sludge are "activated''—oxygenated and mixed. After aeration, the activated sludge is allowed to settle and a portion is recycled to maintain the culture. *3 Activated sludge systems produce a high-quality effluent from varied wastewaters and do not require a great deal of land. Operation of the systems, however, requires more attention than either of the other conventional technologies, due to their tendency to be upset by variations in amount and composition of wastewater. They also cost more to build and consume more energy than either oxidation ponds or trickling filters. [14]

Two new technologies for conventional, centralized wastewater treatment also deserve mention. These processes are hybrids that combine elements of the activated sludge and trickling filter systems. The first, *rotating biological contractors* or "biodiscs," consist of a series of plastic discs which provide a large surface area for the growth of micro-organisms. These discs rotate through wastewater, exposing the micro-organisms to organic wastes. In this respect, the biodisc process is similar to the trickling filter concept, but the discs also aerate and agitate the wastewater as they rotate, like the activated sludge system.

The other hybrid system, the *activated biofilter*, is similar to the trickling filter in that wastewater is trickled over redwood slats covered with micro-organisms. Like the activated sludge system, however, the biofilter system also recycles part of the sludge to maintain a high-density bacterial culture.

Unlike the above secondary treatment systems, which are based primarily on biological processes, conventional advanced waste treatment systems are mostly physical-chemical processes. Advanced processes include the addition of chemicals to remove phosphorus; filtering processes to remove suspended and colloidal solids; filtering through carbon, which absorbs biologically resistant organics; and a variety of biological and physical-chemical processes to remove the different forms of nitrogen. [15]

[13]Ibid.; and *Wastewater Engineering*: Treatment, Disposal, Reuse, Metcalf and Eddy, Inc., 1979.

[14]EPA 1979.

[15]Ibid.

Alternative Wastewater Treatment Systems

Three types of alternative waste treatment systems are currently in limited use in the United States: the first type, land treatment, processes wastewater by applying it to the land; the second type, onsite treatment, includes systems appropriate for the individual home; and the last type, aquiculture, treats wastewater through the controlled cultivation of aquatic plants and animals. [16]

Land Treatment Systems

The most widely used and most reliable land treatment method is *irrigation*. Treated wastewater has been used to irrigate agricultural lands and pastures for over 100 years, but it is also being used to irrigate forest lands and recreational lands, such as golf courses. At present, about 400 to 500 communities in the United States are using some form of wastewater irrigation. [17]

Wastewater is applied to the land through irrigation ditches, by inundating the land with 2 or 3 inches of wastewater at a time, or by spray or sprinkler irrigation. [18] Pollutants in the wastewater are removed primarily through a combination of biological and chemical processes: some are taken up by growing plants; other are decomposed by soil micro-organisms or through chemical processes in the soil. Wastewater irrigation produces a high-quality effluent, which can either be collected for reuse or discharged to ground and surface waters. In some cases, crop production has been higher using wastewater irrigation than using

[16]Office of Technology Assessment, "Energy From Aquaculture" draft report, 1979.

[17]EPA 1980.

[18]*Alternative Waste* Management Techniques *for* Best *Practicable Waste* Treatment (Washington, D. C.: Environmental Protection Agency, Municipal Construction Division, October 1975).

conventional irrigation, and increased revenues from crops have helped to offset the costs of the systems. Irrigation systems, however, require more land than either conventional treatment systems or the second major type of land treatment, infiltration-percolation systems.

In contrast to wastewater irrigation, *infiltration-percolation* relies on rapid flow of wastewater through sandy soils. The soil filters the wastewater and soil organisms decompose organic wastes. Uptake of nutrients by vegetation, however, does not play the major role in this system that it does in irrigation treatment. The infiltration-percolation system is particularly useful in situations where it is useful to replenish ground waters—for example, to avoid saltwater intrusion—but the potential exists for ground water contamination, especially by nitrates. Infiltration-percolation systems require less land and (in most cases) less energy than irrigation systems. However, they have a limited capability for removing nutrients, such as nitrogen and phosphorus compounds; and consequently they require careful management to avoid ground water contamination, which tends to limit both their flexibility and Iifespans. [19]

Onsite Treatment Systems

Onsite systems are wastewater treatment systems that serve individual households or clusters of homes. The most prevalent onsite system, the *septic tank soil absorption system*, serves about a third of the population of the United States. Like the land treatment system, septic tank absorption relies on complex physical, chemical, and biological processes in the soil to remove and decompose wastewater pollutants. While septic tank absorption systems are used widely, their effectiveness and safety in any given location will depend on soil permeability; the depth of the ground water table and bedrock; rainfall and seasonal flooding; and the distance to the nearest surface water or well.

In situations where septic tanks are infeasible, several other onsite systems are available. For example, the *septic tank mound system* disposes of wastewater in sand-filled, aboveground mounds. The engineered mound provides the same treatment functions as absorption beds.

In areas of low soil permeability and high net evaporation, another technique has evolved to dispose of *wastewater—evapotranspiration* (ET). An ET system works by evaporating wastewater from a bed of sand. Plants growing on the surface of the sand bed help increase the rate of water loss. ET systems are fairly widely used, especially in the arid Southwest, and approximately 4,000 to 5,000 are in operation in the United States today. Although ET systems require a great amount of land, they are an effective method of disposal and require a minimum of maintenance.

Two other types of onsite systems are often used at sites where a high-quality effluent is necessary for discharge to surface waters. *Aerobic treatment systems*, like activated sludge systems, maintain a highly concentrated bacterial culture that decomposes organics. These systems provide very advanced treatment, but they are also expensive and require a great deal of operational and maintenance attention.[20] A more practical and cost-effective method of producing a high-quality effluent for surface water discharge is the septic tank sand filter system. This system is similar to the soil absorption systems, except that the wastewater is filtered through subsurface beds of sand and then collected and drained by underdrains.

Aquiculture Treatment Systems

Although still in the development stage, two aquiculture systems have recently emerged as alternative methods of wastewater treatment. Both systems use vascular aquatic plants to increase the surface area on which bacterial decomposition can take place; the plants also absorb some of the nutrients, suspended solids, and heavy metals in the wastewater. The two systems differ in the types of plants they employ.

Natural wetlands have unintentionally served as waste treatment systems for centuries. Recently, however, *artificial wetlands* have been experimentally constructed to provide both primary and secondary treatment. Marsh plants, anchored in shallow oxidation ponds, provide increased sur-

[19] EPA 1979; EPA 1980; and Metcalf and Eddy, Inc., op. cit.

[20] EPA 1980.

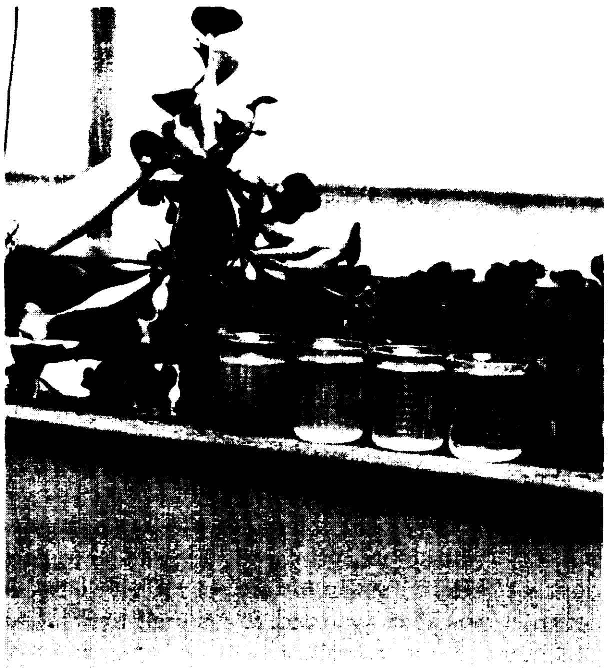


Photo credit: ***Solar AquaSystems***

Plants such as water hyacinths, shown here, absorb some of the nutrients, suspended solids, and heavy metals that are found in wastewater

face area for bacteria and also help remove nutrients from wastewaters.[21]

Aquatic systems combine the large, shallow lagoons of facultative oxidation pond systems with the controlled growth of floating plants, such as water hyacinths or duckweed. Most of the treatment occurs through bacterial action, but the aquatic plants also reduce nutrients, heavy metals, and suspended solids.[22]

The Solar AquaCell treatment system, which is discussed in the following case study, combines elements of the aquatic systems with components of other conventional wastewater treatment systems. The AquaCell technology will be described in greater detail in a later section, but the focus of the case study is on the community's attempt to develop and adopt a wastewater treatment technology that is appropriate to its unique local needs and goals.

[21]Ibid.; and OTA, op. cit.

[22]EPA 1980,

A Case Study of the Hercules AquaCell Project[23]

The Community Setting

The city of Hercules, founded in 1900 as a company town by the old Hercules Powder Co., is located in the northeastern San Francisco Bay area. Its rolling green hills and proximity to the ocean are attractive to newcomers, and since 1974 the town has experienced feverish growth, moving from a village of barely 121 people to a community of 7,000 in just 6 years.

Hercules is basically a middle-class community and has virtually no unemployment. Modal family income in March 1979 was between $23,000 and $29,000, and 90 percent of households had incomes between $18,000 and $60,000. About half the population is white, and of the balance 23 percent are Filipino, 11 percent black, 9 percent Chinese, 5 percent Hispanic, and 2 percent Japanese. The newer part of town, located inland, consists of small-lot, single-family housing tracts that are rapidly consuming the rolling landscape.

In 1977, the city government, led by a City Manager and Council, began looking for additional sewage treatment capacity to meet the needs of its growing population. They wanted a system that could be expanded incrementally as the city grew, and they looked at several options. One was to increase the capacity of the conventional plant where its wastewater was then being treated, in the nearby city of Pinole. Another option, which was being recommended at that time by EPA, was the construction of a consolidated regional sewage treatment facility for four localities—Pinole, Crockett, Rodeo, and Hercules—in line with regulations promulgated under the Federal Water

[23]Material in this case study is based on the working paper, "Solar AquaCell Wastewater Treatment, Hercules, California," prepared by Lee Bourgoin and Alice Levine for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979, pp. 147-242.

Pollution Control Act of 1972. (Before the Clean Water Act Amendments of 1977, Federal water pollution policy promoted the establishment of regional districts to monitor water quality, implement treatment standards, and build regional sewage treatment plants.) A third option was for Hercules to build and operate its own municipal sewage treatment plant.

The first two options, however, would have put limits on the city's growth. The Pinole plant expansion could serve a maximum Hercules population of only 15,000, and a regional plan set forth by the Association of Bay Area Governments (ABAG) had likewise limited the city to a maximum population of 15,000. The city's own master plan, on the other hand, specified a 1990 population of 23,000, to be reached in steps by controlled growth. ABAG's ability to enforce its regional master plan came from its role as a State and Federal grant-approving entity: Hercules could build its own treatment facility, but unless it accepted ABAG's growth ceiling it could expect little outside financial support.

Fortunately for the city, outside financing was not necessary. A few years earlier, the Pacific Refinery, a subsidiary of a Houston-based corporation, had shifted the point of payment for its sales taxes from Houston to Hercules. This resulted in a tax windfall for the city amounting to $2 million per year, which meant that the city would be able to finance the construction of a sewage treatment plant out of its own revenues.

In addition to having a tax base that allowed it to exercise autonomy in building a treatment facility, the Hercules City Council was also interested in trying innovative, environmentally sound methods to deliver municipal services. They were interested in attracting further development, and they recognized the opportunity to make Hercules a showplace community with a reputation for farsightedness and leadership.

Development

During 1976, City Manager Ralph Snyder had read in the trade journals and in a San Diego newspaper about a treatment process designed by Solar AquaSystems, Inc. The process was innovative, and it produced water cleaner than was required by secondary treatment standards. He contacted the firm's president, Steve Serfling, for more information.

Sex-fling and his associates had developed the AquaCell Wastewater Treatment Process as a more marketable version of their earlier experiments with the cultivation of freshwater shrimp and fish in a closed system. After obtaining a patent for the AquaCell in 1976,[24] Serfling and his partner, Dominick Mendola, pooled about $15,000 to set Up a backyard prototype for research and evaluation. During the fall and winter of 1976-77, Solar AquaSystems built and tested a larger wastewater prototype to treat human sewage.

In early 1977, the Hercules city government signed a contract with Solar AquaSystems to conduct a feasibility study for an AquaCell plant. A contract was also awarded to Metcalf and Eddy, Engineers, for a feasibility study of the proposed expansion of the existing Pinole plant. Both studies were submitted in May 1977, and reviewed by the City Council and staff members, including Bill Chapman, the city engineer.

In comparing the two options (see table 22), the city took several cost factors into account, the most important of which was that the annual operating and maintenance costs for the AquaCell system would be much lower than at the Pinole plant. Assuming a population of 23,000 in 1990, these costs for the AquaCell system could be as much as $300,000 per year less than the conventional option:

AquaCell at 2.2 million gal/day (mgd) capacity (Solar AquaSystems' estimate, expressed in 1979 dollars)	$150,000 to $200,000 per year
Pinole expansion for 5,000 homes at $84/yr/connection and 2.2 mgd capacity at 1.5 cents/gal	$453,000 per year

Besides the financial considerations, there was also the question of which option would best handle the projected increase in the city's population. As mentioned above, the Pinole expansion would serve a maximum Hercules population of 15,000,

[24] Solar AquaSystems holds the patent on the system's greenhouse covers, ponds, bioweb substrates, floating plants, aeration system, and the "solar sprayers" that mist water into the air.

Table 22.—Projected Cost and Performance Comparisons of the Hercules AquaCell Facility Versus the Pinole Plant Expansion

	Hercules Municipal Sewage Treatment Plant using the Solar AquaCell System	Pinole Plant expansion of Conventional Activated Sludge System
1977 estimated capital costs per gallon of plant capacity	$2.57	$2.67
Effluent quality	Choice of secondary or tertiary.	Secondary only.
Expansion-contraction flexibility	Simple—change pond size. Can build incrementally as needed.	Difficult—requires new infrastructure. Must build for total future planned capacity.
Energy requirements	250 kWh/million gal treated.	625 kWh/million gal treated.
Disposal requirements	Sludge and hyacinths—225 ft³/million gal if hyacinths are chopped, 165 ft³/million gal if composted.	Sludge—360 ft³/million gal.
Land area required	1.3 acre/1 mgd capacity.	1 acre/1 mgd capacity.
Labor required	1 person, part-time, 1 backup person. Biological/mechanical tasks.	None additional required. 6 people, full-time already employed. Mechanical tasks.
Other requirements	Aquatic plant harvester. Composter on site.	Truck access.
Operations	Flexible—keeps working if component fails. 24 hours to repair before overflow.	Inflexible—loses efficiency if component fails. 4 hours to repair before overflow.
Byproducts of potential value to Hercules	Aquatic plants: compost, animal feed, methane. Treated wastewater: industrial water, greenbelt irrigation, freshwater marsh enhancement, food production.	No current use of wastewater or sludge, although greenbelt irrigation and methane production are possible.

SOURCE: Solar AquaSystems; based on laboratory data and contractor estimates

and this additional capacity would have to be built (and paid for) all at once. Estimated cost to Hercules as of December 1977 was $4 million, against an estimated cost of $3.5 million for the AquaCell. The flexibility of scale in AquaCell construction thus became an important cost consideration: because of the modular design, economies of scale are slight, so the city could build to current capacity requirements and then expand the facility as demand increased, spreading capital costs over time as the city grew.

After considering all of these factors, the City Council selected the AquaCell system by unanimous vote. It could grow with the city, and as ‘one Council member pointed out, "we are buying the flexibility to grow to the [population] limit we want." The appeal of local control over local development was echoed more forcefully by Councilman Joel Zieper:

> If you want to do something right, do it yourself. I couldn't care less whether we get any money from the State, They would probably do it wrong anyway. We'll do it right and then we'll take all the credit.

City Manager Snyder added that the city wanted to make a "contribution to the state of the art, " and summed up the benefits in the following way:

> There comes a time when it is necessary to consider other values than what may appear to be "safe." The merits of energy conservation, water recycling, fish life production and agricultural byproducts use are, to me, very significant and achievable objectives not only in terms of the community but also for the nation and even parts of the world.

The Solar AquaCell Technology

In the Solar AquaCell Wastewater Treatment Process, waste-consuming plants and marine organisms occupy a lagoon enclosed under a greenhouse cover. The technology consists of three components:

1. An inflated polyethylene greenhouse cover is built over three treatment lagoons in order to stabilize water and air temperatures and to prevent excessive evaporation.
2. Anchored, buoyant plastic-mesh ribbons and tubes, called "bio-web substrates," are placed in the lagoons (like marsh plants in an artificial wetland) to expand a hundredfold the surface area where the waste-digesting organisms live and graze. As a result, the organisms multiply more rapidly and hence take less time to digest the waste. As in the conventional activated sludge process, most of

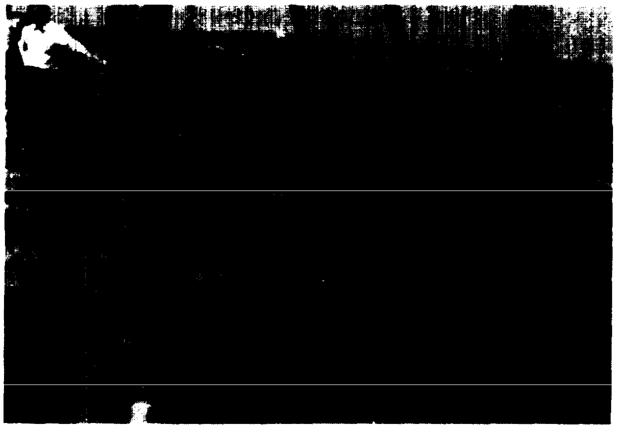


Photo credit: Hercules AquaCell

8-ft-deep lagoon, enclosed by greenhouse cover, where secondary treatment begins

the digestion of waste in the AquaCell occurs by bacterial action.

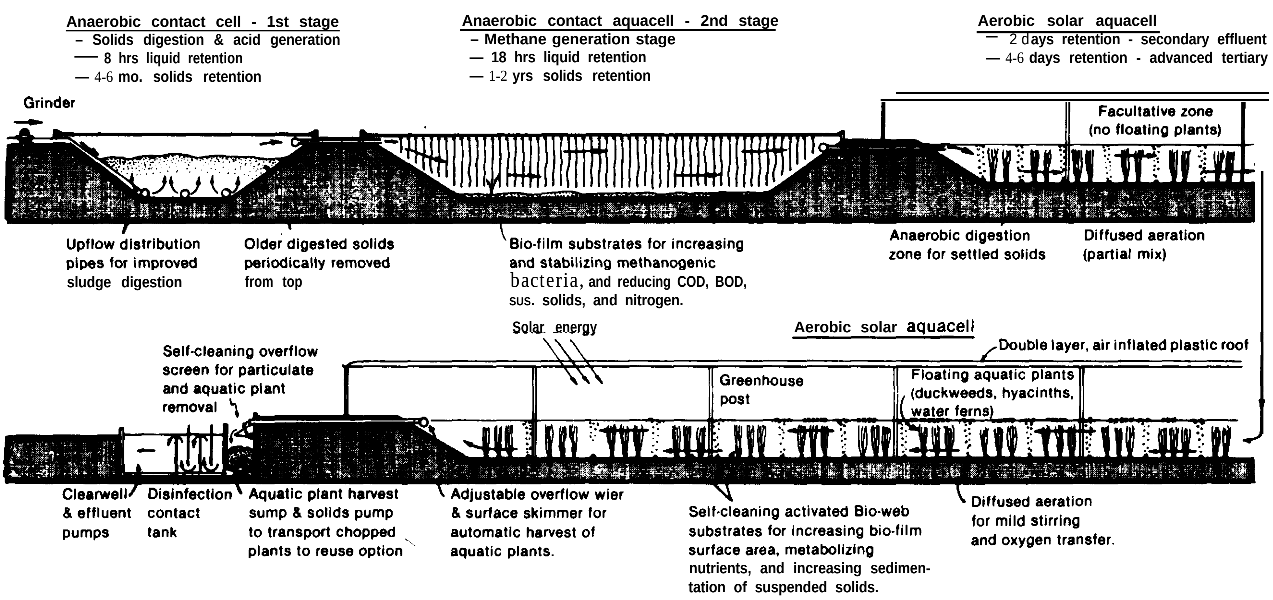
3. Aquatic plants, in this case water hyacinths and duckweed, are grown on the pond's surface. The plants subsist on nutrients from the wastewater, and also serve to screen the pond from sunlight, thereby preventing the growth of undesirable algae.

Figure 28 depicts the AquaCell process. Sewage passes through a grinder into a covered anaerobic pond, where grit and a large portion of the solid wastes settle out. The wastewater then enters a second anaerobic pond, also sealed beneath a floating black rubber cover, where abundant bacteria on the bio-web substrates begin to digest wastes, producing a small amount of methane in the process. Retention time for this stage is 18 hours.

After primary treatment, the treated wastewater flows into an 8-ft-deep facultative lagoon, where secondary treatment begins. This lagoon contains more bioweb substrates, which facilitate the growth of micro-organisms and encourage the settling of solids suspended in the wastewater. Bacteria and grazing micro-organisms continue to digest the wastes. Retention time for the facultative stage is an additional 18 hours.

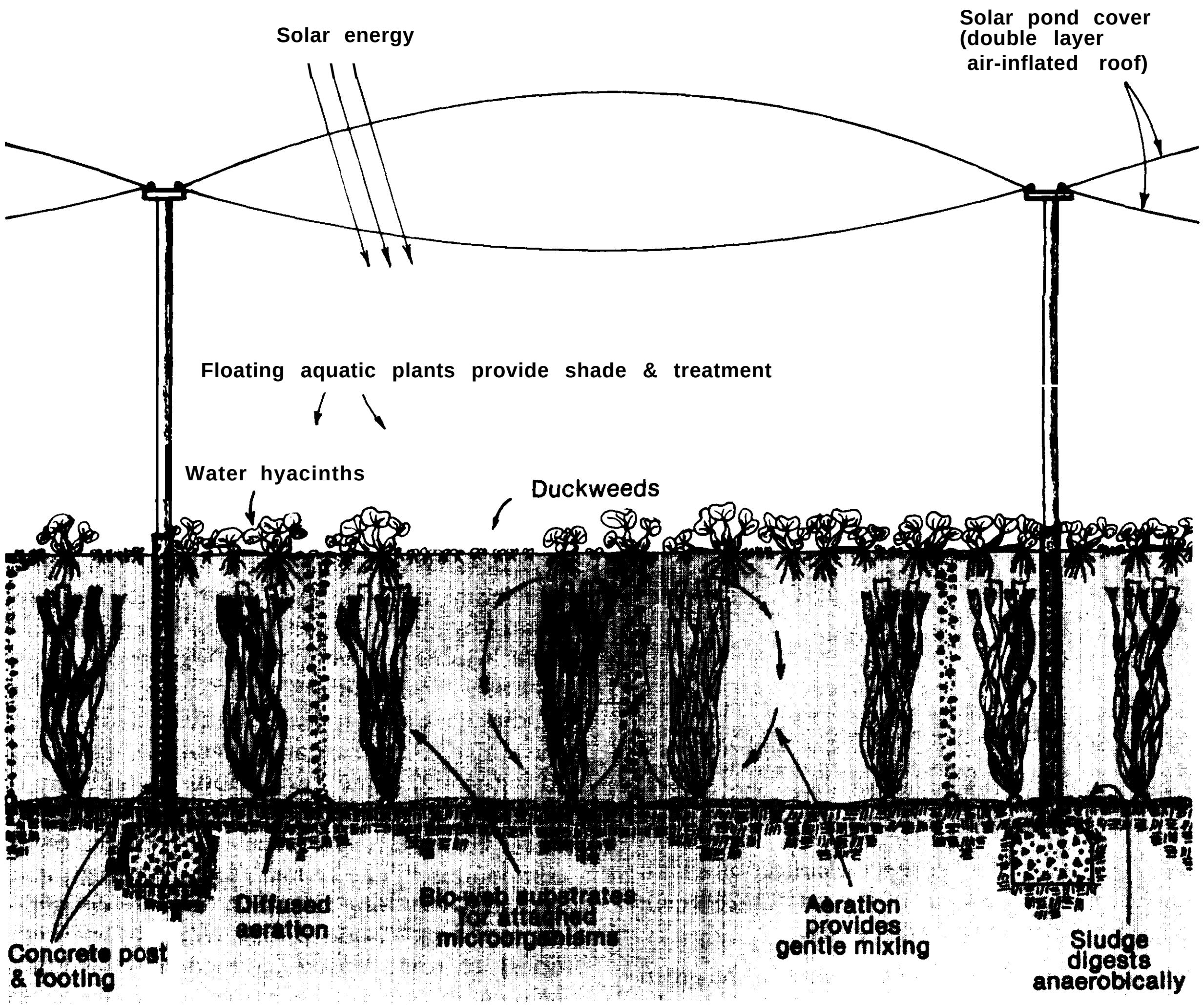
Secondary treatment continues in the main portion of the greenhouse lagoon (see figure 29), where other waste-eating animals have been added: protozoa, amphipods, grass shrimp, hydra, snails, worms, and additional micro-organisms. Water hyacinths and duckweed now cover the water's surface, taking up nutrients and heavy metals from the wastewater and keeping down algae growth by screening out the sun. Anaerobic

Figure 28.—Solar AquaCell System Process Flow Diagram



SOURCE: Solar AquaSystems.

Figure 29.—Section View, Solar AquaCell System



SOURCE: Solar AquaSystems.

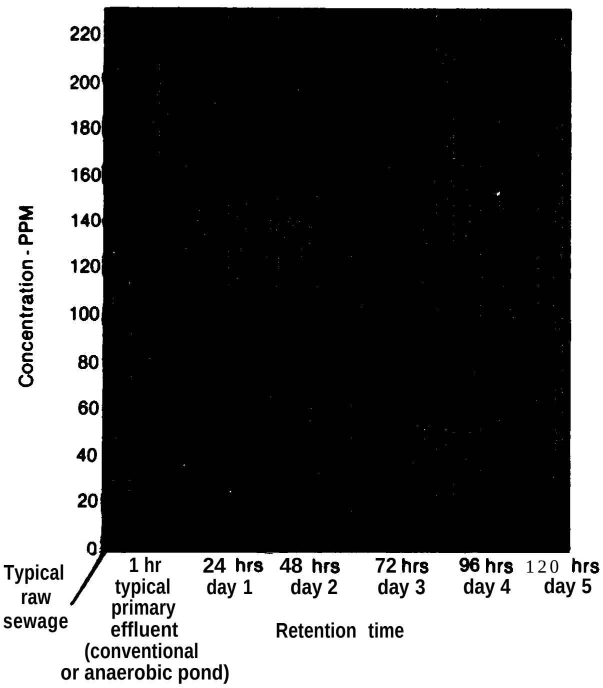
waste digestion occurs on the bottom of the lagoon, where sludge slowly builds up at a rate of between ¼ and 1/2 inch per year.

Trials of the AquaCell process in the 2,000- and 4,000-gpd prototype facilities showed that secondary treatment quality can be achieved with 2 days retention time for a l-acre pond handling 1 mgd of wastewater, a capacity that would serve a population of 10,000.[25] Advanced treatment quality was achieved after 4 or 5 days. However, as illustrated in figure 30, nitrates and phosphorus, which encourage algae growth, are only partially removed from the water within 5 days (50 percent of the nitrates; 10 to 20 percent of the phosphorus). If desired, the remaining phosphorus can be removed by adding lime to the water, and the remaining nitrogen by increasing the retention time.

Most of the pathogenic organisms (disease-causing bacteria and viruses) contained in the wastes die off during the long retention periods. Other pathogens get trapped in the sand filtration system, where they eventually die or are consumed by other organisms. Remaining pathogens are

[25] Data recorded and analyzed by the Environmental Studies Laboratory, University of San Diego.

Figure 30.—Treatment Performance in Relation to Retention Time for the Solar AquaCell Process~



aBased on data collected from the 2,000-gpd pilot-scaie Solar AquaCell Laboratory in Solana Beach, Calif., from October 1976 to March 1977; and current data being collected from the new 4,000-gpd pilot facility located at the Cardiff Wastewater Treatment Facility. Data from Cardiff facility is recorded and analyzed by the Environmental Studies Laboratory, University of San Diego.

killed with ozone in a contact disinfection chamber as the water flows out of the main lagoon and into a clear well to be pumped away.

A crucial component of the system is the greenhouse cover. It traps solar energy during the day and reduces heat loss at night, thereby helping to maintain the effectiveness of the AquaCell during colder winter months and reducing its energy consumption year-round. A water-mist spraying system helps reduce air temperatures during summer months. In dry climates, the greenhouse cover also reduces evaporation from ponds. This is especially valuable for systems whose object is to reclaim the wastewater for other uses. Also, since the greenhouse cover prevents evaporation, and because the aquatic plants and invertebrates consume minerals, the AquaCell system can decrease the concentration of dissolved solids, rather than increasing them as happens in conventional oxidation pond systems. Finally, the greenhouse cover

Photo credit: Hercules AquaCell

Ozone contact disinfection chamber under construction at the Hercules AquaCell Treatment Facility

will help to contain odors, although few are produced in normal operation.

Maintenance requirements include: monitoring environmental conditions, such as temperature, to assure the most efficient metabolic rate; sand filter back washing; removing sludge every 3 to 6 months; and harvesting the aquatic plants. Studies have shown that the aquatic plants used in the AquaCell process are generally hardy and able to withstand some fluctuations in nutrient content, and air and water temperatures, changes in water chemistry, and even the presence of toxic compounds.[26] The system's large holding capacity and relatively long retention time are designed to dilute "slugs" (sudden but transient concentrations) of toxic wastes in incoming wastewater, helping to protect the plants and bacteria from damage. In addition, the large holding capacity will give operators a longer period to correct malfunctions before the system begins to overflow-24 hours instead of the 4 hours of conventional systems.

According to Serfling, the final volume of solids requiring disposal will be less than half the volume produced by conventional activated sludge systems. The harvested plants may be composted alone or with the sludge to produce fertilizer and

[26]William S. Hillman and Dudley D. Culley, Jr., "The Uses of Duckweed," American Scientist, vol. 66, July-August 1978, pp. 442-456; B. C. Wolverton (cd.), *Compiled* Data on the Vascular Aquatic *Plant* Program: 1975-1977, prepared for NASA National Space Technology Laboratories.

soil-enhancing materials (see ch. 7 for a discussion of comporting). Because water hyacinths grown in sewage average 20 percent protein, and duckweed as much as 40 percent, they may also have value as animal feed so long as concentrations of toxic compounds are not excessive. The sale of these by-products, as well as reclaimed water, could further reduce operating costs.

The Hercules AquaCell Treatment Facility

The opening ceremonies for the Hercules Aqua-Cell plant were held on Earth Day, April 22, 1980. However, about 6 months will be needed before the plant can be considered fully operational.

Figure 31 shows the AquaCell treatment facility designed to provide 2-mgd capacity, advanced wastewater treatment for the city of Hercules. The initial phase of construction was designed to han-

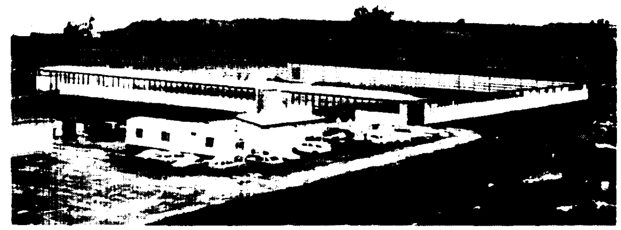
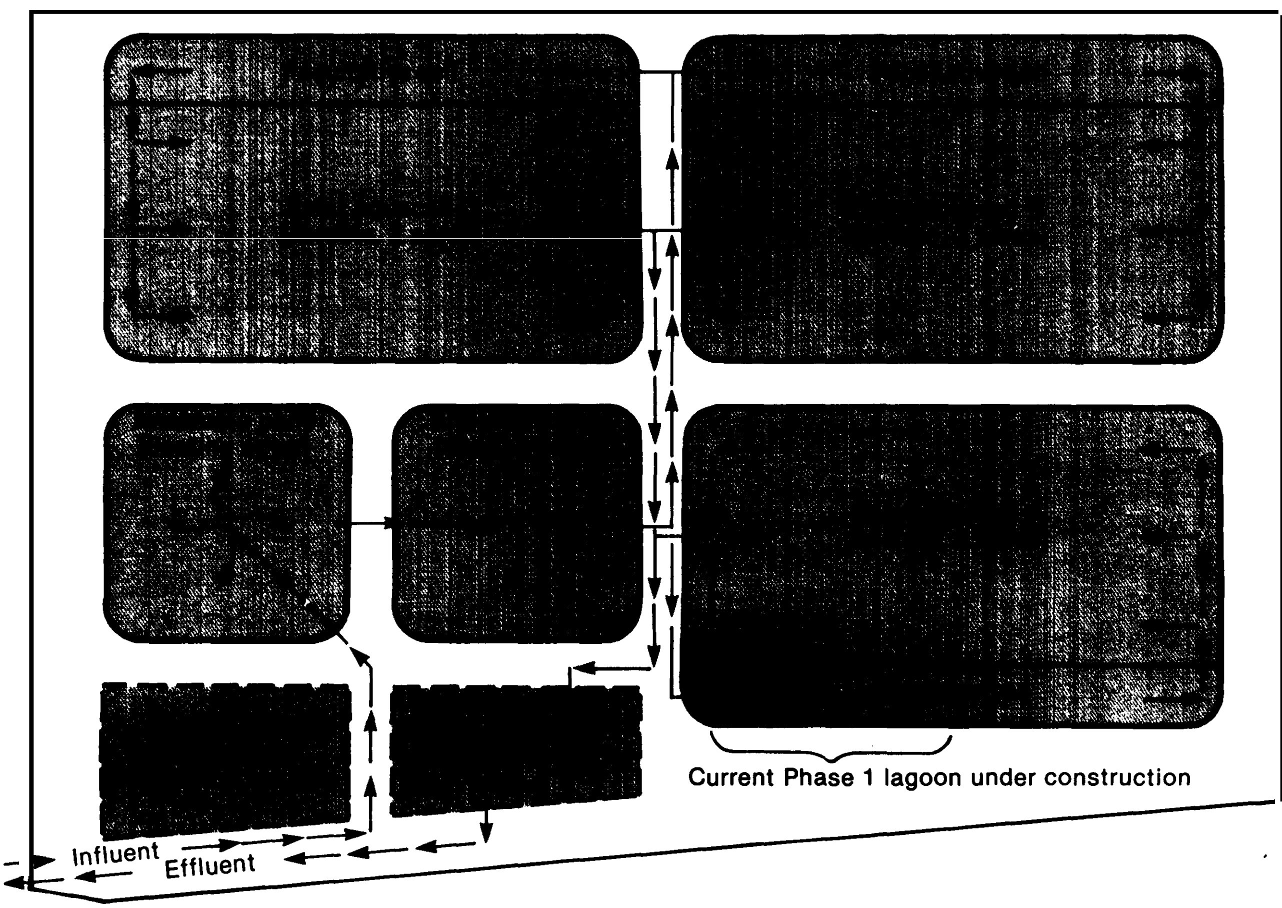


Photo credit: Hercules AquaCell

The Hercules AquaCell Treatment Facility

Figure 31.—Proposed 2. O-MGD Solar AquaCell Facility, City of Hercules



Plan view of the proposed 2.0-MGD Solar AquaCell Lagoon Treatment Facility for the City of Hercules, Calif. Each AquaCell will be 2.0 acres (6 acres total). The 0.35-MGD treatment phase currently under construction consists of a 1.5-acre AquaCell system with anaerobic, facultative, and aerobic stages, approximately one-half of AquaCell A.

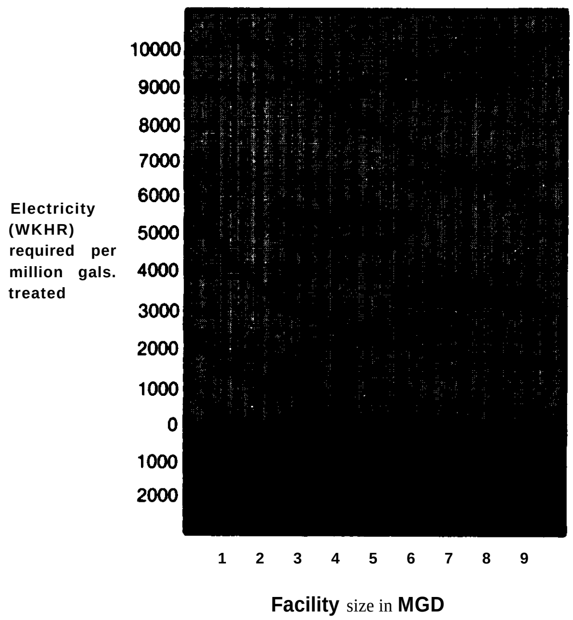
dle 350,000 gpd. A 1.15-acre earthen pond, about 220 by 230 ft has been built; this pond will be enlarged to 2 acres, and two additional 2-acre ponds will be built, when the plant expands. The initial phase does not include a separate anaerobic pond; instead, the single lagoon contains three cells—anaerobic, facultative, and aerobic—separated by walls of heavy rubber.

For the first few months of operation in Hercules, treated water will flow back to the conventional treatment plant at Pinole to be tested and treated again. If the AquaCell system works reliably, treated water will be pumped into San Francisco Bay through an outfall in neighboring Rodeo. In the future, however, Hercules is considering using the treated water for greenbelt irrigation. Nitrogen and phosphorous removal will not be required for this use, since these compounds will act as fertilizers. The city is also investigating the possibility of selling its reclaimed water to Pacific Refinery for industrial use.

Total capital costs of phase I construction for 350,000-gpd capacity were about $2 million, considerably higher than Solar AquaSystems' original estimate. The major reasons for this cost increase were the 50-percent increase in the size of the initial lagoon and the city's decision, anticipating future expansion, to build the initial AquaCell plant with adequate basic elements (tanks, pumps, and pipes) for capacities of up to *4.4* mgd. Another factor in the cost increase is that, because the Solar AquaCell is a new process unproven on a municipal scale, design and construction costs have escalated as engineers and contractors added relatively high contingency fees to cover risk; this added 10 percent to the cost of basic elements alone.

Total capital costs for expansion to full 2.2-mgd capacity are currently estimated at an additional $2 million to $3 million. Although the capital cost of the Solar AquaCell is comparable to Hercules' share of the Pinole expansion, it appears that operating and maintenance costs for the AquaCell will be relatively low. Experiments have shown that the AquaCell also uses less electricity than conventional systems (see figure 32), and (in the

Figure 32.—Electrical Energy Requirements for Conventional v. Ecological Wastewater Treatment Systems



aDeveloped from E. B. Roberts and R. M. Hagan, *Energy Requirements of Alternatives in Water Supply Use and Conservation: A Preliminary Report,* California Water Resources Center University of California Davis, Contribution #155, December 1975; and from A. Cywin, Director of Effluent Guidelines Division EPA, "Energy Impacts of Water Pollution Control", *Energy, Agriculture and Waste Management,* William Jewell, cd., 1975.

bBased on biomass optimization for biofuels and electrical generation (no ozone electricity included).

SOURCE: Environmental Protection Agency. Draft Innovative and Alternative Technology Assessment Manual. EPA 430/9-7S-0001, 1978.

future), methane produced in the anaerobic stage may be used to generate electricity and further reduce costs.[27]

[27]Methane utilization is also a common practice in conventional wastewater treatment technologies. Anaerobic digestion yields a gas that is 65 percent methane and 35 percent carbon dioxide. One ft^3 of gas (enough to light a 60-watt bulb for 6 hours) is generated each day for every 100 gal of wastewater treated. The gas is typically used to provide one-third to one-half of the heating requirements of the treatment plant. (Wastewater Pollution Control Federation, *Wastewater* Treatment *Plant* Design IWashington, D. C., 1977], p. 531). See ch. 5 for further discussion of methane digesters.

Critical Factors

Treatment of wastewater by the Solar AquaCell is too new a technology to warrant a definitive evaluation as yet; there are as yet no reliable performance data. However, as an example of the problems of developing a new technology, the Hercules experience should be of interest to communities thinking of adopting innovative wastewater treatment systems of their own.

Public Perception and Participation

The issue of what to do with Hercules wastewater elicited little general debate among residents. Most of them knew that a new facility was under consideration, but few of them knew any details of the controversy. Apparently they were willing to leave the decision to the City Council, feeling that it would make the right choice and that their sewage would be adequately treated. The recent growth and constant state of change in Hercules seemed to have deterred community involvement: attendance at council meetings was usually low, and there were only a few informal neighborhood groups. Since the decision to go ahead with the AquaCell plant, the project has received a fairly high level of local publicity and support, although public involvement remains low. City officials are organizing neighborhood meetings and publishing a newsletter in an effort to increase citizen participation in this and other city decisions.

The response to the AquaCelI technology was different in two other communities where the firm submitted proposals at about the same time. In early 1977, Solar AquaSystems submitted proposals to build AquaCell plants in San Diego, where the proposal is still pending, and on the Chemehuevi Indian Reservation at Lake Havasu, Calif., where it was rejected. In the latter case, the debate caused by the introduction of so unconventional a technology appears to have been responsible for its rejection. The Chemehuevi submitted a grant application using the system to the Department of Commerce's Economic Development Administration (EDA), but by the time the firm could explain the technology to EDA (who initially turned the proposal down in February 1978, but subsequently approved it), the controversy over the proposal and the prospect of further delays had created so much suspicion in the Chemehuevi community that they decided not to get involved in the technology at all.

In San Diego, on the other hand, Solar AquaSystem's proposal helped to engender local enthusiasm for using an innovative method of sewage treatment. The city subsequently submitted a grant application to EPA to fund some type of aquiculture-related wastewater treatment plant. EPA approved the application in January 1980, and San Diego is currently considering various systems, including the AquaCell.[28]

Whatever the problems in getting them adopted, however, once new ideas become realities they begin to have a ripple effect in the community. This has been the case in Hercules, where many people have taken a cue from the city's approval of an AquaCell to install low-flush toilets and restricted-flow shower heads in their own homes. According to some estimates, these actions will reduce local water consumption by as much as 40 percent. This also results in a more concentrated wastewater flow, which would be a problem in conventional systems.

Essential Resources

The performance of the AquaCell process is affected by climatic conditions and the amount of land available for its treatment ponds. Colder temperatures limit the efficiency of all biological wastewater treatment processes; communities with a less temperate climate than California's would find that retention times in either a conventional

[28]Other examples of aquiculture wastewater treatment projects exist in Lakeland and Disneyworld, Fla.; Mountain View, Calif.; and Vermontville, Mich. (Source: Jerome Goldstein, editor of *In Business* and *Compost Science*, The JG Press, Emmaus, Pa.).

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system or a Solar AquaCell would have to be increased in order to obtain the advanced treatment quality achieved in Hercules. Since the AquaCell has not yet been tested in colder climates, no precise adjustment tables are available, but this does pose a potential limit on the transferability of the technology.

Theoretically, scale is not a limiting factor, since the AquaCell system could be built small enough to handle sewage from 5 to 10 houses, or large enough to handle in excess of 100 mgd, the capacity required for a population of 1 million. Land availability, however, could be a limiting factor. The AquaCell requires about the same amount of land as an oxidation pond system, but more space than an activated sludge facility. In some densely developed urban areas, where land is expensive, this may weigh against the AquaCell; but its other benefits and cost advantages may still make it competitive. AquaCell's greatest competitive advantage may be in smaller communities, where land is less expensive and where there are diseconomies of scale in building conventional facilities.

Another factor limiting the transferability of the AquaCell to other communities is that water hyacinths are considered a weed problem in some regions, particularly in the Southeastern States where overgrowth clogs freshwater canals; the release of hyacinths from the AquaCell could aggravate this problem.[29] In California and many other areas, however, water hyacinths will not survive outside the greenhouse environment.

Technical Information and Expertise

Communities faced with the need to construct, expand, or upgrade their wastewater treatment facilities would profit from a broader knowledge of the technological alternatives available to them. For instance, there is a need for further study of which treatment systems are most appropriate for different kinds of communities—older cities, new towns, rural areas, and suburbs—as well as which are most appropriate to different climates and soil types. The Hercules facility, as the pioneer installation of one new technology, can be a valuable demonstration on a municipal scale and a source of information for other communities, and EPA has expressed interest in studying the Hercules AquaCell during its first 2 years of operation. In addition, conducting surveys to gather information about potential markets for reclaimed water and other system byproducts would be helpful in determining the feasibility of the technology and in planning local development programs.

Communities that decide to use a technology of this type would need the services of a design firm, engineers to adapt the design to a specific site, project development managers, construction workers, system operators, and maintenance personnel. Only the design phases, however, require special expertise. Under competent management, the actual construction should not be difficult, since it is based on typical greenhouse and lagoon designs. Operation and maintenance does differ somewhat from that of conventional plants, but the skills involved (such as harvesting aquatic plants) appear simple enough to develop through short training programs.

For both Hercules and Solar AquaSystems, the first year of the AquaCell plant's operation is crucial to its technological success and economic viability. Once the system is established, it is designed to need only minor adjustments to ensure that it is working at maximum efficiency. The city has given the firm a $54,000 contract to manage the facility during the startup year. As part of this contract, Solar AquaSystems has also agreed to train operators, prepare operation and maintenance manuals, and supervise testing of water chemistry and biological components.

Financing

The capital costs of the AquaCell are equivalent to those of expanding an existing conventional plant, according to current estimates. However, AquaCell costs may well be lower than those of a completely new conventional facility, especially in communities where smaller capacity requirements give conventional plants a higher per capita cost. AquaCell's lifecycle cost advantages are related primarily to the technology's flexibility. First, its modular design makes it simpler and cheaper to upgrade a facility for advanced treatment, and also allows enlargement of the facility to meet the

[29]Thomas Bull, Energy Program, Office of Technology Assessment.

demands of a growing community without requiring the community to spend large initial sums for oversized facilities.[30] Second, the system's biological components are relatively hardy, which allows them to adapt to changes in waste concentrations and reduces the possibility of system malfunction. Third, its operating and maintenance costs appear to be substantially lower than those of conventional systems, partly because the greenhouse cover reduces energy consumption and partly because the system produces less sludge.

Despite these economic advantages, however, the greatest single barrier to developing and implementing the technology has been the lack of a sufficient, steady source of financing. Conventional technologies and proven alternatives are more familiar to private and public sources of funding, and their costs are usually more clear-cut. In adopting new or unproven technologies, on the other hand, potential time delays and added costs should be calculated, or at least formally recognized, in order to arrive at a realistic determination of final costs. In the case of the Hercules project, part of the discrepancy between estimated and actual costs was due to time delays and the addition of contractors' fees and contingencies to cover risk.[31] The element of risk exists at nearly every stage, from the initial feasibility study, through the design and engineering phases, all the way to eventual construction, operation, and maintenance. As uncertainty increases at any stage, so do the potential costs of the project and the hesitation of the sources of financing.

The city of Hercules tried to obtain developmental funding from EPA's Office of Research and Development, but that office did not have the available resources to support a large '{experimental" project. (This situation has improved somewhat with the change of Federal policy reflected by the creation of EPA's Innovative and Alternative Technology Program, discussed later in this chapter.) EPA construction grant funds would have been available only if Hercules agreed to limit its growth and participate in either the Pinole expansion or the proposed regional treatment plant. This would have been a barrier to the transfer of this technology to communities that lack Hercules' tax base; Hercules was fortunate, and perhaps unique, in being able to find the multimillion-dollar AquaCell project out of its own revenues.

The Solar AquaCell case also illustrates many of the financial problems faced by innovators and entrepreneurs in appropriate technology. Lack of funds has prevented Solar AquaSystems, Inc., from hiring a sanitary engineer to help with design and to enhance the firm's credibility, and low salaries have been a strain on staff morale. The company's ability to plan has been restricted, and the size and diversity of its development hardware have been limited. Demonstration (and the capital it requires) is the key step to commercialization, but the firm's marketing operations have been hampered by the inability to visit prospective users or follow up on contacts. For example, the city of Santa Fe, N. Mex., has expressed an interest in the AquaCell system, but as yet the staff has lacked the time and money to make a presentation to that city. Similarly, the company was unable to send representatives to Hercules as often as it wished to facilitate construction there. Solar AquaSystems expects to break even on the Hercules project; only if other communities decide to use the system will they make a profit from their technology.

The failure of the firm to attract outside investment capital has not been for lack of trying. They found, however, that venture capital sources wanted substantial control over the firm before they would invest, usually amounting to 80 or 90 percent of the company. This was in part because of the high-risk nature of the investment, and in part because the venture capital market was extremely tight in 1976, when they were seeking funds. As one source explained:

> Venture capitalists require such a high ownership level because of the difficulty of selling their interest once the enterprise has become successful. Whereas it used to be possible to sell a company for 30 times its annual earning, 10 times earnings would be a more realistic figure today. Thus, to make a return on investment acceptable to the

[30] Council on Environmental Quality, Environmental *Quality—1975, the* Sixth *Annual Report of* the *Council* on Environmental Quality (Washington, D. C.: Executive Office of the President, 1975).

[31] For example, the contractor hired by the city to build the AquaCell greenhouse cover increased contract fees for structural engineering aspects in expectation of added costs due to possible unknowns regarding the unconventional technology.

venture capitalist, he or she must receive a larger share of the ownership in exchange for providing the same amount of capital.[32]

This issue, as it relates to the AquaCell case in particular and to innovative technology enterprises in general, is discussed at greater length in the section on financing in chapter 11.

Institutional Factors

The Hercules AquaCell project experienced relatively little opposition from local commercial interests. Some local builders opposed the proposal, fearing that the introduction of a new technology might cause delays in sewer hookups for new housing units. They urged the City Council to go the conventional route by paying for the Pinole plant expansion. Most such groups, however, saw the same advantages for the community that motivated the City Council.

A far more serious barrier to the implementation of this technology has been the resistance of Federal, State, and regional regulatory agencies. State and regional agencies for water quality control and public health have tended to prefer the conventional systems with which they were more familiar. The California State Water Resources Control Board, for instance, tends to judge wastewater projects by a set of criteria based on compact, mechanized conventional systems—activated sludge in particular. This board is made up of civil and sanitary engineers whose experience is rooted in these mechanical systems.

These engineers, as well as public health officials, have also been resistant to systems that reclaim wastewater for other uses and recycle wastes and other system byproducts. The majority of regulatory board members "believe in deep ocean dumping, " according to one former member;[33] and the State, regional, and county health officials have made it clear that the facility will not be given final certification until procedures for handling solid wastes are demonstrated to their satisfaction.[34] The comporting system at the Hercules facility was therefore vital, since for purposes of disposal the local health department defined the system's harvested water hyacinths as "contaminated, " undigested solid wastes.[35]

[32] John M. Smith, Jeremiah J. McCarthy, and Henry L. Longest, "Impact of Innovative and Alternative Technology in the United States in the 1980's," presented at the Seventh United States Japan Conference on Sewage Treatment Technology, Tokyo, May 1980.

[33] Roy Dodson, Special Consultant to the California Department of Health Services and former member of the California Safe Water Resources Control Board, personal communication, Mar. 23, 1978.

[34] Stephen Serfling, president of Solar AquaSystems, Inc., in a letter to the Hercules City Engineer, May 19, 1978.

[35] Ibid.

Federal Policy

Background

The Federal Government has provided grants for the planning, design, and construction of wastewater treatment facilities since the enactment of the Federal Water Pollution Control Act of 1956 (Public Law 84-660). In 1972, the Federal Water Pollution Control Act Amendments (Public Law 92-500) were passed, setting a uniform national minimum effluent standard of secondary treatment and authorizing an increase in the Federal share to 75 percent of eligible construction costs.

Although the Act encouraged alternative technologies for waste treatment, no incentives were provided. Most of the over $30 billion obligated to date has been used for the construction of conventional wastewater treatment facilities. With the passage of the Clean Water Act of 1977 (Public Law 95-217), Congress directed EPA to offer incentives for the use of alternative technologies for municipal wastewater and other waste treatment needs. In addition to the goals for clean water, Congress placed special emphasis on the use of technologies that:

- reclaim or reuse water;
- use recycling techniques, for example, recycling nutrients back to the land;
- eliminate discharges into surface waters;
- conserve or recover energy; and
- lower treatment costs.

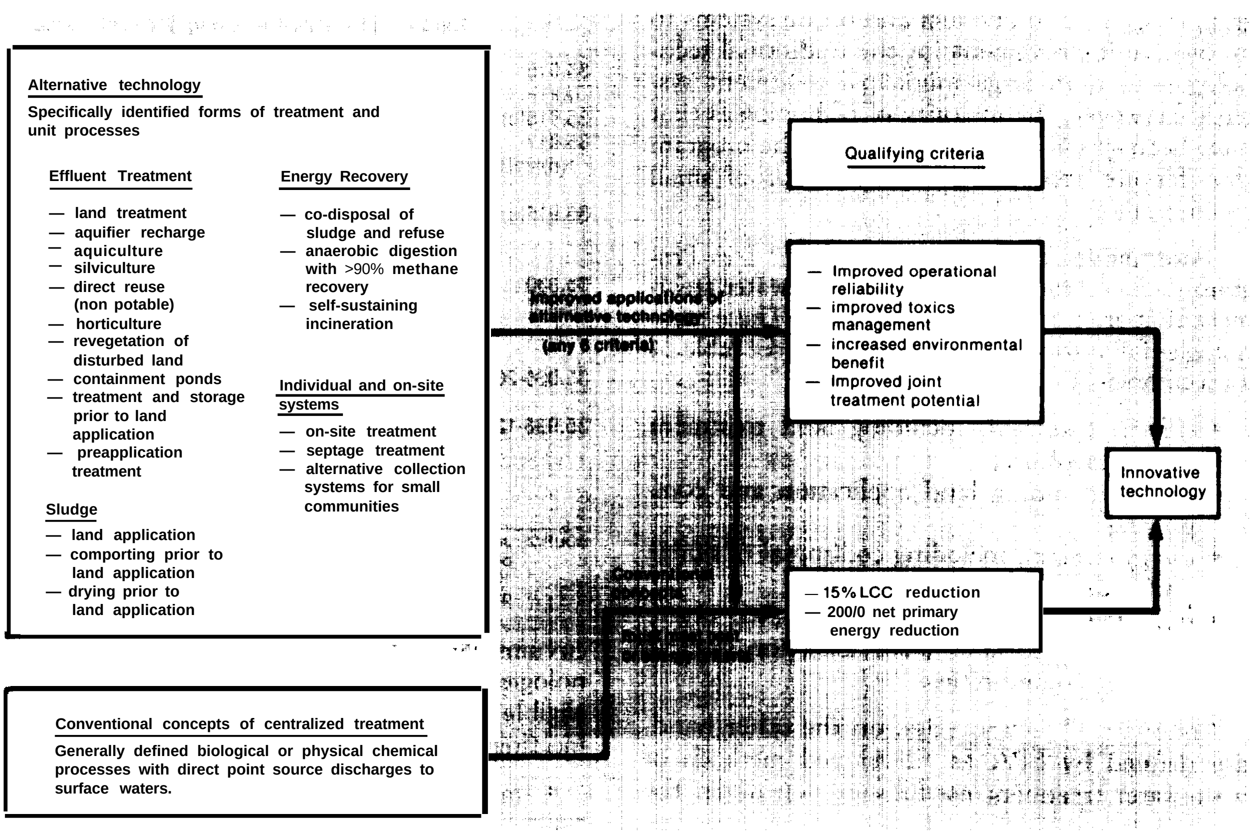
Congress also required all applicants for municipal waste treatment funds to fully study innovative and alternative wastewater treatment options which meet these goals.

Innovative and Alternative Technology Program

In October 1978, EPA established the innovative and Alternative Technology Program (1/A Program). This modification of the normal Federal Construction Grants Program enabled EPA to offer several incentives to communities:

- Increased Federal portion.—Federal grants for new treatment works using innovative or alternative technologies are increased to 85 percent of design and construction costs, as compared to 75 percent for traditional technologies. This means as much as a 40-percent savings to the community, a considerable incentive even when initial capital costs for the two options are the same.
- Set-aside *funds.*-- special fund is set aside from each State's allocation that can only be used to pay for the 10-percent grant increase for innovative and alternative technologies. This set-aside fund was 2 percent for fiscal years 1979 and 1980, and 3 percent for fiscal year 1981; at least 1/3 percent of each State's allocation must be set aside for innovative technologies. These set-asides in effect make more money available for innovative or alternative technologies and give a community wishing to use them an extra advantage in the State priority-setting process.
- Cost *preference.* —Innovative and alternative technologies can qualify for construction grants even if they cost up to 15 percent more

Figure 33.—Generalized Classification of Innovative and Alternative Technology



SOURCE. United States Environmental Protection Agency, *Draft Innovative and Alternative Techology Assessment Manual,* EPA 430/9-7 S-0001, 1978.

than conventional technologies. Thus, even though the alternative treatment facility may be more expensive, the increased Federal share still allows the community to pay less than it would for its larger share of the conventional facility.

- *Risk guarantee.*—Communities that choose innovative and alternative technologies are eligible for 100-percent construction grants for correcting or replacing the systems in the event they fail. This provision removes all financial risks to the community at least for the duration of the I/A Program.

See table 23 for a summary of innovative and alternative technology legislation and regulations.

The set-aside funds available under the I/A Program for fiscal years 1979 and 1980 totaled $84 million, which means that a maximum of $714 million in Federal construction grants were available for innovative and alternative technologies. Waste treatment methods that qualify for the program range from individual and onsite systems to innovative improvements in the traditional technologies used in large municipal treatment systems. However, the majority of technologies that have been specifically encouraged by the program thus far are appropriate for the needs of small communities.

"Alternative" technologies under the I/A Program include *proven* methods of wastewater treatment that are not yet in extensive use. These technologies fall into four major categories (see table 24 for a complete list):[36]

- *effluent treatment,* including land treatment and aquiculture;
- sludge, including land application and comporting;
- energy recovery, including codisposal of sludge and refuse; and
- individual and *onsite systems,* including onsite treatment and alternative collection systems for small communities.

"Innovative" technologies, on the other hand, are defined by EPA as "developed methods of wastewater treatment *not* fully proven under the

[36]EPA 1980.

Table 23.-Summary of Federal Legislation and Regulations Relating to Innovative and Alternative Technology

Legislation-Public Law 95-217, Dec. 27,1977	
Sec.	
201(d)	**Encourages the design and construction of revenue-producing facilities**
201(9)(5)	Requires all **applicants to study innovative and alternative technologies**
201(i)	**Encourages energy consevation in the design of all publicly owned treatment works**
201(e)	**Encourages the reduction of total energy requirements in the design of publicly owned treatment facilities**
201(j)	**Provides for 15% cost preference in the cost-effectiveness analysis for ail innovative and alternative technologies**
202(a)(2)	**Increases Federal grant from 75 to 85%**
202(a)(4)	**Limits grant eligibility to publicly owned treatment works (excludes sewers and sewer rehabilitation)**
304(d)(3)	**Requires EPA to develop guidelines for innovative and alternative technologies**
205(i)	**Authorizes innovative and alternative funding set-asides for fiscal years 1979, 1980, and 1981**
Regulation--40 CFR35, Sept. 27,1978	
Regulations	
35.908	**Describes innovative and alternative policy, funding, priority scheduling and replacement provisions of the Act**
35.9i5 (a)(l)	**Describes State priority system**
35.915(e)	**Provides for EPA review of State priority system**
35.917-l(d)(8)(9)	**Requires innovative and alternative technology and energy review**
35.915(b)	**Provides for establishment of State reserve set-asides to increase Federal share of cost from 75 to 8570**
35.930 (5)(b)	**Provides for 75 to 85% grant increase for new and replacement innovative and alternative projects**
35.935-20	**Provides for EPA postconstruction evaluation and inspection for 5 years**
35.936-13	**Provides exclusion to nonrestrictive specifications for certain innovative and alternative technologies and "buy American" provisions**

SOURCE: John M. Smith, Jeremiah J. McCarthy. and Henry L. Longest. "Impact of Innovative and Alternative Technology in the" United-States in' the 1980' s," presented at the Seventh United States/Japan Conference on Sewage Treatment Technology, Tokyo, Japan, May 1980.

circumstances of their intended use."[37] These technologies (in which category the AquaCell falls) are eligible for funding if they show potential for meeting one or more of the following criteria:

. improved operational reliability;

[37]*Innovative and Alternative Technology,* A *New* Approach *to an Old* Problem, brochure MCD-64, (Washington, D. C.: Environmental Protection Agency, March 1980).

Table 24.—Alternative Technologies for Wastewater Treatment

Effluent treatment systems
—land treatment
—aquifer recharge
—aquiculture
—silviculture
—direct reuse (nonpotable)
—horticulture
—revegetation of disturbed land
—containment ponds
—treatment and storage prior to land application
—preapplication treatment
Sludge systems
—land application
—comporting prior to land application
—drying prior to land application
Energy recovery systems
—codisposal of sludge and refuse
—anaerobic digestion with > 90% methane recovery
—self-sustaining incineration
Individual and onsite systems
—onsite treatment
—septage treatment
—alternative collection systems for small communities

SOURCE: Environmental Protection Agency.

- improved toxics management;
- increased environmental benefit;
- 15-percent reduction in lifecycle costs; or
- 20-percent reduction in energy use.

Modifications of convention, centralized treatment methods that are not yet fully proven are eligible for innovative technology funds only if they meet the last two criteria, reductions in lifecycle costs or energy consumption.

The Status of the I/A Program.–The I/A Program is a 3-year program, terminating at the end of fiscal year 1981 unless extended by Congress. At the end of the first half of the program, 212 innovative and alternative projects had been funded.[38] This amounted to only about 20 percent of the $84 million fiscal year 1979 set-aside funds available. Over 200 additional projects were undergoing review.[39]

Most of the innovative and alternative projects funded to date were already in the planning stage at the beginning of the program. Communities initiating projects after the program started in October 1978 are just beginning to apply for design funds. The alternative technologies have been primarily for small communities; most projects involve some form of land application of wastewater or sludge, but almost 40 onsite treatment systems have been approved, and more than 10 projects incorporate some form of energy recovery. Very few projects have been approved as innovative (or higher risk) technologies. Several systems incorporating land treatment have been classified innovative due to increased environmental benefit, but most of the innovative projects that have been approved has been energy- saving or cost-cutting modifications of conventional systems. Few systems as unconventional as the Hercules AquaCell has yet been funded.

Common to all alternative technology programs is the problem of disseminating information about the technologies and the program itself. To address this problem, the I/A Program has thus far:[40]

- established a clearinghouse and technical support group in the EPA lab in Cincinnati; a Small-Flows Technologies Clearinghouse has also been established;
- published an innovative and alternative technology assessment manual and distributed it to over 6,500 engineers;
- sponsored over 30 innovative and alternative technology seminars and workshops across the country; and
- prepared brochures and movies to give greater public exposure to the program.

The EPA Administrator has recently established an "active" I/A Program, providing extra manpower for technical assistance and promotion of the program. EPA is also considering a mechanism for expediting specific, prequalified innovative and alternative technologies. A quicker, simplified review procedure is being developed for communities wishing to use these technologies.

The midway point may be too early to evaluate the I/A Program's effectiveness, but it appears highly unlikely that the total funds appropriated for the program will be spent before it ends. The

[38] *Quality* Report–1/A Program Through March 31, 1980 (Washington, D. C.: Environmental Protection Agency, April 1980).

[39] Robert Bastian, Innovative and Alternative Technology Program, EPA, personal communication, 1980.

[40] Robert Bastian, Jeremiah McCarthy, Terry Yoise of EpA, personal communications, 1980.

primary reason for this is that 3 years—the length of the program—is a very short time in which to successfully introduce and implement these new systems, for the following reasons:

- Time is needed to hire staff and develop guidelines for the program, and to inform States and communities about the program.
- Conventional design procedures and standards, established in 1947 by the "Ten State Standards" of the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers,[41] have been slow to change. Before alternative systems can effectively compete with traditional approaches, consultants and state engineers must acquire new design and review skills, just as professional schools and State review boards must be convinced to give innovative and alternative systems a fair hearing.
- Performance data for alternative systems are skimpy and often difficult to obtain. Land application systems are better researched than most of the other alternative technologies,[42] and only a few aquiculture systems are well documented. EPA sponsors both R&D and technology transfer programs at its Robert S. Kerr Envionmental Research Laboratory and Municipal Environmental Research Laboratory, but these programs take time, money, and manpower to become effective. Competition from other pressing, research efforts is severe.
- Because the I/A Program is funded for only 3 years some communities and consultants are hesitant to pursue the program.[43] From planning to construction of a wastewater treatment facility commonly takes 6 years under the Construction Grants procedures (of which the I/A Program is a part), and potential developers are concerned that the I/A Program incentives may be discontinued before their facilities are completed.

[41]Smith et al., op. cit.

[42]John R. Benneman, "Energy From Aquiculture Biomass Systems," report prepared for Office of Technology Assessment, U.S. Congress, 1979.

[43]John Hickerson, Director, El Paso Water Facilities, personal communication, 1980.

Issues and Options

Two major questions are raised by the foregoing discussions of the range of available wastewater treatment technologies, the Hercules AquaCell case study, and EPA's I/A Program:

- What should be the goals for Federal involvement with alternative wastewater treatment technologies?
- What types of programs (if any) should be established to accomplish these goals?

ISSUE 1:
The Goals of the Wastewater Treatment Program in Relation to Other Federal Programs and Goals.

Grants for the construction of wastewater treatment facilities represent the largest nonmilitary public works program since the Interstate Highway System.[44] One goal of the program (according to the amendments of 1972) is to achieve water quality that is clean enough for swimming and fishing. The Clean Water Act of 1977 (Public Law 95-217) amended the earlier law to provide additional money for municipalities which use technologies that: eliminate surface discharge, reclaim water or water pollutants, conserve energy, or otherwise achieve cleaner water at a lower cost. Some of these criteria are not traditionally associated with wastewater treatment.

A number of often conflicting national goals are related to wastewater treatment. Energy conservation and resource recovery, for example, are important goals, but they may divert funds from technologies which more directly improve water quality.

Some goals might be accomplished regardless of Federal incentives; others may require active involvement. For example, cost reductions for conventional technologies can occur through the workings of the marketplace. Elimination of surface discharge may not have the same economic incentives, yet it may be an equally important national goal. Traditional engineering firms, when given the option, are more likely to design lower

[44]Copeland, op. cit.

cost conventional technologies than to hire or develop expertise in entirely new approaches to wastewater treatment design.

Wastewater treatment can also have unintended effects on other programs. For instance, its impacts often act as de facto zoning regulations: conventional, centralized wastewater treatment facilities may encourage housing development along sewer mains, but may limit development to sewered areas alone. Community or onsite systems, on the other hand, allow more local control over population growth but make regional planning more difficult. For example, one of the reasons the City of Hercules chose to build the AquaCell facility was to avoid regionally imposed population growth restrictions.

Option 1: Determine the Extent of Federal Involvement.—Several degrees of Federal involvement in alternative wastewater technology are possible. These range from no involvement other than nonincentive funding under the pre-1977 Construction Grants Program, to providing community incentives such as the I/A Program. If Congress decides that the goals that can be achieved by alternative wastewater treatment deserve Federal involvement, the options for legislative action involve three major issues: information transfer, R&D, and community incentives programs.

ISSUE 2:
information Transfer—How Can Communities and the Engineering Profession Learn About Available Alternative Wastewater Treatment Technologies?

This issue is generic to all types of alternative technologies. For wastewater treatment, two types of information are necessary:

- *technical information* to local, State, and consulting engineers for design and review of alternative technolgoies,[4] and
- *nontechnical information* to educate community leaders and citizens about the advantages and disadvantages of the wide range of treatment alternatives.

Option 2: Clearinghouse and Technical Support.–Reauthorization of the EPA's I/A Clearinghouse, technical support group, and other information programs might be considered independently of the rest of the I/A Program. The information transfer accomplishments of the I/A Program (see above) have been quite impressive, given the short time the program has been in existence.

ISSUE 3:
R&D—How Can New Wastewater Treatment Technologies Be Developed?

R&D activities are taking place primarily in the private sector. Some direct Federal support for this research is coming from EPA, the National Aeronautics and Space Administration, and the National Science Foundation, but this support is not extensive.

Alternative wastewater treatment research is funded by EPA's Office of Research and Development under its Water Quality Public Sector Activities Program. Less than $15 million was available in fiscal year 1980 for the entire program. Federal funds devoted to innovative and alternative construction grants also indirectly promote research. However, consulting firms do not receive direct compensation for research activities, and must rely on the new markets encouraged by the program for marketing their products.

An important factor for the successful introduction of new technologies is the mix of laboratory research, pilot-scale projects, and full-scale demonstration. Full-scale demonstration projects are the most costly, but they are necessary for professional acceptance. Engineers are often hesitant to accept the results of small-scale research, precisely because laboratory-scale results do not always accurately predict full-scale performance.

Option 3-A: Direct Federal Research Funds.–Alternative wastewater treatment technologies may be given separate authorization in EPA's R&D budget.

Option 3-B: Demonstration Programs.—A full-scale demonstration program might be established. One option is to establish a design competition, similar to architectural design competitions: communities could be chosen to represent a range of population and geographical conditions, and projects could be chosen to represent a range of alternative technologies. Engineers and community groups would then have the opportunity to inspect a variety of operational facilities.

Option 3-C: Evaluation Programs.–Evaluation of existing alternative wastewater treatment facilities could be separately authorized. Programs to evaluate the entire treatment process, rather than just monitoring the final effluent can provide valuable information on new designs. Innovative and alternative technology construction grants can then fulfill more effectively the dual purpose of meeting community wastewater treatment needs and furthering research efforts.

ISSUE 4:

Community Incentives.

The financial incentives available to a community for using innovative and alternative technologies under the I/A Program were discussed earlier. Several problems were also discussed, including the length of the program and the relatively small number of innovative technologies approved to date.

Option 4-A: Length of **Authorization.**—Authorization for the incentives for innovative and alternative technologies ends in fiscal year 1981. Because of the short length of the program (3 years, as compared with 5 to 6 years from planning to construction), the program may not be able to achieve its full potential. Authorization could be continued for a specified number of years, or based on "sunset" provisions that would fund a predetermined number of alternative and innovative projects in specific areas of the country and of specific types.

Option 4-B: Risk Guarantees.–The Clean Water Act provides for 100-percent construction grants for correcting or replacing innovative and alternative systems that fail. However, the guarantee is authorized only for the duration of the program. Communities are uncertain of funds being available for replacement after the end of the program, and are hesitant to assume the financial risk of failure. The guarantee provision could be authorized for a specified number of years of facility operation.

Option 4-C: Different Financial Incentives for Innovative v. Alternative Technologies.—From the viewpoint of the communities, the financial incentives under the I/A Program are identical for alternative and innovative technologies. Furthermore, consulting firms receive few benefits for the additional work involved in designing innovative technologies and are therefore more likely to suggest proven alternative systems. Providing different incentives for innovative v. alternative technologies may encourage the consideration of unconventional wastewater treatment systems.

Option 4-D: Fast-Tracking Innovative and Alternative Technologies.–Innovative and alternative technologies are currently subject to the same administrative procedures as conventional construction grants. EPA is considering streamlining some of these procedures, and congressional action can further streamline the process by removing some of the requirements stipulated by the Clean Water Act. This can be done either by providing exemptions for innovative and alternative technologies or by removing the I/A Program from the Construction Grants Program.