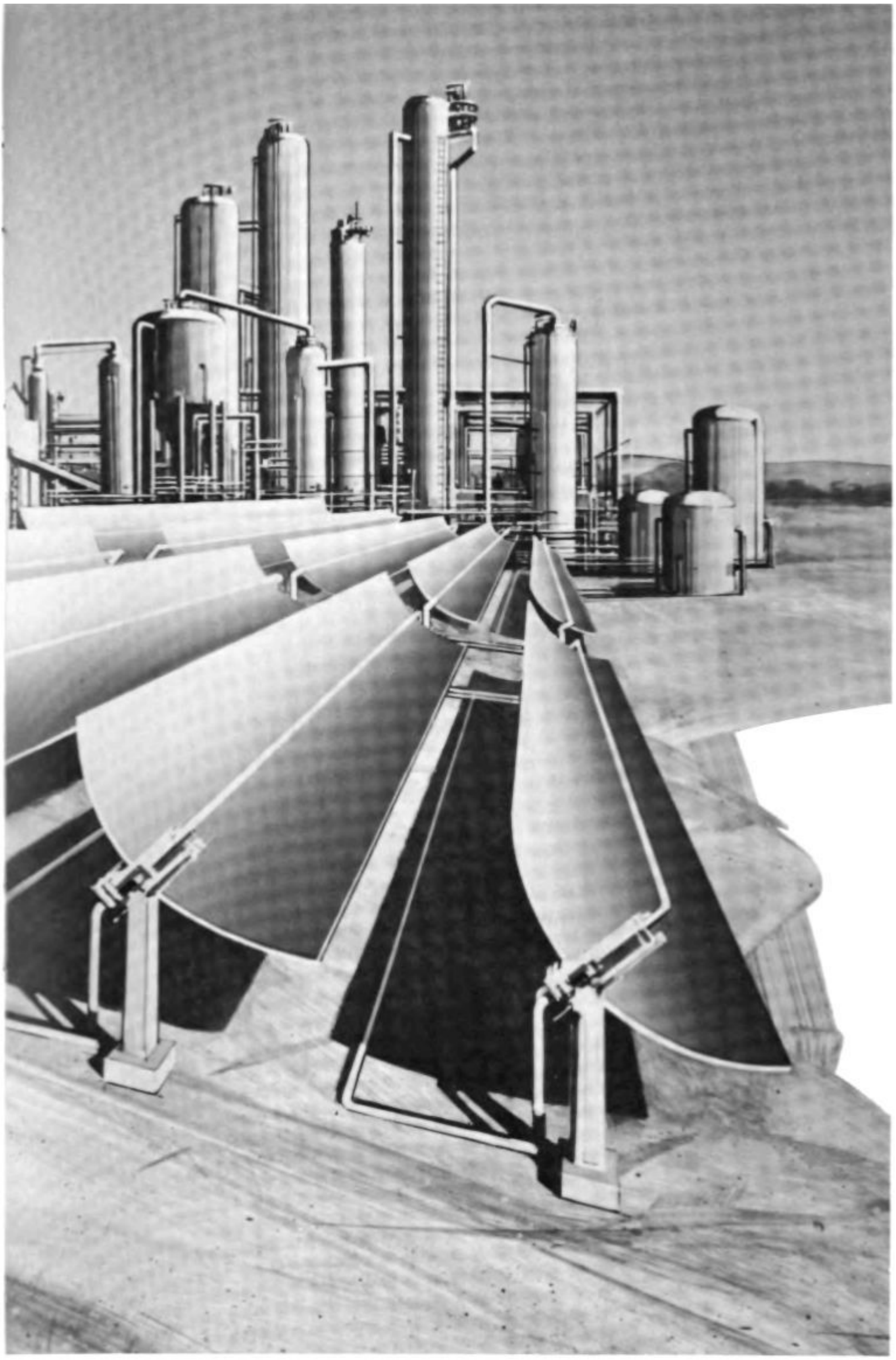
Shedding a New Light on Hazardous Waste

Solar Detoxification

Long, mirrored troughs gleam on the sunlit grounds of a chemical plant. Running the length of each of these troughs is a clear tube carrying contaminated wastewater. Sunlight striking the trough is reflected and concentrated onto the tube, causing a chemical reaction that destroys the contaminants. Clean, treated water exits the array to be reused or returned to the environment.



Shedding a New Light on Hazardous Waste

A futuristic vision? Not anymore. Significant advances in solar detoxification promise it a place in the market by the mid-1990s. The sun may soon become one of our strongest allies in meeting the challenges posed by hazardous waste.

Q What is solar detoxification of hazardous waste?

A The sun's ability to detoxify waterborne chemicals has long been known; polluted streams, for example, become cleaner as they flow through sunlit areas. Solar detoxification harnesses this natural degradation process for beneficial ends, producing simple, nonhazardous substances from hazardous organic chemicals. Solar detoxification systems now being developed break down these chemicals without using the fossil fuels required by conventional technologies.

The phenomenon of solar detoxification occurs naturally when chemicals in water are exposed to sunlight.

Sunlight destroys hazardous waste because of the distinctive properties of photons, the packets of energy that make up sunlight. Low-energy photons add thermal energy that will heat toxic chemicals; high-energy photons add the energy needed to break the chemical bonds of these chemicals. The detoxification process discussed here takes advantage of this latter group of photons found in the ultraviolet portion of the solar spectrum.

Q Why do we need solar detoxification?

A We need effective means to deal with the dangerous chemicals accumulating in our air. water, and soil. Our high-tech society is producing ever-increasing amounts of hazardous waste that the environment is struggling to accommodate. The burgeoning waste problem must be tackled at two levels: waste management and environmental remediation.

Waste management involves preventing, recycling, or disposing of hazardous waste as part of ongoing industrial processes. In 1988 alone, industry produced the equivalent of about a ton of hazardous material per citizen, a total of more than 280 million tons. Our waterways receive the bulk of this waste — nearly 240 million tons. Much of this waste filters into the groundwater supply and in diluted form becomes very difficult to treat.

What isn't released into the water supply is generally injected into underground wells or dumped in landfills. But these avenues are narrowing. Current landfills are approaching capacity, and all means of disposal are carefully scrutinized — and often rejected — by neighboring communities. Across the country, industry is being pressured to comply with more stringent regulations regarding hazardous waste.

We flood our sewers, ponds, and rivers with nearly 240 million tons of toxic waste per year.

Environmental remediation is the daunting task of treating the already existing hazardous waste in contaminated sites. Not surprisingly, because of past practices, contaminated water plagues every state in the nation. In fact, one-quarter of all large, U.S. drinking water systems shows traces of toxic chemicals, including chlorinated solvents. pesticides, and fuels. The long list of Superfund sites designated for cleanup by the Environmental Protection Agency (EPA) is a stark reminder of the scale of the problem.

Unfortunately, conventional detoxification efforts don't always adequately deal with the astounding flow of chemical waste we produce daily or remedy toxic waste contamination from years past. The U.S. Department of Energy (DOE), through a program managed by the Solar Energy Research Institute (SERI) and carried out in cooperation with Sandia National Laboratories, is seeking ways to alleviate this serious problem. The use of solar energy to destroy both waterborne and gaseous chemicals is a particularly attractive solution. Solar detoxification of waterborne contaminants, the technology more nearly ready for the marketplace, is the focus of this brochure.

Q *What are the advantages of solar detoxification?*

A Solar detoxification has created excitement within the environmental community for several reasons. First, it breaks down hazardous chemicals into environmentally benign or easily treatable by-products in a single step. In current industrial practices, toxic chemicals frequently are either released into the air or absorbed by materials that subsequently must be treated to remove these toxic compounds.

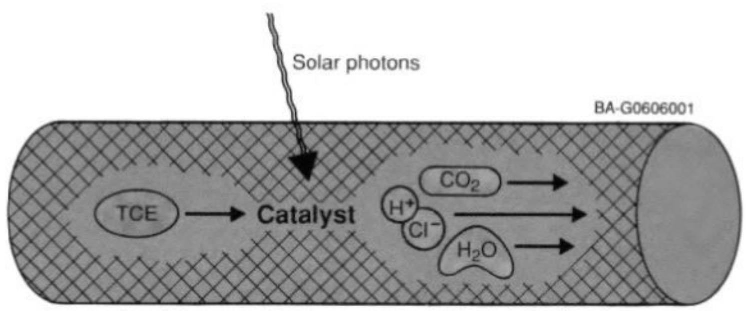
Detoxifying with the sun neither contributes to air pollution nor requires importing liquid fuels.

Second, solar detoxification is powered by the sun—a clean, abundant source of energy that neither contributes to air pollution nor requires imported liquid fuels. Using solar detoxification allows us to defray many of the hidden environmental, social, political, and economic costs confronting conventional processes. It offers us an excellent, long-term opportunity to establish greater energy self-sufficiency while cleaning up our wastes.

Third, detoxifying water with the sun minimizes the number of times contaminants are handled. Conventional processes typically remove wastes from the water and transport them off site for treatment. Detoxifying water with the sun eliminates the removal process: contaminants are treated directly in the water. As a result, the solar process limits the site owners liability to on-site operations and eliminates the need to handle the same wastes several times as well as the possibility of further contamination of the environment.

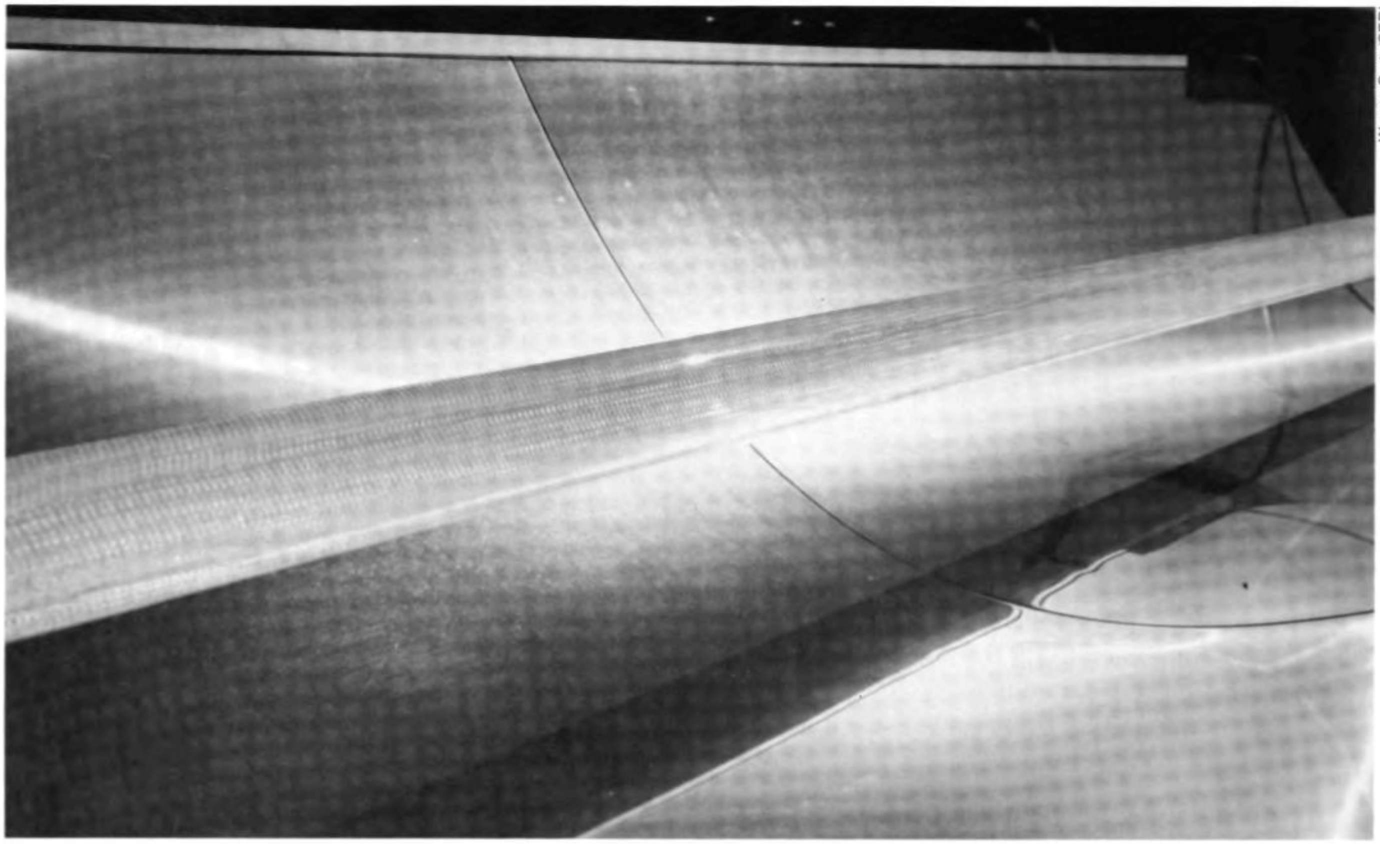
Q *How does the process work?*

A The detoxification of water is a photochemical rather than a thermal process, which means that it destroys contaminants by the chemical action of light. Much is known about this process; however, more research is needed to fully understand it and develop practical solar detoxification systems.



By absorbing the energy of photons, the catalyst forms reactive chemicals that break down the contaminant molecules, shown here as trichloroethylene (TCE), a common groundwater contaminant.

The process works by subjecting contaminated water to the combined forces of sunlight and a semiconductor catalyst. A commonly used catalyst is titanium dioxide (TiO_2), which serves as a coloring agent in paints, plastics, and toothpaste. This catalyst may be mixed into the water, creating a slurry, or fixed onto a lattice-type structure through which the water flows. The solar detoxification process treats water at room temperatures, roughly 70°- 100°F (20°-40°C).



Warren Gretz/SERI

In a concentrating system, contaminated waterJlows through a catalyst-filled tube illuminated by the equivalent of 5-30 times the normal *intensity of sunlight.*

When exposed to the sun. the catalyst absorbs the high-energy photons—light from the UV portion of the solar spectrum—and reactive chemicals known as hydroxyl radicals are formed. These radicals are powerful oxldizers that break down the contaminant molecules. The contaminants react with the oxidizers to form carbon dioxide, water, and dilute concentrations of simple mineral acids such as hydrochloric acid. The acid is neutralized in a post-treatment process before the treated water is discharged.

Q *What would a solar detoxification system look like?*

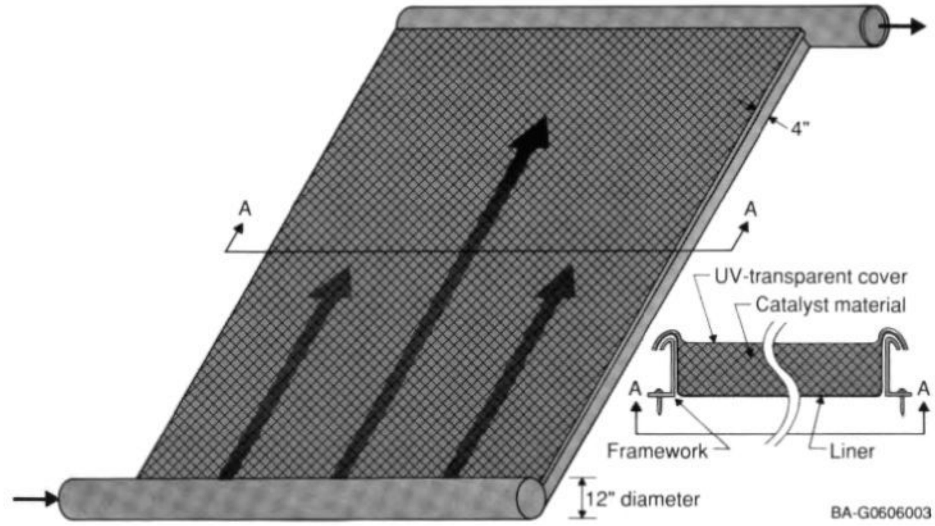
A That depends on whether or not it uses concentrated sunlight. Concentrating systems for detoxifying water use low concentrations of sunlight, generally less than 5-30 times its natural intensity. Their design is adapted from that of systems that provide process heat or electricity. These systems employ curved mirrors that serve as solar collectors by tracking the sun and reflecting its light onto a clear tube that runs the length of each mirror. The

Warren Gretz/SERI

Strings of collectors in a concentrating solar detoxification system would resemble this system, which produces industrial process heat.

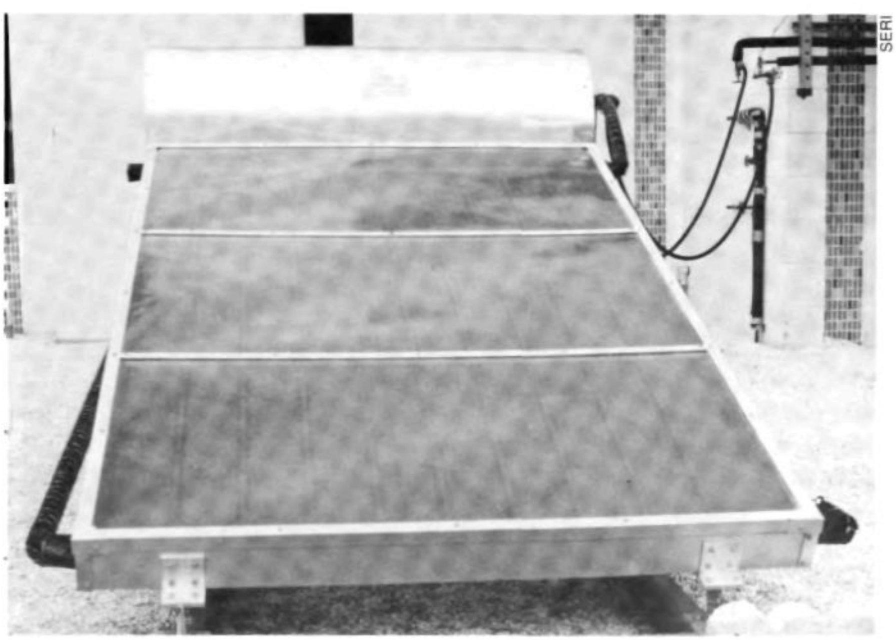
contaminated water flows through this tube.

Concentrated sunlight is not a must for detoxifying water: recent research shows that nonconcentrating systems can achieve the same ends as concentrating systems. In a nonconcentrating system, contaminated water flows through large, catalyst-filled panels resembling the flat-plate solar collectors placed on rooftops for domestic hot water.



This schematic illustrates the basic configuration of the nonconcentrating system. The contaminated water would Jlow across the surface of the large. catalyst-filled panel.

Like many solar-driven processes, both concentrating and nonconcentrating systems have the advantage of being modular. A concentrating system could be built as multiple strings of troughs ranging from just a few to many, covering several acres. Similarly, a nonconcentrating system would comprise the number of panels needed to detoxify a given amount of water. Both these systems would also include other components such as storage tanks or reservoirs, pumping stations to circulate the wastewater, instrumentation for testing the chemical composition of the water, and pre- and post-treatment facilities.

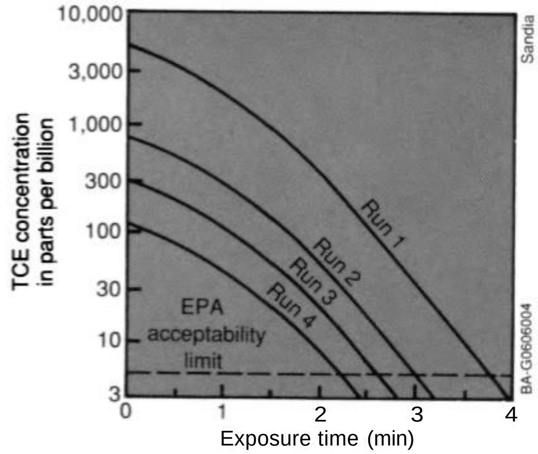


The design of a nonconcentrating system would be similar to that of a flat-plate collector used for domestic hot water heating, as shown here.

To adapt to the intermittent nature of sunlight, either process can be carried out in a batch mode. Contaminated material could accumulate in a reservoir during the night or when it is cloudy. Then, when the sun is shining, the stored waste material would be pumped through the detoxification system.

Q What chemicals are treated effectively with solar detoxification?

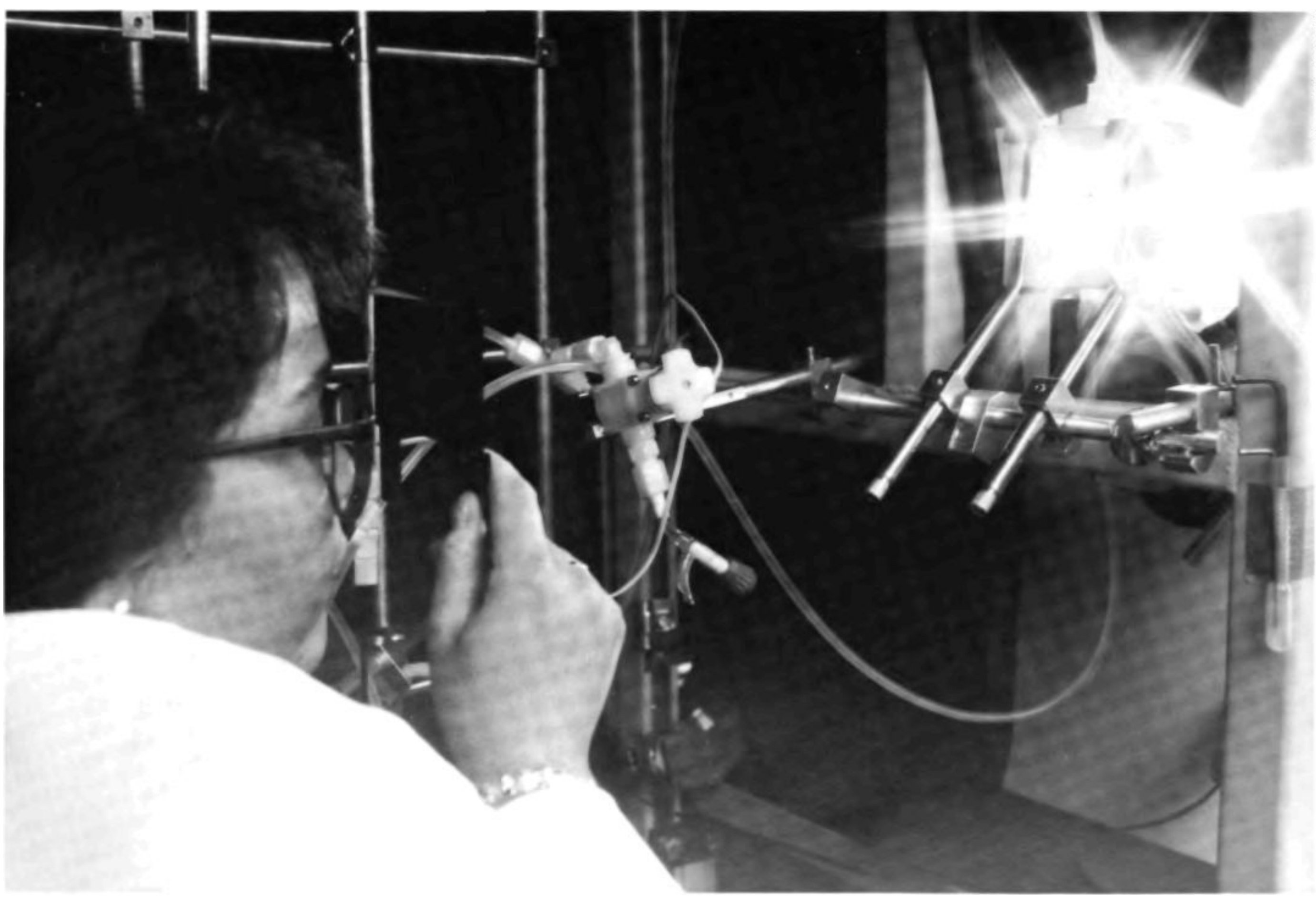
A The EPA recently distributed an inventory of toxic chemicals released into the environment. More than 80 of these compounds could be treated with the solar process. These include common industrial solvents and feedstocks, pesticides, and wood preservatives.



As shown in these four experimental runs, the amount of sunlight needed to detoxify TCE-laden water samples increases as the concentration of the contaminants increases.

Many industrial solvents commonly found in contaminated water have been destroyed in laboratory and field tests. These tests show that the solar process is well suited to environmental remediation. For example, researchers have recently treated actual groundwater samples contaminated with trichloroethylene (TCE) and other chlorinated solvents. TCE is the contaminant most commonly found in groundwater.

Solar detoxification can also destroy dyes such as those found in textile mill effluent. Other potential targets are fuels of various types (oil, gasoline, diesel, or jet fuel) that are dispersed from spills or from leaking underground storage tanks.



Researchers have successfully treated waterborne contaminants in laboratory experiments using simulated sunlight.

Q *Are any solar detoxification plants in operation?*

A Not yet. However, an experimental water detoxification system will be constructed soon at a Superfund site on the grounds of Lawrence Livermore National Laboratory (LLNL) in California. Groundwater at this site, formerly a World War 11 naval air station, was contaminated by wartime disposal of TCE and other chemicals. The contaminated groundwater is migrating toward the nearby town of Livermore,

When operational, the experimental system in California will look like this test system.

To combat this problem, LLNL began a remediation program that includes dozens of wells to pump the water and conventional technologies to treat it. Solar troughs will process the contaminated groundwater. Researchers will measure the system's performance under a variety of operating conditions and make comparisons to the conventional technologies.

Q *Can solar detoxification systems complement conventional detoxification systems?*

A Yes. Numerous opportunities exist for combining solar and conventional detoxification. One proposed method involves a continuous, 24-hour detoxification process combining the solar process and one that uses ultraviolet lamps. Ultraviolet lamps offer an effective, but costly, means of detoxifying wastes. Operators using the solar process in the daytime and the artificial, UV-lamp process at night could use less electricity than if they used only the lamp process.

A possible future application of the water process is to aid in bioremediation. Bioremediation is a process in which microorganisms digest organic wastes. Highly chlorinated compounds found in some contaminated water hamper the growth of some species used in bioremediation. With solar detoxification, researchers can pretreat the water to reduce the concentration of organically bound chlorine and thus speed up the bioremediation process.

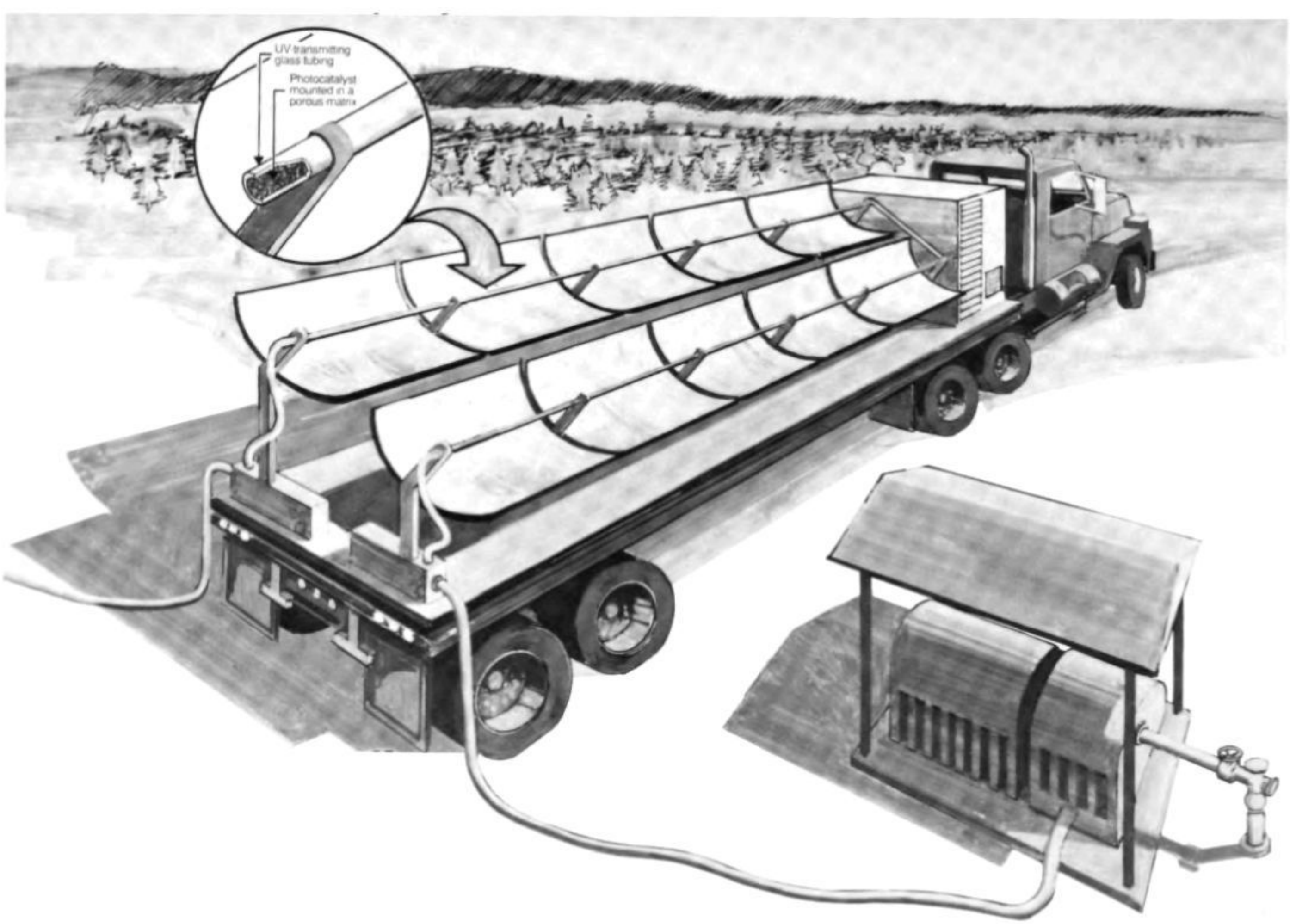
Q How can U.S. industry get involved in commercializing solar detoxification?

A Industry is a critical link in the successful commercialization of solar detoxification. Industrial participation is necessary in both technology development and market development. DOE is encouraging suppliers, especially those in the solar and water treatment industries, to become involved in technology development. It Is also soliciting potential users, those with waste management and environmental remediation problems, to take part in market development.


J.O. Russo

Agencies faced with the remediation challenge of cleaning up Superfund sites have expressed an interest in the promising technology of solar detoxification.

DOE's technology development effort focuses on improving both the system cost and the performance of the technology. As these factors improve, so does the opportunity



Mobile treatability laboratories will give users the chance to find out if solar detoxificaion can treat their wastestreams.

for market penetration. The goal of this effort is the commercial readiness of the water process in the mid-1990s. Industries interested in taking part will work closely with DOE in cost-shared efforts to produce advanced components and systems that will be used in commercial demonstrations.

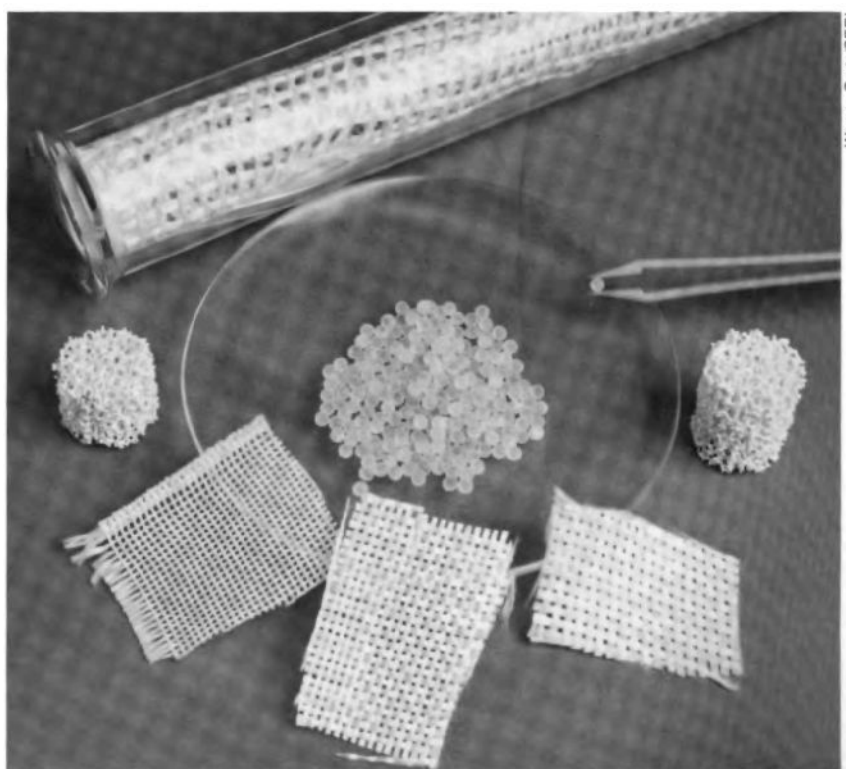
The market development effort creates partnerships with potential users of the solar detoxification technology. Potential users include federal, state, and local agencies and organizations as well as private industry. Because of their involvement in the cleanup of Superfund and other contaminated sites, the Department of Defense, EPA, and various offices in DOE have all expressed an interest in solar detoxification.

Potential users will soon have the opportunity to find out whether solar detoxification will treat their specific waste problems. DOE is developing facilities for performing "treatability" tests on industrial wastestreams. These tests could be run off site in treatability laboratories or on site in mobile units set up on industrial or remediation sites. An advantage of mobile units is that users could test large quantities of contaminated water directly from the source without the time delay and transportation problems associated with laboratory testing. The mobile systems will also be displayed in various exhibitions so that both industry and universities can have hands-on experience with the process.

Q *What is the focus of current research on solar detoxification?*

A This research is directed at making the solar process competitive with conventional treatment methods. Two research thrusts are to improve overall system performance and to lower the capital cost of these systems.

Researchers can improve system performance in the short term by improving the design of the systems, finding new ways to affix the catalyst to lattices, and using more effective pretreatments for the contaminated water. Possible pretreatments include adding chemicals that would promote the catalytic reaction or modifying the pH of the water. In the long term.



Catalysts, so central to the solar detoxification process, can be affixed or coated onto several different materials, from glass beads to mesh.

Controlled laboratory testing will improve system performance, thereby making solar detoxification more competitive with conventional detoxification systems.

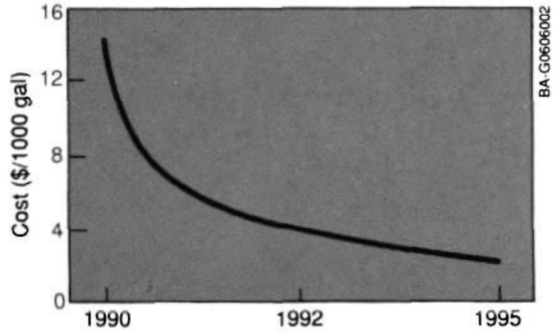
researchers are working toward better efficiency of the catalyst through heat treating and making surface modifications. They are also seeking new catalysts that use more of the solar spectrum, such as other forms of TiO_2 and some forms of iron oxide.

Capital costs for concentrating systems can be lowered as researchers adapt the concentrator, originally designed to produce electricity, to meet the less stringent requirements of detoxifying water. Specifically, concentrators used to detoxify water do not need to produce the high temperatures required to generate electricity. Different materials can be substituted—aluminum reflectors in place of silver ones, for example—and concentration ratios need not be as high. Reductions in the weight of the concentrator are also possible.

The cumulative effect of this research and development will be to reduce the cost of processing contaminated water through a solar detoxification system. Cutting processing costs will make the process more competitive with conventional treatment technologies. Projected costs show that solar detoxification may be competitive in small plants in 1993. Further improvements will make the technology competitive in larger plants throughout the country.

Q What does the future hold for solar detoxification?

A The future of solar detoxification is promising because of the tremendous need for solutions to our hazardous waste problems. No one doubts that some dangerous chemicals will be our unwelcome neighbors for years to come. We face an immediate challenge to devise new detoxification methods that will be more than mere stopgap measures to hazardous waste disposal. There are no simple solutions: the problems of widespread contamination require thoughtful, long-term solutions that consider health and environmental impacts as well as economics.



R&D improvements such as increasing catalyst efficiency and decreasing collector costs will reduce costs and move solar detoxification into the marketplace by the mid-1990s.

Solar detoxification offers the kind of clean, far-sighted solution sought by industry, government, and the general public alike. By directly lapping the sun's energy to destroy hazardous wastes, we arm ourselves with a powerful natural weapon. Toxic materials will long be with us, but shedding the new light of solar detoxification on them could greatly alleviate their threat.

Randy Montoya/Sandia

The process of detoxifying contaminated water with sunlight represents a promising, long-term solution to the hazardous waste problems we now face.

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Contacts

For further technical information, please contact the Solar Detoxification Project, SERI, 1617 Cole Boulevard, Golden, CO 80401, or call the SERI Technical Inquiry Service at 303/231-7303.

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