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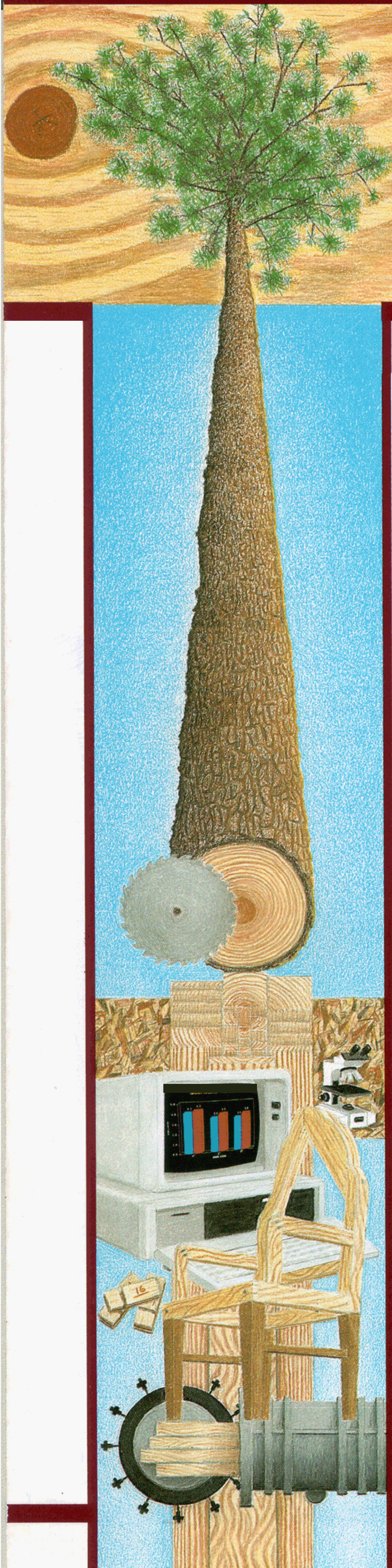

Bioremediation: It's Working

ABSTRACT

Industial sites contaminated by past use of pentachlorophenol and creosote are being cleaned up by nature's own bacteria and fungi. Research by the Environmental Biotechnology Group of the Mississippi Forest Products Laboratory (MFPL) is identifying microorganisms and methods of carrying out this process, which is called Bioremediation. Bioremediation is proving far less costly than older clean-up methods such as burning or extracting the soil to eliminate contaminants. There are more than a dozen sites in Mississippi where Bioremediation may save owners from $1 million to many millions of dollars each. If the great numbers of sites around the country where the process would work are eventually treated by Bioremediation, the savings over former clean-up methods should be in the tens to hundreds of millions of dollars. Industry and the national Environmental Protection Agency (EPA) have something to say about all this: "Keep up the good work."

Twenty-four hours a day, 365 days a year, two 17,000-gallon tanks at a South Mississippi site treat water pumped from soil once contaminated by wood-treating chemicals. After treatment, the clean, contaminant-free water (80,000 gallons daily) is returned to the soil through nearby injection wells, or discharged into publicly owned treated-water channels (sewage).

Special bacteria-discovered by Dr. Hamid Borazjani and other Mississippi Forest Products Laboratory scientists-inhabit these tanks, which are called bioreactors. These microorganisms quickly destroy the toxic chemicals (pentachlorophenol and creosote) present in the water. MFPL scientists call the process Bioremediation.

The bacteria do get something for their diet in addition to the wood-

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Graduate Student Kim Walker and Dr. Hamid Borazjani measure toxicity of highly contaminated waste water. Bioremediation of such water is the subject of Walker's thesis. Soil, water, and solids such as utility poles all appear suitable for Bioremediation.

treatment chemicals. Daily, 7 pounds of 13-13-13 fertilizer are added to each bioreactor to maintain the needed levels of ammonia and phosphorus. Still, the organisms subsist mostly on the contaminants. Borazjani's group provides the JP-Isolate bacterial cultures that break down creosote- and pentachlorophenol (PCP)-laden water. Just 2 liters of these organisms (a liter is slightly more than a quart) are needed to replenish the microorganism population in each reactor weekly.

The Bioremediation process begins with nine wells pumping water from the ground into a collection system. From there, the water goes into the bioreactors. Stirred and aerated by devices inside the tanks, and broken down or "digested" by the bacteria, the contaminated water moves continually through the big containers.

From the bioreactors, the water is pumped into another huge vessel called a clarifier. Here the bacteria settle to the bottom and are transferred automatically back to the reactors.

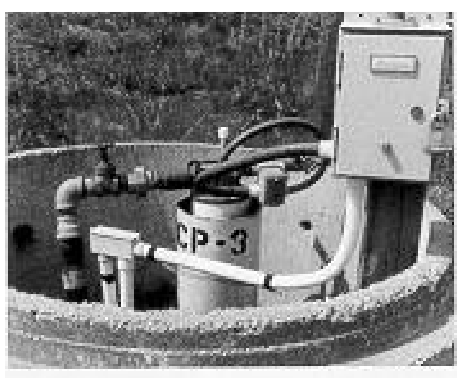
The treated water rises in the clarifier until it spills over a circular wear plate near the outer rim and flows to a holding tank. Gravity flow then takes it several hundred feet to the injection wells-eight of them-which return the water to the soil. "The water is tested by rigid standards after treatment;' says a spokesman at the South Mississippi site. "Federal and state agencies require regular reports showing its BOD (biological oxygen demand), dissolved solids, and other factors."

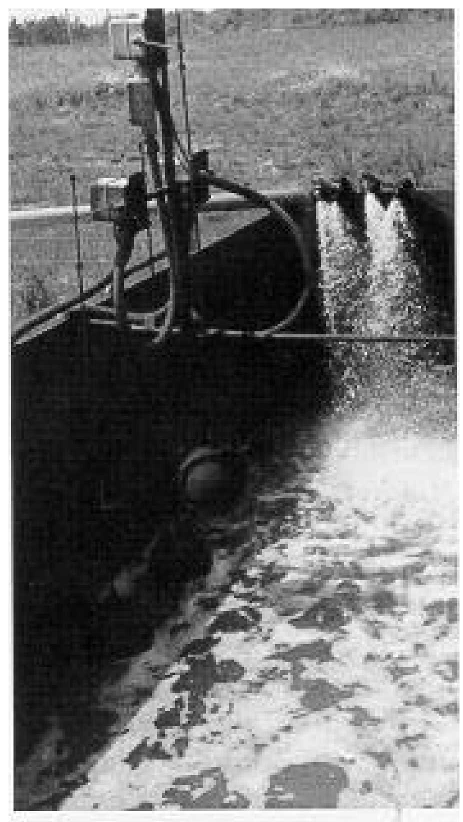
For the past 3 years, since the operation has been in full swing, reports from the site have been acceptable to the monitoring agencies.

The once-contaminated site shows much progress toward a return to a more natural state. Where nothing would grow in the chemical-laden soil a few years ago, there is now a good crop of grass and other ground cover. Most detectable traces of creosote or PCP on the ground surface or in earthen holding tanks are gone.

As the eye witnesses the improvement in ground contamination, the nose indicates that the process needs to continue; water being pumped out of the ground still has a noticeable chemical smell. That means Bioremediation and return of treated water to the ground will continue for the foreseeable future.

"Industry has spent millions of dollars in clean-up work at this one site, as well as at 10 other locations in Texas, Montana, California, Washington, North Carolina, South Carolina, Missouri and Louisiana (and another in Mississippi)," says Borazjani. "But the cost for bacteria (or, in some cases, fungi) to clean up chemical contamination still is small compared to older decontamination methods. So we expect savings of tens to hundreds of millions of dollars through Bioremediation.





Contaminated water is obtained from retrieval wells like that at left; nine wells are used to obtain the water for Bioremediation. First stop is this holding and aerating tank, from which the water is pumped to two 17,000-gallon bioreactors.

"Bioremediation - bacterial decontaminaton - costs approximately $1.25 per thousand gallons of water. That is one-fourth to one-third the cost of cleanup by activated carbon treatment, which was about the best method we had before the advent of Bioremediation."

The Environmental Biotechnology Group at the MFPL continues to look for the most suitable bacteria and fungi for environmental cleanup. Bioremediation is applicable not only to soil and water, but to utility poles, lumber and other treated products.

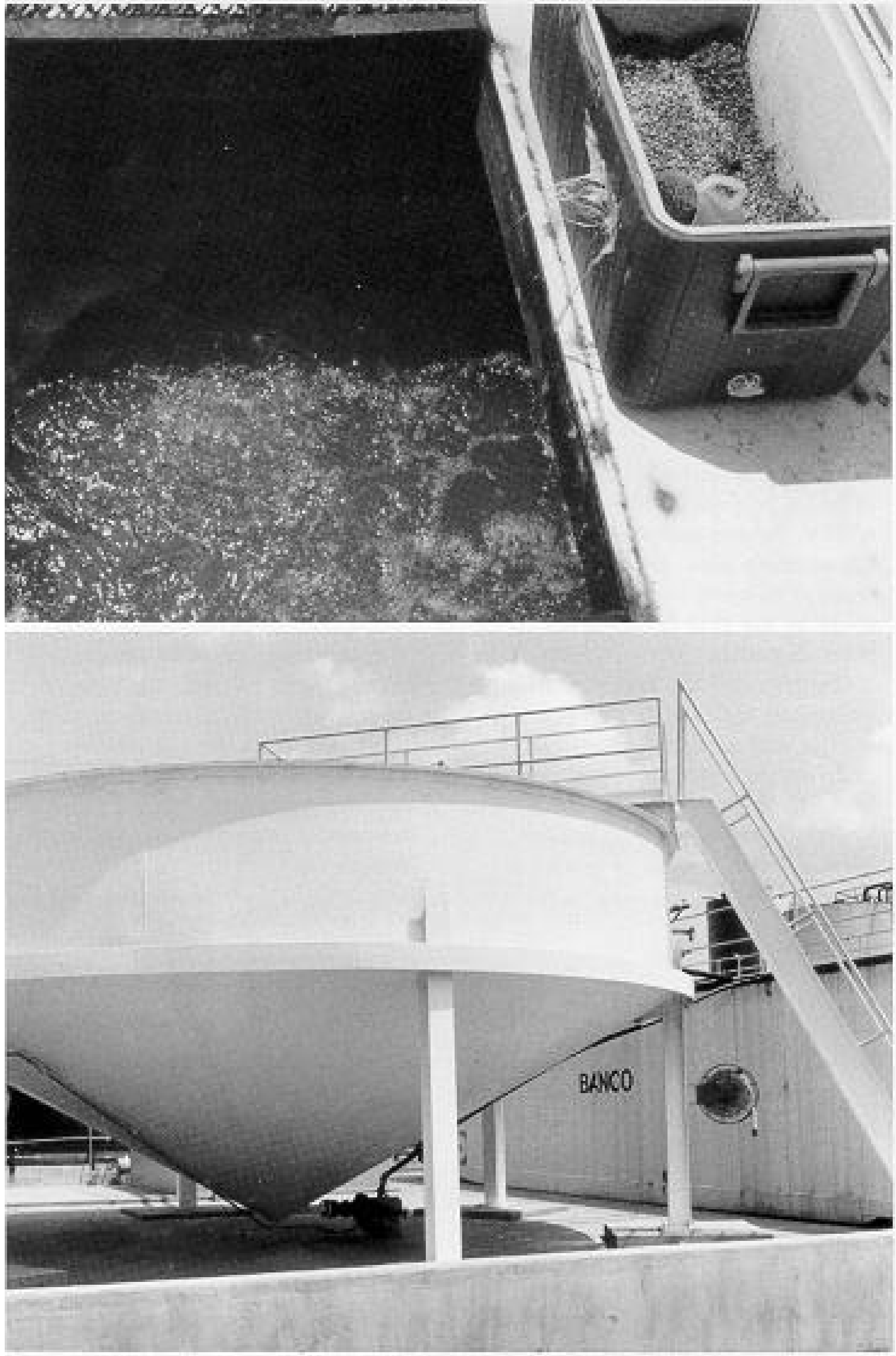
Research Assistant Curry Templeton is testing the microorganisms in a novel way. He fills hollow tubes or columns with particulate material laden with the clean-up bacteria.

Creosote or PCP-contaminated water is fed into the top of a column, where it slowly percolates through the medium. Before the water exits the bottom of the column, the contaminants have been successfully removed. The success rate has been high with this method, and Templeton is refining it by using different types of media and different organisms. Eventually this more efficient method may replace the need for large bioreactors and further reduce costs.

Both bacteria and fungi have been tested on wood particles treated with PCP and creosote to simulate the effect they would have on ground-up utility poles. These poles "umber up to 100 million in the United States, and disposing of them in a way friendly to the environment after they have served their purpose is an urgent problem.

In the study with wood from utility poles, an MFPL graduate student found that both the bacterium ***Arthrobacter*** sp. and the fungus ***Cladosporium*** sp. broke down the creosote that had been used to preserve the wood. But only ***Arthrobacter sp.*** was effective for Bioremediation of PCP-treated wood.

Another approach to Bioremediation is the use of thermophilic (heat-adaptable) microorganisms. These thermophiles thrive in places where the heat would immobilize or destroy most microorganisms. Since chemical reactions are accelerated at higher temperatures, use of these microorganisms may make Bioremediation even more efficient. Borazjani says not much work has yet been done with these microorganisms, but what has been done is promising.



A daily dose of fertilizer to water in bioreactors (top) helps keep Bioremediation going. Water is then pumped to the clarifier (above) from the bioreactor, shown at rear right.

The best approach to Bioremediation in the future may be significantly different from current methods: it may be possible to let enzymes do the clean-up work instead of using enzyme-containing bacteria.

Enzymes serve as catalysts for a number of well-known chemical reactions, such as food digestion, conversion of sugar to alcohol, and a host of others.

Just as past research has focused on finding the bacteria and fungi that will do clean-up work and identifying the best ones for various tasks, much work now is needed to determine if enzymes can do these tasks better. So, MFPL scientists are now trying to isolate enzymes that

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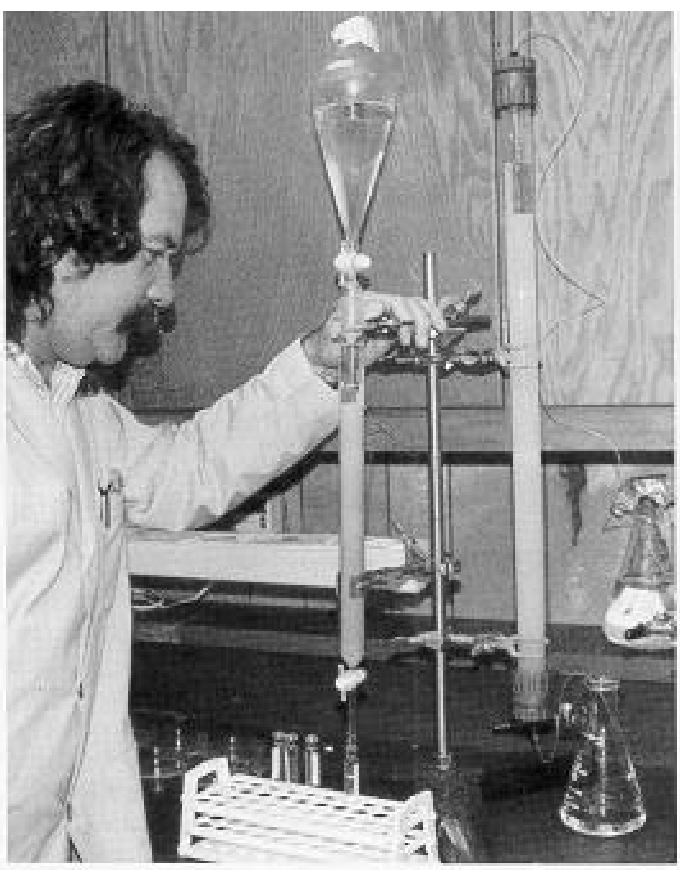
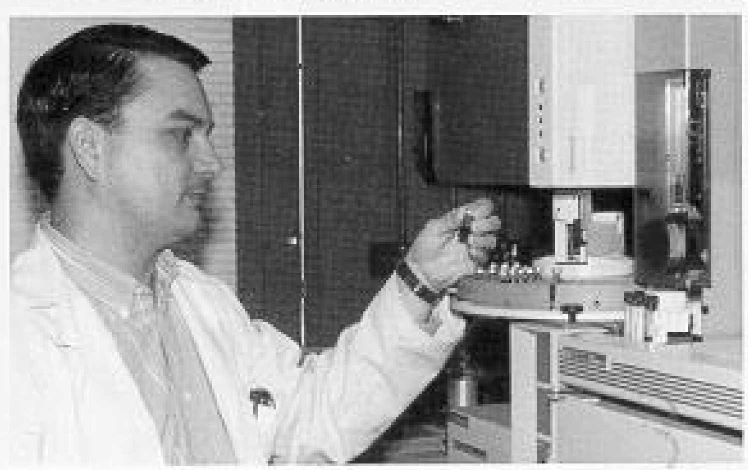
will be useful in such direct clean-up.

The use of bacteria for clean-up of wood-treatment chemicals, oil spills in the sea and other tasks is still relatively new. Taking the shortcut of using enzymes directly could be the next great advance in Bioremediation.

"Determining the extent of contamination with which we must deal as well as the effectiveness of clean-up methods is quite a challenge!" So says Senior Research Assistant David Strobel. He supervises a team of analytical chemists whose sole mission is to identify and quantitate chemical contamination in soil and water. Using state-of-the-art equipment and procedures developed by the EPA, the team members can analyze chemicals that may exist only at the parts-per-billion (ppb) level.

"Each environmental sample is unique," says Strobel, "and we have to analyze thousands of them each year. It's a difficult job, but we know that this information is essential in determining the effectiveness of different Bioremediation techniques."





Research Assistant Curry Templeton (above 1.) filters contaminants through particles holding microorganisms. Injection wells (top r.) return treated water to the ground. Plants (center T.) How grow on once-contaminated ground. Senior Research Assistant David Strobe1 (above r.) and his team can find contaminants at the parts-per-billion level.