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NAVAL OCEAN SYSTEMS CENTER San Diego, California 92152-5000

Technical Document 1253

May 1988

Degradation of Hazardous Organic Wastes by Microorganisms

Paul Kenis

AD-A196 671



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NAVAL OCEAN SYSTEMS CENTER

San Diego, California 92152-5000

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INTRODUCTION

This report addresses the detoxification of hazardous organic compounds before and after they have contaminated soil, groundwater, ponds, and other areas. The majority of companies in the U.S. which provide products and services to degrade hazardous organic wastes by microorganisms are included in Appendices A-P of this report. The *Hazardous Materials Control Directory 1987-1988** was the primary source of these companies.

In situ degradation of hazardous organic materials by microbes is often the most cost-effective cleanup approach. When a site and the hazardous organic material are amenable to *in situ* biodegradation, the cost for this treatment is often substantially lower than the cost of removing and hauling the contaminated soil to a hazardous waste dump site, the cost of on-site incineration, or the cost of any other treatment currently available. In addition, on-site treatment has the advantage of minimizing the potential legal liability associated with transportation and the potential continuing liability even when the hazardous material is at a disposal site.

The degradation (detoxification) of most hazardous organic materials occurs best under aerobic conditions by bacterial oxidative processes. The toxic organic compound serves as the energy or carbon source for bacterial metabolism and multiplication, with oxygen as the final electron acceptor. The ultimate degradation products from bacterial oxidation are water and carbon dioxide.

Bacteria can also degrade some organic compounds without using the compound as an energy or carbon source. This "cometabolism" results when enzymes or series of enzymes which degrade a substrate for the bacteria's use also partially degrade a hazardous organic compound, but do not use the hazardous compound as an energy or carbon source.

Some hazardous wastes are degraded slowly or not at all by microorganisms. Substitutions to aromatic compounds may alter the molecule to greatly reduce or prevent degradation (halogens, nitro, or sulfonate groups). Polyhalogenated aliphatics such as trichloroethylene are degraded slowly by soil and aquifer microbes. Complex molecules such as polychlorinated biphenyls (PCB's) and dioxin, and chlorinated pesticides may be very resistant to microbial degradation by naturally occurring microbes. Laboratory-selected and -mutated microbes may be used to increase degradation rates of these resistant compounds. Table 1 lists organic compounds readily degraded by *in situ* microbes and Table 2 lists resistant compounds. Appendices D and K through P include companies which supply specialty cultures to use in toxic organic waste cleanup. One company even claims to degrade PCB's (Appendix L).

Microorganisms capable of degrading many hydrocarbons, simple aromatic compounds, and other organics occur naturally in soils and groundwater. Natural degradation occurs very slowly, however, because oxygen and nutrients are lacking.

**Hazardous Materials Control Research Institute, Silver Spring, MD.*

By adding oxygen, nitrogen, phosphorus, and trace nutrients, the microbes can be stimulated to use the organic contaminant as a carbon and energy source. Oxygen can be added in the form of hydrogen peroxide, which degrades to produce molecular oxygen, or by injecting air into aeration wells. Nitrogen can be added as ammonia or nitrate, and phosphorus can be added as a suitable form of phosphate. Some soils have a high affinity for phosphates, and it is therefore necessary to perform studies in the laboratory to determine the most effective form of phosphate for each specific site.

Table 1. Compounds amenable to biodegradation. (From: *Aquifer Remediation Systems*, International Technology Corporation, Princeton, NJ.)

General Classification	Examples of Specific Contaminants
Hydrocarbon fuels	Gasoline, diesel, aviation fuels Fuel oils Petroleum distillates
Hydrocarbon solvents	Benzene Toluene Xylene
Simple alkyl substituted aromatics	Ethylbenzene Cumene Styrene
Small polynuclear aromatics	(< 4 rings)
Hydroxylated aromatics	Phenol Cresol Catechol
Aromatic acids	Benzoic Phthalic Terephthalic
Oxygenated compounds ($C_1 - C_6$)	Alcohols Ketones Ethers Esters Acids Glycols
Simple amines ($C_1 - C_6$)	

Table 2. Compounds resistant to biodegradation. (From: *Aquifer Remediation Systems*, International Technology Corporation, Princeton, NJ.)

General Classification	Examples of Specific Contaminants
Polyhalogenated aliphatics	TCE PERC EDB
Complex molecules	PCB's Dioxins
Chlorinated pesticides	

Companies which use biological processes to clean up hazardous wastes may do so by any one or any combination of the following methods:

1. By adding nutrients and oxygen to stimulate natural microbial populations for *in situ* biodegradation. See Appendices F to J.
2. By adding specialty cultures which have been selected or mutated to more effectively degrade the hazardous material of interest. See Appendices D and K through P.
3. By using permanent or portable treatment plants that employ microbes to degrade hazardous organics. See Appendices A to E.

SUITABILITY FOR *IN SITU* BIODEGRADATION

Not all sites and organic wastes are suitable for *in situ* biodegradation technology. Soils which do not percolate readily, such as clays and fine silt, may be unsuitable. Also, some soils and aquifers do not contain adequate numbers of hydrocarbon-degrading bacteria. Resistant organic compounds not readily degraded by microbes may best be treated by other techniques. Laboratory studies can demonstrate the feasibility of *in situ* biodegradation for specific sites.



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METHODS OF ACHIEVING BIODEGRADATION

DEVELOPING SPECIALTY CULTURES

Microorganisms can be adapted to be more effective in degrading common organic contaminants and even in degrading complex or halogenated organic molecules which would normally not be degraded at a practical level for waste cleanup operations.

Laboratory culture-enrichment techniques can be used to develop more efficient microbes for the degradation of common organic wastes and of organics not readily degraded by *in situ* microbes. Microbes can be cultured in the laboratory to obtain those capable of degrading the organic compound of interest. The fastest growing strains and those which are least inhibited by high concentrations of the toxic organic material can be further adapted and isolated. Microorganisms with the greatest growth rates can then be irradiated to induce random genetic mutations. These mutants can then be screened to isolate those which most effectively degrade the hazardous organic of interest.

Genetic engineering techniques can be used to add plasmids, which contain the genetic information for the production of the desired degradative enzyme. Laboratory techniques can also be employed which enable plasmids to exchange naturally between microbes, without resorting to genetic engineering procedures.

Adapted, mutated, or engineered bacteria can be produced in batch culture and preserved by freeze-drying, air-drying, or by stabilizing on bran fiber. Continuous application of the bacteria is required during the cleanup of hazardous wastes because these highly specialized microbes have a competitive disadvantage when in the presence of natural microbial populations in soils or groundwater.

LANDFARMING

Landfarming is a specialized form of *in situ* biodegradation of hazardous organic wastes. In landfarming, contaminated soil to which water and nutrients have been added is tilled to provide aeration to promote microbial degradation. Most landfarming operations are limited to a depth of 5 feet. Concentrated organic wastes can be added to soil at a suitable loading level to provide cost-effective on-site detoxification.

Landfarming operations may be limited by government air-emission standards because of the volatile organics emitted. One way to avoid this problem is to perform landfarming in an enclosed structure and carbon-filter the air leaving the structure into the atmosphere to remove volatile organics. In addition, the farming area can be surrounded by concrete or by some other suitable barrier to prevent the contamination of groundwater.

The landfarm selects for microbes effective in degrading the organic molecules which make up the added organic wastes. However, manufacturers of specialty microbial cultures claim that degradation can be enhanced by adding these cultures regularly. Added specialty cultures may be of most value in the degradation of resistant molecules. See Appendices D and K through P for suppliers of specialty cultures.

BIODEGRADATION IN CONJUNCTION WITH OTHER TECHNOLOGY

The biodegradation of organic wastes can be used in conjunction with other procedures. Where very low concentrations of organics must be achieved, such as groundwater and lakes, carbon polishing may be used to remove the residual amount remaining after microbial degradation. Microbial degradation is effective in reducing organic materials to low levels, but considerably more time is required for the microbes to degrade low level to nondetectable levels (or to environmentally acceptable low levels). By using biodegradation to degrade organics to low levels and then resorting to carbon scrubbing to remove the remaining trace levels, the overall cost can be greatly reduced compared to the process of carbon scrubbing alone.

Microbial degradation of recalcitrant organics may become practical by partially degrading these molecules with high-intensity ultraviolet light or oxidation by ozone or hydrogen peroxide. After partial degradation by these processes, the molecule may become more amenable to biodegradation.

POTENTIAL NAVY INVOLVEMENT IN HAZARDOUS WASTE CLEANUP

From this summary of the capabilities of industry in hazardous waste cleanup, it can be surmised that the Navy's future involvement in this highly active field will most likely be specialized in nature. The following areas may warrant involvement by the Naval Ocean Systems Center:

1. The state of existing technology could be assessed. What are the gaps in existing technology? How does the Navy write contracts and monitor results to insure that cleanup is performed most cost-effectively?
2. Demonstration projects could be evaluated to determine the effectiveness of specialized technologies which apply to Navy cleanup needs.
3. Specialized technologies not currently addressed by industry could be developed. (This is difficult since industry has currently addressed most hazardous waste cleanup problems.) The Navy's use of organotin antifouling coatings and torpedo Otto fuel may provide unique hazardous waste cleanup problems. One area of possible Navy specialization is biodegradation research to develop bioreactors to detoxify solid and dissolved organotin fractions from dry-dock operations and contaminated sediments in harbors. Another area involving unique Navy needs is the *in situ* biodegradation of soil containing Otto fuel and bioreactors to detoxify Otto fuel wastes.
4. Navy involvement may include the development of improved technology for the biological degradation of organic materials. Hazardous wastes of concern to the Navy may be more effectively degraded by microorganisms which have been engineered or mutated to yield maximum degradation. This is currently being done by

industry, but only by relatively few companies, and to a limited degree. The Navy should be able to contribute to this "wide open" field by using its biochemical and microbiological expertise.

5. Specialized analytical capabilities could be developed for monitoring hazardous materials of interest to the Navy. The Navy's expertise in the development of real-time analytical capabilities for heavy metals, organotins, and other contaminants may be extended to develop real-time analytical capabilities for organic hazardous wastes.

- a. Biosensors using antigen-antibody reaction may be incorporated into sensors for the real-time monitoring and analysis of specific hazardous organic materials of interest to the Navy.
- b. Analytical instrumentation may be automated for real-time monitoring applications of interest to the Navy.

6. Biotechnology could be developed to deal specifically with the marine environment. This may be of value where hazardous materials have contaminated either near-shore marine sediments or seawater in isolated areas.

7. Existing technologies could be optimized. For example, specialty bacterial cultures produced by industry may be optimized for use in commercially available bioreactors.

ADDRESSES OF COMPANIES IN APPENDICES

BIOLOGICAL REACTORS TO DEGRADE ORGANIC HAZARDOUS WASTES

APPENDIX A

Cecos International
2321 Kenmore Avenue
Buffalo, New York 14207
(716) 873-4200

Sequencing batch biological reactor to degrade organics in waste water.

APPENDIX B

Detox, Inc.
P.O. Box 324
Dayton, OH 45459
(513) 433-7394

Regional Office:
1600 Dove St., Suite 408
Newport Beach, CA 92660
(714) 476-8361

Submerged fixed-film growth and decay reactors.

APPENDIX C

Dorr-Olivier, Inc.
77 Havermeyer Lane
P.O. Box 9312
Stamford, CT 06904-9312
(203) 358-3200

Aerobic and anaerobic fluidized bed and suspended growth/ultrafiltration reactors.

APPENDIX D

Manville Sales Corporation
Research and Development Center
P.O. Box 5108
Denver, CO 80217-5108
(303) 978-2000

Immobilized microbes or enzymes on inorganic custom biocatalyst carriers for detoxification of organic wastes in liquid streams.

APPENDIX E

Smith and Loveless, Inc.
14040 Santa Fe Trail Drive
Lenexa, Kansas 66215
(913) 888-5201

Prefabricated fixed film activated sludge treatment for dissolved organic wastes.

COMPANIES USING *IN SITU* MICROBES TO DEGRADE ORGANIC WASTES

APPENDIX F

Aquifer Remediation Systems
International Technology Corporation
23456 Hawthorne Blvd., Suite 220
Torrance, CA 90505
(213) 378-9933

APPENDIX G

Bioremediation Systems
Cambridge Analytical Associates
Western Field Office
1111 Civic Drive, Suite 250
Walnut Creek, CA 94598

P.O. Box 7109
Princeton, NJ 08543
(609) 275-5005

APPENDIX H

Groundwater Decontamination Systems, Inc.
140 Route 17 North, Suite 210
Paramus, NJ 07652
(201) 265-6727

APPENDIX I

Groundwater Technology, Inc.
4080 Pike Lane, Suite D
Concord, CA 94520
(415) 671-2387

[no literature available]
The Earth Technology Corp.
3777 Long Beach Blvd.
Long Beach, CA 90807
(213) 595-6611

APPENDIX J

Texas Research Institute, Inc.
9063 Bee Cave Road
Austin, TX 78733-6201

SPECIALTY CULTURES TO DEGRADE ORGANIC WASTES

APPENDIX D

Manville, Filtration and Minerals
P.O. Box 5108
Denver, CO 80217-5108
(303) 978-3176

APPENDIX K

Biosystems Corp.
P.O. Box 330
Roscoe, IL 61073
(815) 623-7411

APPENDIX L

Detox Industries, inc.
12919 Dairy - Ashford
Sugarland, TX 77478
(713) 240-0892

APPENDIX M

Environmental Engineers and Associates
Regional Office
4860 Ironton, Suite 9D
Denver, Co 80239-2472
(303) 371-2640

APPENDIX N

Microlife Technics
Box 3917
1833 57th Street
Sarasota, FL 34230
(813) 355-8561

APPENDIX O

Sybron Chemicals, Inc.
Plant and Research Center
111 Kessler Mill Road
Salem, VA 24153
(703) 389-9361

APPENDIX P

Solmar Corp.
625 W. Katella Ave., Suite 5
Orange, CA 92667
(714) 538-0881

**APPENDICES OF CORPORATION
LITERATURE AND INFORMATION**

Appendix A

CECOS INTERNATIONAL

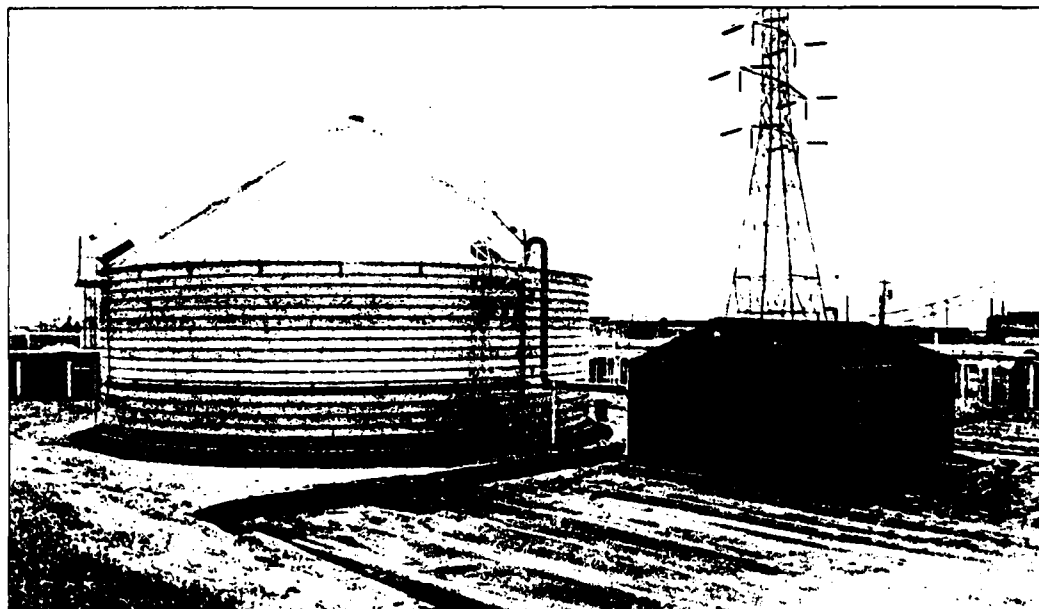


FACT SHEET

Answers to environmental questions from CECOS International

Number 11

CECOS Unveils Innovative Water Treatment System



Sequencing Batch Reactor Tank and adjoining process control building add to processing capability of CECOS' Niagara Falls phase II wastewater treatment facility (in background).

Niagara Falls, New York—CECOS International, Inc. has begun operation of an innovative, energy saving treatment system for aqueous wastes at the company's Niagara Falls Wastewater Treatment Plant. The system, called a Sequencing Batch Reactor, (SBR) uses biological organisms or "bugs" to degrade organic contaminants such as phenol in waste water.

The project is co-funded under a demonstration contract with the New York State Energy Research and Development Authority and in part by Jet-Tech, Inc., manufacturer of the SBR's aeration and decant system. The purpose of the project is to demonstrate to New York State industry the potential energy savings and treatment benefits of the SBR over conventional technology.

The Sequencing Batch Reactor

The SBR is a fill-and-draw activated sludge system in which a 500,000 gallon tank is filled during a discrete period of time and then operated in a batch treatment mode. The major difference between the SBR and conventional continuous flow activated sludge systems is that the SBR tank performs equalization, aeration and sedimentation

processes in a timed sequence and in a batch tank rather than several tanks.

Five phases of treatment are performed during the SBR process:

1. Fill Phase, at which time wastewater is added to the tank. During this phase, aeration is used to introduce oxygen to the system and the "bugs" begin eating the organics in the waste stream.
2. React Phase, during this phase, wastewater is no longer being added to the tank, but the aeration system continues to provide oxygen to allow the bugs to consume the residual organics.
3. Settle Phase, during which time the aerators are turned off and the "bugs" eventually settle to the bottom of the tank.
4. Draw Phase, at which time the top portion of the water is removed for further treatment and final discharge. In the CECOS wastewater treatment system, carbon adsorption is used as a secondary treatment method for polishing. After carbon treatment, the water then goes into a batch tank for sampling and final discharge into the Publicly Operated Treatment Works.
5. Idle Phase, when the system remains idle for a short time before resuming the next cycle of treatment.

CECOS has conducted a four month testing program on the SBR, the results of which are being made available to potential users in New York State through an extensive information dissemination program.

CECOS Receives Energy Authority Contract

In 1982, CECOS initiated studies that verified the feasibility of using biological degradation for the treatment of organic components in wastewaters prior to carbon adsorption polishing. CECOS evaluated a wide range of biological treatment systems that would prove to be flexible, energy efficient and cost effective. Although not previously applied in the chemical wastewater treatment area, the Sequencing Batch Reactor appeared to be the optimal system.

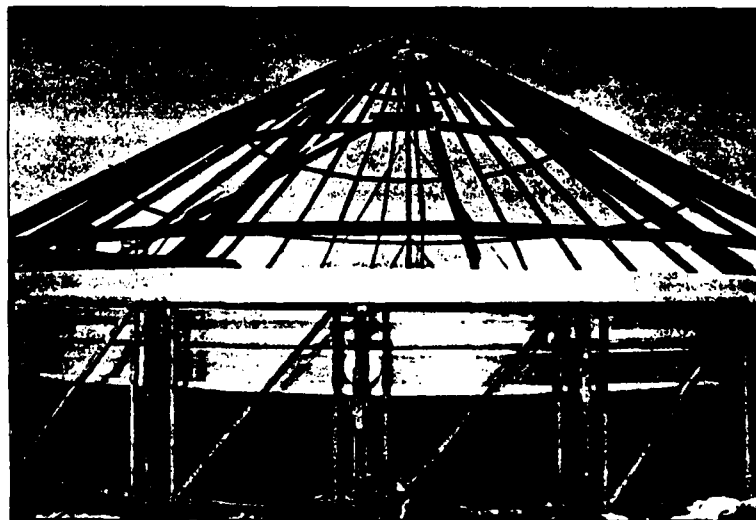
Concurrently, the state's Energy Research and Development Authority was seeking candidates for co-funding on advanced biological treatment systems. CECOS' Corporate Manager of Research and Development, Michael J. Hanchak, and Philip Herzbrun, laboratory manager, worked on a proposal for the Energy Authority with Dr. Robert L. Irvine. Dr. Irvine, president of

SBR Technologies, Inc., had already conducted a successful full-scale demonstration of the SBR on a municipal application for the U.S. Environmental Protection Agency, and developed the technology to its present level of efficiency.

The CECOS proposal met the Energy Authority's criteria and was selected for co-funding. The contract was awarded to CECOS in the spring of 1983.

Laboratory scale testing using the SBR began in August 1983 with an initial treatment period designed to acclimate the bacteria to the waste water. The bacteria were obtained from a standard municipal activated sludge digester.

Laboratory personnel then began operating the Sequencing Batch Reactor in 24-hour cycles. Waste waters were introduced into the system for 10 hours, followed by a 10-hour react



Six-foot steel guide structure in place during construction of SBR's outer shell.

period, two-hour settle phase, and two-hour discharge and idle period.

In general, laboratory studies showed the Sequencing Batch Reactor would achieve a 70-80% removal of organic materials and 98% removal of phenol. The laboratory testing also determined design parameters for CECOS' full scale system:

1. Treatment Strategies — The system's overall treatment efficiency was monitored while the volume of feed material was varied from 10-80% of the total tank volume.
2. Cold weather operations — In simulated cold weather conditions, the SBR achieved successful biological treatment of materials at 40°F.
3. Power failure — Following a simulated power failure, the system's treatment cycle resumed without a loss of treatment efficiency.

At the CECOS facility, the full scale SBR system has been designed to treat up to 250,000 gallons of contaminated wastewater per day.

Construction and Operation of the SBR System

Before construction of the SBR tank and adjoining process control building began, excavation work was performed on the 3,849 square foot area formerly used as the drum processing pad at Phase II of the Wastewater Treatment Plant.

Concrete bunkers formerly used for flammable materials were removed, and the pad's asphalt and concrete floor was excavated to a depth of seven feet to the earth's natural clay



Unique construction method joins coils of galvanized steel in a continuous spiral.

base. A layer of fresh stone was placed into an 80-by-80 foot area and compacted in 6 to 12 inch lifts with a 10-ton vibratory roller. Two French drains were installed at the north and south ends of the pad for collection of precipitation entering the site during the construction period. Construction crews dug a 2½ by 3 foot ring wall and poured a base of eight inch reinforced concrete slab for the base of the tank.

Next, Jet-Tech's contractors began construction of the tank and installation of the process equipment. A ⅝-inch thick plate steel floor was installed on the pad, and a six foot high rotating guide structure made of steel was then erected around the perimeter of the concrete base to serve as the drive mechanism for construction of the tank wall.

The SBR tank was constructed using a Swiss patented rolled tank process. This unique method uses two electric crimping machines, the steel guide structure and rollers to join together coils of galvanized steel in a continuous spiral.

Coils of steel, each 18 inches in width, were rotated around the 70 foot diameter of the tank and crimped together for maximum bonding with hoop strings to form the tank wall. When two lifts of the tank had been installed, construction crews then installed the cone top of the tank. After this phase was complete, the final rows of steel were installed to complete the tank. Silicone caulking was applied during the crimping process to seal the layers of steel together securely. The height of the completed tank is 21 feet.

The inside of the SBR tank was sandblasted and painted with an 18 mil coating of flake tar epoxy. The outside of the tank was coated with 1½ inches of multicellular polyurethane foam insulation to insure adequate operation in winter temperatures.

Two hundred feet of fiberglass jet aeration header and piping was then installed along with four submersible pumps and three rotary blowers. The jet aeration system supplies oxygen for the process and maintains complete mixing. This allows the bugs to

destroy as much of the organic waste materials as possible. The floating effluent decanter (also made of fiberglass) was installed at this time as well.

The SBR is constructed within a bermed containment area.

The Sequencing Batch Reactor will be operated by a computerized system that has been installed in the adjoining process control building. The newly constructed building measures 20 feet by 30 feet, and houses the computer and the three jet

aeration blowers, which supply air to the SBR tank.

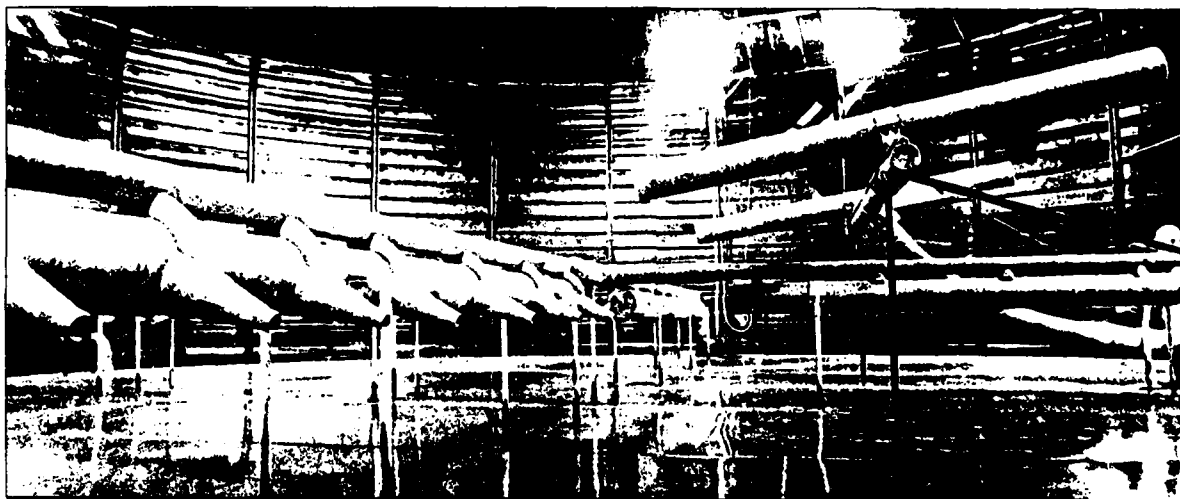
Because the computer will control all phases of the treatment process, the system requires minimal monitoring. Due to the system's specialized programming, the computer can control the oxygen flow by regulating the use of the blowers. The entire system allows for an energy savings of 720,000,000 BTU per year.

The computer system is also equipped with a fully automated alarm should any irregularities

occur. At this time, operations personnel can examine the system, correct any problems, and program the unit to resume treatment.

The SBR system will be self-operating, but operations personnel will routinely examine the process during its 24-hour treatment mode.

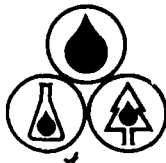
For further information on the Sequencing Batch Reactor, contact the Corporate Communications office of CECOS International, Inc. at 716/873-4200.



The jet aeration system designed and installed by Jet-Tech Incorporated supplies oxygen for the process and/or maintains complete mixing. Cylinders at right are part of the SBR's floating decant system.

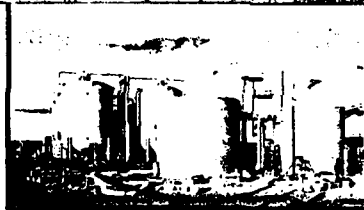
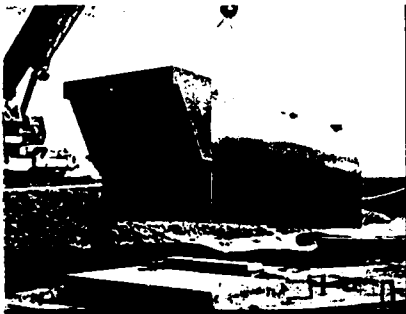
CECOS
INTERNATIONAL

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Buffalo, New York 14207
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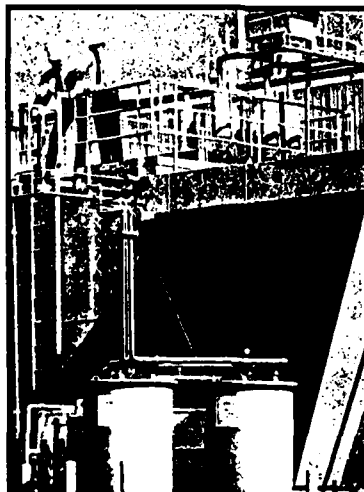
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Appendix B
DETOX INC.



GROUNDWATER
TREATMENT

DETOX[®] inc.
an American Ecology company

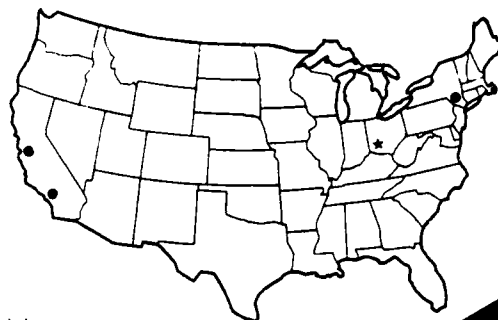


Company Background

DETOX, Inc. was founded in 1983 to design and manufacture groundwater treatment equipment. Our first system was installed in May, 1983. By 1984, DETOX had initiated a research program to develop new technology for the groundwater treatment market. In 1985, we became a subsidiary of *American Ecology Corporation*, a diversified environmental company. This association provided DETOX with the opportunity to expand our services and research activities.

With American Ecology's support we now have offices in critical areas across the country, and DETOX has installed groundwater treatment systems throughout the United States. In 1986, we successfully installed our first new technology, developed from our research efforts: The low concentration Biological Reactor (L-Series).

DETOX continues to grow based upon the innovative designs of our equipment. Our products and services have been developed to protect and enhance the environment without bankrupting American industry or the American public. While our primary focus is *groundwater treatment and subsurface clean-ups*, we also offer equipment and expertise in vapor-phase control, municipal drinking water supply, and industrial wastewater treatment.



★ Headquarters
Dayton, Ohio

● Regional Offices

Products and Services

DETOX offers a wide variety of technologies and equipment to treat contamination. These systems are supplemented by our support services which include design conceptualization, "Preview/Review" reports, Laboratory & Pilot Testing, Turn-key Installation, and Operations and Maintenance.

Our main line of equipment includes H and L-Series Bioreactors, Air Strippers, Carbon Adsorption Systems, Clarifiers and Filters. We also provide auxiliary equipment such as chemical and nutrient feed systems, pumps, and control systems. Our thorough knowledge of all these systems allows us to apply the single technology, or combination of technologies, that is appropriate for conditions at a particular site.

All of our equipment is portable, and can be used at more than one site. DETOX will lease equipment for short term clean-ups or help to reuse or resell equipment that has finished its work at a clean-up site.



*Detox's First Groundwater Treatment System
Installed May, 1983
Robstown, Texas*

We have engineered our equipment to be largely self-regulating. This trims operational costs by requiring little or no operator training and by minimizing operator attention on a week to week basis.

Our non-equipment services include: "Preview/Review" reports, which provide a concise analysis of potential treatment options and costs for a specific contaminated groundwater; Laboratory or Field Pilot tests, utilizing one of our portable pilot units; and a complete laboratory to perform treatability studies.

Finally, equipment systems can be delivered for owner installation or DETOX can provide "Turn-key" installation. Operation and maintenance contracts are also available to insure the continued optimum performance of your system.

Facilities and Resources

Our new headquarters facility in Dayton, Ohio, houses our main engineering group, research and analytical laboratory, final assembly area for treatment systems, and administrative staff. DETOX regional offices provide local support and service for our projects.

Our engineering group uses CAD systems for all design and drafting projects. This system, with modern linkups to our regional offices allows for fast and accurate changes to be made as a project progresses. We maintain a large database containing treatment data on various compounds and performance histories of our installations.



The purpose of our laboratory is to provide support for pilot testing and research new technologies, rather than providing certified chemical analysis. Our chemists can often significantly reduce the cost of assessments, studies, and monitoring programs by using valid but less expensive test procedures when certified results are not required. We also have the capability to conduct either physical, chemical, or biological treatability testing in our laboratory.

Our Design Philosophy

Technology vs Engineering Judgement

"Give me a lever long enough...
and I can move the world" -- Archimedes

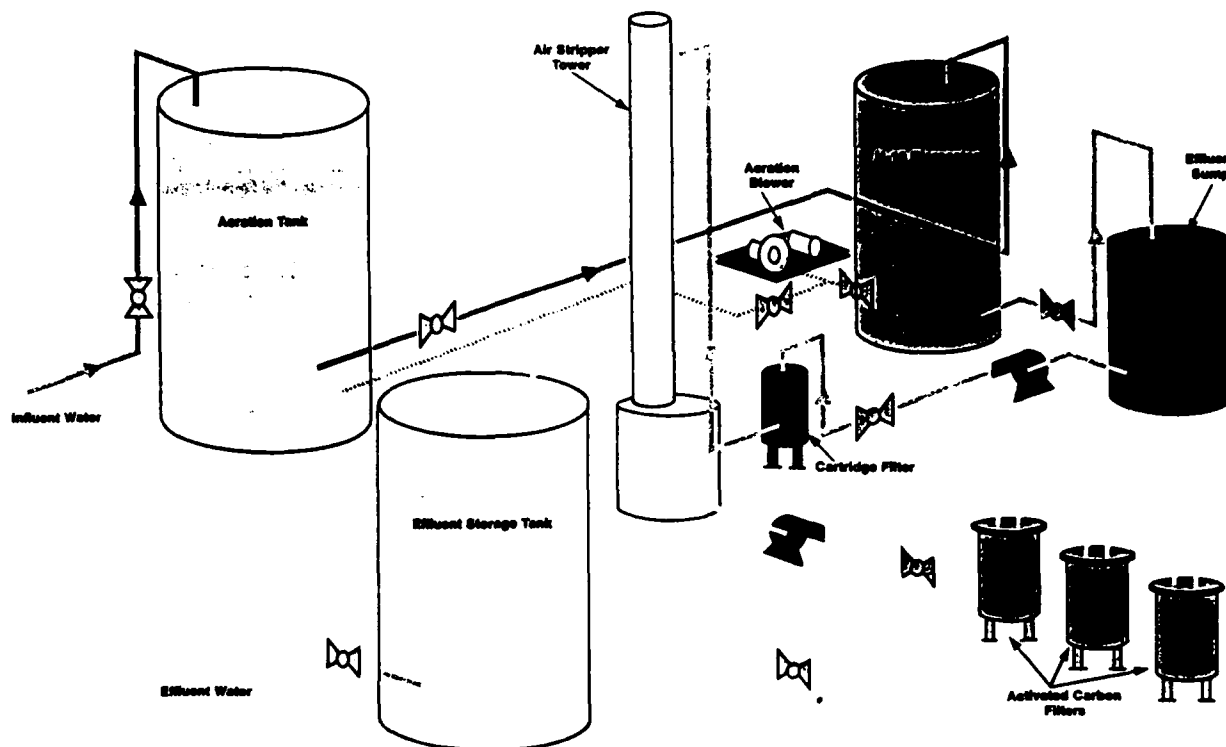
Much the same can be said about water treatment. Given enough time, money and equipment, every single contaminant can be completely removed from water. Our industry's technology base has grown impressively over the last decade, and is still being expanded in response to regulatory and economic pressures. At DETOX, we ourselves have developed several new treatment approaches.

However, even the best technology has its limitations when misapplied. All too often a 'high-tech' solution is suggested when a simple application of basic technology will suffice. This overreliance on sophisticated systems can result in unnecessary expense and treatment systems that do not work.

A good example of our design philosophy in action is the "Life-Cycle Design" concept. This concept recognizes that most groundwater treatment systems are subjected to changes in flow and concentration during the life of a clean-up. It capitalizes on the fact that operational costs (not capital costs) are usually the majority of the costs encountered in a site. Rather than taking the standard approach of a simple 'worst-case' design, we examine the changes that will occur and design our systems in response. Using smaller, modular units allows for decreased operational costs as influent levels drop and units are taken off line. This approach assures that the process train will be flexible enough to respond to changes, yet still be economical to run at startup as well as 10 months or 10 years into a remediation project.

Sound engineering judgement must be used to avoid these problems. From both a practical and theoretical perspective, DETOX scientists and engineers understand groundwater treatment. Our personnel have authored numerous books and articles on groundwater treatment, and regularly teach courses on groundwater treatment technology to universities, government agencies, and private industries. In addition, every single professional at DETOX has also spent time in the field, testing, installing and operating treatment systems. We believe that this combination of theoretical knowledge and practical 'hands-on' experience allows us to provide the best treatment equipment available to our customers.

INTEGRATED GROUNDWATER TREATMENT SYSTEM



REPRESENTATIVE DETOX GROUNDWATER TREATMENT INSTALLATIONS

Dayton, OH Groundwater Treatment

Wright Patterson Air Force Base
Low ppb, TCE & PCE in drinking water
2000 gpm low concentration Air Stripper
> 85% TCE, PCE removed
\$0.02/1000 gal. treatment cost

Santa Clara, CA Groundwater Treatment

Electronics Company
300 ppm MEK
2 H-50 bioreactors in series, filters
and 2 carbon adsorption units
99% MEK removed with biosystems alone
\$210,000. installed cost

Skaneateles Falls, NY Landfill Leachate

Specialty Chemical Company
2000 mg/l COD
H-10 bioreactor
\$20,000. capital cost

Springfield, OH Site Cleanup

Oil Company
Gasoline spill in fractured bedrock
in-situ soil vacuuming and in-situ
biological treatment
6 mos. for site cleanup
\$25,000 project cost

Sacramento, CA Groundwater Treatment

McClelland Air Force Base
250 gpm; 5-10 ppm MEK, Acetone
2 L-125 low concentration bioreactors
\$220,000. installed cost

Salinas, CA Gasoline Station

Oil Company
6-10 gpm, 1-5 ppm BTX
L-6 low concentration bioreactor, filter
and carbon adsorption
< 0.7 ppb Benzene effluent
\$20,000. capital cost



759 Congress Park Dr.
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San Francisco, CA • (415) 863-3912
Los Angeles, CA • (714) 478-8361



an American Ecology company

LABORATORY & FIELD PILOT TESTING SERVICES

The key to a successful groundwater treatment equipment design is accurate data. The first step is a theoretical analysis to pick the most probable treatment technologies (see *PREVIEW/REVIEW* data sheet). The next step is a Laboratory Treatability study to provide the initial data on the actual water that will be treated. This data should then be confirmed with Field Pilot Testing under actual treatment conditions.

DETOX has full service capabilities for providing the data to design a groundwater treatment system. We have developed an extensive series of laboratory treatability tests and field pilot equipment to simulate full scale operation of treatment processes and equipment. These procedures are based on our thorough knowledge of groundwater treatment and equipment design. Inexpensive laboratory tests can produce design information quickly and economically, while our field pilot equipment subjects our designs to the real-world rigors of your treatment site. Together or separately, these services can provide you with the extra margin of safety required on critical projects, and the assurance that your treatment system will work right the first time.

LABORATORY TREATABILITY TESTING:

- Groundwater, soils and vapor-phase characterizations.
- Microbiology laboratory for complete biodegradation studies.
- Laboratory-scale facilities for heavy metal removal.
- Physical/chemical treatment studies for advanced treatment methods.
- Field sampling and shipping services.



FIELD PILOT TESTING:

- Easily portable small-scale equipment designed to duplicate full-scale installations.
- Rapid testing - as little as a single day on-site for data gathering.
- Equipment can be operated by our trained technicians or by your personnel.
- Flow rates from 1-40 gpm.

Listed below are descriptions of a few of the more common popular laboratory tests and pilot studies DETOX can provide. This list is by no means complete, but rather is intended to give a representation of the types of problems that can be addressed. Our staff of scientists and engineers is ready to design the exact test or series of tests to provide you with answers at minimum cost.

AIR STRIPPING — ON-SITE PILOT TEST

A single day, on-site test using our portable 22' tall air stripper. This test will determine the design parameters of an air stripper such as tower height, tower diameter, air:water ratios and blower sizing. Samples taken at different water and air flow rates are analyzed by gas chromatography to determine contaminant removal efficiencies and mass transfer characteristics.

BIOLOGICAL TREATMENT — LABORATORY TOXICITY/INHIBITION TESTS

A quick one-week laboratory test that is suggested as a first step for most biological treatment systems. This test is designed to discover if any chemicals or factors present in a water or soil will inhibit or prevent biological growth, thereby making biotreatment impossible.

BIOLOGICAL TREATMENT — FIELD PILOT STUDIES

All DETOX biological processes can be piloted in the field. Field testing determines the exact level of treatment obtainable, defines the sizing and design parameters of a unit, and exposes a system to the natural shocks and changes that will be encountered on a full scale site. Most biological pilot tests take one to three months.

IN-SITU BIODEGRADATION — SAMPLING & LABORATORY ANALYSIS SERVICES

This packaged analytical service tests for the important physical and chemical properties that effect in-situ degradation. Soil, soil gas and groundwater samples are analyzed for dissolved oxygen, nutrients, micronutrients, pH, temperature, contaminant levels, total bacteria, specific organic degrading bacteria and other factors. This test is especially helpful for determining the feasibility of in-situ treatment, and also for monitoring an in-situ cleanup process.

CARBON ADSORPTION — LABORATORY AND/OR FIELD PILOT TESTS

Isotherms or column tests run in the laboratory on a small sample, or in the field on a small slip-stream. Testing determines the required contact time, contactor sizing and carbon usage rates. Especially useful for multi-contaminant sites.

METALS & INORGANIC REMOVAL — LABORATORY & FIELD STUDIES

DETOX has a variety of equipment to simulate most metal and inorganic removal processes. Included are precipitation, flocculation, clarification, filtration and ion exchange. Laboratory tests can usually be completed in one week.



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Agoura Hills CA • (818) 991-7361

BIOLOGICAL TREATMENT OF ORGANIC CONTAMINANTS USING SUBMERGED FIXED-FILM REACTORS

George J. Skladany

DETOX Inc., 1600 Dove St., Suite 408, Newport Beach, CA 92660

Kevin M. Sullivan

DETOX Inc., P.O. Box 4735, Ithaca, NY 14852

Biological treatment of contaminated ground water and process waters is an efficient and cost effective remediation technology. Fixed-film biological processes have demonstrated excellent removal efficiencies and stability both in the laboratory and in the field. This poster will present laboratory and on-site results of submerged fixed-film biological treatment systems treating both high and low influent organic concentration waters.

Much of the theoretical and real-world experience to date has centered on the treatment of high (greater than 50 ppm) concentrations of organics. While this condition is usually met in industrial pre-treatment waste streams, ground water contaminant concentrations are frequently much lower. Academic research using submerged fixed-film systems has demonstrated that biofilms have a limited ability to survive when exposed to carbon concentrations below those needed for active growth. Expanding on this work, biological reactors can be designed to capitalize on the maintenance and decay of organisms present in a biofilm, rather than classical microbial growth processes. This technology has been used in the laboratory to treat influent streams containing 1-5 ppm of benzene and/or methyl ethyl ketone to less than 5 ppb each. Pilot-scale work in the field has reduced influent benzene concentrations of 500-600 ppb to less than 2-3 ppb. Data from full scale operations will also be presented.

More commonly, influent organic concentrations are greater than 50 ppm. Under these conditions, submerged fixed-film bioreactors are able to reduce influent concentrations to the low ppm or high ppb range. These designs have been used to treat waters contaminated with phenols and various organic solvents. Data from the operation of several of these installations will be presented.

Poster presented at the conference
**"Reducing Risks from Environmental Chemicals
Through Biotechnology."**
Seattle, Washington
July 19-22, 1987



BIOLOGICAL TREATMENT SYSTEMS

H - Series & L - Series

WHY BIOLOGICAL TREATMENT?

- Biological Treatment is *Environmentally Sound* - contaminants are destroyed, not transferred into the air or onto carbon. Potential liability is ended.
- Biological Treatment is *Economical* - >99% destruction at 1/40th the cost of activated carbon.
- Biological Treatment is *Proven* - at over 70,000 sites over the last 80 years.

ABOVE-GROUND BIOREACTORS OR IN-SITU TREATMENT?

Both biological treatment technologies have their place and their advantages; indeed, DETOX often employs them together on the same site. Above-ground bioreactors are easier to control and require less monitoring. They can assure treatment of an entire flow stream when discharge to sewer, stream or re-injection into the ground is required.

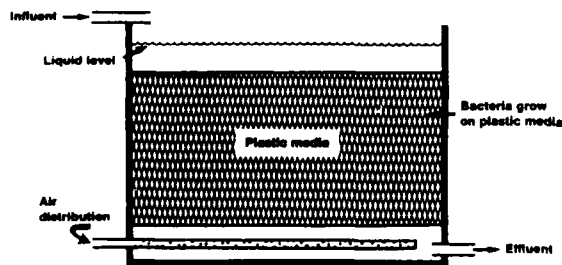
WHEN IS BIOLOGICAL TREATMENT MOST EFFECTIVE?

For contaminants with low volatility (poor strippability) such as ketones, phenols, and petroleum hydrocarbons, biological treatment is best. If vapor-phase treatment is required on air strippers, even easily stripped compounds like benzene are good candidates for biodegradation (see graph on back). Generally, heavily chlorinated compounds are poor candidates for biotreatment.

WHAT BIOLOGICAL TREATMENT PROCESS IS BEST SUITED FOR GROUNDWATER?

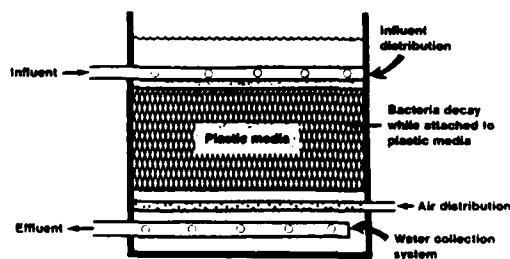
Our R&D efforts have developed two *submerged fixed-film* designs that avoid the operational problems caused by activated sludge, trickling filters and RBC's. Both are very suitable for effective Life Cycle Designs.

H - SERIES



- Completely mixed
- High organic loads: 50-10,000 ppm
- Low effluent: 10-20 ppm BODs, 30-50 ppb specific organic

L - SERIES



- Plug flow
- Low organic loads: 1-20 ppm
- Low effluent: 1-10 ppb specific organic

The DETOX Approach to Biological Treatment

Step 1 - DEGRADABILITY STUDIES

These studies are often suggested by the inexperienced to "prove" the biodegradability of a compound, but they are usually **NOT REQUIRED**. Because of our experience in biological treatment, we can generally predict a contaminant's degradation characteristics without resorting to expensive, time-consuming studies trying to identify the proper microbes and environmental conditions to use. When necessary, our laboratory can perform full biodegradation studies.

Step 2 - TOXICITY/INHIBITION TEST

Because many different factors can be toxic or harmful to micro-organisms (such as pH, heavy metals, or pesticides) we usually suggest a brief (less than one week) test at our Dayton laboratory to check for the presence of these potentially harmful compounds. We can usually provide a **PERFORMANCE GUARANTEE** for your particular waste stream after this test.

Step 4 - DESIGN & FABRICATION

All DETOX units are designed to provide effective treatment with minimal operator attention, in keeping with our **"LIFE-CYCLE DESIGN"** concept. Removal efficiencies of **greater than 99%** and effluent levels as low as **1 ppb** of specific organics are achievable. We are constantly improving and updating our designs in response to operational experience at a variety of sites. Fabrication can be in a variety of materials to suit site conditions and relevant structural codes.

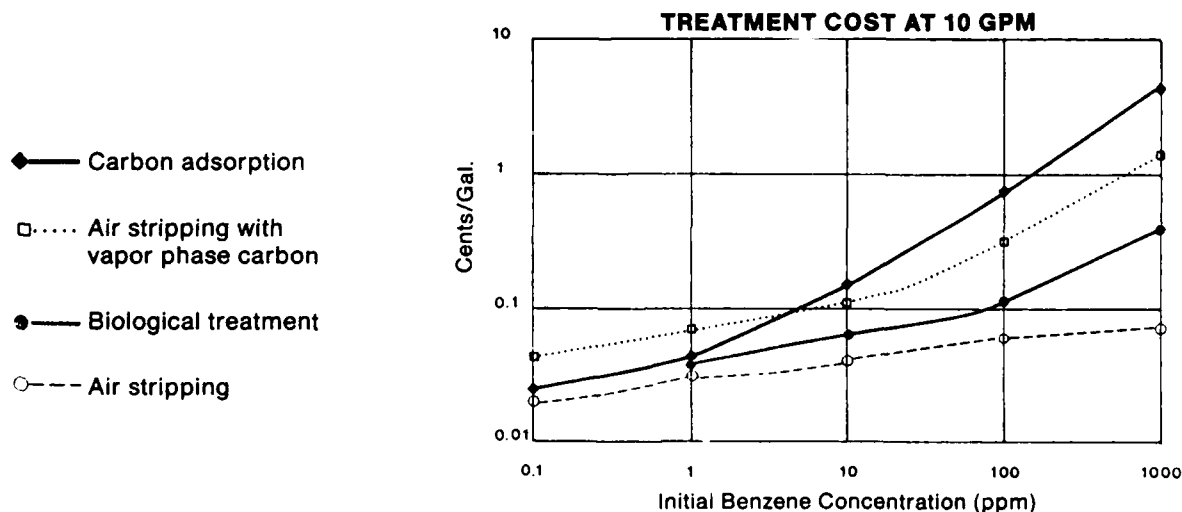
Step 3 - FIELD PILOT TESTING

For extra security, or for regulatory approval, we offer pilot scale models of all our reactors to run at your site. These tests take two to three months, and subject a system to the actual conditions that will be encountered. **EXACT** design specs, nutrient usage rates, and performance predictions can be made from this test.

Step 5 - INSTALLATION & START-UP SERVICES

DETOX can provide **turnkey** installation services. Our portable units require a minimum of site disruption and support equipment. After start-up, most biological systems take 3-6 weeks to develop a healthy biomass and become fully operational. DETOX can assist with system monitoring and control during this time, and we can provide training for your personnel. We also offer complete **"Operations and Maintenance Contracts"** to ensure excellent performance during the life of your cleanup.

Biological treatment costs compared to air stripping and carbon adsorption.



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Appendix C

DORR-OLIVER INCORPORATED



CORPORATE HEADQUARTERS
77 HAVEMEYER LANE
P.O. BOX 9312
STAMFORD, CT 06904-9312
TELEX 965912
TEL. 203-358-3200

February 24, 1987

Mr. Paul Kenis
Naval Ocean Systems Center
Code 521
San Diego, CA 92152-5000

Dear Mr. Kenis:

Responding to your letter of 12 February, we are pleased to enclose a technical paper and other information on three Dorr-Oliver products which are used for the treatment of aqueous hazardous wastes. All three systems employ biological treatment and where appropriately applied, offer the advantages of significantly lower operating costs and the minimum production of residuals which require further treatment or disposal.

These products are:

OXITRON® A fluid bed biological reactor which uses an inert media, normally finely graded sand, onto which a biological film is attached. The media is hydraulically expanded (fluidized) producing a very large surface area for both the growth of bacteria and uniform exposure of the bacteria to wastewater components. Because the biomass concentration is so high, high-purity oxygen is supplied in lieu of compressed air with the result that there is virtually no air stripping of volatile organic compounds into the atmosphere. Oxitron should be considered when wastewater contains volatile or non-volatile components such as carbon tetrachloride, naphthalene, ethylbenzene, toluene, benzene, methylene chloride and various ketones.

OXITRON ACTIVATED CARBON This is an Oxitron system which uses activated carbon as the fluidized media. During operation rapidly biodegradable wastewater components are consumed by the biomass with recalcitrant and more slowly biodegradable components adsorbed by the activated carbon. Many of the organic components adsorbed on the carbon are eventually biologically consumed with the result that carbon life is significantly extended. Oxitron Activated Carbon should be considered when the wastewater includes components such as trichloroethylene, tetrachloroethylene and pentachlorophenol.

MARS™ A suspended growth reactor is combined with an ultrafiltration membrane system to provide the most complete treatment of any known biological system. The membranes are installed in a recirculation loop around the reactor and retain 100% of the biomass and all other suspended solids until such time as they have been solubilized and consumed. The oxygen requirement for MARS can be met from either compressed air or high-purity oxygen where VOC emissions are a consideration. Activated carbon can be mixed in the reactor to adsorb recalcitrant and slowly degradable organic components. The system is also available in an anaerobic version where it can become an economic unit process for the conversion of high strength organic wastes often found in landfill leachates.

DORR-OLIVER 

Page 2

February 24, 1987

Mr. Paul Kenis
Naval Ocean Systems Center
San Diego, CA 92152-5000

In addition to the supply of equipment on a purchase or rental basis, Dorr-Oliver has the capacity to operate the equipment in the field or train and supervise others in its operation which is largely automated and requires only a minimum of operator attention.

If you have some specific groundwater or leachate candidates which contain organic solvents, we would be pleased to make a preliminary assessment as to their treatability by one of these technologies and provide an estimate of their capital and operating costs.

Sincerely,



F. B. Leonard
Marketing Manager
Biological Systems

FBL/gz
Encls.

OXITRON® ACTIVATED CARBON

DESCRIPTION

Aerobic fluidized bed plus activated carbon wastewater treatment system combining biological treatment, carbon adsorption and carbon regeneration in a single unit process.

PRIMARY ADVANTAGES

- Combines several unit processes into a single relatively simple system.
- Effluent quality equivalent to packed bed activated carbon column.
- Biological regeneration of activated carbon extends carbon life.
- Most contaminants removed biologically at much lower cost than carbon column.
- Lower capital and operating costs than alternatives.
- Automated operation without the need for complex instrumentation and control systems.
- High tolerance for hydraulic and concentration shocks. Greatly increased flows can be accommodated without loss of biomass or loss of treatment efficiency.

- Uniform effluent quality under variable load conditions.
- High resistance to toxic shock.
- Rapid restart after extended shutdown periods.
- Removal of volatile organic compounds without air stripping to the atmosphere.

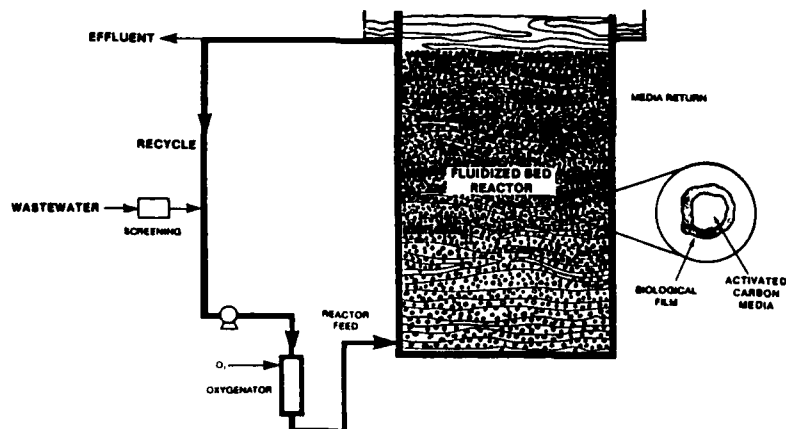
WHEN TO CONSIDER

Ground and surface water clean up operations where something more than air stripping is required. Oxitron Activated Carbon will provide more complete treatment than air stripping as well as eliminate the need for activated carbon treatment or incineration of the VOC-laden air.

Industrial wastewater treatment applications where wastewater contains components which are slow to biodegrade or where activated carbon treatment or incineration would otherwise need to be considered.

FOR MORE INFORMATION
SEE REVERSE SIDE

OXITRON® ACTIVATED CARBON PROCESS SCHEMATIC



DORR-OLIVER

77 Havemeyer Lane, Stamford, CT 06904: (203) 358-3430

AEROBIC MARS™

DESCRIPTION

Aerobic wastewater treatment system which produces the highest quality effluent of any biological system. Aerobic MARS combines a well mixed suspended growth reactor with an ultrafiltration membrane system. Powdered activated carbon can be included in the reactor for the purpose of absorbing the more slowly degradable organic components with carbon life greatly extended via biological regeneration.

PRIMARY ADVANTAGES

- Highest quality effluent of any biological system.
- Compact and self contained.
- Automated operation without need for complex control system.
- High resistance to toxic shocks.
- Uniform effluent quality under variable loading conditions.
- No loss of biomass to effluent.
- Can use air or high purity oxygen to reduce VOC emissions.

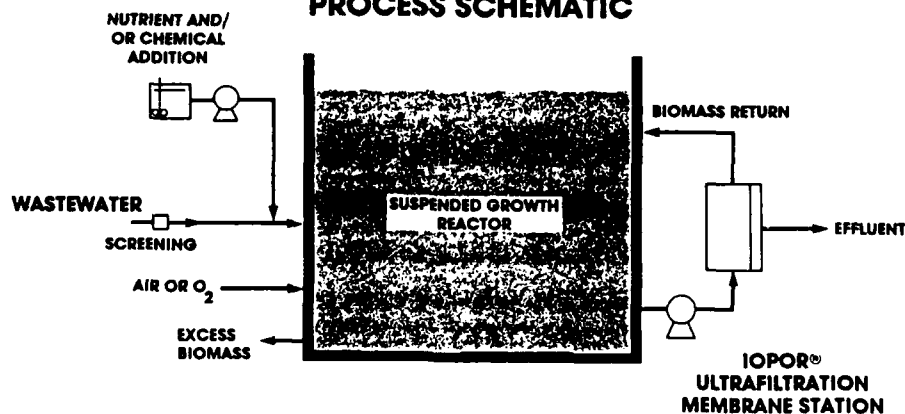
WHEN TO CONSIDER

- Emulsified oil present in wastewater.
- High quality effluent required.
- Potential exists for reuse of water.
- Use of specific bacteria is desirable.
- Wastewater contains organic suspended solids.
- Wastewater contains slowly degradable soluble organic components.
- Low to moderate flows.
- Potential exists for toxic or high bod loading shocks.
- Space is at premium.

FOR MORE DETAILS CONTACT

Dorr-Oliver Biological Systems
77 Havemeyer Lane
Stamford, CT 06904
(203) 358-3430

MEMBRANE AEROBIC REACTOR SYSTEM PROCESS SCHEMATIC



OXITRON[®] SYSTEM

DESCRIPTION

Aerobic or anoxic fluidized bed treatment system for industrial and sanitary wastewaters: carbonaceous BOD removal, nitrification and denitrification.

PRIMARY ADVANTAGES

- Compact, requires less than 25% of the space required for a conventional activated sludge system.
- Is frequently installed in a building for easy maintenance and minimal heat loss.
- Automated operation without need for complex instrumentation and control system.
- High tolerance for hydraulic shock. Greatly increased flows can be accommodated without loss of biomass or reduced treatment efficiency.
- Uniform effluent quality under variable loading conditions.
- High resistance to toxic shock.
- Rapid restart after shutdown periods.

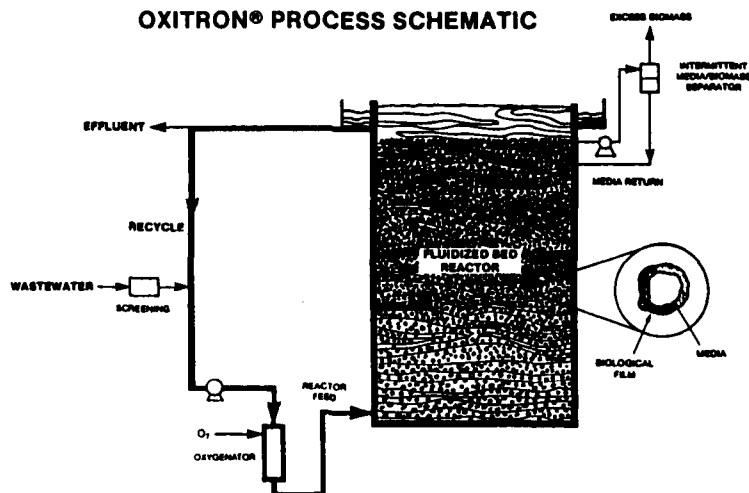
- Does not air strip volatile organic compounds and release them to the atmosphere.

WHEN TO CONSIDER

- Space at a premium.
- Advantages to locating treatment system inside a structure.
- Wastewater has variable strength or flow.
- Need uniform effluent quality.
- Potential for toxic shocks.
- Simple operation with minimal operator skills has value.
- Volatile organic compound release to atmosphere is a consideration.

FOR MORE INFORMATION
SEE REVERSE SIDE

OXITRON[®] PROCESS SCHEMATIC



DORR-OLIVER 

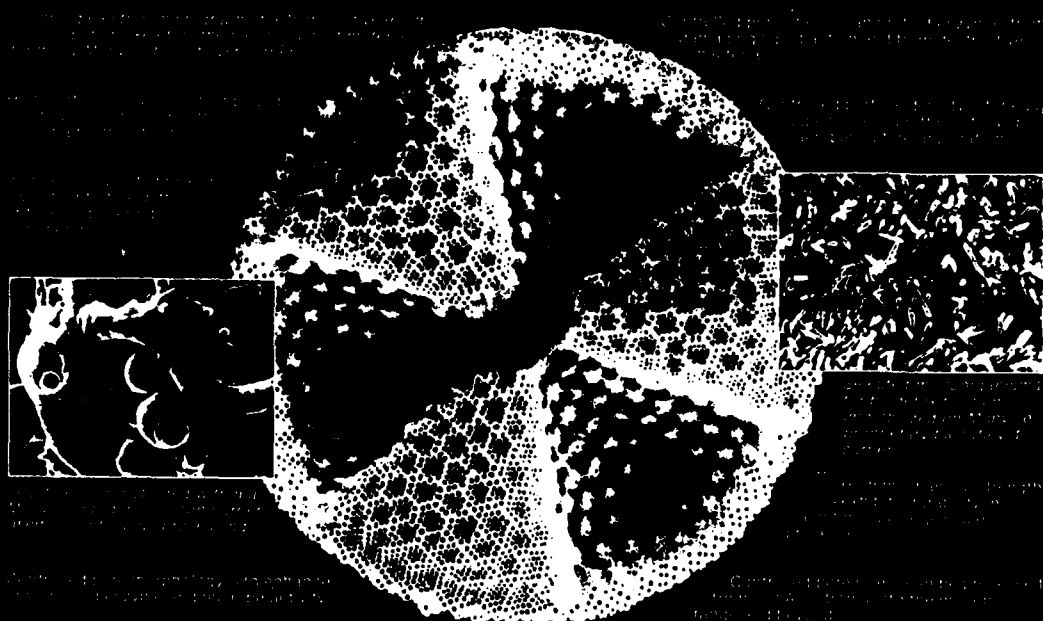
77 Havemeyer Lane, Stamford, CT 06904: (203) 358-3430

MANVILLE

**BIO/CATALYST
CARRIERS**

Manville makes enzyme and microbe immobilization processes effective and economical.

From bench to commercial production.



The purity and surface chemistry of these carriers can be specifically controlled. Thus bench use can be scaled up through the pilot stage to full-scale production — without costly adaptation

of equipment and processes

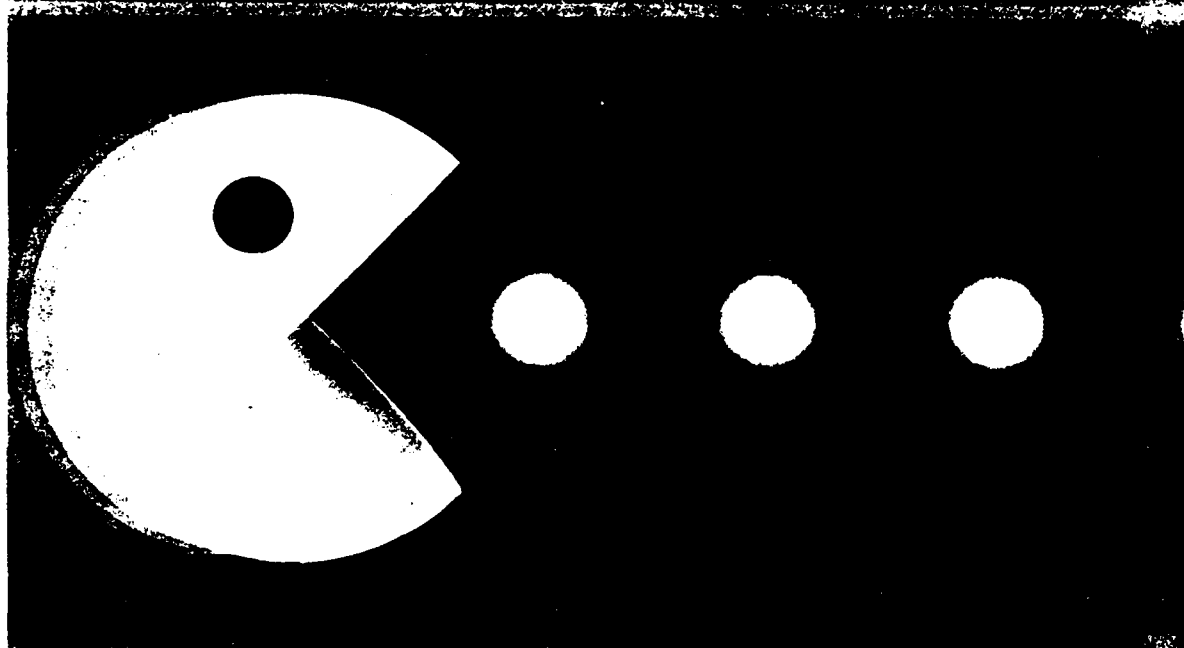
The names of the processes are new, the technology of inert carriers is not - for Manville. We've been helping scientists scale up their catalytic processes for many years.

And now Manville has developed a special R&D lab to evaluate bioprocesses and custom design biocatalyst carriers. Let us work with you.

For more information regarding your specific biocatalyst carrier requirements, call Tom Crossman at 303-978-3176.

Manville

Manville's new, on-site solution to toxic waste is based on a rather simple principle.



Manville has isolated unique micro-organisms that literally feed on a growing number of toxic waste substances.

The economic solution to your toxic waste disposal problem may be closer than you think. Manville, working with the Louisiana State University Institute for Environmental Studies, has successfully minimized microorganisms on inorganic custom biocatalyst carriers. Mutually maintained, these microorganisms will metabolize even the most hazardous waste substances, including non-toxic, soluble or recoverable materials.

For your toxic waste treatment process means that your toxic waste problem will be virtually eliminated. It may also offer significant cost reductions over currently available methods for handling these types of wastes.

Manville is prepared to work with you to custom design a system for your needs. From selecting the right microbe and carrier, to feasibility studies, to a complete scale-up of a continuous process commercial system, we have the technology and the expertise that could end your toxic waste problems.

For more information call Tom Crossman, marketing development manager, at 1-303-978-3176. Or contact Manville Filtration & Minerals, P.O. Box 5108, Denver, CO 80217-0108 U.S.A.

Manville

Manville Filtration & Minerals is a subsidiary of Manville Corporation, a public company listed on the New York Stock Exchange under the symbol MAN. Manville Corporation is a leading manufacturer of asbestos-free fiber and mineral products. For more information, contact Manville Filtration & Minerals, P.O. Box 5108, Denver, CO 80217-0108 U.S.A. or 1-303-978-3176.

Cellite Catalyst Carriers for Enzyme and Microbe Immobilization

The immobilization of enzymes and microbes in commercial production allows the use of continuous processes rather than traditional batch reactors. The more economical continuous system has the advantages of improved utilization of both the feed stocks and the enzymes or microbes and better process control.

The carriers most commonly required for large scale use are made of glass or ceramic materials. Manville has developed a series of these carriers designed expressly for the biotechnology industry. Their manufacture is based on more than fifty years of experience with silica and silicates. Manville also has experience with various types of fiber glass and ceramic materials.

Immobilization requires closely-sized pores in the carriers. Properly-sized pores provide a number of advantages:

1. They maximize the concentration of the enzyme or microbe in the reactor.
2. They protect the enzyme or microbe from damaging fluid movement.
3. They help to protect the enzyme from destructive bacteria within the reactor system.

The new series of catalyst carriers from Manville provides low-cost materials with controlled pore sizes. The low cost aspect makes many potential processes economical. Intended for use in pharmaceuticals, chemicals, waste disposal and many other applications, these carriers provide the combination of properties necessary for an efficient operation.

The carriers shown in this brochure are just an example of Manville's capabilities. There are very few standard processes in the biotechnology field and, therefore, custom-made products for specific applications must be considered. Manville will work with individual customers in developing carriers best suited for specific applications. Information on alternatives in selecting pore sizes and volumes, carrier strength, sizes and shapes can be supplied.

Additional information on other Cellite catalyst carriers can be obtained in Technical Bulletin FF-390A.

Carrier Selection

Selecting a carrier involves defining the properties which are most important in the carrier. Typically, pore diameter and volume, strength, chemical inertness and carrier shape are most critical. These and other properties are interrelated and compromises can be made to

produce the most economical carrier.

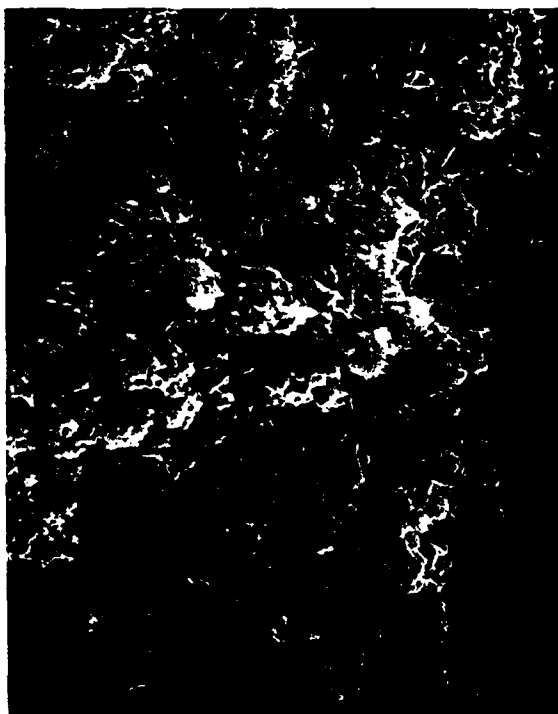
Pore Diameter

Production rates are greatly affected by the concentration of the enzymes or microbes and by the ease of diffusion to them. It has been found that by maximizing the concentration and accepting the resulting diffusion rates gives the best performance. The highest loadings are obtained when the pore diameters are based on the enzyme or microbe diameters. Pores which are one to five times the size of the largest involved element typically provide the highest production rates.

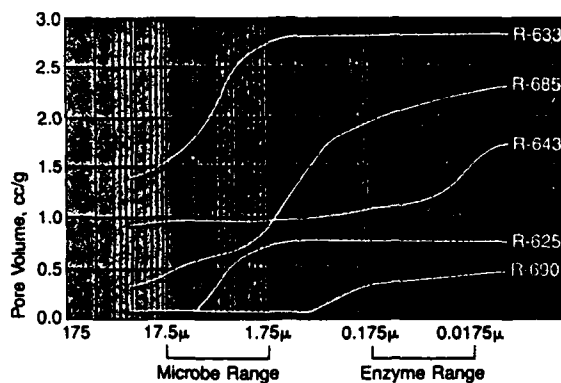
In whole cell immobilization, the pore diameters are based on the major cell dimensions. Living systems require additional care to insure adequate space for cell reproduction. Typically, diameters of 1 to 25 microns are needed to accommodate the cells.

In enzyme processes, the desired pore diameter is based either on the enzyme's

Scanning electron micrograph of typical enzyme carrier pore structure. 5000X magnification.



Manville Bio-Catalyst Carrier Pore Size Distribution Curves*



Pore Diameter, microns

*Mercury Intrusion Method (4 to 15,000 psi)

dimensions or possibly on the dimensions of the reacting organic molecules. The desired diameters are usually between 200 and 2000 Angstroms.

Pore Volume

The pore volume is very important since it indicates the quantity of available sites at which the microbes or enzymes can be located. Specifically, only the volume of the pores within the useful size range should be considered. High pore volumes maximize the concentration per volume in the reactor. Although the pore volume can be controlled, there are trade-offs with other carrier properties, especially the carrier hardness.

Surface Area

The surface area is an indication of the number and shape of the carriers' pores. A high surface area is expected in a small pore carrier. The small pore carriers, such as Celite 640 and Celite

650, have surface areas of over 80 square meters per gram. The microbe carriers have relatively low surface areas due to the low surface-to-volume ratio of large pores.

Hardness

The mechanical strength of the carrier is determined by the composition, production process and physical size. The porosity of the carrier very significantly affects its strength. Increases in pore volume have a large negative impact on particle strength. A minimum acceptable strength should be established for a given application, thereby allowing the optimization of the carrier's remaining properties.

Particle Size

Celite catalyst carriers can be produced in several forms: powder, pellet and sphere. The shape of these carriers can be custom fabricated in sizes ranging from 1.0 to 10 millimeters in diameter.

Diffusion limitations in reaction processes often require smaller sizes. The more commonly used carriers are in the range of 0.3 to 1.0 millimeters. However, powders can be produced in the sub-micron range.

Chemical Composition

Manville catalyst carriers are made of rigid, inorganic materials. These materials provide the advantages of thermal and chemical stability, mechanical strength and rigidity and microbial resistance.

Diatomite, one of the basic raw materials, is compatible with a very wide range of aqueous and organic environments. It is currently used in the filtration of drugs, pharmaceuticals, beverages, acids and petrochemicals. Although each individual application must be considered separately, Celite

catalyst carriers are recommended wherever high-silica glass is appropriate.

Typical chemical composition for a few of Manville's carriers is shown in Table 1.

These concepts are the basis for the selection of an immobilization carrier. They are to be considered as general guidelines in determining the parameters required for specific applications. Manville's technical staff can aid you in the selection of the most appropriate carrier.

Materials can also be custom-tailored to meet your specific enzyme and microbe immobilization needs. Contact Manville for additional information, samples and recommendations with regard to carrier requirements.

Table 1

Typical Physical Properties

Grade	R-625	R-633	R-643	R-685	R-690
Form	pellet 1/8"	sphere 30/50 mesh	crushed pellet 30/50 mesh	powder	pellet
Mean Pore Diameter μm	5.5	6.5	0.03	0.0	0.15
Surface Area m ² /g	12.4	1.3	67	140	122
Pore Volume cc/g	0.74	1.47	0.94	2.03	0.43
Water Absorption % by Weight	86	240	220	hydrophobic	66
Hardness	1.6 kg	27-28%	9-14%	—	3 kg
Bed Density Lbs/cu ft	32	22	24	17	38

Typical Chemical Composition by Weight, %

SiO ₂	84.8	83.2	87.0	63.9	54.0
CaO	1.7	0.5	0.9	0.4	0.6
Al ₂ O ₃	6.4	3.5	6.1	3.1	35.0
Fe ₂ O ₃	2.1	1.3	1.6	1.5	1.5
LOI (@ 1000°C)	0.4	0.3	2.1	13.0	6.05
pH, by Slurry	10.0	10.4	8.5	7.4	8.3

Range of Manville Bio-Catalyst Carriers

Grade	Form (mesh size)
R-600	Pellet
R-610	Pellet
R-620	Pellet
R-625	Pellet
R-630	Sphere (3/5)
R-631	Sphere (8/14)
R-632	Sphere (14/30)
R-633	Sphere (30/50)
R-634	Sphere (50/100)
R-640	Pellet
R-641	Crush (8/14)
R-642	Crush (14/30)
R-643	Crush (30/50)
R-644	Crush (50/100)
R-645	Fines
R-646	Sphere (8/14)
R-647	Sphere (14/30)
R-648	Sphere (30/50)
R-649	Sphere (50/100)
R-650	Pellet
R-660	Pellet
R-665	Sphere
R-670	Pellet
R-675	Pellet
R-680	Powder
R-681	Powder
R-682	Powder
R-685	Powder
R-690	Pellet
R-695	Pellet

Appendix E

SMITH AND LOVELESS, INC.

FAST[®]

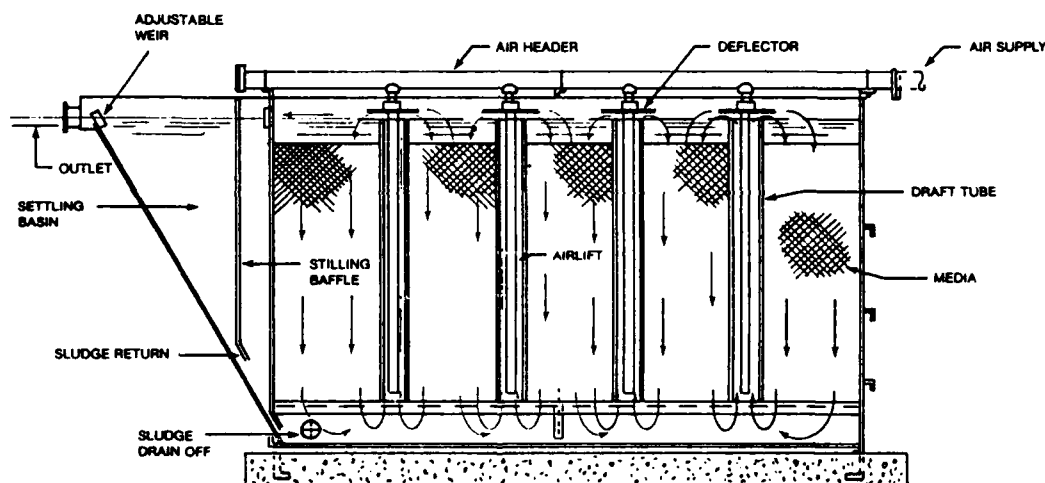
FIXED ACTIVATED SLUDGE TREATMENT Pre-fabricated wastewater treatment plants.

The cost advantages of biological treatment without the operational problems.

The Factory-Built Concept.

Lower Installed Costs — Perfected by years of experience, a factory fabrication system is far more efficient — and thus costs less — than field-built systems.
Portable — Unit can be easily moved where it's needed, and is available in many sizes.

On-Time Start-Up — All components have been completely tested prior to shipping so that the unit is operational when installed. Unit is also **not affected by weather** in the field.



Three methods of transfer combine to provide high efficiency oxygen transfer.

1. Bubble Transfer
2. Thin Film Transfer
3. Surface Turbulence Transfer

Bacteria grow on the high surface area plastic support media. The thickness of the bacteria is proportional to the organic concentration in the wastewater. Equivalent mass loads can reach 5000-7000 mg/l.

Bacteria concentration in the aeration zone is self-regulating. An increase in food creates a thicker film (more bacteria). A decrease in food and the film becomes thinner. True activated sludge treatment is maintained

without the need for costly process control or personnel. (All changes are gradual in order to maintain maximum removal efficiency.)

Completely Mixed-Air released in the lift tubes acts as a standard air lift pump. The contents of the tank are turned over every 3 to 4 minutes.

Solids from the aeration zone are separated in the clarifier zone reducing suspended solids in the effluent.

Biological solids are returned to the FAST[®] aeration zone. This increases the concentration of bacteria in the final section with a resulting decrease in effluent organics (BOD, COD, and TOC).



Smith & Loveless, Inc.

S-138

A Wide Variety of Applications for the Patented FAST® System.

Municipal

When unattended operation is important, the FAST® plant provides a self-regulating treatment system that produces low effluent BOD and suspended solids.

Industrial

For good quality effluent, low maintenance costs and low personnel costs in the following industries:

Petrochemical, chemical, refinery, textile, pulp and paper, plastics, pharmaceuticals, food processing, steel, automotive, military and more.

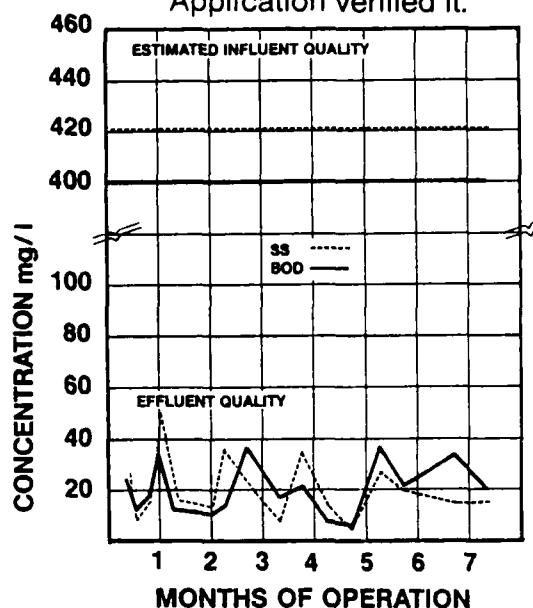
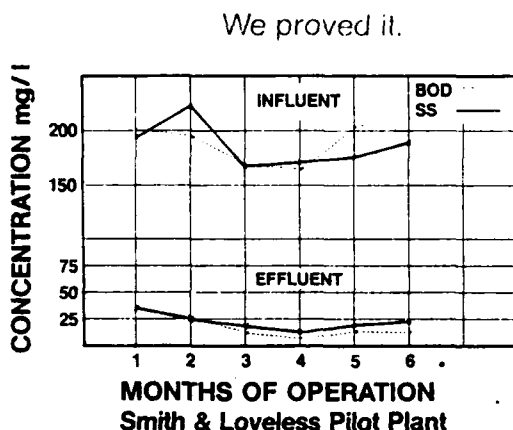
Groundwater

FAST® Package Treatment units are portable, highly-resistant to toxic shock, and they can be left unattended. These features make the FAST® system perfect for low cost decontamination of groundwater and surface impoundments.

A Broad Range of Chemicals

Industrial wastewater and groundwater have a wide variety of organic compounds. 99.99% of all known organic compounds can be degraded by bacteria.

Application verified it.



They certified it*
FAST® — A proven system.

PARAMETERS	UNITS	INFLUENT	EFFLUENT	% REMOVAL
BOD	mg/l	564	6	98.9
COD	mg/l	1507	120	92.0
Suspended Solids	mg/l	1568	4	99.7

* National Sanitation Foundation Certified Test

ECONOMICS — For Treatment of Organic Wastewater, Nothing Compares to a FAST® System. And at only 1/10 the cost of alternate energy.

	CARBON ABSORPTION		CHEMICAL TREATMENT		HAULING		FAST® SYSTEM	
Waste Strength	100 mg/l	1000 mg/l	100 mg/l	1000 mg/l	100 mg/l	1000 mg/l	100 mg/l	1000 mg/l
Cost (¢)/gal. waste	.5¢ — 1¢	5¢ — 10¢	.6¢ — 1.3¢	6¢ — 12¢	6¢ — 50¢	6¢ — 50¢	0.03-0.1¢	0.1-0.4¢

LEASING: Smith & Loveless offers the latest in leasing plans for both municipal and industrial users. Contact us about alternative financing.

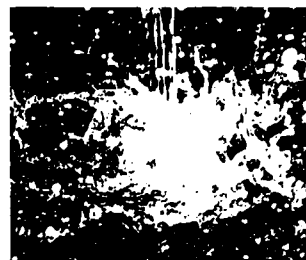


Smith & Loveless, Inc.

14040 Santa Fe Trail Drive
Lenexa, Kansas 66215
(913) 888-5201
TELEX: 42282 (SMITLOVLS LENX)

Appendix F

FMC CORPORATION



Aquifer Remediation Systems

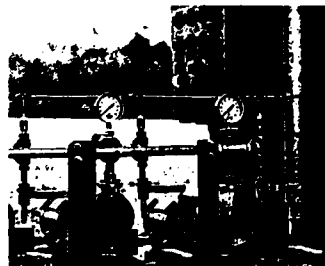
Aquifer Remediation Systems (ARS) is an environmental services business of FMC Corporation, specializing in the treatment of contaminated groundwater and soils. Based in Princeton, NJ, ARS uses proprietary in situ treatment techniques to provide cost-effective remediation of many subsurface contamination problems.

ARS is leading the way with Bio XL_{SM} enhanced bioreclamation services. Enhanced bioreclamation is a fast, proven and more complete alternative to conventional technologies. By stimulating common soil bacteria, a wide range of contaminants can be degraded, including petroleum products and many industrial solvents. Other conventional remediation techniques are

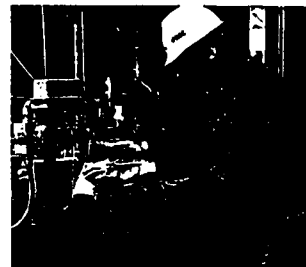
limited to either containment of the problem or relocation of the contaminant for treatment on the surface.

ARS is totally dedicated to providing in situ remediation services. Our team of professionals has a broad range of experience in applying these techniques. Through the development of an early understanding of critical site parameters, ARS quickly identifies what is required to meet the remediation objectives for a given site.

As the leader in enhanced bioreclamation, ARS provides Bio XL services, including the equipment and nutrients required to apply this in situ technique to site-specific needs. The ARS "hands-on" approach provides full support from project conception through closure.

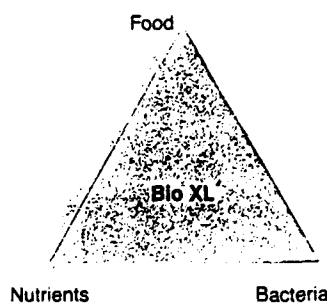


ARS is leading the way with Bio XL — The Effective Alternative for groundwater restoration. Let ARS propose a tailored solution to your site-specific conditions and remediation needs.





Bio XLSM — The Effective Alternative



Bio XL enhanced bioreclamation is a site specific groundwater treatment technique which works by accelerating a natural biological process. Contamination in both the groundwater and the soil is reduced as harmful constituents are metabolized into natural elements (i.e., CO₂ & water), which no longer pose an environmental risk.

The Bio XL triangle helps to explain the process. In a subsurface environment, the rate at which indigenous bacteria can consume the contaminant (Food) is normally limited by the availability of life-sustaining nutrients such as nitrogen, oxygen and phosphorus. The Bio XL process is the controlled addition of these nutrients to the subsurface environment.

By assessing the key factors related to site hydrogeology, microbiology and chemistry, ARS determines how the proper subsurface environment can be created and controlled, to yield a successful clean-up.

To accelerate natural biodegradation, the Bio XL process uses custom-formulated Restore[™] microbial nutrients, specialized equipment and proprietary application



techniques, for which patents are being applied for worldwide. By creating a bioactive zone in both the groundwater and soil, the process treats the contamination as well as its source.

Because enhanced bioreclamation is a dynamic biological process, the subsurface environment must be continually monitored and adjusted to maintain optimum consumption rates. ARS provides all the Bio XL services, including equipment and nutrients, to make enhanced bioreclamation successful and cost-effective.



Aquifer Remediation Systems

A Systems Approach to Enhanced Bioreclamation

ARS provides a systems approach to design and implement cost-effective solutions for subsurface contamination problems. Bio XL_{SM} enhanced bioreclamation services are conducted in 3 phases, and emphasize an early understanding of the critical site factors.

In Phase 1, ARS assesses feasibility and identifies any "knock-out" factors. Phase 2 determines remediation levels achievable, timing and associated costs. Phase 3 is the actual on-site implementation of a Bio XL program to achieve the remediation goals for site closure.

Phase 1—Site assessment

During site assessment, ARS conducts preliminary assessment of feasibility and identifies any site-specific complications. This phase provides a general understanding of microbial activity at the contaminated site and assesses whether microbial activity can be effectively accelerated to consume the groundwater contaminant. Key issues related to site hydrogeology and chemistry are also evaluated to determine if they present significant complications.

The initial phase typically involves an on-site visit to collect groundwater samples for laboratory evaluation. Laboratory analyses of chemical and microbiological indicators are performed to characterize the groundwater microbial activity under existing and nutrient enriched conditions.

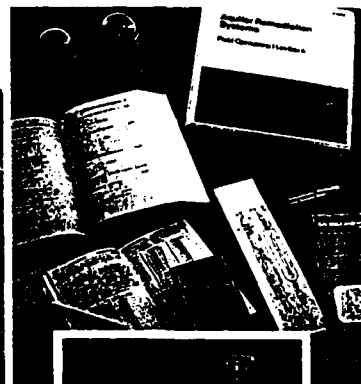
This data is then reviewed, along with site information which has already been gathered, to provide an assessment of feasibility.

Phase 2—Process design

The process design phase identifies the level of remediation achievable, and provides cost and time estimates. During this phase, additional groundwater samples and soil core samples are taken from the site. The samples are evaluated to:

- Quantify site contamination
- Determine contaminant consumption rates and levels
- Define nutrient requirements
- Evaluate injection strategies.

Cost and time estimates are provided to allow for economic comparisons to other treatment options. A conceptual design of the remediation plan is provided for discussions with management and regulatory agencies as required.



Phase 3—

Project implementation

Project implementation is the actual on-site execution of a Bio XL_{SM} enhanced bioreclamation program to achieve your remediation goals. On-site activities are performed in four stages.

Project engineering

- Formulate site-specific Restore_{SM} microbial nutrients
- Specify nutrient addition and monitoring schedules
- Design recirculation system
- Finalize installation requirements

Installation and start-up

- Deliver and install customized injection equipment
- Train on-site operators
- Start-up Bio XL process
- Monitor bacterial response

Operation and monitoring

- Optimize contaminant consumption rate
- Quickly respond to operating variables
- Report routinely on remediation status
- Provide 24 hour support

Site closure

- Remove equipment and unused nutrients
- Review results
- Issue final report



Selection Criteria

Bio XL_™ enhanced bioreclamation is a versatile remediation tool for use on biodegradable contaminants. It can be used as the exclusive treatment process or in conjunction with other treatment techniques.

In determining the applicability of the Bio XL process for a site, it is necessary to evaluate three primary site factors—hydrogeology, microbiology and chemistry. Successful application requires that the:

- contaminant subject to treatment is biodegradable,
- site hydrogeology allows for controlled and timely transport of nutrients,
- soil and water chemistry is compatible with the addition of Restore_™ microbial nutrients, and will allow the stimulation of the subsurface microbial community.

ARS has the experience to evaluate these factors and design a Bio XL program to treat the problem. To date, Bio XL has been successfully applied in variable geological formations on a range of petroleum hydrocarbons with different source conditions.

The Bio XL process will treat the full range of compounds listed in Table 1. These materials are structurally similar to naturally occurring compounds which are known to be biodegradable by aerobic bacteria.

In addition, there are several other contaminants which are not degradable by aerobic bacteria, and which are therefore not treatable with our current Bio XL process



(Table 2). Because many of these contaminants are of extreme environmental concern, our development efforts are directed toward finding cost-effective ways to apply our proprietary technology to these compounds. ARS is committed to extending our technology, through basic research and cooperative development efforts with industry, government and leading universities.

Compounds amenable to direct chemical modification are also being assessed for their responsiveness. ARS is currently undertaking laboratory screening on such compounds to identify key factors which will affect the future use of direct chemical reclamation techniques.

ARS will remain in the forefront of the development of in situ remediation techniques. We have the experience, resources and commitment to continue leading the way.

Appendix G

CAMBRIDGE ANALYTICAL ASSOCIATES SERVICES



Bioremediation Systems Division
Cambridge Analytical Associates

SERVICES OVERVIEW

FROM START TO FINISH WE ARE ALWAYS READY TO SERVE YOU

Headquartered in Boston, Massachusetts, Cambridge Analytical Associates (CAA) Bioremediation Systems provides quality environmental services at a very competitive price. We specialize in the development and commercial application of clean-up and leak detection technologies. CAA Bioremediation Systems offers a full range of environmental services from underground storage tank monitoring systems to on-site pollution clean-up services.

Currently, we have field offices in Walnut Creek, California and Princeton, New Jersey with several more opening soon in the Southwestern and Southeastern areas of the United States. All of our offices provide complete services to aid you in your environmental needs.

Headquarters
CAA Bioremediation Systems
1106 Commonwealth Avenue
Boston, MA 02215

Eastern Field Office
CAA Bioremediation Systems
P.O. Box 7109
Princeton, NJ 08543

Western Field Office
CAA Bioremediation Systems
1111 Civic Drive - Suite 250
Walnut Creek, CA 94598

Our environmental services include underground tank management programs, leak and contaminant surveys, vapor extraction and soil venting, recovery of free product, on-site soils treatment, ~~in-place water and soils treatment, biological treatment of hazardous waste and EPA approved analytical services.~~ Our full-service capabilities allow us to clean-up a wide variety of priority pollutants such as petroleum hydrocarbons, organic solvents, and coal tar residues. We have developed commercial technology to clean-up soils and ground waters on-site and many times, in-place. Also, we have researchers dedicated to finding more innovative processes to deal with hazardous wastes.

CAA is equipped to handle all of your environmental needs accurately and cost effectively. The only phone call you will ever need to make for all of your environmental concerns is (609)275-5005 for full environmental service, from start to finish.

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Appendix H

GROUNDWATER DECONTAMINATION SYSTEMS, INC.

SERVICES

(1) Licensing

GDS technical experts will act as consultants to assist you in setting up and running your own GDS system. The license fee is based on the capacity and complexity of the system involved.

(2) Design

GDS can design an entire system which will specifically meet the characteristics of the site and the contaminants present.

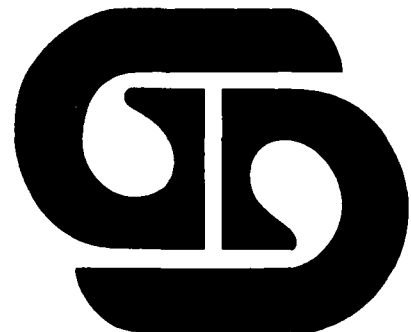
(3) Construction

GDS can design, engineer and construct an entire system to solve your particular contamination problem.

(4) Monitoring

GDS will monitor your installation and train your personnel to assure its efficient operation.

For more information on the GDS system—or to arrange a visit to a GDS system installation—write or call:



**Groundwater
Decontamination
Systems, Inc.**

Suite 210 • 140 Route 17 North
Paramus, New Jersey 07652
(201) 265-6727

GDS—the system for soil and groundwater decontamination

The GDS system had its beginning when a firm producing semi-synthetic penicillin developed a decontamination problem. Biocraft Laboratories' Waldwick (NJ) plant was faced with the great expense of shipping large quantities of contaminated waste water as far away as Ontario, Canada. Biocraft management decided to search out an on-site method that would solve their problem.



In 1978, microbiologist Dr. Vidyut Jhaveri conducted a series of experiments to see if the contaminants could be biodegraded on-site by utilizing naturally occurring microorganisms. Subsequently, a research team consisting of Dr. Jhaveri, Biocraft president Harold Snyder and plant manager Alfred Mazzacca developed a biostimulation-decontamination system that greatly accelerated the natural biodegradation process.

Biocraft began use of the GDS process in 1981, after it was approved in a consent order by the New Jersey Department of Environmental Protection. Reduction of contaminant levels in the activation tanks occurs at a rate of 98% or better. Initially the overall reduction of contaminants on site occurs at a greater rate above ground in the activation tanks; as the contaminant levels drop most of the decontamination (biodegradation) occurs in the ground. The cost is less than two cents a gallon—a small fraction of normal disposal costs. It is estimated the spill will have been cleaned up within 5 years (cleanup by more conventional methods would have taken decades).

Based on the success of the GDS system, Groundwater Decontamination Systems, Inc. was formed to market the process.

GDS has been granted a patent on its unique process—a system that has shown it can effectively clean up a chemical spill in a fraction of the time, and at a savings of up to 90% over other cleanup procedures.

How the system works.

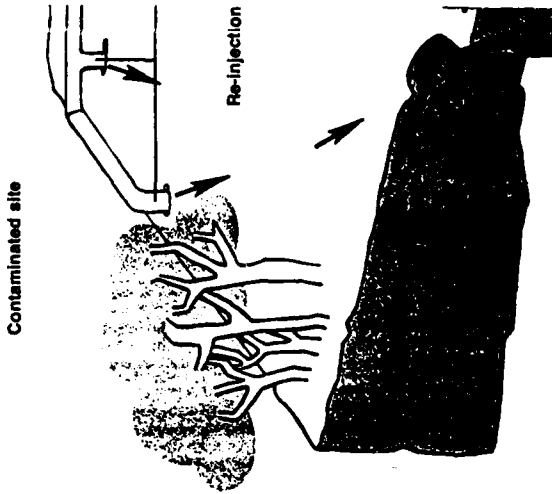
The GDS process involves pumping contaminated groundwater into activating tanks where the microorganisms found in the water are enriched with compounds of phosphates and ammonia, similar to those found in ordinary garden fertilizers. In some situations, trace amounts of inorganic salts of iron, manganese and magnesium are also added.

From the activating tanks, the water is transferred to settling tanks; treated water, rich in oxygen, nutrients and microorganisms is pumped into the trenches for recirculation throughout the site. This permits the biodegradation process to occur *in situ* as well as in the tanks. Aeration of the groundwater and soil through air injection wells further increases the rate of biodegradation. The combination of above-ground and in-ground systems permits highly detailed monitoring of the entire process.

GDS always points out to its clients that it is essential that laboratory studies be made of the contaminated ground and groundwater to determine the optimum conditions for maximum biodegradation. When optimum growth conditions are maintained, the bacteria grow exponentially and increase in number as much as 10,000 times, thus greatly accelerating the rate of biodegradation.

Why the GDS system is so cost effective.

The GDS method is based on the acceleration of Nature's own process of biodegradation. The GDS system effectively decontaminates both soil and groundwater.



The entire GDS system operates right at your facility with a minimum disruption of normal business activity and traffic. There are no contaminated materials to be hauled away to distant locations.

You know beforehand whether or not the system can do the job—before you make any major financial commitments. GDS tests and evaluates the types of contaminants you are faced with to make sure the GDS system can eliminate them effectively.

Finally, there are considerable savings in both money and time. Complete cleanup costs are less than any other method. Complete cleanup time can be achieved in a matter of years—instead of the decades that other methods may require.

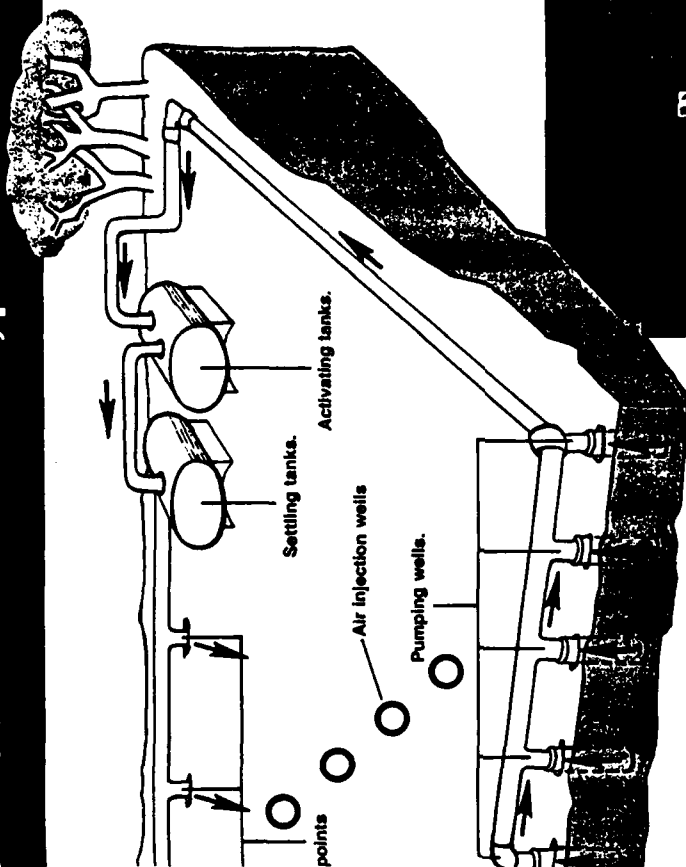
on that's cost effective, performance effective and it's patented.

How GDS works with you to develop your on-site decontamination facility.

Groundwater Decontamination Systems, Inc., can literally tailor its services to meet the decontamination needs of each of its clients. Services can range from technical consultation through a complete turnkey installation.

The GDS laboratory is at your service—both to determine if the GDS system is applicable, and to determine the exact nature of on-site contamination.

The GDS system installed at Biocraft Laboratories in Waldwick, New Jersey, was originally estimated to require five years to cleanup the site. Present projections indicate the task will be completed earlier than expected — at a savings of 90% over alternative cleanup methods!



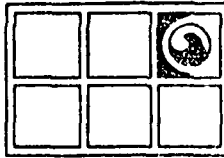
How to make sure the GDS system will work for you.

Groundwater Decontamination Systems, Inc., maintains a pilot plant and a New Jersey DEP-certified water pollution laboratory. These facilities are ready to determine the applicability of the GDS system for your contaminated site.



Appendix I

GROUNDWATER TECHNOLOGY, INC.



GROUNDWATER
TECHNOLOGY

A DIVISION OF OIL RECOVERY SYSTEMS, INC.

4080 Pike Lane, Suite D, Concord, CA 94520-1227 (415) 671-2387

April 24, 1987

Mr. Paul Kenis
Code 521
Naval Ocean System Center
San Diego, CA 92152

Dear Mr. Kenis,

For your general awareness I'm outlining below a general overview of our company's capabilities.

Since the inception of our company in 1975, Groundwater Technology, Inc. has continued to evolve to meet the growing needs of our clients and now are able to offer full service and support capabilities for both groundwaters and surface waters. Groundwater Technology, Inc. now offers expertise for all environmental problems be they air, soils, surface or groundwaters. Our staff of over 380 includes trained and experienced.

- | | |
|-----------------------------|---------------------------|
| • Hydrogeologist | • Geologist |
| • Chemical Engineers | • Mechanical Engineers |
| • Microbiologists | • Chemists |
| • Electronics Technician | • Mechanical Technicians |
| • Licensed Drillers | • Graphics Personnel |
| • Computer Operators | • Trained Administrators |
| • Medical Doctor | • Human Health Monitoring |
| • Physical Environmental | • Specialists |
| • Scientists | • Right to Know Chemical |
| • Public Health Scientists | • Specialists |
| • Foresters/Soil Scientists | |

As a full service company we offer a wide spectra of services including those listed below:

Evaluation Services:

- Groundwater quality and contamination assessments.
- Surface water quality and contamination assessments.
- Engineering feasibility studies for waste and process water.
- In vitro feasibility studies for biologic degradation of waste and contaminants.
- Full scale laboratory analysis for priority pollutants.

Other offices: Redondo Beach, CA; Tampa, FL; Mandeville, LA; Norwood, MA; Novi, MI; Minneapolis, MN; Greenville, NH; Chadds Ford, PA; Montreal, Quebec, Canada

Mr. Paul Kenis
April 24, 1987
Page 2

- ° Groundwater risk surveys/analysis.
- ° Human health and environmental risk analysis.
- ° Toxicological evaluation and legal representation.

Training Programs:

- ° Work shops for addressing new regulations.
- ° Aquifer impact and restoration short courses.
- ° Treatment technologies and alternatives.
- ° Toxicological training.

Design Services:

- ° Comprehensive design programs for aquifer restoration:
 - a. Organic vapor control and removal
 - b. Phase separated organic and inorganic compounds
 - i. Lighter than water
 - ii. Heavier then water
 - c. Dissolved aqueous phase organic and inorganic compounds
 - d. In situ programs for elimination of adsorbed phase organic chemicals
 - e. Human health care maintenance plan
- ° Comprehensive design programs for surface waters, waste streams and air discharges
 - a. Chemical process engineering design
 - b. Air process and vapor process engineering designs

Manufacturing - Installation

- ° Comprehensive manufacturing and assembly capabilities
- ° Construction of pollution abatement and water treatment equipment.
 - a. Sensor controlled pumps for hydrocarbon/water separation.
 - b. Air stripping towers for removal volatile organics.
 - c. Positive pressure and vacuum control systems for organic vapor mitigation.
 - d. Carbon units for low level organic removal.
 - e. Portable field sampling and analysis device for vapor, dissolved and phase separated organic compounds.
 - f. Specialized systems to meet facility design or regulatory criteria.

Mr. Paul Kenis
April 24, 1987
Page 3

Operations and Maintenance

- ° Groundwater Technology, Inc. stands behind its technical evaluation, design staff and manufacturing group by providing the client with installation, maintenance, and monitoring system.
- ° Emergency response systems and service for when you need us.
- ° Automated and telemonitored systems for continuous monitoring and evaluation of site conditions.
- ° Comprehensive data collection, evaluation and adjustment for operating systems.

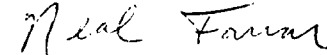
Expert Testimony

- ° Groundwater Technology, Inc. is an organization of professionals. Where there is a need, we can and have provided expert testimony on behalf of our clients.

Groundwater Technology, Inc.'s corporate philosophy is to provide you, the client, with sound professional aide and assistance in meeting your environmental needs and concerns in a responsive fashion at a reasonable cost.

If you have any questions or need additional information, please feel free to contact my office.

Sincerely,
GROUNDWATER TECHNOLOGY, INC.



Neal Farrar
Geologist/
District Sales Representative

NF:tb

Appendix J

TEXAS RESEARCH INSTITUTE, INC.



TEXAS RESEARCH INSTITUTE, INC.

HAZARDOUS WASTE BIORECLAMATION STUDIES



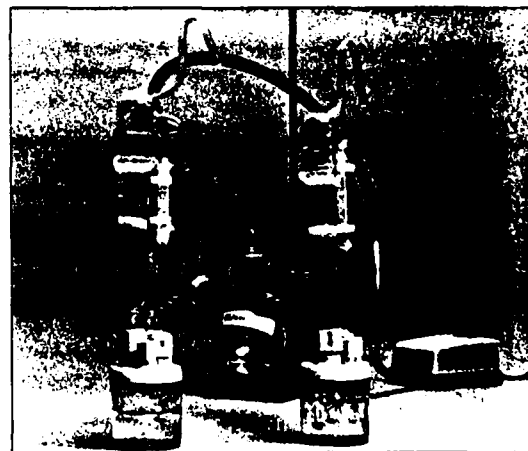
Microbial Growth Being Monitored
in an Anaerobic Atmosphere.

The development of bioreclamation technologies must take into consideration that every site is unique with respect to types and quantities of waste, site geology, and other subsurface conditions. TRI advocates that bioreclamation projects be initiated with treatability studies. These studies identify the feasibility of the various active bioreclamation strategies. TRI has the facilities and experienced staff to develop the following bioreclamation approaches:

- Stimulation of the indigenous microbial population.
- Addition of microorganisms that are especially suited for the conditions at the site.
- Removal of contaminated soil and groundwater and treatment above ground by conventional biotreatment processes.

The contamination of soil and groundwater with hazardous substances has created unusual problems for remediation. Conventional physical and chemical methods are not always successful or feasible. The Superfund Amendments and Reauthorization Act (SARA) of 1986 requires that permanent remedies be implemented. Microorganisms, already at work in nature's carbon cycle, could provide the basis for permanent treatment methods.

Texas Research Institute, Inc. (TRI), is committed to developing site-specific methods for bioreclamation. The Environmental Sciences Department at TRI is actively involved in research and development of this emerging technology.



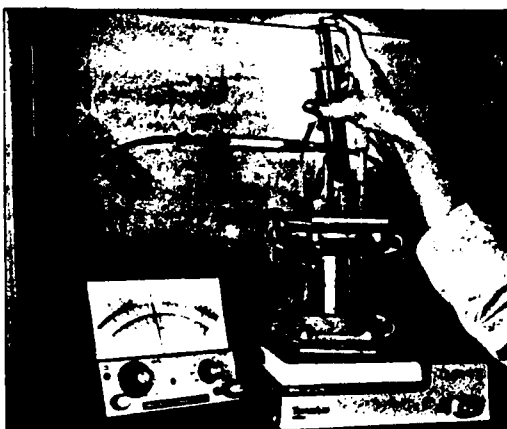
Simulation of Subsurface Conditions
in Microcosm Experiments.

ADVANTAGES OF BIORECLAMATION

- **PERMANENT REMEDY.** Organic contaminants are eventually mineralized.
- **POTENTIALLY COST EFFECTIVE.**
- **IN-SITU AND ON-SITE CLEANUP.** Physical disturbance at the site is minimized.
- **GROUNDWATER AND DEEP SUBSURFACE RESTORATION.** In many cases it is the only realistic way to reduce the levels of organics to acceptable concentrations.

ELEMENTS OF A TREATABILITY STUDY

- Identification of contaminants.
- Examination of indigenous microbial population.
- Evaluation of environmental parameters that affect biodegradative processes.
- Quantification of rates and extent of degradation.
- Determination of feasibility and development of strategies for remediation.



Sampling of Chemostat-Grown Culture.



Analyzing Microbial Enzymes by UV Spectroscopy.

TRI CAPABILITIES

- Treatability/Feasibility studies.
- Geomicrobiological studies.
- Monitoring of bioreclamation projects.
- Laboratory-scale, pilot-scale, and field demonstrations.
- Basic research and development; process design and testing.
- Third-party technology evaluation.
- On-site consulting.
- Chemical analytical services.

*For further information,
contact the*
Environmental Sciences Dept.

Texas Research Institute, Inc.
9063 Bee Caves Road
Austin, TX 78733
512/263-2101

Appendix K

BIO-SYSTEMS ENGINEERING



BIO-SYSTEMS engineering

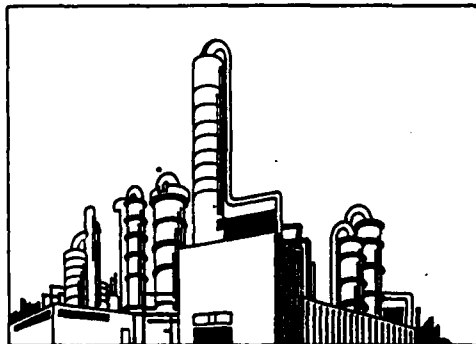
BIO-SYSTEMS™ CX-80/B-110 and CX-85/B-350 series of products contain special blends of microorganisms, enzymes, nutrients and surfactants to treat a wide variety of organic chemicals including: benzenes, petroleum, phenols, kerosenes, creosols, paraffins naphthalene, lubricating oils, amines, mineral oils, alcohols and unrefined petrochemical components.

FEATURES

BIO-SYSTEMS™ CX-80/B-110 and CX-85/B-350 series have demonstrated the ability to:

- rapidly establish a biomass in newly commissioned biological wastewater treatment plants handling effluents containing organic chemicals
- biodegrade cyanides and phenolic compounds in wastewaters
- successfully treat wastewaters from petrochemical installations
- reduce toxicity to enhance nitrification

BIO-SYSTEMS™ CX-80/B-110 and CX-85/B-350 are available in premeasured water soluble plastic bags for direct addition to the treatment plant.



CONCEPT

BIOAUGMENTATION, or bacterial seeding, is widely used in the brewing and pharmaceutical industries to optimize performance of fermenters. Its use in the wastewater treatment industry has developed over the last twenty years, and currently there are a wide range of applications.

In waste treatment plants the use of bioaugmentation offers significant benefit as described above. The bacteria grow rapidly in the treatment plant, downstream from the point of addition, and achieve predominance in the biomass. Continuous maintenance of the population by regular reseeded enables the selected bacteria to predominate in the treatment plant, thereby obtaining continued benefit.

BIO-SYSTEMS™ CX85/B350

BIO-SYSTEMS™ CX80/B110

APPLICATIONS

CASE 1 — CHEMICAL PLANT

During a 48 day test period this client used 78 lbs. of BIO-SYSTEMS™ B-110 (packaged in regular 25 lb. pails), when the recommended application rate was 1 lb./day on a maintenance basis. The next 48 day test period the 25 lb. pails were replaced by the new water soluble packaging, and product consumption dropped 35% to 48 lbs. The performance data indicates better organic removal and more consistent operation of the bioreactor due to regular application of the BIO-SYSTEMS™ B-110.

Plant personnel confirm that the new packaging is easier and more convenient. Dust and odor have been significantly reduced.

CASE 2 — REFINERY

A refinery wastewater treatment plant lost nitrification due to a pH excursion and could not reestablish ammonia removal over a six week period. Nitrifier toxicity was measured at 95% on the day that BIO-SYSTEMS™ B-350 was added. Two days later there was no nitrifier toxicity and 70% ammonia removal was achieved.

STORAGE: BIO-SYSTEMS™ CS-80/B-110 and CX-85/B-350 should be stored in a cool dry place. Avoid contact with moisture. DO NOT FREEZE.

APPLICATION: Rates of use are dependent upon specific operating and system parameters, and our engineers will prepare a recommendation on request.

PACKAGING: BIO-SYSTEM™ CX-80/B-110 and CX-85/B-350 are packaged in 25 lb. plastic pails with resealable plastic liner. Also available in pre-measured 1 lb. and ½ lb. water soluble packets in units of 25 lb.

SAFETY: Each customer receives an End-User Manual describing the application of BIO-SYSTEMS™ to their system. This manual includes comprehensive safety and application information.

SPECIFICATION:

APPEARANCE	Free flowing
COLOR	Tan
ODOR	Musty, Yeast
BULK DENSITY	4.2 to 7 lbs./gal.

OPTIMUM CONDITIONS

pH range	5.5 to 9.0
Minimum Temperature	5°C (40°F)
Maximum Temperature	43°C (110°F)

DISCLAIMER

The information in this Technical Data Sheet is believed to be accurate and reliable. This information is representative only and there are no warranties of performance, expressed or implied. BIO-SYSTEMS Corporation has no control over storage, handling, or product application; therefore BIO-SYSTEMS Corporation shall not be liable for damages of any kind arising from the presence or use of the products described.

BIO-SYSTEMS Corporation • PO. Box 330 • Roscoe, IL 61073 • (815) 623-7411
Printed in U.S.A.

Publication No. LPD 252



BIO-SYSTEMS engineering

* A N N O U N C E M E N T *

U P D A T E

NEW PACKAGING CONCEPT - PREMEASURED!

WATER SOLUBLE!

CONVENIENT!

NEW PACKAGING!

Recently we sent information on the availability of water soluble packaging for our bioaugmentation products. This packaging has proven to be excellent and the following case studies show how effective it can be.

CASE 1 - Chemical Plant

During a 48 day test period this client used 78 lbs of Biolyte Systems CX-80 (packaged in regular 25 lb pails) when the recommended application rate was 1 lb/day on a maintenance basis. The next 48 day test period the 25 lb pails were replaced by the new water soluble packaging and product consumption dropped 35% to 48 lbs. The performance data indicates better organic removal and more consistent operation of the bio reactor due to regular application of the Biolyte Systems CX-80.

Plant personnel confirm that the new packaging is easier and more convenient. Dust and odor have been significantly reduced.

CASE 2 - Municipal

A Midwest municipal authority had tried numerous chemical and microbial treatments for grease control in sewers with varying degrees of success. On a recent Monday they tried Biolyte Systems MX-30 in water soluble bags dropped directly into a pump station on restaurant row. By Friday they had instituted a much wider program resulting in immediate reorders, and were recommending the product to their neighbors.

Operations personnel confirm that the Biolyte Systems program is safer than other chemical methods tried, and simple to use thereby ensuring regular application.

* F I F T Y P E R C E N T D I S C O U N T *

For an initial order for up to one years' supply of product, we are currently offering 50% discount off list price.

Appendix L

DETOX INDUSTRIES, INC.

DETOX INDUSTRIES, INC.

12919 DAIRY - ASHFORD
SUGAR LAND, TEXAS 77478
(713) 240-0892

June 18, 1987

Mr. Paul R. Kenis (Code 521)
NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

Subject: Hazardous and Toxic Waste Clean-Up by New Technology
Site-Specific Solution: PCB Accelerated Microbial Degradation

Dear Mr. Kenis:

Thank you kindly for the opportunity to describe toxic and hazardous waste clean-up by the new and emerging Detox technology. As discussed, Detox has discovered how to select, grow and apply natural microbes which metabolize only the toxic substances or contaminating hydrocarbons. These non-pathogenic microbes utilize the substrate as their sole carbon (food) source.

Heretofore, science had not discovered a methodology of taking bench scale microbes to the field -- too many deleterious environmental impediments, competing microbes, temperature, anti-microbial field contaminants, etc. Now, this has changed with the emergence of the Detox process which can handle large toxic plumes of a variety of natures under field conditions.

Detox is currently the only company in the U.S. possessing EPA approval for bio-decontamination of PCB's (Region VI). Further, Detox has the country's only proven accelerated biodegradation process to decontaminate herbicides, pesticides, polynuclears, aromatics, aliphatics, and all types of halogenated products. The Detox process is capable of processing large acreages at significant depth in approximately 6-12 months, complete, depending on site characteristics.

All kinds of solid matrices are handled including clays, sludges and soils up to one-half inch in diameter. Solid objects are cleaned separately, chunks of concrete, heavy gravel, etc. A job minimum of 5,000 cubic yards is established for all solids handling projects.

Detox's track record is shown in the table below. The company is adding to this record via a significant contract with a major U.S. manufacturer to biodegrade PCB-contaminated sludge at the firm's plant in the Northeast United States. In addition, the Detox microbial process is now on the EPA's list of Superfund Innovative Technologies Evaluation (SITE) Program. This SITE Program will allow Detox to attain national EPA approval for its PCB destruction methodology.

Mr. P.R. Kenis
June 18, 1987
Page Two

Job Description	Toxic Waste: PPM		%	Time	Depth: Ft
	Before	After			
1. Montgomery County (PCP) ^a	2,900	<1	100.00	4 mo.	4
2. Hearne, TX (PCB)	2,000	<4	99.98	4 mo.	Surface
3. Texas A&M (PCB)	46	<1	100.00	2 mo.	Liquid
4. Houston, TX (PCP) ^b	1,656	270	84.00	4 mo.	15


a 14,000 cubic yards
b 19,000 cubic yards

As you can probably see, this process is especially applicable to real estate PCB and PCP problems where a site must be cleaned prior to a successful sale of the property. While the Detox process can be applied to depths of approximately three feet at a time, many real estate properties are in a category of needing attention to only "cosmetic" depth, less than three feet, which greatly facilitates the immediate processability and completion of the clean-up, within 4-6 months after the microbes are initially added.

Wood treating properties, on the other hand, usually display waste plumes deeper than three feet. As indicated in the record above, Detox has decontaminated two PCP properties, both in excess of 10,000 cubic yards, in four months each.

Our track record indicates this technology is already field-proven. Our feasibility studies demonstrate its versatility. Economically, we believe that we can readily beat landfilling and incineration.

Yours truly,


Joseph J. Dailey
Marketing Director

JJD:mec
Encl.

Appendix M

ENVIRONMENTAL ENGINEERS AND ASSOCIATES

REGIONAL OFFICES:

FLORIDA

Lakeland 33801
5440 S. Florida Avenue
Suite M
Dr. Robert Novak (813) 644-6899

GEORGIA

Atlanta
(Mail to Marietta, 30066)
1300 Williams Drive
Walter Cook, P.E. (404) 427-9456

INDIANA

Indianapolis 46220-4871
Corporate Office
5150 E. 65th Street
William Dubois, P.E. (317) 849-4990

MARYLAND

Columbia 21045-4780
(Baltimore/Washington)
8918 Hermann Drive
Mike Nickles, P.E. (301) 381-0210

TEXAS

Dallas 75229-3382
11310 Newkirk Street
Mark Kawalek, P.E. (214) 243-8931

COLORADO

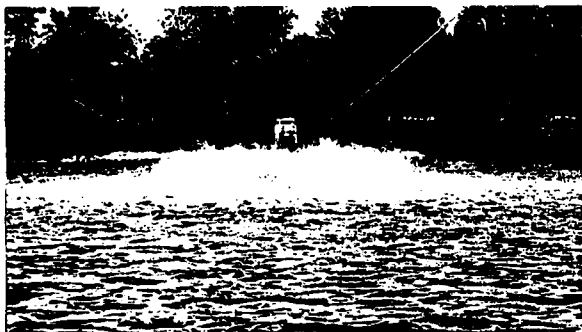
Denver 80239-2472
4860 Ironton, Suite 9D
Godfrey McKenzie, P.E. (303) 371-2640

EEA Environmental
Engineers
& Associates

An organization dedicated to environmental reclamation through science,
technology and engineering to give our children a clean environment.

Solutions to your Waste Problems

Environmental Engineers and Associates (EEA, a division of ATEC Associates, Inc.) is a multi-disciplined engineering company providing economical solutions to today's and tomorrow's environmental problems. The complex technologies used in solving the critical waste challenges facing society today require the best expertise available—EEA. The EEA solutions bring together experience, technology and a firm commitment to find the right solution to waste treatment and clean-up.



Solutions Using Biological Technology

Classical methods, such as mechanical clean-up and chemical neutralization, are often ineffective and costly for cleaning up hazardous wastes. EEA's technical staff has a wide spectrum of microbes available which rapidly break down spills and wastes. We supply numerous biological active seed cultures under the name ENVIROZYME™.

After determining the nature of the clean-up, EEA's staff establishes and administers an application program from conception to completion. Most clean-up projects performed by EEA have been accomplished to a higher standard of excellence than the classical methods and at far reduced costs.



Solutions to Lagoon, Pond and Lake Pollution

Sediments cause a multitude of environmental problems. EEA is a pioneer and leader in bio-augmentation technologies used to clean-up lagoons, ponds and lakes. Biotechnology offers the option of cleaning up the surface without the staggering expense of mechanical cleaning or the problem of locating and paying for a permitted dump site.



Solutions to Sludge Dewatering Problems

EEA uses biologically active seed cultures to devour sludges and transform these contaminants to harmless compounds. The biggest advantage associated with "in-situ" decontamination technology is the cost savings. "In-situ" clean-ups and/or impoundment restoration can reduce costs over traditional mechanical clean-ups up to 50%, due to elimination of transportation and off-site disposal costs. This solution usually requires less than 90 days to restore the impoundment.



Solutions to Odor Control

Modern environmental concerns make odors less tolerable than in previous years. Noxious odors from wastewater treatment and collection systems adjacent to communities are most troublesome. This leaves generators vulnerable to enforcement actions by regulatory agencies and the general public.

EEA has developed a technology which uses large amounts of ENVIROZYME products to remove offensive odors and organic waste build-up. This methodology significantly helps control senseless odors, lowers maintenance costs, eliminates enforcement actions, and has improved plant performance up to 50%.



Solutions to Aquaculture Challenges

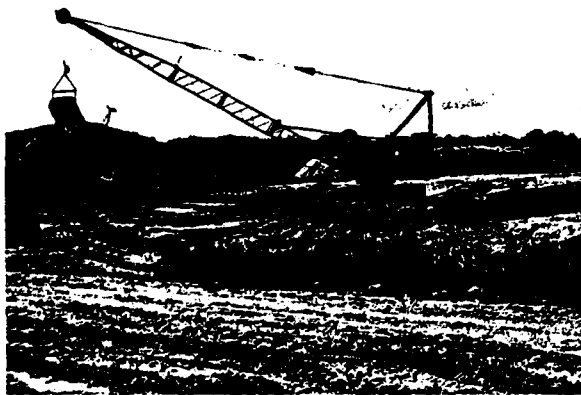
EEA specializes in the field of aquaculture. Our products and technology are used to economically and safely clean-up and maintain living environments for food and tropical fish production.

Our product, ENVIROZYME-AQ™, is used for improving the nitrogen cycles in food fish. The technology assist in eliminating stress on the fish during shipment, and in reducing the amount of sludge material and scum which accumulates in ponds and other containments. Our product also helps reduce fish kills.



Solutions for Theme Parks

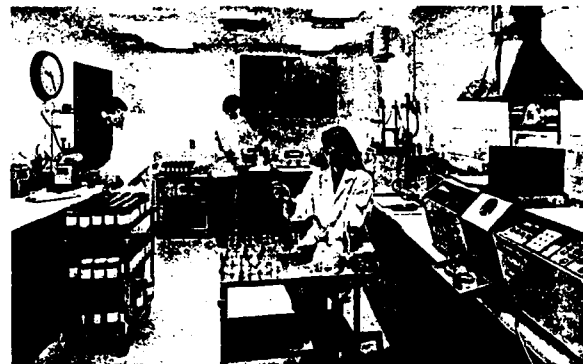
EEA is uniquely qualified to furnish an extensive range of technical talent for water resources management in "THEME PARKS". EEA has made significant contributions to the advancement of water-related attractions such as river rapids, gardens, ponds, lakes, rides and associated facilities. Our proprietary filter system uses a combination of microbial augmentation and deep bed filtration to reproduce a totally natural setting.



Solutions the "EEA" Way

Problem solving the "EEA Way" means a team solution. From initial client consultation through restoration, our team of experts is involved. Our engineers, biologists, and geoscientists use advanced scientific technologies to produce results that are timely, applicable and cost-effective.

EEA stands ready to assist you in developing a program of bio-augmentation. Our goal is to help eliminate your operational and pollution problems and establish a preventative maintenance program for a continuous pollution free operation.



Solutions through Support Services

EEA is a division of ATEC Associates, Inc. ATEC, established in 1958, has become one of the nation's leading, multi-disciplined engineering firms. With offices strategically located in principal cities throughout the United States, ATEC's support services are readily available to EEA.

- Environmental Engineering
- Geotechnical Engineering
- Metallurgical Engineering & Testing
- Hydrogeology
- Exploratory Drilling & Sampling
- Observation and Recovery Well Installation
- Chemical Testing (GC/MS)
- Hazardous Waste Studies and Clean-Up
- Underground Tank Testing
- Materials Testing
- Asbestos Abatement and Removal
- Air Monitoring
- Regulatory Compliance
- Permitting

Appendix N

MICROLIFE TECHNICS

MUNOX® Mission

Improve Efficiency/ Reduce Costs of the Treatment System

To improve the efficiency of the wastewater treatment system by removing stubborn organics which inhibit and slow down normal existing bacterial performance and result in:

- lower BOD (Biological Oxidation Demand)
- lower COD (Chemical Oxidation Demand)
- lower TSS (Total Suspended Solids)
- less F.O.G. (Fats, Oils, and Grease)

Effect:

- eliminate or delay the necessity and cost for a new treatment plant
- eliminate or delay the necessity and cost for plant expansion
- reduce or eliminate surcharge assessments
- reduce overall cost of operation by improving efficiency of the system

A Solution to the Problem of Toxicity

To reduce levels of toxicity caused by stubborn compounds by separating specific organic wastes and pre-treating them before they enter the general treatment system.

Effect:

- prohibits stubborn toxic compounds from being present or inhibiting the overall biological activity of the system
- removes the small concentrations of stubborn compounds that pass through the system unchanged and eventually causes toxicity to higher life forms in the receiving body of water

Clean up Operations and Hazardous Wastes

To use biological inoculations

- for remediation of soils, sludges, area groundwater, contaminated by spills or previous industrial activity
- as an alternative technology for disposal of hazardous organics generated during laboratory or industrial activities that are currently barreled for shipment to the incinerator or hazardous waste landfill sites



**Microlife
Technics**

BOX 3917 • 1833 57th STREET
SARASOTA, FLORIDA 34230 • (813) 355-8561
TELEX 52747 MICROLIFE SARA • FAX (813) 355-3387

MUNOX[®] Features and Benefits

Quality Cultures

Put your confidence in a leader. We know the science of producing bacterial cultures. With over 50 patents worldwide, Microlife Technics is the renowned leader in bacterial starter cultures in the food processing industry. That same technical expertise brings you MUNOX. Our advanced production technology of selective mating and blending in our laboratories assures a superior natural product. Since all of the bacteria in MUNOX were isolated from natural sources, there is no artificial mutation or genetic engineering involved . . . MUNOX IS ALL NATURE'S OWN MATERIALS.

Freeze-Dried (Lyophilized)

100% effective. MUNOX is prepared, "freeze-dried," and stored frozen before shipment. This unique manufacturing process holds the culture in suspended animation and assures MUNOX is at 100% strength levels at time of application.

Shipped Factory Direct To You

Means quality performance "all" of the time. MUNOX is shipped direct to you in "refrigerated" containers to guarantee maximum use viability. We do not allow MUNOX to stand on warehouse shelves to deteriorate in the field.

More Organisms At Time of Application

MUNOX offers more living organisms than any product in the industry . . . over one billion count per gram weight. Because MUNOX is uniquely freeze-dried and shipped direct to you, we can accurately measure our viability count at the time of application. Other brands may claim equal or even higher count levels, but their counts are made at time of production and will continually die off with normal shelf life and lose their effectiveness.

Convenient to Use Packaging

Designed with you in mind. MUNOX is user friendly and safe. Packaged in convenient to use, light-weight, moisture-proof packages, MUNOX is designed for ease of application. No messy bottles, cans, or heavy, difficult-to-store fifty-five gallon drums.

Ready to Use

MUNOX is ready to use immediately. Unlike other dry powder products, MUNOX requires "NO" premixing or soaking before use. MUNOX saves time, saves space, and eliminates unnecessary man-hours of preparation.

Unconditional Guarantee

It's true! . . . you have virtually nothing to lose. We maintain the highest levels of confidence in our MUNOX product and applications/service program. So high in fact . . . that you will be entitled to a full refund if not satisfied for any reason, after trying MUNOX at recommended inoculation levels for a period of thirty (30) days.

Competent Technical Staff

Technical assistance at your finger tips. Factory trained, degreed microbiologists, are at your disposal to render the technical help that you need, both in the field and in our state-of-the-art laboratories. MUNOX representatives are committed to helping you resolve your wastewater treatment problems, or to improve your present treatment system performance.

Complete Applications and Service Program (at no cost to you)

We don't just sell you a product . . . we provide you with a program. The MUNOX customer applications/service program begins with your first pre-application sample. From that point on, a comprehensive program of testing and evaluation is provided . . . at no additional cost to you. The MUNOX program provides a vital communications link between field and factory that is unsurpassed in the industry.

Proven Effective

The MUNOX applications/service program is time-proven effective. Our rapidly growing family of satisfied MUNOX users will substantiate that a regularly scheduled program of MUNOX inoculation to your treatment system will continue to provide desired results in system maintenance.

Confidentiality

We at Microlife Technics know and understand that wastewater problems are often "not" the favorite topic of conversation. It is for precisely this reason you have our sincere pledge to you that each individual case is maintained in strict confidence at all times. It is through this pledge of integrity that we have been able to help so many people in industries like your own.

Total Commitment

Your assurance of continued support, Microlife Technics, a subsidiary of National Starch and Chemical Corporation, has over 22 years of respected experience in the development and production of microbial products . . . we are here to stay! Unlike many companies who have come and gone in recent years, or who are marketing products under private label arrangements, Microlife Technics is committed to serving the wastewater treatment industry . . . your industry. We develop, produce, and market our own products. This philosophy allows us to maintain the highest engineering, production and marketing standards . . . OUR COMMITMENT TO YOU!



Microlife Technics

Box 3917 • 1833 57th Street
Sarasota, Florida 34230 • (813) 355-8561
Telex 52747 Microlife Sara • FAX (813) 355-3387

MUNOX®

Product Information Bulletin

How MUNOX Can Benefit You

MUNOX is a natural bacterial product that can directly improve your bottom line and help you tackle your toughest organic waste treatment problems. Comprised of a blend of naturally occurring strains of bacteria with exceptionally high degradation capabilities, MUNOX has been successfully applied to improve the wastewater treatment system or in clean-up operations of hazardous and nonhazardous wastes in the following types of operations:

- Chemical and Solvent Manufacturers
- Wood Preservatives Operations
- Textile Mills and Textile Product Manufacturers
- Meat and Poultry Producers
- Food Processors
- Seafood Processors
- Oil Reclaimers and Refineries
- Edible Oil Manufacturers
- Military Installations
- Utilities
- Municipalities
- Citrus Processors
- Cutting Oil and Machine Coolant Dischargers
- Fruit Juice Processors

These are just a few of the applications for MUNOX. Here is how MUNOX can benefit your operation:

Reduction of Excessive Surcharges

Increased environmental restrictions set in motion by the Federal Pollution Control Act amendments of 1972 have pushed the current wastewater treatment plant technology to the upper limits of its capabilities. Hence, local, state and national environmental protection agencies are imposing severe end-of-pipe surcharges to industries in violation of their pretreatment standard permits. Industrial users are finding that a program of routine application of MUNOX enhances their system efficiency, resulting in low BOD and TSS levels, and lower surcharge bills.

Elimination or Delay in Necessity & Cost for New or Expanded Treatment Plant

Wastewater treatment facilities are getting heavier loads and are receiving greater volumes of difficult to degrade and sometimes toxic industrial organic wastes.

MUNOX offers a cost effective alternative to improving existing facilities, and can postpone or even prevent the need to expand or rebuild treatment facilities to accommodate increasing governmental pressures.

Reduction of Overall Cost of Treatment Plant Operation

Improved efficiency of operation means improved cost of operation. No matter how efficiently the treatment system may appear to be functioning, MUNOX is designed to complement even the best of systems. Measurable improvements will show up where it really counts — on the bottom line.

Meeting State and Federal Government Clean-Up Regulations

MUNOX has been field-proven extremely effective in remediation operations where government regulations require that contaminated soils, sludges and groundwater areas be returned to acceptable background levels. MUNOX product application speeds up clean-up time and saves man hours. MUNOX has an exceptional ability to degrade oils and petroleum hydrocarbon products.

MUNOX is an alternative technology for disposal of hazardous organics that are generated during laboratory or industrial activities and are currently being barreled for shipment to incinerator or hazardous waste landfill sites.

MUNOX is a Proven Performer

- **MUNOX Targets Tough Organics** — The strains of bacteria present in MUNOX are among nature's most powerful and useful degraders. Microlife scientists have selected these strains for their exceptional abilities to oxidize a wide range of stubborn organics and priority pollutants.
- **Reduces BOD and TSS*** — The exceptional point-of-use viability of MUNOX assures the addition of billions of bacteria at the peak of their activity cycle, and with very versatile and sophisticated appetites. They provide enhanced removal efficiency of common wastewater organics. This increased efficiency not only allows higher organic loading, but also reduces effluent discharge of BOD and TSS.
- **Degrades Fats, Oils and Greases** — The excellent fat and oil oxidizing capabilities of MUNOX reduce operational difficulties due to build-up. The sludge-settling and dewatering characteristics will be improved, and effluent discharge levels will be reduced. MUNOX has also demonstrated effectiveness in reducing fat and protein accumulation in lift stations and grease traps.
- **Reduces Toxicity** — Many regulatory agencies are adapting toxicity tests of wastewater discharges using fish and other aquatic life forms as the test animals. MUNOX degrades many toxic organics commonly found in industrial effluent streams, thereby reducing the impact on the aquatic species used in these toxicity tests.
- **Shock Recovery** — A program of regularly scheduled treatments with MUNOX will establish high numbers of hardy and versatile bacteria which will diminish the effects of shock upsets, as well as provide quick recovery to acceptable operation parameters.
- **Odor Control** — MUNOX bacteria will out-compete and replace common odor producing microbes, thereby reducing or eliminating overall odor production.
- **Grows in up to 5% Saline Solution** — This will allow for applications in brackish water, coastal marine industries and seafood industries including brined food production effluent and seagoing vessel holding tank effluent treatment.

Where can MUNOX Be Effective?

Here are just a few of the specific compounds where MUNOX's exceptional degradation capabilities have demonstrated proven success.

2-Chlorotoluene	m,o,p-Xylene
3-Chlorotoluene	Butyl acetate
3,4-Dichlorotoluene	Phenol
2,6-Dichlorotoluene	Camphor
Cresols	Naphthalene
Benzoate	Tetrachloroethylene
4-Chlorobenzoate	Hexane
2,4-Chlorobenzoate	Heptane
Methanol	Octane
Methylene chloride	Nonane
Ethyl acetate	Diesel Fuel
Cyclohexanone	Waste oil
Toluene	Bunker "C" oil
Ethylbenzene	d-limonene
1,2-Dichloroethane	linalool
2,4-Dichlorophenoxyacetic acid	geraniol
2,4,5-Trichlorophenoxyacetic acid	citronellol

*BOD: Biological Oxidation Demand
TSS: Total Suspended Solids



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Technics**

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Appendix O

SYBRON CHEMICALS INC.

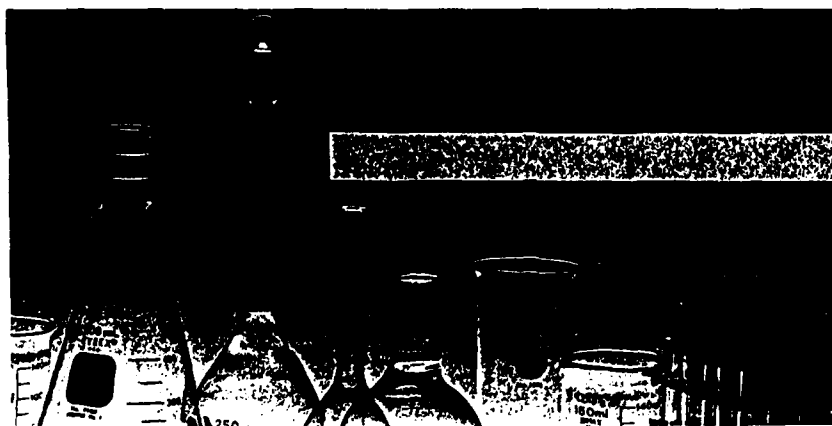
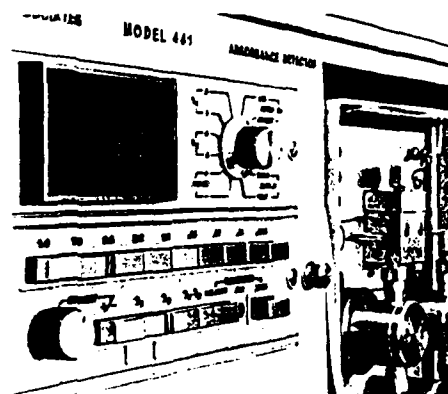
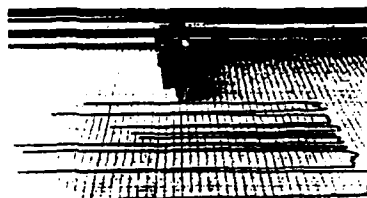
As the leader in wastewater treatment biotechnology, Sybron has the most effective bacterial products for bioaugmentation available today and the technical resources to back them up.

Sybron maintains a staff of scientists including PhD level microbiologists, chemists, and environmental engineers and over two million dollars worth of

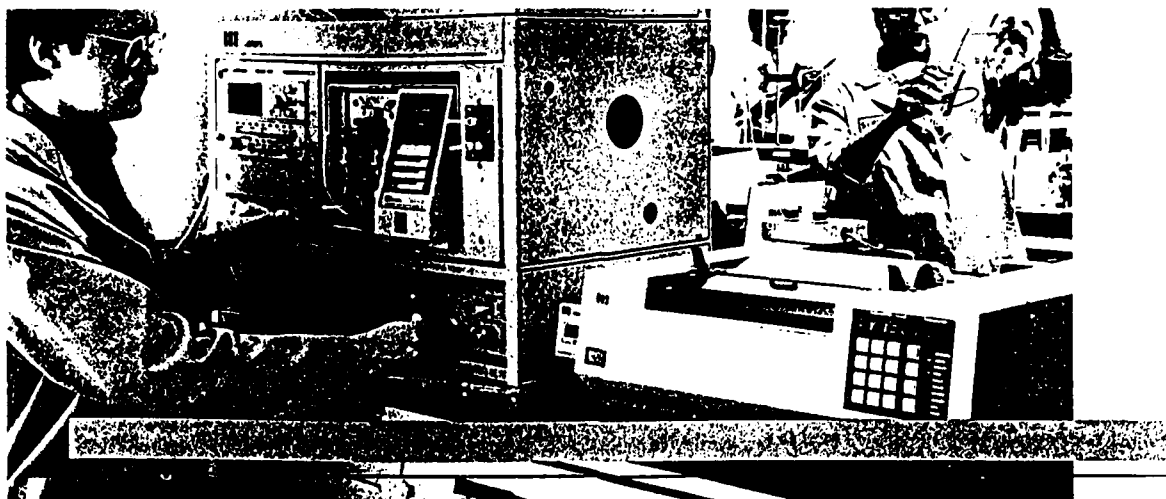
RESEARCH AND DEVELOPMENT

laboratory equipment. Our research and development program is continually working to develop new products and improved application technologies. Biokinetic studies involving treatment systems assess product effectiveness. Sybron has been awarded several patents on microorganisms developed to improve wastewater degradation. Sybron is involved in joint development programs with industry to develop new cultures and techniques.

Our researchers work closely with staff consultants from nearby universities to keep abreast of the latest developments in microbial and wastewater treatment technologies. Specialized research projects are contracted out to universities to give added dimension to our own programs, giving Sybron the fastest growing technology in the field of bioaugmentation.



SYBRON
Chemicals Inc.

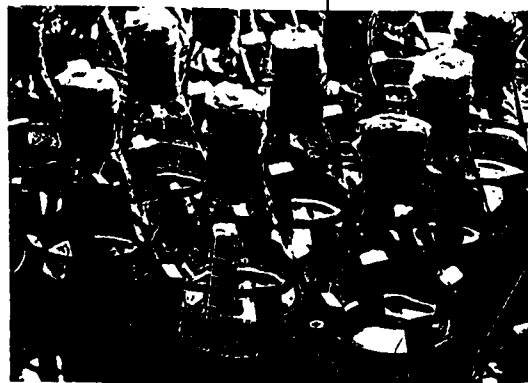


Sybron has regional technical service representatives located throughout the United States.

EFFECTIVE TECHNICAL SERVICE

Our field representatives have expertise in chemistry, microbiology, and engineering. They are specially trained in troubleshooting biological treatment systems and applying bioaugmentation to optimize the working biomass. In addition, we have a centralized technical service center where engineers, chemists, and microbiologists are available to discuss your unique application.

Laboratory testing programs are available to assess the treatability



of various wastes and optimize the application of bioaugmentation. In addition, Sybron provides on-site troubleshooting to guarantee the performance of our products

Services offered:

Wastewater treatment system
survey

Wastewater treatability analysis

Pilot system studies

Start-up assistance

On-Site troubleshooting

Regular service visits by
technical representatives

Specialized application
technology

HERE'S HOW WE CAN HELP



SYBRON
Chemicals Inc.

Plant & Research Center
111 Kessler Mill Road
Salem, Virginia 24153
703/389-9361
TLX 32-2422/ELN 62849402

Sales Office
Birmingham Road
Birmingham, N.J. 08011
609/893-1111
TLX 685-1227 or 834446

Appendix P

SOLMAR CORP.

PRODUCT DESCRIPTIONS

Formulations commercially available include:

Advanced Bio Cultures Formulation M-101

Designed for use in aerobic systems handling domestic sewage. It is particularly effective in handling many of the problem components of domestic sewage, including heavy grease loadings, incoming industrial wastes, cosmetics, salad oils, petroleum derivatives, etc.

Advanced Bio Cultures Formulation C-102

This product is particularly useful for high carbohydrate and starch wastes. Effective with many aliphatic chemical wastes.

Advanced Bio Cultures Formulation L-103

Tailored to handle high loadings of animal, fish and vegetable oils, particularly where protein levels are low. Usually the product of choice with light weight oils and many petrochemical products.

Advanced Bio Cultures Formulation L-104

Formulated to deal effectively with the heavy, tarry types of oils, coal tars and organic sludges. Particularly well suited for phenolic and other aromatic chemical structure wastes. Usually the product of choice for coking and wood preserving wastes.

Advanced Bio Cultures Formulation P-105

This product is well suited for industrial wastes having exceptionally high loadings of proteins, blood and fats. Develops an excellent floc for handling many settleability problems.

Advanced Bio Cultures Formulation AN-106

Particularly useful in dealing with domestic wastes being treated anaerobically. Typically enhances organic digestion and gas production in digesters. Handles many of the problems associated with operations of septic tanks, Imhoff tanks, and anaerobic lagoons.

Advanced Bio Cultures Formulation I-107

This is a very versatile product for highly complex industrial wastewater streams. It is the product of choice with many petrochemical, petroleum, food, textile and paper product streams.

The product descriptions given above serve only as guidelines. Due to high variability of non-domestic wastestreams (even within a given industry) treatability studies should be conducted to determine which (if any) formulation should be used. Studies at Solmar Corp.'s laboratory will also indicate the degree of improvement which can be expected. Contact your representative for details.

With its unique in-house research and development capabilities, Solmar Corp. can customize formulations where warranted.



SOLMAR CORP.

625 West Katella Avenue, Suite 5
Orange, California 92667
(714) 538-0881

ADVANCED BIO CULTURES PRICE LIST

<u>PRODUCT</u>	<u>SINGLE 25 LB. PAILS</u>	<u>100 LB. LOTS</u>	<u>1000 LB. LOTS</u>
Formulation M-101	\$262.50 (\$10.50/lb)	\$250.00 (\$10.00/lb)	\$237.50 (\$9.50/lb)
Formulation C-102	\$336.25 (\$13.45/lb)	\$323.75 (\$12.95/lb)	\$311.25 (\$12.45/lb)
Formulation L-103	\$336.25 (\$13.45/lb)	\$323.75 (\$12.95/lb)	\$311.25 (\$12.45/lb)
Formulation L-104	\$351.25 (\$14.05/lb)	\$338.75 (\$13.55/lb)	\$326.25 (\$13.05/lb)
Formulation P-105	\$342.50 (\$13.70/lb)	\$330.00 (\$13.20/lb)	\$317.50 (\$12.70/lb)
Formulation AN-106	\$312.50 (\$12.50/lb)	\$300.00 (\$12.00/lb)	\$287.50 (\$11.50/lb)
Formulation I-107	\$338.75 (\$13.55/lb)	\$326.25 (\$13.05/lb)	\$313.75 (\$12.55/lb)

PRICES SHOWN ABOVE ARE PRICE PER PAIL.

FREIGHT TERMS

F.O.B. Orange, California. Method of routing normally determined by Solmar Corp. Where special handling is requested by customer, the customer will also be responsible for any special handling charges.

PAYMENT TERMS

On approved credit: 2%-10; NET 30 DAYS. Past due accounts will be subject to a periodic charge of one and one-half percent per month, which is an annual charge of eighteen percent. This charge will be due and payable as it occurs.

WARRANTY

All sales are made without seller's warranty or representation, expressed, implied or statutory. No claims beyond replacement of unacceptable material confirmed by Solmar Corp.

Claims for shortages or deductions for erroneous charges must be presented within thirty (30) days after receipt of goods or they will not be allowed.

Claims for damaged merchandise should be filed with the carrier by the customer.

MERCHANDISE RETURN

No material will be taken back and credited or replaced unless arrangements for return with written authorization have made.

MINIMUM ORDER

Minimum invoice shipment is 25 pounds.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE

Effective July 1, 1987

003-067