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Research Workshop on the Treatment/Disposal of Pesticide Wastewater

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PROCEEDINGS: RESEARCH WORKSHOP ON THE TREATMENT/DISPOSAL OF PESTICIDE WASTEWATER

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The research workshop on the treatment/disposal of pesticide wastewater was developed in order to better understand how to deal with the on-site management/disposal of dilute pesticide wastewaters. It was organized and conducted by the Agricultural Research Service, USDA and the Environmental Protection Agency, and these proceedings were prepared to document the results of this effort. It is hoped that the content of these proceedings will stimulate action that will reduce pollution from the agricultural application of pesticide wastewater.

Francis T. Mayo, Director
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ABSTRACT

A research workshop on the treatment/disposal of pesticide wastewater generated by the agricultural application of pesticides was held at the U.S. Environmental Protection Agency's Andrew W. Breidenbach Environmental Research Center in Cincinnati, Ohio on July 30-31, 1985. The purpose of this workshop was to address issues regarding the effectiveness of current state-of-the-art capabilities, identification of emerging techniques or technologies that may be applicable along with technologies being applied in other areas, and the need for research efforts capable of providing results in a 3 to 5 year time frame as they pertain to the treatment/disposal of dilute pesticide wastewater.

The format of the two-day workshop included the sixty-one invited participants representing an appropriate cross-section of interests and expertise attending at their own expense. Participants were mostly individuals actively involved in related research as well as adequate representation from the user and regulatory community to assure that the problem and candidate solutions were kept in proper perspective. The first-day plenary session addressed twelve technologies as follows: (1) pesticide rinsewater recycling, (2) granular carbon adsorption, (3) UV-ozonation, (4) small-scale incineration, (5) solar photo-decomposition, (6) chemical degradation, (7) evaporation, photodegradation and biodegradation in containment devices, (8) genetically engineered products, (9) leach fields, (10) acid and alkaline trickling filter systems, (11) organic matrix adsorption and microbial degradation, and (12) evaporation and biological treatment with wicks. The second day divided the participants into two workgroups. Workgroup A was entitled, "Physical/Chemical Treatment and Recycling" and Workgroup B was entitled, "Biological Treatment & Land Application".

This publication is a compilation of the sixteen speaker's abstracts, both workgroup results and a conclusion with recommendations. Workgroup A and Workgroup B were each divided into six sub-work groups to review and assess their respective technology(s). The conclusion and recommendations developed as Section 2 of these Proceedings represent the results of these sub work-groups. These collective appraisals were the basis of research recommendations.

The results of this research workshop will be of particular interest at the 1986 National Workshop on Pesticide Waste Disposal in addition to recognizing immediate research needs.

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U.S. Environmental Protection Agency, Office of Research and Development

A special note of appreciation is extended to the research workshop participants who presented the specific related research at the plenary session. The presentation and discussions of all the attendees/participants during the workgroup sessions involved each individual and this action accounts for the success of the workshop. Dr. Philip C. Kearney, Chief of USDA's Pesticide Degradation Laboratory and Mr. Francis T. Mayo, Director of EPA's Water Engineering Research Laboratory did an excellent job of moderating the sessions and kept the meeting on a timely schedule. Thanks also go to Mr. Raymond F. Krueger and Mr. Matthew Straus for their participation in discussing the regulatory aspects of pesticide wastewater. Of course, nothing actually gets done without administrative and typing support and we are grateful to Mrs. Jane DeMaris for all of her tremendous hard work.

SECTION 1

INTRODUCTION

BACKGROUND

Regulation of pesticide waste disposal at the federal level is a relatively recent development. The 1972 amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) specified that the label statement must include recommendations for disposal. More recently, under authority of the Resource Conservation and Recovery Act (RCRA) and the RCRA amendments, the Environmental Protection Agency (EPA) has promulgated a complex and dynamic set of regulations that are intended to control the management of hazardous wastes (some of which are pesticides) from cradle to grave.

Compliance with RCRA as-well-as other State and local pesticide disposal regulations will require significant involvement by the agricultural pesticide applicator as in many cases he will be defined as a hazardous waste generator.

1985 NATIONAL WORKSHOP ON PESTICIDE WASTES DISPOSAL

On January 28 and 29, 1985 a National Workshop on Pesticide Wastes Disposal was held in Denver, Colorado. The objective of this workshop was to provide a national forum for Federal and State agencies, pesticide user groups, pesticide producers, agricultural organizations and academia to jointly assess:

1. Waste disposal needs of pesticide users.
2. Pesticide waste disposal technology.
3. Requirements for making selected technology available to pesticide users.
4. Applicable Federal, State and local regulations.
5. Recommendations and future actions.

This workshop was co-sponsored by numerous national associations and government agencies representing the agricultural chemicals industry, agricultural interests, state and local pesticide control agencies, U.S. Department of Agriculture (USDA) and EPA. An original attendance estimate at 100 to 150 people blossomed to approximately 400 people representing a broad spectrum of State and Federal agencies, pesticide applicators, chemical manufacturers, universities, farmers, waste disposal consultants and contractors, pesticide retailers and trade associations.

Three categories of problems were identified:

1. Disposal of dilute pesticide wastewater.

2. Disposal of pesticide containers.

3. Management of soil and residuals contaminated with pesticides.

Review and evaluation of the 1985 workshop by the coordinating committee identified the immediate need for a follow-up effort to better understand how to deal with the on-site management/disposal of dilute pesticide wastewaters. It was emphasized many times during that workshop that there was a need to identify, develop and demonstrate practical, effective and economical methods for treating and disposing of pesticide wastewater which can be operated at or near (within a 50 mile radius) the farm. The 1984 "small generator" amendments to RCRA make this a matter of special importance to pesticide applicators with on-site rinsate management problems.

Sources of these wastes include:

1. Waste from the mixing, loading and cleaning operations.

2. The washing of application equipment including the outer skin of aircraft and the exteriors of ground equipment.

3. Rinsate generated by the triple rinsing of pesticide containers.

There was agreement on the need to (1) appraise the effectiveness of current state-of-the-art capabilities, (2) identify emerging techniques or technologies that may be applicable along with technologies being applied in other areas, and (3) identify information gaps which can be filled through research efforts in a 3 to 5 year time frame. The first two items are necessary for current regulatory development and implementation. However, it is recognized that the regulatory process is an iterative process which must be based upon the best available information at the time but which also must be reviewed and revised periodically as new information is generated. Furthermore it was perceived that after the state-of-the-art capabilities, emerging technologies and technology transfer opportunities were assessed that data gaps would be identified that can only be addressed through research efforts (i.e., item #3).

RESEARCH WORKSHOP

Discussions between representatives of the Agricultural Research Service (ARS), USDA and the EPA concluded that a cooperative effort in addressing these issues would fall under the umbrella of the recent Memorandum of Understanding between EPA and the USDA.

A specific cooperative ARS/EPA proposal was developed to hold a Research Workshop to address these issues by an invited group of 40-60 participants. For purposes of this workshop, "on-site disposal" included near vicinity collection and disposal of limited volumes of wastewater, but not long distance transport to more distant waste disposal facilities.

While there are approximately 680 active pesticide ingredients used in American agriculture, this workshop was to focus on the treatment and disposal of wastewater contaminated with the most commonly used formulated pesticides with emphasis on those that are identified as hazardous constituents under RCRA. (See Appendix A).

FORMAT

The Research Workshop was held in Cincinnati, Ohio at the Andrew W. Breidenbach Environmental Research Center on July 30 and 31, 1985. Sixty-one invited participants (see Appendix B) representing an appropriate cross-section of interests and expertise attended at their own expense. Participants were composed principally of individuals actively involved in related research. However, there was also adequate representation of the user and regulatory community to assure that the problem and candidate solutions were kept in proper perspective.

The first day (see Appendix C) was taken up by sixteen 20 minute presentations and discussions on specific subject areas at a plenary session. Abstracts of these presentations are given in Section 3. Each presenter was asked to address as appropriate for his subject the following three aspects:

1. State-of-the-art capabilities.

2. Emerging technology and/or technology transfer opportunities.

3. Research needs with a 3-5 year payout.

In addition, each presenter was asked to explain the following features of his topic as it applies to the on-the-farm treatment/disposal of dilute pesticide wastewater.

1. Current applications.

2. Perceived and potential difficulties.

3. Cost.

4. Ease of use (i.e. mobility, technically uncomplicated, failproof, etc.).

5. Size.

6. Shortcomings (durability, reliability, range of use, etc.).

7. Key points from both the user and regulator viewpoints.

The morning of the second day (see Appendices D and E) was devoted to two concurrent work group sessions dealing with the following types of treatment and management techniques:

Work Group	Subject area
A	Physical/Chemical Treatment & Recycling
B	Biological Treatment & Land Application

The objective of these work group sessions was to develop collective appraisals of needs and opportunities and develop recommendations for follow-up action. The afternoon of the second day was used for presentation of a report by each of the groups and a short overview session.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Based upon information generated during the 1985 National Workshop on Pesticide Wastes Disposal, it is clear that the applicators percieve an urgent need to identify and prove effective and economical technologies for managing dilute pesticide wastewater.

During this Research Workshop, twelve different technologies were identified as possible methods for this purpose which could be operated at or near the farm. Of these, only four were considered proven technologies for this application which are readily available. These are:

1. Recycling Pesticide Rinsewater.

2. Granular Carbon Adsorption.

3. Evaporation, Photodegradation and Biodegradation in Containment Devices.

4. Leach Fields.

It was the general consensus that applicators should plan their operation so as to minimize the quantity of wastewater that must be managed. This involves mixing only the volume of material needed for the spray operation and using rinseates from containers where possible and where approved for further spray operations. It appears that reusing rinsewaters for subsequent sprays is widely practiced to various extents by many appplicators. Expanding and maximizing this technique offers a very promising and cost effective method for solving a major portion of the problem. However, implementation of this expansion requires that a number of questions be resolved via research efforts.

While granular carbon adsorption is considered a proven technology, it has been utilized on a very limited basis for pesticide wastewater. In addition, there are a number of questions that need to be answered to take maximum advantage of this technology.

Universities and other research facilities have been employing evaporation, photodegradation and biodegradation in containment devices (often referred to as "pits") to treat pesticide wastewaters for over fifteen years. However, this method is not widely utilized for several reasons. These include such unknowns as the potential for the treatment to further produce hazardous wastes, uncertainty of the science and the product results and lack of understanding of the treatment process on specific pesticides.

Leach fields are being used by many small fruit farms in New York. However, additional information is needed to fully assess the groundwater pollution potential posed by this system.

Two of the technologies (UV-Ozonation and Chemical Degradation) were considered technology transfer opportunities. UV-Ozonation is being used to remove toxic pollutants from water in Europe and chemical degradation is currently used for industrial waste clean-up and spills. The remaining six technologies are all emerging technologies which require significant research and development before they could be made available for widespread use.

Insufficient information is available at this time to rank these technologies and it is recognized that the optimum method of managing this wastewater will probably involve the utilization of a combination of technologies. However, it is clear there is an immediate need to initiate a research effort to:

1. Address those research needs identified for the currently available, proven technologies such that utilization of these methods can at least be maximized on an interim basis.

2. Conduct preliminary assessments of the effectiveness of the technology transfer and emerging technology opportunities and rank them for further development. Consider the combination of technologies as part of this effort.

3. In priority order, address the identified research needs for the technology transfer and emerging technology opportunities.

SECTION 3

ABSTRACTS

PRACTICAL SYSTEM TO TREAT PESTICIDE-LADEN WASTEWATERS GENERATED BY APPLICATORS[1]

The treatment system described is based on recirculation of pesticide-contaminated wastewater through a bed of granular activated carbon(GAC) and was developed for use at a residential pest-control facility at Fort Eustis, VA. This in-house research program was conducted by the U.S. Army Medical Bioengineering Research and Development Laboratory, Fort Detrick, Frederick, MD. Testing demonstrated that a mixture of seven pesticides could be removed from 400 gal of water with 45 lb of GAC. The most challenging test purified 400 gal of water containing 400 ppm of each pesticide. The process has a mathematical basis and thereby is predictable. The system is inexpensive and simple to operate, and the spent carbon has a very low leaching rate. Now that the utility of this system has been demonstrated for chemicals used to control residential pests, we plan to evaluate it for onsite use by agricultural pesticide applicators.

PESTICIDE RINSEWATER TREATMENT[2]

The disposal of sediments and rinsewater from agricultural spraying by aerial applicators and land-based operations has become a large cost component in the use of these materials. The problem has been magnified by the RCRA reauthorization that prohibits the use of adsorbents to solidify otherwise liquid rinsewaters. Canonie Engineers was requested by the Western Agricultural Chemical Association (WACA) to develop a rinsewater treatment system that could be easily maintained and would not require large capital expenditures for equipment. The criteria for the system were as follows.

The equipment should be small enough to be placed on concrete pads currently in use for the rinsing of equipment by applicators. A lined sump should be part of the facility so that rinsewater can be collected preparatory to treatment. The system should be capable of sediment removal, and it should be able to handle both oil- and water-based formulations. The system should minimize operator contact through the treatment process and be capable of treating to a level that would permit the process rinsewaters to be reused in future formulations.

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[1]David W. Mason, Robert H. Taylor, Jr., Daniel R. Coleman, Southern Research Institute, Birmingham, AL 35255. William H. Dennis, Jr., Consultant, Braddock Heights, MD 21714.

[2]Phillip E. Antommaria, Canonie Engineers, Inc., Chesterton, IN 46308.

To accomplish these ends, Canonie developed the treatment train shown in Figure 1. The first step in the treatment is passage of sediments containing pesticides to a cyclone separator for the removal of coarse solids. Solids from this process are discharged to a 55-gal drum, and liquids inherent in the process are returned to the sump for future treatment. Once coarse sediments are removed, smaller particles are removed using a diatomite filter. A diatomite filter was selected because of its low cost and ability to remove certain pesticides. In addition, the diatomite filter requires very small volumes of backwash water. The treated water then goes to a pretreatment tank from which it is pumped to a Calgon Clean-Sorb unit. Clean-Sorb, which contains activated alumina, can break oil-water emulsions and will remove any oil-based material from the streams. After treatment in the Clean-Sorb unit, the effluent is passed to two or more Calgon Vent-Sorb units that contain activated carbon for final treatment of the pesticide rinse. The rinsewater then goes to a treated water storage tank where it can either be used for future rinsing of equipment and vehicles or for the reformulation of pesticides for application.

Total capital cost for this system is $20,000. The California Department of Agriculture has funded a 1-year study for the installation of two systems in the State of California and the requisite analytical work as a proof of process design. The State of California has waived the permitting as a treatment facility under RCRA to permit this experimental system to go forward. The U.S. Environmental Protection Agency has concurred with this action. The systems are currently being installed by one aerial and one ground-based applicator. Data on this operation will be available within the year.

TREATABILITY STUDIES OF PESTICIDE WASTEWATERS BY GRANULAR ACTIVATED CARBON, HYDROLYSIS, CHEMICAL OXIDATION, AND UV-PHOTOLYSIS[3]

Compliance with existing effluent guidelines and with those being prepared for pesticide wastewaters will require the investigation of physical-chemical methods for treatment of process effluents and final discharge. Although granular activated carbon (GAC) has been well established as a treatment method, a limited data base exists on its effectiveness for reducing pollutant concentrations of specific pesticides to discharge levels. Conventional performance testing of GAC generally requires the use of pilot columns and is time-consuming and expensive. Performance data or other physical-chemical treatment methods are also limited. However, many of these methods have the potential for cost-effectively meeting the discharge requirements by decomposing the pesticide.

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[3]L.J. Bilello, Environmental Science & Engineering, Inc., Gainesville, FL 32602, and Shri Kuhlkarni, Radian Corporation, Research Triangle Park, NC 27709.

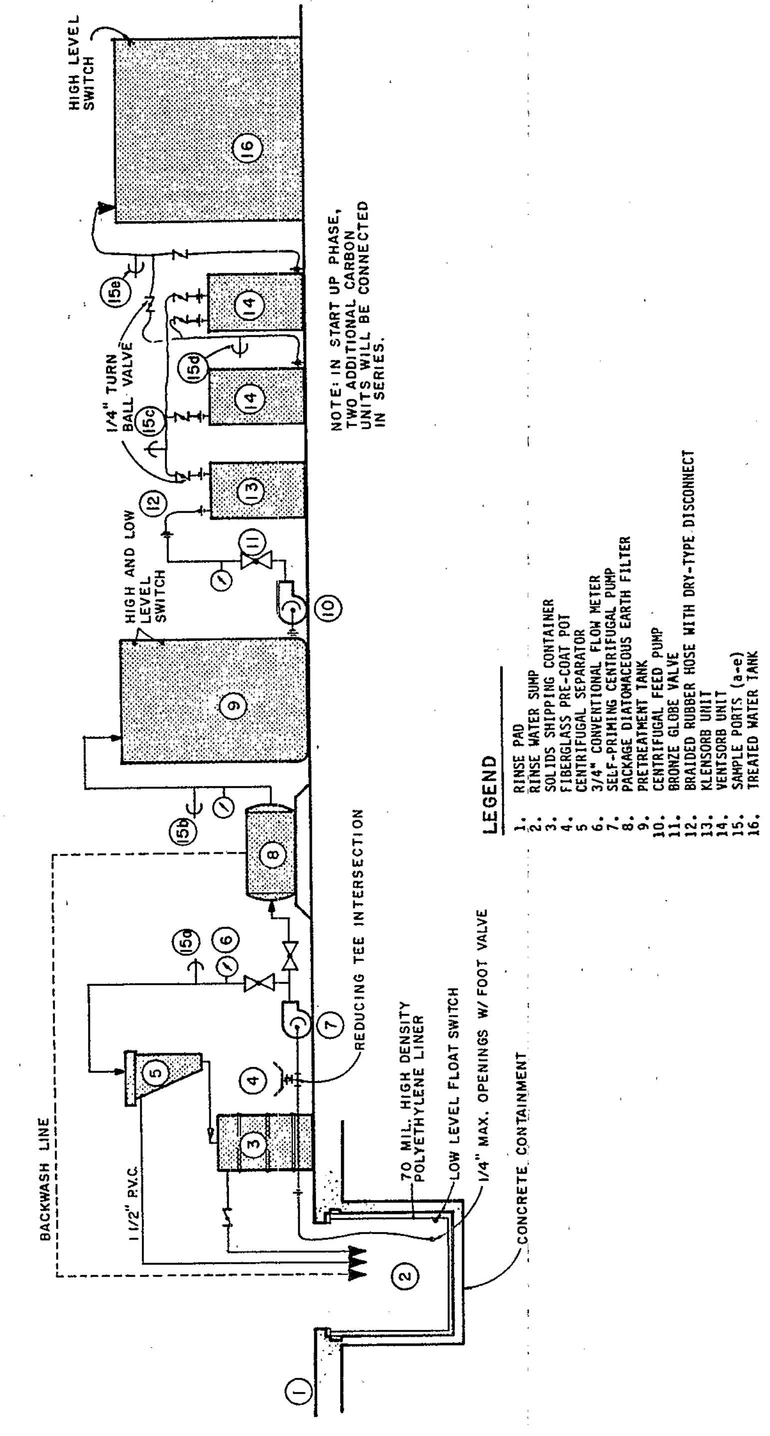

Figure 1. Pesticide rinsewater treatment system.

Environmental Science and Engineering, Inc. (ESE) and Radian were asked by EPA to assess available treatment methods, to select potentially effective methods for bench-scale studies, and to develop and demonstrate bench-scale treatment methods for screening these selected alternatives. Following an extensive literature and industrial user survey, chemical oxidation, hydrolysis, and UV-photolysis were recommended for bench-scale methods development.

As a follow-up before GAC development studies, ESE was to demonstrate the use of the dynamic mini column adsorption technique (DMCAT) as a means of rapidly evaluating GAC performance.

This presentation discusses the rationale and methods used in selecting the technologies for study and the results of laboratory investigations. Four pesticides, 2,4,-D, Linuron, Prometron, and Methomyl, were evaluated in the laboratory using the procedures developed to evaluate the technologies. The objectives of these experiments were twofold: 1) to assess the validity of the experimental protocol, and 2) to determine the decomposition rates of each of the pesticides at various conditions to determine whether the technology was effective and the conditions preferred. Hydrolysis studies were performed at pH 3, 7, and 9 and at temperatures of 50^{o} and $30^{o}C$. Hypochlorous acid, hydrogen peroxide, and ozone were used as the chemical oxidants. UV-photolysis experiments were conducted to determine the effect of light intensity, exposure time, pH, temperature, and the pressure of inhibitors or additional oxidants on the decomposition rates of each of the pesticides.

DMCAT is a rapid GAC evaluation method that provides data on pollutant breakthrough, GAC usage rates, order of pollutant breakthrough, and determination of the limiting pollutant. DMCAT pumps wastewater through a 2-mm column packed with pulverized GAC. Samples are collected routinely through a closed sample system.

The experimental plan consisted of validation of DMCAT procedures, comparison with side-by-side pilot columns, and comparison with operating full-scale systems. Wastewater containing Atrazine and toluene was used in this experimental program. Additional DMCAT tests were performed to evaluate GAC performance on Terbacil.

PESTICIDE RINSEWATER RECYCLING SYSTEMS[4]

During the 1984 spray season, Growmark, Inc., and the Illinois Environmental Protection Agency researched the concept of recycling pesticide rinsewaters by mixing them into succeeding spray solutions as an alternative to treatment and/or disposal. Wastewater management systems at 13 commercial agrichemical facilities were examined.

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The basic design of the wastewater collection and recycling systems includes a wash pad and receptacle for rinsewater containment. The wash pad component is typically a reinforced, 18- by 36-ft concrete slab that catches water generated in the washing and rinsing of most spray equipment, drippings from hoses, and foamovers that occur while loading.

The most efficient device for collecting rinsewater draining from the wash pad is a 1000-gal concrete tank. A pre-cast tank or a poured tank made of high-density, 6000-psi concrete is used for this purpose. The collection tank set up varies depending on the scope of the operation. At a minimum, one tank is required for containment of rinsewater and incidental spillage. Two tanks are used to segregate corn and bean chemical rinsate.

A basic unit including the wash pad, tanks, plumbing, and pumps can be installed for less than $10,000.

To study the feasibility of recycling rinsewater, water samples were collected from the containment facilities at the 13 agrichemical sites and analyzed for the pesticides introduced into each respective system. Concentrations in the rinsewater mixtures were compared with those in standard spray solutions to assess potential contamination problems and to determine dilution factors for reuse.

The results indicate that the addition of rinsewater to fresh spray solutions of the commonly used corn and soybean herbicides at a 5-percent rate by volume will very slightly influence the total active ingredient concentrations. In each case, the total amount falls well within the limits allowed for the primary active ingredient when used alone, which tends to support the reuse concept (Table 1).

TABLE 1. RINSEWATER EFFECTS ON SPRAY SOLUTION CONCENTRATIONS

Herbicide	Standard Spray Solution Concentration*	Allowable Rate Variation**		Recycle Variation with 5% Rinsewater
	(ppm)	(+/-ppm)	(+/-%)	(%)
Atrazine	14,100	1,500	10	0.60
Cyanazine	15,000	3,000	20	.56
Metalochlor	12,000	1,500	12	.70
Alachlor	16,300	3,000	18	.52
Metribuzin	2,600	375	14	3.23
Linuron	1,870	375	20	4.49
Pendimethalin	7,500	1,500	20	1.12
Butylate	21,300	2,300	11	.39
Trifluralin	4,500	750	17	1.87

*Based on median recommended application rates applied with water at 20 gal per acre.
**Based on manufacturers' label recommendations.

Blending of the rinsewater into the spray solutions does raise some questions, particularly for regions where more diverse and sensitive specialty crops are grown. The main concerns rise from tank mixing of pesticides not labeled for such use. Trace amounts of these pesticides could be phytotoxic to the crop, and the potential exists for residues in excess of established tolerances. Follow-up studies are proposed to address these issues.

PESTICIDE WASTE DISPOSAL[5]

The Louisiana Department of Agriculture began enforcement of pesticide waste disposal regulations on January 1, 1985. These regulations pertain to all commercial pesticide applicators. Basically, they require that applicators have facilities to clean the equipment spray tank, spray system, mixing tanks, and pesticide containers without contaminating the soil, groundwater, or other bodies of water.

Water used to wash the spray system can be disposed of in several ways. Approximately 35% of the aerial applicators plan to rinse the aircraft over the field being treated. This process involves returning the aircraft to the loading area and loading 50 to 60 gal of clean water. The aircraft is then returned to the area being treated, and the washwater is sprayed over the field. The aircraft then returns to the loading area for a second load of 50 to 60 gal of clean water. This second load of clean water is then applied to the area being treated. This process is repeated until the residue remaining in the spray system has a very low pesticide concentration.

Aircraft normally have 6 to 8 gal of residue in the spray system at the end of a spray operation. Adding 60 gal of clean water to the spray system will reduce the concentration to 10% to 12% of normal field strength. This washwater can normally be applied to the field being treated without exceeding the label rate. This concentration can be reduced by about 40% if the spray system is modified to remove all pesticide from the spray tank.

The general consensus is that it will cost less for applicators who fly fewer than 300 hrs per year to triple rinse the aircraft over the field rather than to construct facilities for recycling washwater.

In other cases, the applicator can change pesticides without washing the aircraft. As an example, most applicators can switch from soybean herbicides to soybean insecticides to soybean fungicides without cleaning the aircraft. This can be accomplished without exceeding the label rates or violating the label of the pesticides involved. For example, when mixed with 300 gal of water, the residue in the aircraft will have a concentration of less than 3% of normal field strength.

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[5]Darryl Rester, Louisiana State University Agricultural Center, Baton Rouge, LA. 70308.

About 60% of Louisiana's aerial applicators have built wastewater recycling facilities. These facilities consist of three to five wastewater containment tanks. Each tank will hold 200 to 500 gal of pesticide waste. After the completion of a spray job, the aircraft will be washed to remove the residue from inside the spray system. The washwater and pesticide residue will be collected and pumped into the desired containment tank. In most cases, this washwater will contain pesticide waste at less than 10% of normal field strength. This washwater will then be used as a dilution agent on the next job where compatible chemicals are used. As an example, most applicators will have a tank for cotton herbicides and insecticides, soybean herbicides and insecticides, rice herbicides, and other pesticides, as the situation dictates.

In most situations, the applicator will use 1 part pesticide washwater with 4 or 5 parts of fresh water. This step reduces the pesticide waste to less than 2.5% of normal field strength. This is an inexpensive technique for recycling the wash water and thus insuring rapid disposal. Using very dilute wastewater (less than 2.5% of normal field strength) will reduce the possibility of illegal residue on and damage to crops, and it still insures rapid disposal of the washwater.

About 80% of Louisiana's aerial applicators are based on rented land. Most applicators are reluctant to build wastewater processing facilities on rented land. Financing is often difficult to obtain for building a facility of this nature on rented land.

Use of a wastewater recycling system requires very careful management. Filtration of the wastewater to remove solid contaminants can be difficult. This problem can be reduced by removing the wastewater from the containment tanks as soon as possible. Also, modifying the aircraft to pump the washwater from the spray system to the containment tank will greatly reduce contamination.

Several applicators have taken steps to modify the aircraft and remove the pesticide from the aircraft in flight. These applicators have extended the pump intake inside the spray tank. This will reduce the volume of pesticide remaining in the aircraft by approximately 40%. A few applicators have added remotely operated valves to the outer end of each spray boom. This allows removal of pesticide residue from inside the spray system in flight. In most cases, less than half a gallon of pesticide will remain in the aircraft. The applicator then uses a fresh water wash tank on board the aircraft to wash the remaining residue from inside the spray system while in flight. This system works extremely well for aerial applicators who change pesticides several times per day; it also works well for applicators who use several air strips during the course of a normal day.

Louisiana aerial applicators feel that they can comply with existing regulations and still apply pesticides in an economical manner. However, they are very concerned about the possibility of having to contain the washwater from the exterior of the aircraft. Containing exterior washwater will increase the amount of contaminant that must be removed. If exterior washwater is contained, it will not be feasible to modify the aircraft for cleaning in flight.

ULTRAVIOLET-OZONATION IN PESTICIDE WASTEWATER DISPOSAL: STATE-OF-THE-ART, TECHNOLOGY TRANSFER, AND RESEARCH NEEDS[6]

The use of large-scale ultraviolet-ozonation($UV-O_3$) units holds promise for on-the-farm treatment of pesticide wastewaters. Its greatest potential will be in combination with microbial metabolism, either as a pre- or post-treatment step, with indigenous or engineered organisms. The major advantages are onsite destruction, mobility, low cost, ease of operation, and versatility in oxidizing a potentially large number of organic pesticides.

The state-of-the-art capabilities of $UV-O_3$ for pesticide disposal have been reported only in a few studies to date. One onsite demonstration with a 66 lamp UV unit successfully degraded formulated Atrazine (4480 ppm) and 2,4-D (1086 ppm). Paraquat (1500 ppm) destruction required the addition of acetone to accelerate the process. None of the degraded products isolated and identified to date are halogenated.

The emerging technology of genetic engineering for selected degradative strains in combination with $UV-O_3$ offers a number of new opportunities for destroying pesticide wastes in situations where either process alone may be only partially successful. A recent example is a two-step pretreatment of the insecticide Coumaphos [O,O-diethy O-(3-chloro-4-methyl-2-oxo-2H-benzopyran-7-yl)phosphorothioate], taken directly from an animal dip vat operation. Because of the turbidity and extraneous organic material present in these solutions, the rates of $UV-O_3$ were too slow to be effective as a disposal option. A Flavobacterium sp. rapidly hydrolyzed the phosphorothioate linkage to yield chlorferon (3-chloro-4-methyl-7-hydroxycoumarin) and diethylthiophosphoric acid. The reaction is catalyzed by an enzyme known as phosphotriesterase. The microorganism could not cleave the ring product. $UV-O_3$ of this solution rapidly fragmented the ring and killed the microorganism. This latter effect has important implications in preventing the release of engineered microorganisms into the environment. The DNA fragment encoding phosphotriesterase has been isolated and characterized. The phosphotriesterase has a broad substrate specificity for other organophosphorus insecticides; therefore, experience with Coumaphos can be readily transferred to other waste situations. An Acromobacter sp. that rapidly hydrolyzes several methylcarbamate insecticides has recently been reported from our group. This microbe could be used in the two-step pretreatment process to include an even larger group of insecticides.

A number of research needs must be met over the next 3 to 5 years before the process can be fully implemented. A reasonably priced $UV-O_3$ unit must be developed to make this an economical process. One estimate is that a production line unit could be manufactured for less than $20,000. The mobility of the unit makes cost-sharing between a large number of potential users over several years an attractive economic consideration. Second, the rates and products for each of the major pesticides or pesticide classes must be determined. Currently, this information is being developed for the 20 leading pesticides that comprise more than 90% of the U.S. market. Finally, the process(es) must be optimized for time and cost per gallon processed.

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[6]Philip Kearney, U.S. Dept. of Agriculture, Beltsville, MD 20705.

DESCRIPTION OF A SMALL, AUTOMATED, FLUIDIZED-BED COMBUSTOR SYSTEM AND ITS POTENTIAL FOR THE INCINERATION OF PESTICIDE WASTE and WASTEWATER[7]

Incineration is a viable method for the disposal of pesticides if it is properly carried out. In general, this means controlling the amount of oxygen for combustion, the temperature level, and the time of exposure. Two incineration guidelines that have been developed to date are:

1) A dwell time of 2 sec at 1200°C with 3% oxygen, or

2) A dwell time of 1.5 sec at 1600°C with 2% oxygen.

These guildeines have been developed for incineration systems using two separate burner sections: a rotary kiln and a secondary burner system. Recent work using fluidized-bed technology suggests that complete destruction can be achieved at much lower temperatures.

In 1981, the Ohio Agricultural Research and Development Center (OARDC) began construction of a small, efficient (22 kW/hr) fluidized-bed combustor (FBC) using corncobs as a fuel source (Keener, H.M., J.E. Henry and R.J. Anderson, 1982. Corncob burner prototype developed and tested. Ohio Report 67(4):71--July-August. OARDC, Wooster, OH). The burner is made up of a 6-in. diameter stainless steel pipe as the combustion chamber and a unique fluidized-bed-to-air heat exchanger system. The burner produces a clean, high-temperature output (800°C) air stream for process and space heating purposes, and possibly for generation of electricity.

In the fall of 1982, an automatic control system was added to the unit to complete the developmental phase. Results of the 1982 tests showed that the OARDC-FBC burns corncobs cleanly, delivers clean, heated air efficiently, and requires minimal maintenance over long periods of time when properly operated (Keener, H.M., J.E. Henry and R.J. Anderson. 1983. Controllable fluidized-bed direct combustor produces clean high temperature air. Presented at Montana State University, Bozeman, MT, June. ASAE Paper No. 83-3037, American Society of Agricultural Engineers, St. Joseph, MI).

Success has been demonstrated in burning other fuels. Coal burns especially well in this FBC, though no attempts have yet been made to deal systematically with coal-burning pollution problems. A second prototype of 44 kW thermal capacity is now under construction.

Adoption of this system to the incineration of aqueous pesticide waste appears quite feasible. Figure 2 is a schematic showing one possible arrangement for such a unit fired with corncobs. With this system, some heat recovery is desirable to minimize fuel usage. By burning 9.1 kg/hr of corncobs (5 % moisture, wet basis) it is estimated that up to 50 kg/hr of

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wastewater could be incinerated (5.5 kg water/kg of fuel). Without heat recovery, only 16 kg/hr could be handled. Operating 24 hr a day, 312 days a year, this small portable system could possibly handle 375,000 kg (100,000 gal) of aqueous pesticide waste per year.

However, questions that need to be answered before such a system is viable are (1) which pesticide materials can be successfully destroyed at 800^{o} to 900^{o}C, (2) how long a residence time is needed in this FBC if material goes into the burner section as a vapor, (3) what excess oxygen levels are required, (4) what fuel additives are needed to control corrosion and/or emissions, and finally, if viable, (5) what are the economic factors for fixed and operating costs.

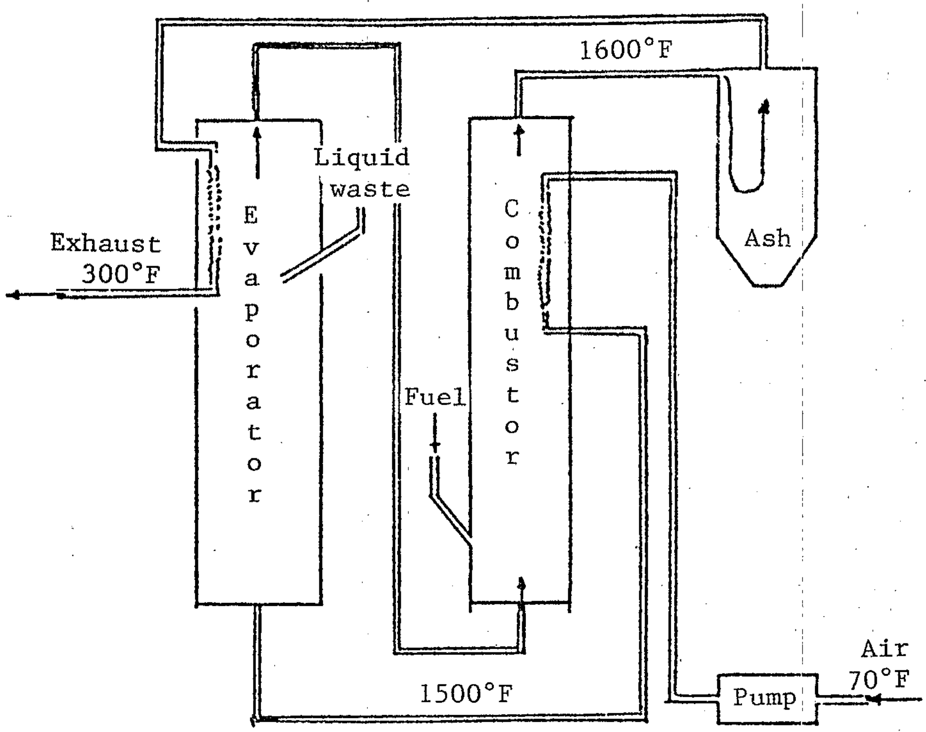

Figure 2. Schematic of OARDC burner system coupled to an evaporator for the incineration of aqueous waste.

REMOVAL OF PESTICIDE WASTES BY MEANS OF SOLAR PHOTODECOMPOSITION[8]

A proposed new approach to the treatment and removal of pesticide wastes involves solar photodecomposition of the organic pollutants. In this scheme, photocatalytic semiconductor powders and colloids are suspended in contaminated wastewater; under solar irradiation, the photocatalytic semiconductor particles drive photoredox reactions on the particle surface. These redox reactions convert organic compounds to CO_2 and H_2O.

The approach is based on the fact that semiconductor particles can absorb sunlight to produce electron-hole pairs that separate, move to the surface, and promote oxidation-reduction reactions. This process will occur either because of built-in electric fields at the semiconductor-liquid interface (space charge layers), preferential trapping or reaction of the electron or holes, or because the particle is small enough to permit carrier diffusion to the surface with subsequent charge transfer to solution before bulk electron-hole recommendation occurs. For some reactions involving slow intermediate steps, the process can be greatly enhanced by depositing catalytic metals on the semiconductor surface.

Initial experiments were performed at the Solar Energy Research Institute using undoped TiO_2 (anatase) powders (0.4 g/L) suspended in aqueous solutions containing model toxic compounds (chlorotoluene and phenol). Under illumination with simulated sunlight, nearly complete removal of 78 ppm phenol and 53 ppm chlorotoluene was achieved within about 4 hr. Additional results of other researchers are presented on removal of 4-chlorophenol, chloroethylene, cyanide, toluene, and PCB's. Problems and future research areas required for practice implementation of the photoelectrochemical solar approach are discussed.

DISPOSAL OF DILUTE PESTICIDE WASTES BY EVAPORATION AND BIODEGRADATION USING CONCRETE PIT* SYSTEMS[9]

All agricultural spray operations generate variable quantities of dilute pesticide wastes as surpluses in spray tanks, rinsates from spray equipment and containers, and from outdated or leftover materials. Well planned and managed operations minimize the quantity to be disposed of and the possibility of environmental pollution.

Pesticide applicators should (1) mix only the volume of material needed for the spray operation, (2) apply the mixture to the area for which it was approved, (3) use rinsates from containers where possible and where approved for further spray operations, and (4) triple rinse and properly dispose of all containers.

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*The term pit used in this abstract meets the technical definition of a tank as described by RCRA.

For the past 15 years, a pesticide disposal system that involves containment, evaporation, and biodegration has been used successfully and safely at the Iowa State University Horticulture Station near Ames. Residual wastes from more than 50 pesticides have been deposited in the evaporation pit, with an average of approximately 6000 gal being evaporated annually. The evaporation pit is a reinforced concrete structure 12 x 30 x 4-ft deep, filled with 1-ft layers of gravel (3/4 x 1 1/2-in.) and a field soil with 3% organic matter (gravel-soil-gravel). The pit has a tile system underneath for sampling and monitoring leakage, and it has an automated movable cover to exclude rainfall.

The pit is connected with the pesticide building, which is used for storage of chemicals and spraying equipment. All washwater from the mixing operations is pumped from a sump into the evaporation pit.

The safety and success of this system was confirmed by a 3-year study sponsored by the U.S. Environmental Protection Agency from 1976-78, results of which were published by the National Technical Information Service in 1981 (P.B. 81-797-584). This report shows that no leakage had occurred, aerobic soil bacterial activity was about normal, and the capacity for evaporation exceeded that required for the operation. Also, pesticide degradation by biological activity and chemical action prevented the buildup of any hazardous problems.

In 1983, a small model with the same components was installed at the Horticulture Station. This model is 4-ft in diameter, 4-ft deep, and has a hinged fiberglass cover. Both systems are described in the American Chemical Society Symposium Series 259, 1984.

The Iowa State University system has served as a model for farmers, chemical companies, other research stations, and commercial applicators. The following modifications from the original system are recommended:

1. Include a 30-mil-plus, nonphotodegradable membrane liner inside the concrete pit.

2. Install a rigid, raised, hinged cover with (1) sufficient air circulation space to maximize evaporation, and (2) adequate overhang to prevent rainfall from entering. Also, a wire enclosure should be installed on the support posts to prevent children, animals, and débris from entering.

3. Provide a collector for dumping into the pit.

4. Provide a sampling system underneath the pit for leakage detection. In areas where there is danger of flooding, the pit should be erected above ground level and sufficiently bermed to prevent the danger of rupturing by freezing.

5. Provide a recirculation spray system to enhance evaporation in more humid areas.

6. Provide an enclosed equipment wash rack with drain connected from a sump into the pit.

The design criteria may differ for various geographic areas, but in all cases, it should be practical for use.

One area that should be vital to future recommendations and the basis for disposal regulations is a study of the effectiveness of systems currently in use. Such a study should result in a manual of acceptable methods and instructions for use.

DISPOSAL OF AQUEOUS PESTICIDE WASTES AT UNIVERSITY OF CALIFORNIA AGRICULTURAL FIELD STATIONS[10]

The University of California Agricultural Field Stations have been disposing of pesticide wastes in lined evaporation beds for many years. The sources of the wastes have been primarily rinsates from pesticide containers and application equipment. All of the beds located throughout the state have the same basic design in that the rinsates are supplied to the bed from underneath the soil surface through PVC leach lines located at the bottom. The leach lines are covered over with a couple of inches of rock followed by up to 24 in. of soil. Starting in 1980, the beds were sampled and analyzed for pesticide content, and those beds that were considered heavy users were sampled at least annually. Soil core samples were taken from quadrants inside the bed at depths of 0 to 1, 1 to 6 and 6 to 12 in. Air samples were also taken along the edge of the bed starting in 1981. Results from these investigations showed that the beds do not generally build up high levels of pesticides and that the levels found in the air were quite low. Pesticide concentrations were generally much higher at the 0 to 1 in. sampling, which means that the pesticides rise to the surface by mass transport. This discovery has initiated some studies for determining some simple but effective degradation practices to incorporate into the beds for enhancing degradation of the pesticides. Recent laboratory studies regarding the effects of various soil factors and amendments on the degradation of pesticide mixtures in waste disposal systems has shown that of all the variables studied, pesticide concentration was the single most important factor in determining degradation rate. This result may be attributed to at least three processes-- that is, (1) limitation in the availability of active sites involving soil surface catalyzed reactions, (2) low water solubility of the pesticides studied (thereby making them rate-limiting), and (3) inhibition of microorganisms in large pesticide concentrations (thereby reducing microbial degradation). The other factors examined in combination with each other were pH, organic matter amendment, soil type, soil moisture, and soil sterilization.

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As a result of these studies and recent California legislation, a type of evaporation bed has been proposed that contains and degrades pesticide rinsates without threatening the environment. The system involves an above-ground, double-lined evaporation bed located on top of an impervious liner covered with an inert material such as sand or rock and surrounded by a berm. Visible monitoring for leakage or damage between the liners is part of the design, and the components of the bed are essentially above ground, including the wash pad where the materials are originally deposited. The design also contains a storage and supply tank where the rinsates are initially desposited and where they can be pretreated before being transferred into the bed. The proposed bed contains soil and amendments similar to that found in our present system.

ONSITE PESTICIDE DISPOSAL AT CHEMICAL CONTROL CENTERS[11]

In cooperation with the U. S. Department of Agriculture Soil Conservation Service (USDA-SCS), chemical control centers have been installed on many small fruit farms in the 20- to 300-acre range. These facilities consist of a water source, catch basin, leach lines, and pesticide storage; they help minimize danger to the worker and damage to the environment in the mixing and filling stages of pesticide spraying operations. In this study, surface water and deep soil samples were analyzed to detect any migration or runoff of waste pesticides from typical chemical control centers. Both a 1- and a 5-year-old facility were monitored for 13 months with no evidence of leaching into surrounding water sources or into soil within 18 in. of the leach lines. Entomological evaluation of soil biota and monitoring of dermal exposure to pesticides of mixer-applicators took place throughout the 1980 season. No adverse effects were detected as a result of the chemical control centers.

These centers are currently operational. Though financial assistance is no longer being made available for installations on individual farms, the USDA-SCS is providing information to farmers wishing to construct them. They are a practical, economical alternative to pond or streamside pesticide handling, and they have had good user acceptance. More thorough evaluations of chemical migration should be undertaken if this method is to be considered for widespread usage.

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BIOLOGICAL AND CHEMICAL DISPOSAL OF WASTE PESTICIDE SOLUTIONS[12]

Pesticide applicators and dealers are faced with a waste disposal problem that may vary according to the size and type of operation. Wastewater from vehicle washing, spray or nurse tank rinsewater, haulback solutions, facility runoff, spilled materials, obsolete or unidentifiable chemicals, containers, and incompatible mixtures are all recognized sources of waste pesticide solutions.

Various methods of treatment and disposal of waste pesticide solutions have been proposed and evaluated. Such methods include land disposal (land cultivation, soil mounds and pits), evaporation basins and lagoons, chemical treatment, physical treatment (adsorption and reverse osmosis), biological treatment (trickling filters and activated sludge), and incineration. In a report to the U.S. Environmental Protection Agency the SCS Engineers stated that soil mounds could be the most readily implementable disposal method for dilute pesticide solutions.

The objective of this study is a continued assessment of a biological and chemical treatment system for wastes and spilled pesticide solutions. Specifically, the study assesses the reliability of an acid and alkaline trickling filter system that can economically treat and dispose of pesticide wastewater. The population of pesticide-decomposing microorganisms has been monitored over time and correlated with pesticide activity (bioassays). The collected information provides preliminary data for a long-term goal: To develop a relatively inexpensive, reliable, and convenient disposal system for waste pesticide solutions that is suitable for use by the chemical applicator or dealer.

DISPOSAL OF DILUTE AND CONCENTRATED AGRICULTURAL PESTICIDE FORMULATIONS USING ORGANIC MATRIX ABSORPTION AND MICROBIAL DEGRADATION[13]

Studies are proposed to provide information on disposing of dilute or concentrated pesticide solutions. These studies will include laboratory and field studies. If these prove successful, on-the-farm demonstrations of this process will be provided and offered as a means for disposing of pesticides asssociated with U.S. Agriculture. The disposal process will involve absorption of selected pesticides onto an organic matrix (concentration and containment phase) followed by degradation using microorganisms in a nutrient-enriched composting environment (degradation/product neutralization phase). Preliminary work done in our laboratory has shown that under appropriate conditions, absorption of pesticide solutions (Diazinon) onto selected organic media can be quite significant. For example, the Diazinon level in a 200-ml solution containing 10,000 mg/kg was reduced to 55 mg/kg when exposed to (mixed with or filtered through) 5 g of peat moss for only 24 hr. The Diazinon

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was concentrated onto the peat moss by a factor of 19 (10,000 mg/kg in the initial solution concentration, resulting in a level of 190,000 mg/kg peat moss). Other forms of organic media, including activated carbon, could possibly be used in the concentration and containment phase.

We have demonstrated both in laboratory studies (using radio-labeled Diazinon) and in field studies that Diazinon can be degraded quite rapidly in a nutrient-enriched microbial system (composting environment). For example, in field studies, it was found that when Diazinon was applied at high levels (32,000 mg/kg peat moss), this level was reduced to 61 mg/kg in 8 weeks and subsequently to 7 mg/kg in 18 weeks. Based on the results of these experiments and other studies, more extensive experimentation is warranted with other pesticides.

If adequate funding is made available to support further work on this process, it is quite possible that delivery of a safe, simple, inexpensive, and effective system for dealing with specific pesticides could be made to the agricultural industry within 3 to 5 years. This would obviously require a coordinated effort between research (laboratory/field), extension (demonstration), and regulation agencies.

TOXIC SUBSTANCE SOLVENT EVAPORATOR[14]

This paper presents the concept of the toxic substance solvent evaporator (TSSE). The state-of-the-art capability, emerging technology and/or technology transfer opportunities, and further research needs are discussed. The TSSE is an off-shoot of the biological incinerator that was developed to first biodegrade organic contaminants using thermophilic bacteria in an aerated, closed container and concurrently evaporate the water by saturating the air, which is discharged through a stack. By wicking the pesticide waste material onto a large surface area, evaporation is greatly accelerated. Since the solid component of these pesticide wastes is less than 0.1%, evaporation creates a major volume reduction. In fact, the very dilute nature of the pesticide waste residues being considered reduced the necessity for also biodegrading the waste in some cases.

A pilot unit has been operated in New Orleans and provided data from which to make evaporation rate predictions. Because of the simplicity of the concept, a do-it-yourself kit can be supplied to the applicators to keep the costs of the evaporator very low. Methods exist for accelerating the evaporation rate through mechanical means, but the basic system derives its energy from the sun and is operable over most of the United States during the growing season.

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Various configurations of the evaporation/biological metabolism combinations are available as a function of waste volume, strength, and composition. The wick provides a large surface area for immobilizing microorganisms, and it provides a combination of anaerobic and aerobic metabolism when used in conjunction with a closed container.

The TSSE is aimed primarily at helping the small hazardous waste generator, and it applies to all chemical waste streams containing dilute quantities of a toxic material. However, this technology could have applications in almost any liquid waste treatment scenario, including the enhancement of biological processes. The simplicity of the concept and the hardware makes the TSSE a candidate for use in third world countries.

Further research is required to determine the resulting biological metabolites or the physical and chemical properties of the residues left on the wick. Also, the physical integrity of the system and the choice of materials need further development.

MICROBIAL DEGRADATION OF PESTICIDES[15]

Microbial degradation of pesticides may be classified into several categories. By far the most important class of microbial metabolism is incidental metabolism, where pesticide degradation is coincidental to basic carbon and energy utilization of the microorganisms. In such cases, microbes grow freely without pesticides. Two radically different subclasses exist within this class of metabolism. They are wide-spectrum and analog metabolism. The former reactions are usually carried out by enzymes that have a wide enough substrate spectrum to degrade pesticides. A good example is the case involving hydrolases. Malathion degradation at carboxylester bonds by varieties of Trichoderma viride clearly depends on the nonspecific hydrolases this species produces.

By contrast, analog metabolism involves enzymes that are rather specific, requiring normal induction (acclimatization) through the use of specific carbon sources. For instance, it is possible to select out some PCB-degrading microorganisms by an enrichment approach with biphenyl or monochlorobiphenyl as sole carbon sources. These microorganisms acquire specific enzyme systems to degrade biphenyl-type chemicals (e.g., dioxygenase), which in some cases happen to metabolize chlorinated analogs as substrates. Wide-spectrum and analog metabolism may be distinguised on several accounts. First, wide-spectrum metabolism may be directly correlated with indicators for general microbial activities such as biomass, ATP production, etc., whereas analog metabolism is not. Second, the addition of general nutrients such as glucose, mannitol, etc. increases the wide spectrum but decimates the analog activities.

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The second major class of pesticide metabolism is catabolism, a process in which microorganisms derive energy by metabolizing pesticides. In many instances, the second and third addition of a pesticide in the same locality have been reputed to increase microbial degradation of a pesticide. Note that such activities should include cases in which microorganisms use only part of a pesticide molecule as long as they derive energy by doing so. Metabolic use of mexacarbate is a good example. Catabolism differs from incidental metabolism in that it requires high levels of pesticides in a given locality to sustain the microbial activities. In incidental metabolism, the pesticide levels are not vital and are usually very low, since pesticides are not the normal substrates to those enzymes.

The third major class of metabolic activities is resistance metabolism. In such cases, microorganisms actually spend energy to detoxify pesticides for their own survival. By definition, such pesticides must be toxic to the metabolizing microorganisms (e.g., antibiotics, fungicides, etc.).

PHANEROCHAETE CHRYSOSPORIUM: ITS POTENTIAL USE IN THE BIOLOGICAL DEGRADATION AND DISPOSAL OF AGRICULTURAL CHEMICAL WASTES[16]

Phanerochaete chrysosporium, an example of a white rot fungus, is able to degrade a broad spectrum of structurally diverse organopollutants. Pesticides of interest that are degraded by *P. chrysosporium* include DDT, DDE (a DDT metabolite), Dicofol, Lindane and Toxaphene. Evidence suggests that this ability is due to the lignin-degrading system of this microorganism. Studies using DDT as a model compound have shown that both lignin and DDT degradation (as measured by $^{14}CO_2$ evolution) were promoted by nutrient nitrogen starvation, whereas degradation was suppressed in nutrient-nitrogen-sufficient cultures. Similarly, the temporal onset and disappearance of $^{14}CO_2$ from ^{14}C-DDT and ^{14}C-lignin appeared to coincide. Waste treatment systems inoculated with *P. chrysosporium* may prove to be a useful and economical process for the small-scale disposal of agricultural wastes. For example, aerobic composting or the use of rotating biological contactors are two waste treatment processes that may be economical, easy to operate, and otherwise suitable for onsite use. Although biological treatment is a potentially attractive method for chemical waste disposal, there are a number of research areas that must be explored for this process to be applied in pesticide disposal systems. Some of these research areas are as follows: 1) Studies must demonstrate what conditions are most favorable for growth of the introduced microorganisms and what conditions favor biodegradation. For example, *P. chrysosporium* requires nutrient nitrogen starvation and acidic pH for growth and biodegradation. 2) Conditions that discourage competition by undesired microorganisms may have to be examined.

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3) The relative toxicity of pesticides for pesticide-degrading microorganisms must be determined. 4) The rates of certain pesticides undergoing degradation must also be studied with the objective of enhancing these rates. 5) Other lignin-degrading fungi should be studied to determine their relative suitability for use in such systems.

SECTION 4

WORK GROUP RESULTS

INTRODUCTION

Work groups A (Physical/Chemical Treatment & Recycling) and B (Biological Treatment & Land Application) were each sub-divided into six sub-work groups. Appendices F and G provide the titles and membership of these sub-work groups.

Each work group was asked to review and assess its respective technology(s) in a consistent manner. To facilitate this, a form (Sub-Work Group Summary Sheet, Appendix H) was developed and used by each sub-work group to report its findings and this provided the basis for the information reported in this Section.

Among other things each technology(s) was placed in one of the following three categories:

1. Technology is currently being utilized on a commercial basis to treat and dispose of dilute pesticide wastewater. (i.e., proven technology).

2. Technology is being utilized commercially to treat other types of waste and offers promising opportunities for pesticide wastewater. (i.e. technology transfer opportunities).

3. Technology is not being utilized commercial but experimental data indicates it is a promising candidate technology for pesticide wastewater, (i.e., emerging technology).

Table I summarizes the results of this categorization for both work groups.

WORK GROUP A, PHYSICAL/CHEMICAL TREATMENT AND RECYCLING

Pesticide Rinsewater Recycling

Pesticide rinsewater recycling systems are various wastewater volume reduction techniques used in combination with a containment facility for collecting rinsewater, incidental spillage and leftover spray solution which are subsequently recycled into new spray mixtures.

TABLE 1. CATEGORIZATION OF TECHNOLOGIES

Technology	CATEGORY Proven Technology	Technology Transfer	Emerging Technology
Physical/Chemical Treatment & Recycling			
1. Pesticide Rinsewater Recycling	X		
2. Granular Carbon Adsorption	X		
3. UV-Ozonation		X	
4. Small-Scale Incineration			X
5. Solar Photo-Decomposition			X
6. Chemical Degradation		X	
Biological Treatment & Land Application			
1. Evaporation, Photo-degradation & Bio-degradation in Containment Devices	X		
2. Genetically Engineered Products			X
3. Leach Fields	X		
4. Acid & Alkaline Trickling Filter Systems			X
5. Organic Matrix Adsorption & Microbial Degradation			X
6. Evaporation & Biological Treatment with Wicks			X

Current Applications --

This technique is practiced to various extents by both ground and aerial commercial applicators. During 1984 a broader utilization of this approach was evaluated in Illinois and about 60% of Louisiana's aerial applicators have built wastewater recycling facilities. While some states have approved recycling procedures, there may be potential conflicts with FIFRA such as 1.) illegal tank mixing and 2.) application of chemicals to non-targeted areas.

Advantages, Disadvantages and Key Points --

The advantages of recycling are that it is economical, technically uncomplicated, provides total containment, may be adapted to specific site situations and minimizes the amount of wastewater that must be treated and disposed.

The disadvantages are that it may result in phytotoxic problems, illegal residues and yield suppression if segregation of chemicals is not practiced. It may not be feasible where a large number of chemicals are used on a variety of crops.

The key point of this technique is that it eliminates adverse environmental consequences resulting from site runoff; minimizes quantity of waste that must be disposed; is compatible with loading, mixing and washing operations and requires less specialized monitoring and treatment skills than other treatment options.

Status and Cost --

This technique is currently available. Its capacity is based on the scope of the operation. Capital cost range from $5,000 to $10,000 and operating cost are minimal.

Research Needs --

1. Determine the acceptable concentration of chemicals in rinse solutions that can be recycled without causing phytotoxicity, crop residues or yield suppression.

2. Design volume reduction systems to minimize quantities of rinsewater, i.e., injection systems and flush systems.

3. Define criteria for system utilization, including the identification of concentrations of pesticides acceptable for reuse.

4. Develop a "quick test" to analyze rinse solutions on-site.

5. Develop engineering design specifications.

6. Develop user education and training materials and programs.

Granular Carbon Adsorption

Wastewater contaminated with pesticides is passed through a bed of granular carbon, and the pesticides are removed through adsorption onto the carbon. Some pretreatment is usually required to remove suspended solids and break oil-water emulsions.

Current Applications --

This technology has been used to remove organics from a variety of wastewaters. Of particular interest, the Army is employing a system based on the recirculation of pesticide - contaminated wastewater through a bed of granular activated carbon to treat wastewater generated by the residential pest-control facility at Fort Eustis, VA.

In addition, two systems (located at one ground based and one aerial applicator's site) have recently been installed in California for evaluation. The state of California waived the permitting of this treatment facility under RCRA to allow this experimental system to go forward. The U.S. EPA concurred with this action.

Advantages, Disadvantages and Key Points --

This is a proven technology for treating other types of wastewater and when properly designed it is almost foolproof. Other advantages include the possibility for system mobility and this technology is accepted, convenient and uncomplicated.

The presence of solids and emulisifiers may cause operating problems if not properly handled in the pretreatment step. In addition, pesticides that are not adsorbable must be removed by some other process.

Status and Cost --

This technology is available and its capacity is unlimited. Capital cost range from $100 to $400 per gallon per minute and operating cost are approximately two dollars per pound of carbon used which includes the cost of disposing of the spent carbon as a hazardous waste.

Research Needs --

1. Evaluate biodegradation on the carbon filter alone or with other materials.

2. Evaluate powdered carbon.

3. Prepare isotherms for the most commonly used pesticides as formulated.

4. Evaluate biological treatment (composting) of the spent carbon.

UV-Ozonation

Pesticide laden wastewater is subjected to ultraviolet (UV) light and ozone. This alters the pesticide molecule to make it more polar, less toxic and more biodegradable. Normally, this technology should be utilized in combination with microbial metabolism, either as a pre- or post- treatment step.

Current Applications --

It is currently being used for water purification on a commercial basis in Europe to remove toxic pollutants. Experimental studies have reported successful degradation of formulated Atrazine (4480 ppm) and 2,4-D (1068 ppm). The possibility of combining UV-ozonation and engineered organisms holds promise.

No known permits have been issued for this technology to treat pesticide wastewater.

Advantages, Disadvantages & Key Points --

The advantages of this technology include the fact that it destroys the pesticides (i.e., as opposed to concentrating them) and can treat all organic pesticides as formulations. In addition, it can be mobile (i.e., many users) and is easy to handle.

However, degradation products are not known and there has been limited testing for this application.

Key questions that must be answered from both the user and regulator viewpoint include: 1.) what percent conversions will be required, 2.) what residue levels will be permitted in the soil and 3.) what follow-up research will be required.

Status and Cost --

This technology is in the experimental stage for pesticide wastewater treatment. Capacity ranges from 3 to 20 gallons per hour. Capital and operating costs are approximately $20,000 and 7¢/hr., respectively.

Research Needs --

1. Development of a monitoring system on the unit to determine product conversion.

2. The identification of degradation products.

3. Evaluate the economics and co-treatment opportunities.

Small-Scale Incineration

When exposed to adequate temperatures for a minimum period of time and with the appropriate amount of oxygen, the pesticide molecule is destroyed.

Current Application --

Approximately 250 incinerators are in operation in the U.S. that are currently being used to destroy a variety of organic wastes. However, these incinerators are typically very expensive (capital cost is approximately $35,000,000) and very, very large compared to the volumes of waste being considered.

Experimental work has been conducted with a small-scale, fludized-bed combustor utilizing corncobs as a fuel. The potential exists to modify this system for the disposal of dilute pesticide waste either with a mobile system or on a regional basis.

Permits and test burns would be required for each site, although a class permit might be a possibility. This requirement would represent a significant effort and a special problem for these small-scale systems.

Advantages, Disadvantages and Key Points --

The advantages of this approach include the system can be mobile, it destroys the pesticide and other on-the-farm waste (i.e., corncobs) could provide the fuel source.

However, the heavy metals in some pesticide presents a special problem. The cost of permitting, construction and operation would be relatively high and the potential for mechanical breakdowns exists.

The key point of this technology from the user viewpoint is that it offers the potential of acceptable disposal within a reasonable distance to the generated waste. However, class permitting would likely be necessary for its practical utilization.

Status and Cost --

This system is in the experimental stage and could possibly be made available in 2 to 3 years following successful research and development. The capacity of the current test unit is 10 to 15 gal/hr. Capital cost are estimated at $20,000 to $50,000 and operating cost are not available.

Research Needs --

1. Determine the minimum dwell time and temperature.

2. Evaluate the economics of a mobile system versus a regional facility.

3. Evaluate the destruction efficiency for representative pesticide wastewater including the sampling for POHC's and PIC's.

4. Test and evaluate other small-scale designs.

5. Evaluate the impact of co-firing with other wastes.

Solar Photodecomposition

Photoactive (photocatalytic) semiconductor pesticides ranging in size from 100 Å to 1μ, are suspended in wastewater and subjected to solar illumination. The pesticides absorb sunlight and photo catalytically degrade organic pesticides into CO_2, H_2O, and HCl. Air is bubbled through the water to enhance the rate of degradation.

Current applications --
Using model compounds such as phenol and chlorinated hydrocarbons, this technique of pesticide degradation has only been studied in a laboratory environment with application oriented towards energy conversion. This technology would be subject to RCRA if used under certain conditions such as with underground ponds. There is a possibility that above ground treatment would not be subject to RCRA. This technology could also be used with a solar photoreactor to treat pesticide wastes within a very short time.

Advantages, Disadvantages, and Key Points --
The advantages of this technology are that it is relatively simple, passive system with high quantum efficiency that can sensitize to visible light using simple no toxic photocatalysts (TiO_2 & Fe_2O_3). There are no intermediate residues as it takes the pesticide waste all the way to CO_2. This technology can be used in present holding ponds and may be combined with artificial UV sources.

The disadvantages include a lack of knowledge on the effect of dirt and the effectiveness for insoluable pesticides. Also unknown are the consequences of cloudy and/or rainy days on the process of degradation.

One application is to incorporate heterogenous photo catalysts into existing holding/evaporation ponds. From the user's viewpoint this approach would be a relatively non-complex approach as an add-on to existing holding/evaporation pond technology.

Status and Cost --
This technique is currently in the research stage but could be implemented without a great deal of difficulty. The capitol and operating costs are unknown however expected to be very low. If this technology is used as an add-on to existing holding/evaporation pond, the cost may be negligible.

Research Needs -

1. Conduct lifetime studies of photocatalysts.

2. Conduct laboratory studies using real pesticides.

3. Study the effects of mixed semiconductors.

4. Study the effects of artificial UV (lamps) in UV-ozonation system.

5. Study the effects of particle size with technique.

6. Develop a scale-up project for demonstration.

7. Determine pesticide degradation rates in existing systems.

8. Study the effects of turbidity in ponds using this technology.

Chemical Degradation

Several chemical means are used for degradation of pesticide wastes. These chemical techniques are used to either detoxify or decompose the selected waste and may also serve as a pretreatment for further pesticide waste . Existing chemical degradation technology include: gas phase methods, liquid phase methods, chemical fixation, and catalytic liquid phase methods. The methods/techniques described at the workshop were UV-Photolysis, chemical oxidation, hydrolysis and activated carbon.

Current Applications --

Few applicators use this technology because of the considerable capital expense required for those specific techniques which have been researched. All of the chemical methods appear to be more expensive than physical treatment or/and disposal. These methods are being used for industrial waste clean-ups and spills. This technology may be acceptable to EPA under RCRA permits for treatment.

Advantages, Disadvantages, and Key Points --

This technology is chemically predictable with some data available on certain pesticide wastes. Other advantages are easily monitored, technically simple, mobile, can rapidly degradate wastes, and relatively foolproof in operation.

Disadvantages are that the technology is not applicable to all pesticide wastes (particularly mixed wastes), treatability needed, and directions must be cookbook style for the user. Reactions can be violent and chemicals and sludges may be hazardous. This technology may not be an ultimate disposal and products may be toxic.

The user must be educated in the use and the system must be safe and user friendly. A key viewpoint for the user and regulator is that an ultimate disposal must be arranged.

Status and Cost --
This technology is available, however, the costs are generally greater than the small quantity pesticide user can economically afford. Less expensive chemical treatment technique may be developed which will be more suitable to pesticide waste rinseates from the farm.

Research Needs --
1. Determine destruction specifications for each pesticide.

2. Address practices for the disposal of sludges and treated effluent.

3. Develop cost and user data at existing site demonstration.

4. Develop a user's manual for education of technique, cost estimation and equipment information.

5. Evaluate as a pre-treatment step.

WORK GROUP B, BIOLOGICAL TREATMENT AND LAND APPLICATION

Evaporation, Photodegradation and Biodegradation in Containment Devices

This technology is described as the treatment of dilute pesticide rinsewaters by evaporation, photodegradation and/or biodegradation. Treatment is conducted in containment devices, either above ground or in-ground. The treatment process of evaporation has the objective of reducing the liquid and solid pesticide waste to a sludge for ultimate disposal by the conversion of much of the waste into a vapor. In connection with or through separate treatment, photodegradation treats the pesticide wastes by means of radiant energy, especially light. Evaporation and photodegradation occurs on or near the surface of the wastes, however the biodegradation can occur throughout the treatment process as the chemical breakdown of pesticides by microorganisms, enzymes, plants and other subcellular systems. Reactions such as oxidation, reduction and hydrolysis result to degrade waste pesticides to the ultimate products of carbon dioxide, water and salts.

Current Application --
This technology is being used by universities and other research facilities to treat wastes, but it is not widely practiced. Several reasons for this lack of application are the unknowns such as the potential for the treatment to further produce hazardous wastes, uncertainty of the science and the product results and lack of understanding of the treatment process on specific pesticides.

Advantages, Disadvantages and Key Points --
The advantage to these treatment options is these technologies are passive and should not require heavy economic investment.

A major disadvantage considering the use of various containment sites is the potential for leakage which may require considerable monitoring to comply with RCRA.

Status and Cost --
The technology is readily available, but the extent of use depends on regulatory acceptance. Capacity of the containment system depends on physical dimensions, climatic conditions, and the pesticides involved. Capital costs of $10,000 plus were projected with minimal operating costs. However, lower capital cost would be required for smaller scale systems.

Research Needs --

1. Develop improved structural designs and containment facilities.

2. Study the wastes characteristics during the chemical, physical and biological processes.

3. Identify chemical degradation products.

4. Determine methods for enhancement of evaporation.

5. Study the optimization of degradations by the addition of supplements; research of volume, surface areas, media, etc.

Genetically Engineered Products

Genetically engineered products are described as including (1) recombinant microorganisms (living) and their products (non-living) (2) naturally occurring organisms manipulated by man, and (3) microorganisms and plasmids produced by any methods other than DNA recombinant techniques.

Current Applications --
Most of the genetic engineering options are in various stages of theoretical, experimental, and developmental processes.

Advantages, Disadvantages, and Key Points --
This technology is not yet a practical option because of its unavailability; however, expected advantages include flexibility, uniqueness, and economical aspects.

The disadvantage in the case of living transformants is that their environmental fates are not known. At this point there is too much unknown for reproducibility and practical applicability. To be acceptable as an option, there needs to be public education to generate confidence and better clarification on the nature of genetically engineered products.

Status and Cost --

Costs and capacity are not available yet in some cases the technology should be economical. For non-living products and naturally occurring organisms, availability may be 1-3 years away. For living transformants utilization, expected availability is over 5 years away.

Research Needs --

1. Address envrionmental fates.

2. Address environmental and laboratory stability.

3. Develop methods for containment and destination of organisms.

4. Determine innovative application of genetic engineering technology.

5. Evaluate environmental hazards.

Leach Fields

This field-sited method is currently being utilized on an individual basis to treat and dispose of dilute pesticide wastewater. Rinses and spills are channeled into a leach field rather than collected for other treatment or allowed to runoff into surrounding surface water. Leach lines are generally two to four feet below grade and within the field operations.

Current Applications --

This technology is widely used by small fruit farms in the state of New York.

Advantages, Disadvantages, and Key Points --

This technology is of low cost to the operator and is currently being used as an easily maintained multipurposed method to collect and treat pesticide wastewater.

The obvious disadvantage of this technology is that its operation is not isolated from the groundwater. The soil conditions, site choices, drainage, and climate are very critical to the successful operation and the site is not mobile.

Status and Cost --

This technology is available and can be ready for use within 1 - 2 weeks, serving continuously depending on weather and spraying operations. The capital cost is minimal with the operating cost being negligible.

Research Needs --

1. Demonstration of safety and efficiency by monitoring existing systems.

2. Gather of existing data.

3. Evaluation of fate and transport according to various site conditions.

Acid and Alkaline Trickling Filter Systems

Pesticide wastewater is recirculated through either an acidic or alkaline filtration medium and the pesticide is treated by a combination of chemical and biological methods. The acidic or alkaline filtration medium facilitate chemical hydrolysis, and microorganisms attached to the medium biodegrade the pesticide.

Current Applications --

Trickling filters are a proven technology for treating a variety of municipal and industrial wastewaters. However, the proposed modification to enhance hydrolysis of pesticide is a new concept in the experimental stage. Facilities for conducting this research have been installed on the Southern Illinois University - Carbondale campus. Dilute and concentrated solutions of wastewater containing triazines, dinitroanilines and methyl-carbonates have been studied in both filtration systems with encouraging results.

Advantages, Disadvantages and Key Points --

This system is projected to be relatively inexpensive and uncomplicated. Operators could be easily trained and the system can be sized according to need. Research to date indicates the system would effectively treat the most commonly used herbicides and insecticides in Illinois and no further disposition of residue is required. The system probably has a wide range of use.

However, there has been a persistance of triazines in the alkaline systems and the infiltration rate through the acidic medium is low. The recirculating pumps must be constructed of non-corrodable material and products of degradation and pump life are unknown.

The key points of this technology is the alkaline system is easy to maintain while the acidic system is somewhat more difficult. This technology has the potential of a wide range of use and space requirements are directly related to the volume of wastewater generated.

Status and Cost --

This is an emerging technology which could be available in 3 to 5 years following successful research and development. Capital and operating cost are estimated at $6,000 and 2,500/year, respectively.

Research Needs --

1. Identify products of degradation.

2. Characterize and quantify emissions.

3. Evaluate the treatment of a broader spectrum of pesticides.

Organic Matrix Absorption and Microbial Degradation

The pesticide contaminate is absorbed onto an organic matrix (phase 1, concentration and containment phase) which is then biodegraded in a nutrient-enriched composting environment (phase 2, degradation/product neutralization).

Current Applications --

This combination of technologies is not presently being employed. However, the elements are being used to treat pesticide wastewater to some extent. As discussed earlier, granular carbon adsorption is being used by the Army and is being evaluated in the State of California. This is pertinent since activated carbon would be a possible alternative for the organic matrix adsorption phase.

Biodegradation is an important mechanism for treating pesticide wastewater in containment devices which have been operated at Iowa State University and the University of California Field Station for many years. Composting is a proven technology for treating other types of wastes, particularly municipal waste.

Advantages, Disadvantages and Key Points --

This system could be divided into two modules (one from each phase). The module for the phase 1 process could be moved from site to site with the concentrated pesticide on the organic matrix being treated at a central location (phase 2). In addition, it is compatible with certain other treatment alternatives such as engineered organisms and granular carbon adsorption (i.e., disposal of spent carbon). It is expected to be relatively uncomplicated and foolproof.

However, this system is in the early development stage and needs to be evaluated and proven before it could be applied to the treatment of dilute pesticide wastewater.

The key points of this system is it would be capable of treating a wide range of pesticide concentrations, the required operating skills could be met by people mormally employed by certified applicators, the cost are expected to be relatively low and the system promises to effectively contain and destroy the pesticide contaminant.

Status and Cost --
The system is an emerging technology which could be available in 3 to 5 years following successful research and development. Capital and operating costs are not available.

Research Needs --

1. Evaluate the biodegradability of pesticides in a composting environment and identify the products of degradation.

2. Compare below and above ground composting pits.

3. Evaluate candidate organic matrices.

4. Conduct bench- and pilot-scale studies with real wastewater containing mixtures of pesticides.

5. Perform field demonstration studies.

6. Develop field monitoring techniques.

Evaporation and Biological Treatment With Wicks

Wastewater is wicked onto a large surface area and treated by a combination of biological degradation and evaporation.

Current Applications --
Wicks are currently being used to absorb oil for oil spill control and incineration of wicks has been tested. Wicks are not currently being used for wastewater treatment.

Advantages, Disadvantages and Key Points --
The advantages of this system include extreme simplicity (there are no mechanical parts), very low capital and operating costs, zero discharge, ease of operation, above ground operation (minimizes groundwater contamination potential) and mobility.

However, further development is required to protect this system from extreme weather and rainfall. Evaporation might have to be assisted by mechanical means in some geographical regions and it requires a relatively large area which might be considered unsightly by some. The wicks would have to be replaced on some frequency and expended wicks might have to be disposed as hazardous waste.

The key points of this approach is it is very simple to operate. There are no effluents to monitor and no permanent structures or underground tanks are required. The system can be designed for aerobic and/or anaerobic degradation of the pesticide.

Status and Cost --

This technology is in the experimental stage and availability will depend upon the rate at which this research is pursued. The capacity ranges from 1 to 3 gal per day per square yard of wick material. However, this can be increased through the use of fans and heat. Capital and operating cost are not available. However, operating cost are expected to be very low and the wick material cost ranges from 1 to 2 dollars per square yard.

Research Needs --

1. Determine wick life.
2. Assess air emission.
3. Determine degree of biodegradation achieved on the wick.
4. Evaluate disposal options for expended wicks.
5. Evaluate system performance via pilot-scale studies.

APPENDIX A

MOST COMMONLY USED PESTICIDES IN AMERICAN AGRICULTURE

TABLE A-1. MOST COMMONLY USED INSECTICIDES IN AMERICAN AGRICULTURE

	Common Name	Trade Name
1.	carbaryl	Sevin
2.	carbofuran	Furadan
3.	chlorpyrifos	Dursban
* 4.	methyl parathion	Penncap
* 5.	parathion	Folidol
6.	phorate	Thimet
7.	synthetic pyrethroids	many
8.	turbufos	counter
* 9.	toxaphene	Alltox
10.	malathion	Cythion

TABLE A-2. MOST COMMONLY USED HERBICIDES IN AMERICAN AGRICULTURE

	Common Name	Trade Name
1.	alachlor	Lasso
2.	atrazine	AAtrex
3.	butylate	Sutan
4.	trifluralin	Treflan
5.	metolachlor	Dual
6.	cyanazine	Bladex
* 7.	2,4-D	many
8.	metribuzin	Sencor, Lexone
9.	propanil	Stam
10.	bentazon	Basagran

*Identified as a hazardous constituent by RCRA

APPENDIX B

LIST OF ATTENDEES

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APPENDIX C

AGENDA FOR JULY 30, 1985

RESEARCH WORKSHOP ON THE TREATMENT/DISPOSAL
OF PESTICIDE WASTEWATER GENERATED
BY THE AGRICULTURAL APPLICATION OF PESTICIDES
Auditorium, AWBERC, Cincinnati, Ohio

AGENDA

Time	Description	Presenter
8:00 - 8:30	Registration	
8:30 - 8:40	Welcome	Mr. Francis T. Mayo
8:40 - 9:00	Status of Regulatory Development for the Treatment/Disposal of Dilute Pesticide Wastewater	Mr. Raymond F. Krueger
9:00 -11:55	SESSION A, PHYSICAL/CHEMICAL TREATMENT AND RECYCLING	Dr. Philip C. Kearney
9:00 - 9:20	Practical System to Treat Pesticide-Laden Wastewater Generated by Applicators	Mr. David W. Mason
9:20 - 9:40	Pesticide Rinsewater Treatment	Dr. Phillip Antommaria
9:40 -10:00	Treatability Studies of Pesticide Wastewaters by Granular Activated Carbon, Hydrolysis, Chemical Oxidation, and UV-Photolysis	Mr. Louis J. Bilello
10:00 -10:15	BREAK	
10:15 -10:35	Pesticide Rinsewater Recycling Systems	Mr. A.G. Taylor
10:35 -10:55	Pesticide Waste Disposal	Mr. Darryl Rester
10:55 -11:15	UV-Ozonation in Pesticide Wastewater Disposal State-of-the-Art, Technology Transfer and Research Needs	Dr. Philip C. Kearney
11:15 -11:35	Description of a Small Automated Fluidized Bed Combustor System and its "Potential" for the Incineration of Pesticide Waste/Wastewater	Dr. Harold M. Keener
11:35 -11:55	Removal of Pesticide Wastes via a Photo-electrochemical Solar Approach	Dr. A.J. Nozik

11:55 - 1:15	LUNCH	
1:15 - 4:10	SESSION B, BIOLOGICAL TREATMENT & LAND APPLICATION	Mr. Francis T. Mayo
1:15 - 1:35	Disposal of Dilute Pesticide Wastes by Evaporation and Biodegradation Using Concrete Pit Systems	Dr. Charles V. Hall
1:35 - 1:55	Disposal of Aqueous Pesticide Wastes at University of California Agricultural Field Stations	Mr. Wray Winterlin
1:55 - 2:15	On-Site Pesticide Disposal at Chemical Control Centers	Dr. Terry D.Spittler
2:15 - 2:35	Biological and Chemical Disposal of Waste Pesticide Solutions	Dr. Brian P. Klubek
2:35 - 2:50	BREAK	
2:50 - 3:10	Disposal of Dilute and Concentrated Agricultural Pesticide Formulations Using Organic Matrix Absorption and Microbial Degradation	Dr. Donald E. Mullins
3:10 - 3:30	Toxic Substance Solvent Evaporator	Mr. Robert W. Claunch
3:30 - 3:50	Microbial Degradation of Pesticides	Dr. Fumio Matsumura
3:50 - 4:10	Phanerochaete Chrysosporium: Its Potential Use in the Biological Degradation and Disposal of Agricultural Chemical Wastes	Dr. John A. Bumpus

4:10 - 4:30	Explanation of Next Day's Agenda	Mr. Francis T. Mayo
4:30 - 5:00	Questions and Answers Concerning the Regulatory Aspects of Pesticide Wastewater	Mr. Raymond F. Krueger and Mr. Matthew Straus
5:00	ADJOURN	

APPENDIX D

AGENDA FOR WORKGROUP A ON JULY 31, 1985

PHYSICAL/CHEMICAL TREATMENT & RECYCLING
(Room 120/126, AWBERC, Cincinnati, Ohio)

Time	Description	Presenter
8:15 - 8:30	Finalize Sub-Work Group Members and and Leaders, Explain Objectives, and Convene in Sub-Work Groups	Dr. Philip C. Kearney
8:30 - 9:30	Sub-Work Group Meetings, Development of Initial Findings and Recommendations	Sub-Work Group Leaders
9:30 - 9:45	BREAK	
9:45 -11:45	Presentation, Discussion and Approval of Sub-Work Group Findings and Recommendations to Each Work Group	Dr. Philip C. Kearney and Sub-Work Group Leaders
11:45 - 1:00	LUNCH	

WORK GROUPS A & B RECONVENE TOGETHER IN AUDITORIUM AT 1:00 P.M.

Time	Description	Presenter
1:00 - 1:30	Summary of Work Group A Findings and Recommendations	Dr. Philip C. Kearney
1:30 - 2:00	Summary of Work Group B Findings and Recommendations	Mr. Francis T. Mayo
2:00 - 2:15	Conclusions & Adjournment	Dr. Philip C. Kearney and Mr. Francis T. Mayo

APPENDIX E

AGENDA FOR WORK GROUP B ON JULY 31, 1985

BIOLOGICAL TREATMENT & LAND APPLICATION
(Room 130/138, AWBERC, Cincinnati, Ohio)

Time	Description	Presenter
8:15 - 8:30	Finalize Sub-Work Group Members and Leaders, Explain Objectives, and Convene in Sub-Work Groups	Mr. Francis T. Mayo
8:30 - 9:30	Sub-Work Group Meetings, Development of Initial Findings and Recommendations	Sub-Work Group Leaders
9:30 - 9:45	BREAK	
9:45 -11:45	Presentation, Discussion and Approval of Sub-Work Group Findings and Recommendations to Each Work Group	Mr. Francis T. Mayo and Sub-Work Group Leaders
11:45 - 1:00	LUNCH	

WORK GROUPS A & B RECONVENE TOGETHER IN AUDITORIUM AT 1:00 P.M.

Time	Description	Presenter
1:00 - 1:30	Summary of Work Group A Findings and Recommendations	Dr. Philip C. Kearney
1:30 - 2:00	Summary of Work Group B Findings and Recommendations	Mr. Francis T. Mayo
2:00 - 2:15	Conclusions & Adjournment	Mr. Philip C. Kearney and Mr. Francis T. Mayo

APPENDIX F

WORK GROUP A, PHYSICAL/CHEMICAL TREATMENT & RECYCLING

Sub-Work Group	Members
1. Pesticide Rinsewater Recycling	A.G. Taylor* Donald Paulson Eugene Speck Darryl Rester
2. Granular Carbon Adsorption	Phillip Antommaria* Joan McCaffery Kenneth A. Dostal Hyung-Yul Cho George W. Rambo
3. UV OZonation	Phillip C. Kearney* Mark L. Bruce James N. Seiber Shri Kuhlkarni William Keane
4. Small-Scale Incineration	Harold Keener* Donald Oberacker Ray Krueger James Bridges Roy Detweiler
5. Solar Photodecomposition	A.J. Nozik* Phillip C. Kearney Shri Kuhlkarni Mark L. Bruce James N. Seiber
6. Chemical Degradation	Lou Bilello* Jim Pritchard Cal Blystra Ed Raleigh

*Sub-Work Group Leader

APPENDIX G

WORK GROUP B, BIOLOGICAL TREATMENT & LAND APPLICATION

Sub-Work Group	Members
1. Evaporation, Photodegradation and Biodegradation in Containment Devices	Charles Hall* Matthew A. Straus John A. Bumpus Wray Winterlin Harold Collins Thomas Gilding Dennis Redington
2. Genetically Engineered Products	Fumio Matsumura* Ian L. Pepper Don Tang Richard Taylor Orlo Ehart James V. Parochetti
3. Leach Fields	Terry D. Spittler* Ronald Ney Robert Morgan
4. Acid and Alkaline Trickling Filter Systems	Brian P. Klubek* Catherine Schmidt
5. Organic Matrix Absorption and Microbial Degradation	Donald E. Mullins* David Watkins Charles Earhart, Jr. Jimmy W. Worley Roderick Young Richard Hegg Glen H. Hetzel
6. Evaporation & Biological Treatement with Wicks	R.W. Claunch* Clyde R. Dempsey

APPENDIX H

SUB-WORK GROUP SUMMARY SHEET

Instructions

Sub-Work Groups have been organized by technology or groups of technologies to develop initial recommendations concerning the application of that technology(s) to the treatment/disposal of dilute pesticide wastewaters which can be operated at or near the farm. These recommendations will then be presented to the full Work Group for discussion, modification and approval.

Each Sub-Work Group is to summarize their recommendations for each technology on this form.

Briefly Describe Technology: ____________________

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Check Most Appropriate Box:

____ Technology is currently being utilized on a commercial basis to treat and dispose of dilute pesticide wastewater.

____ Technology is being utilized commercially to treat other types of waste and offers promising opportunities for pesticide wastewater.

____ Technology is not being utilized commercially but experimental data indicates it is a promising opportunity for pesticide wastewater.

State-of-the-Art Capabilities

Current Application(s): ____________________

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Regulatory Status (i.e., Indicate where this technology has received state approval to treat pesticide wastewater): ____________________

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Capacity: ____________________

Capital Cost: ____________________

Operating Cost: ____________________

Availability or Expected Availability (i.e., delivery date): ____________________

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Advantages (i.e., mobile, technical uncomplicated, failproof, etc.): ____________________

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Disadvantages (i.e., environmental shortcomings, durability, reliability, range of use, etc.): ____________________

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Key Points From Both the User and Regulator Viewpoint: ____________________

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Research Needs

Identify the data gaps that need to be addressed for this technology to be utilized for the treatment and disposal of dilute pesticide wastewater. Limit consideration to those questions that can be answered in a 3 to 5 year time frame:

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Sub-Work Group Members:

Leader ______________________________

Members: ______________________________

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