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(3) Wear rubber gloves while handling containers of POISON pesticides.

(4) DO NOT put your fingers to your mouth or rub your eyes while working

(5) Wash your hands before eating, smoking or using the toilet. Also wash immediately after loading, unloading or transferring a shipment of POISON pesticides.

b. *Five rules for working safely*

(1) Inspect containers of POISON pesticides for leaks before handling them.

(2) DO NOT mishandle containers and thereby create emergencies by carelessness.

(3) If a leak or spill of POISON pesticides does occur, keep people away and report it immediately to your supervisor.

(4) DO NOT store pesticides next to food or other articles intended for consumption by humans or animals.

(5) After POISON pesticides have been unloaded, inspect vehicle for contamination. DO NOT release a contaminated vehicle.

6. **Fire and Explosion Hazards**

Pesticide formulations may be highly flammable or explosive. Oils burn readily and are usually stored in drums or glass containers. The containers may rupture or explode when overheated. Aerosol containers will explode when overheated. Many pesticides are highly flammable. Finely divided dusts may ignite about as easily as gases or vapors. Chlorates present in some herbicides are flammable and explosive. Partially empty chlorate containers should *not* be stored.

Fires in pesticide storage areas can be very dangerous, since they add the possibility of poisoning to the usual fire hazards. The water or chemicals used to fight the fire, if not handled properly, could spread contamination over a wide area. The heat of the fire or air currents created by the fire can vaporize certain pesticides and cause particles to become airborne. Also, the toxicity and hazard of many pesticides burning together in the same fire are unknown. Smoke or fumes may be phytotoxic as well as highly toxic to firefighters and residents.

The following suggestions will help reduce hazards caused by fire:

a. Plainly label the outside of each storage area on all sides with "DANGER," "POISON," "PESTICIDE STORAGE." Consult with the local fire department on possible use of the hazard signal system of the National Fire Protection Association.

b. Post a list of the types of chemicals on the outside of the storage area.

c. Inform the fire department, hospitals, public health officials and the police department, in writing, of the nature, quantities and hazards these compounds may present in the event of a fire. If some products should not be contacted by water, these should be segregated and marked. A floor plan of the storage area indicating where the different pesticide classifications are stored should be provided to the fire department. The plan should not be changed without notice to the fire department. Ask the fire chief to inspect your facility at least once a year.

d. Keep the above officials informed by letter and telephone of any major change in the nature, quantities and hazards that those compounds may present in the event of fire.

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e. The fire chief should be furnished with the home telephone number of the persons responsible for the pesticide storage facility.

Firemen should be instructed to:

a. Wear air-supplied breathing apparatus and rubber clothing when fighting pesticide fires.

b. Avoid breathing or otherwise contacting toxic smoke and fumes.

c. Wash completely as soon as possible after an encounter with smoke and fumes.

d. Wash clothing, boots and other equipment thoroughly after such a fire.

e. Take cholinesterase tests after fighting a fire involving organophosphate pesticides if they have been heavily exposed to the smoke.

f. Evacuate persons near such fires who may likely come in contact with smoke and fumes or contaminated surfaces.

g. If possible, water from the fire-fighting operation should be impounded.

7. Monitoring

A vital component of the safe operation of any type of storage facility is the establishment of an adequate monitoring system. Since pesticides managed in a storage site are present in higher concentrations than normal use, the risk of environmental contamination is also higher. Samples of the various parts of the system and of the surrounding air, water, soil, wildlife and plant environment must be analyzed in a regular program to make certain that no risk is present.

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RESEARCH SUGGESTIONS

As can be seen from the foregoing, many of the questions regarding proper collection, storage and disposal of surplus pesticides, unused pesticides, pesticide wastes and pesticide containers remain unanswered. Basic and applied research should in time provide most of the answers; to point the way to the most needed research the following is provided:

1. Alternate uses for pesticides in surplus supply presently restricted or banned in some states

2. Recycling of pesticides and pesticide concentrates

3. Chemical, biological and thermal methods of pesticide detoxification (with special emphasis on incineration research)

4. Effects of long-term storage of pesticides as they may create potential hazards of environmental pollution

5. Manufacture of packages and containers that are combustible, including aerosol containers (Emphasis should include combustible plastic containers)

7. Recycling techniques for 5-gallon and larger sizes of pesticide containers

8. A lock or other device to preclude container refilling by other than authorized persons

9. Soil characteristics and specifications for disposal in soil

10. Effective methods to provide continuing motivation to persons to bring in and properly dispose of surplus pesticides and containers

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PRESIDENT'S CABINET COMMITTEE ON THE ENVIRONMENT
SUBCOMMITTEE ON PESTICIDES

Date: November 17, 1970
Reply to Attn of: CS-22

Subject: Emergency Program, USDA-FS-70-10E

To: Files

1. On Friday, November 13, 1970, five emergency projects were received by messenger from Mr. [redacted] Forest Service, USDA.
b6

2. The projects were:

a. For the protection of conifer seed from small rodents and birds by aerial (helicopter) application of seed treated with 1 lb. of endrin, 2 lbs. of Arasan and ½ lb. of green dye per 100 lbs. of seed, seed sown at the rate of ½ to 1 lb. of seed per acre, with a resultant toxicant spread of .0025 to .005 lb. endrin per acre and .005 to .01 lb. Arasan per acre. Application to be made over 76 areas, a total of 2,984 acres of forest lands in the Siskiyou, Siuslaw, Snoqualmie, Umpqua, Wallowa-Whitman and Willamette National Forests in Oregon and Washington. Buffer strips of 1/8 mile will be maintained along live streams; program clearance will be obtained from the State Departments of Game, Health and Environmental Quality; and areas will be monitored for any effects on nontarget species. Application to be made in the fall of 1970.

b. For the control of small rodents by using either hand placed or aerial (helicopter) application of a 1080/grain bait over the same areas as in "2.a." above, with similar precautions and coordination. Hand placed bait to be formulated 2 oz. toxicant per 100 lbs. grain and spread at the rate of ½ to 2.5 lbs. per acre, and the aerial bait, 10 oz. toxicant per 100 obs. grain and spread ½ lb. per acre, with a resultant spread of .0025 to .0031 lb. of 1080 per acre. Application in fall of 1970 and spring of 1971.

c. For the control of the pine bark beetle (round-headed pine beetle) in an outbreak, by treating individual trees with a low-pressure sprayer using a 0.5% solution of ethylene dibromide. 1,100 trees on 160 acres of the Coronado National Forest, Arizona, to be treated in November 1970. Human exposure will be avoided by supervising treating crews and by requiring that protective clothing be worn. Infested trees around Riggs Lake will be pulled back 100 yards before treating.

d. For the control of *Dioryctria amatella* in an outbreak, by treating individual trees with a low-pressure hydraulic sprayer using dimethoate, 3 pints of the 30.5% emulsifiable concentrate in 100 gallons of water, resulting in 2 lbs. a.c. per acre. 4,500 seed orchard trees on 45 acres of the Beech Creek Seed Orchard, Murphy, North Carolina,

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to be treated in November 1970. Human exposure will be avoided by a pest control entomologist supervising treating crews and by requiring that protective clothing be worn. This is a pilot control test. Dimethoate is not registered for use against this insect; however, the American Cyanamid Company has applied for a temporary permit. Forest Service entomologists will collect data on the insecticide's effectiveness against this insect.

e. For the control of vegetation by treating the 6-foot radius around individual power poles with a cyclone seeder/spreader using borax (Ureabor) pellets at the rate of 3/4 lb. a.i. per power pole. 1,500 power poles in the Umatilla National Forest in Oregon and Washington to be spot treated in November 1970. Human exposure will be avoided by using trained crews and supervision by the Pacific Power and Light Company. The borax pellets will be incorporated into the soil.

3. The following members of the Working Group were called:

Mr. [redacted] DOD	Dr. [redacted] USDA
Dr. [redacted] DHEW	Mr. [redacted] USDI (for Dr. [redacted])
Mr. [redacted] DOT	Mr. [redacted] D/State

b6

4. There were no objections raised to these projects; however, Mr. [redacted] b6 consistent with his opinion of 1080, did not specifically approve the 1080 application. Mr. [redacted] was notified on Monday, November 16, 1970, that the Working Group had no objections to the projects.

[redacted] b6

Assistant Executive Secretary
Working Group

cc:
Working Group
Program Review Panel

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Smith said this would not be true if the dating were extended to non-perishable categories such as canndd foods. If such a system were introduced, he continued, housewives would almost without exception select the most recent date and push the earlier ones to the back of the shelf so that eventually the very spoilage about which concern is expressed could occur and would occur on a far broader basis than is now the case.

He said that most canned foods clear grocers' shelves well within an 18-month period from the date of pack, which compares "very favorably" with the minimum time specified by the military for purchases which frequently and of necessity cannot be handled and stored at temperatures under as ideal circumstances as would happen if the product were in regular wholesale and retail distribution channels.

CANADA ANNOUNCES REVIEW OF SOME PESTICIDE USES

The Canadian Department of Agriculture has announced that it will re-evaluate a number of insecticides, herbicides, and fungicides as to their acceptability for registration under the Pest Control Products Act.

The Plant Products Division of the Production and Marketing Branch invited comments by Feb. 1, 1971, on the following pesticides that are to undergo review:

Endosulfan, carbaryl, malathion, diazinon, asinphos methyl, dicofol, chlorobenzilate, Perthane, Strobane, calcium arsenate, lead arsenate, captan, thiram, folpet, metiram, 2,4,5-T, 2,4-D, fenoprop, and arsenical herbicides (including disodium methyl arsonate, octyl and dodecyl ammonium methyl arsonates, monosodium acid methane arsonate and sodium arsenite).

Canada had previously revised its schedule of uses for methoxychlor, TDE, lindane, BHC, aldrin, dieldrin, heptachlor, endrin, chlordane, toxaphene, and parathion (See FOOD CHEMICAL NEWS, Aug. 3, Page 21), after announcing earlier in the year that it was reviewing the use patterns for these pesticides (See FOOD CHEMICAL NEWS, March 16, Page 13).

Department of Agriculture officials in this country have similarly been reviewing the use of pesticides, and have ordered a number of actions cancelling or suspending uses (See FOOD CHEMICAL NEWS, Aug. 31, Page 28).

Canada's Department of Agriculture also announced that it would no longer allow the use of TDE (DDD, Rhothane), as of Jan. 1, 1971, except at the discretion of the Minister of Agriculture and upon the advice of the Federal Inter-Departmental Committee on Pesticides for public health or plant quarantine purposes where no suitable alternative is available.

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In another announcement, the Plant Products Division invited comment by Sept. 30, 1970, on reevaluation of hexachlorobenzene (HCB) and quintozene (PCNB) for registration in 1971. The Trade Memorandum said that registration next year will be contingent upon demonstrated need for use and the submission of suitable toxicological and residue data to satisfy current criteria for registration.

A revision of the registration status of 2,4,5-T was also announced by the Plant Products Division, which pointed out that the use of the word "ditches" should be interpreted as meaning ditches draining into irrigation or potable water (See FOOD CHEMICAL NEWS, May 25, Page 31). The Trade Memorandum noted that it was the intention of the Department to prevent 2,4,5-T contamination of water used for drinking purposes or for irrigation of crops. Usually, the memo said, this would not mean ditches along railways or highways, where the use of 2,4,5-T is acceptable.

NIMAL DRUG EXEMPTION FOR APPROVED ANTIBIOTICS URGED

The Food and Drug Administration has been urged to revise its proposed administrative regulations under the New Animal Drug Law to exempt antibiotics which are already approved.

Concern over the need for clearance for antibiotics and complete feeds containing them was expressed in many of the comments filed last week on the FDA proposals (See FOOD CHEMICAL NEWS, May 18, Page 36).

The Animal Health Institute said that new clearances should not be required for antibiotics exempted from certification requirements under the antibiotic regulations (§144.24-§144.26). AHI said that if these must be covered, the requirements should "clearly be prospective in effect only, and all prior uses deemed approved . . . should continue to be governed by the antibiotic exemption regulations."

The proposed requirement for new clearances for the antibiotics was called "a patently erroneous application of the provisions of the Animal Drug Amendments, which were intended to codify existing clearance procedures and not impose new re-clearance requirements on products which were the subject of approvals at the time of the passage of the Act," the Institute said. The letter added, "This is not only clear from the legislative intent, but is also demonstrable when one takes into account how these products were treated under pre-existing statutory provisions, and the special provisions for these products built into the Animal Drug Amendments."

AHI said that in the past antibiotic premixes manufactured in conformity with the exemption regulations were not required to obtain approved New Drug Applications, and that finished feeds were not required to obtained approved Forms D-1800. "There can be no other conclusion than that these drugs were not deemed 'new drugs' by the Commissioner," AHI said, adding:

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21 OCT 1970

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From Dr [redacted] b6

DEPARTMENT of the INTERIOR

news release

FISH AND WILDLIFE SERVICE
Bureau of Sport Fisheries and Wildlife

For Release to PMs Thursday, July 2, 1970 — Carroll 343-5634

MERCURY FOUND TO BE ANOTHER ENVIRONMENTAL MENACE FOR BALD EAGLES

Add mercury to the list of environmental menaces for America's declining national bird--the bald eagle.

Interior Department scientists at the Bureau of Sport Fisheries and Wildlife's Patuxent Wildlife Research Center near Laurel, Md., have implicated mercury as a cause of death in bald eagles.

Four birds examined in a new mercury testing program at the Center contained residues of this heavy metal--two from Minnesota had lethal amounts of 130 parts per million (ppm) and 117 ppm in the kidneys. Autopsy findings and microscopic studies of the kidneys had pointed to heavy metal poisoning.

The other eagles, which had been shot in Wisconsin, had sublethal amounts in the kidneys--7.9 ppm and 7.7 ppm.

Dr. [redacted] b6 Assistant Secretary of Interior for Fish and Wildlife and Parks, announced that in the future all bald eagles examined at Patuxent Wildlife Research Center will be tested f r mercury. Most bald eagles found dead in the United States are sent here for study.

Dr. [redacted] b6 Director of the Research Center, believes the eagles are picking up mercury through the ingestion of fish. Mercury contamination of the Great Lakes already is causing serious concern; the Bureau is investigating the effects of heavy metals on the fish and wildlife in the Great Lakes and its tributaries.

Canada estimates that 250,000 pounds of mercury are deposited in the Great Lakes by Canadian industry each year. The United States' contribution may exceed 500,000 pounds annually.

Mercury and other heavy metals are exceedingly persistent in nature, remaining perhaps 50 to 100 years in stream and lake bottoms. Means of removal are still unknown, but the Bureau is seeking answers.

Another environmental menace for eagles is dieldrin pesticide. On June 5, Sport Fisheries and Wildlife announced that poisoning from dieldrin has been detected in growing numbers of bald eagles found dead in this country.

The national bird is declining in numbers in the United States, although no accurate estimate of the bald eagle population can really be made for these far-ranging birds.

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PENNWALT CORPORATION

900 FIRST AVENUE, KING OF PRUSSIA, PENNSYLVANIA 19406 · (215) 265-3200

Microencapsulated Methyl Parathion

The following is a brief account of preliminary effectiveness and toxicology results with methyl parathion encapsulated by the Pennwalt Corporation encapsulation process. Although capsule size can be varied, the average methyl parathion capsule size is about 50 microns.

Effectiveness -- Greenhouse screening and limited field tests have shown that by using encapsulated methyl parathion, fractions of a pound per acre can be applied to achieve control where commercial methyl parathion formulations fail to control. Put another way, longer insect control was achieved by using less methyl parathion than current practices of applying methyl parathion.

The crops and insects on which the methyl parathion capsules have been tested include: cotton boll weevil and bollworm; bean foliage (bioassayed utilizing crickets), gypsy moth, soybean heliothis, spider mites, and alfalfa weevils.

Approximately 300 pounds (active) of encapsulated methyl parathion is being field tested by a number of cooperators at the present time. All preliminary reports have been favorable.

Toxicology -- Results of toxicity studies carried out by Pharmacology Research, Inc., Darby, Pennsylvania, indicate significant safety advantages can be realized by applying encapsulated methyl parathion compared to present practices with commercial formulations (besides the important advantage of needing less insecticide for better control).

The acute oral toxicity of encapsulated methyl parathion in mice is about nine times less toxic than methyl parathion emulsifiable concentrate (compared in terms of equal active ingredient).

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Using the standard dermal toxicity test procedure on non-abraided rabbit skin, encapsulated methyl parathion was non-toxic up to 3 g. of capsules (75% active) per Kg body weight. According to the literature, 80% technical grade methyl parathion has a dermal LD_{50} of 300-400 mg/kg.

The capsule wall material (Nylon-type plastic) having the same composition as the capsule wall being used for methyl parathion was found to be nontoxic in the acute oral toxicity test. The largest dose was administered which could be given (4g/kg) without the possibility of causing viscoral trauma. No effects of any kind were induced and the animals (mice) thrived well after treatment.

Additional toxicology work is in progress to better define safety advantages.

21 OCT 1970

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U.S. ARMY

MEDICAL ENVIRONMENTAL ENGINEERING RESEARCH UNIT

EDGEWOOD ARSENAL, MARYLAND 21010

UNITED STATES ARMY

MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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13. ABSTRACT

The disposal of Department of the Army (DA) surplus pesticides of all types presents serious problems. Significant among the various types of pesticides are large quantities of organochlorine insecticides and phenoxy acid herbicides. Thermal degradation or ground deposition are the disposal methods with the greatest potential for handling large quantities of material in these categories. Chemical treatment has disposal potential for decontamination of empty pesticide containers. Recommendations are made concerning research to determine: methods for the small-scale disposal of all types of pesticides and empty pesticide containers generated during routine pest control operations at DA installations; thermal degradation temperatures for organochlorine insecticide and phenoxy acid herbicide formulations and degradation products; techniques hardware, and monitoring systems for incineration of organochlorine insecticides and phenoxy acid herbicides, including methods for the secondary disposal of ash and scrubbing liquids; criteria for the ground disposal of pesticides by deposition in a sanitary landfill or other special excavation, or by deposition in chemically- or biologically-active soils; methods for the decontamination and disposal of empty pesticide containers; and commercial pesticide disposal techniques and facilities that may have application to DA needs. (U)

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Chemical						
Container						
Disposal						
Herbicide						
Organochlorine						
Organophosphorous						
Pesticide						
Phenoxy Acid						
Thermal						

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AD

USAMEERU REPORT NO. 73-01

PROBLEM DEFINITION STUDY: EVALUATION OF HEALTH AND HYGIENE EFFECTS OF THE DISPOSAL OF PESTICIDES AND PESTICIDE CONTAINERS

BY [redacted]

CPT [redacted]

August 1972

3A062110A806/00/135

U. S. ARMY MEDICAL ENVIRONMENTAL
ENGINEERING RESEARCH UNIT
Edgewood Arsenal, Maryland 21010

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ABSTRACT

The disposal of Department of the Army (DA) surplus pesticides of all types presents serious problems. Significant among the various types of pesticides are large quantities of organochlorine insecticides and phenoxy acid herbicides. Thermal degradation or ground deposition are the disposal methods with the greatest potential for handling large quantities of material in these categories. Chemical treatment has disposal potential for some pesticides on a small-scale basis, and may have application in the decontamination of empty pesticide containers. Recommendations are made concerning research to determine: methods for the small-scale disposal of all types of pesticides and empty pesticide containers generated during routine pest control operations at DA installations; thermal degradation temperatures for organochlorine insecticide and phenoxy acid herbicide formulations and degradation products; techniques, hardware, and monitoring systems for incineration of organochlorine insecticides and phenoxy acid herbicides, including methods for the secondary disposal of ash and scrubbing liquids; criteria for the ground disposal of pesticides by deposition in a sanitary landfill or other special excavation, or by deposition in chemically- or biologically-active soils; methods for the decontamination and disposal of empty pesticide containers; and commercial pesticide disposal techniques and facilities that may have application to DA needs.

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INTRODUCTION

The Department of the Army (DA) operates a pest control program which dispenses large quantities of pesticides annually for the control of insects and rodents that affect military operations by acting as disease vectors, by reducing morale and efficiency, or by causing property damage. Large quantities of pesticides are stocked by DA to operate such a pest control program and to maintain combat readiness. The maintenance of these large pesticide stocks is unique to DA and other Department of Defense (DOD) organizations. By virtue of the quantities alone, unique problems exist concerning storage, replacement, and disposal of unserviceable DA pesticides.

OBJECTIVE

The objective of this study is to determine if adequate, environmentally-sound methods for the disposal of surplus DA pesticides and pesticide containers exist through establishing the requirement for the disposal of surplus pesticides; providing information concerning the probable magnitude of the surplus pesticide problem; providing information concerning environmental considerations in DA pesticide disposal activities; and providing information on the various methods of pesticide disposal and the present level of knowledge concerning each. If adequate methods do not exist, recommendations will be made as to where research is required to provide information which will permit DA agencies to dispose of surplus pesticides by methods which will produce minimum environmental impact.

THE PESTICIDE PROBLEM

Sources of Information. Information concerning the problem of surplus pesticides and their disposal was obtained as follows. Liaison was established and maintained with the following agencies to determine current policies and programs in the area of pesticide disposal: Defense Supply Agency; Department of the Army agencies; Department of the Air Force agencies; Department of the Navy agencies; The Armed Forces Pest Control Board; US Department of Agriculture; The Council of Environmental Quality through the Research Panel of the Working

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Group on Pest Management; and The Environmental Protection Agency. Computer searches of the literature pertaining to pesticide disposal were conducted by utilizing the following systems: Biological Abstracts; Smithsonian Institution (Scientific Information Exchange, Inc.); National Library of Medicine (MEDLARS System); Defense Documentation Center; and Armed Forces Pest Control Board (Military Entomology Information Service).

Department of the Army Surplus Pesticides. Certain pesticides in DA stocks are presently considered surplus for one or more of several reasons. Some pesticides have been procured in quantities in excess of DA requirements, while others cannot be immediately used for their intended purpose due to deterioration of the containers or due to degradation of the pesticides themselves. Still others, such as DDT (Department of Defense, 1970)[1], have had restrictions placed upon previously recommended usage, meaning that some pesticides, or specific formulations thereof, can no longer be used for any purpose. The problem of pesticide disposal within DA is twofold. First, there is the immediate need to dispose of relatively large surplus pesticide stocks and associated containers located at the depot level. Second, there is the recurring requirement for disposal of relatively smaller quantities of pesticides and empty containers generated by routine pest control operations at the local level.

Policy guidance has been provided by the Assistant Secretary of Defense, Health and Environment (Department of Defense, 1971)[2], concerning the disposal of surplus DA pesticides. The most desirable method of disposal is to utilize the surplus pesticides for their purpose within DA. This is particularly applicable to those pesticides which have been procured in excess quantities, provided such materials are still in sound containers, have not degraded, or have not had restricted usage imposed. Pesticides in deteriorated containers can be repackaged and used for their intended purpose. Pesticides which have degraded can still be used for their intended purpose, if the degree of degradation is not great enough to render them ineffective. Pesticides which cannot be utilized by DA, but which are still suitable for use, either as is, or after repackaging or determination of degree of degradation, can be transferred to other Federal agencies. Beyond this, consideration can be given to the donation of such surplus materials to other eligible agencies or sale to the general public. All surplus pesticides which cannot be disposed of by use, redistribution, donation, or sale will require destruction.

It is expected that it will be impossible to entirely dispose of DA surplus pesticide stocks by methods other than destruction. These ultimately requiring destruction represent a variety of pesticide types and formulations, but are primarily of the organochlorine type. The pesticides will be in large quantities and may be consolidated at several widely dispersed locations. Methods of destruction suitable for the disposal of large quantities of consolidated surplus pesticide stocks will not necessarily be the best methods for use at the local level.

Environmental Considerations in Pesticide Disposal. The National Environmental Policy Act of 1969 (NEPA) (Anonymous, 1970)[3] established a Federal policy concerning implementation of major actions which will significantly affect the quality of the environment. The NEPA requires, among other things, that Federal agencies provide detailed information concerning the environmental impact of intended actions. Guidance concerning environmental considerations in DA actions (Department of the Army, 1971)[4] supplements the NEPA and applies to all DA installations, activities and facilities throughout the world in requiring an assessment of the environmental consequences of any proposed action. An assessment is required even though a proposed action, such as the disposal of surplus pesticides by means other than for their intended use, will ultimately be beneficial to the environment.

The immediate problem, then, is to determine the most suitable method, or methods, for destruction of the various types of surplus DA pesticides which are located for the most part in large quantities at the depot level. The secondary problem is to determine the most suitable means of destroying pesticides and empty containers generated in small quantities at the local level. In each situation it is imperative to develop, through research, methods of disposal which will minimize environmental pollution and provide DA activities with precise and specific information concerning the environmental impact of a given disposal method, any adverse effects which cannot be avoided if a given method is utilized, the relationship between short-term adverse environmental effects and long-term enhancement of the environment, alternate methods of disposal, and any irreversible environmental effects which may occur as a result of the use of a given disposal method.

Magnitude of Surplus Pesticide Stocks. The immediate problem of pesticide disposal is concerned with the surplus stocks presently on hand. In order to establish certain priorities concerning research into the various methods of destruction, it is imperative to determine, at the earliest possible time, the specific types, and relative quantities thereof, of DA pesticides requiring destruction. Currently, the Defense Supply

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Agency (DSA) is in the process of disposing of surplus pesticides (Department of Defense, 1971)[2] by redistribution, donation, or sale. Until such time as the effectiveness of this program is known, it is difficult to obtain accurate qualitative and quantitative estimates of materials which will have to be destroyed.

DSA has provided guidance concerning pesticides that are likely to pose significant or controversial problems from the standpoint of disposal (Department of Defense, 1970)[5]. These materials include primarily organochlorine insecticides and phenoxy acid herbicides and are listed in Appendix A according to type of formulation and container size. Without reference to quantities involved, these are the pesticides most likely to require destruction when other methods of disposal have been exhausted.

METHODS FOR THE DISPOSAL OF PESTICIDES

A variety of methods are available for the destruction of organochlorine insecticides and phenoxy acid herbicides. Among these are ocean disposal, recycling, thermal degradation, ground disposal, chemical treatment, and biological treatment. Ocean disposal is not recommended because food chain organisms, many of which serve as food for the human population, are readily contaminated. General recycling of pesticides for other uses is not feasible, either because techniques are not available or because costs are prohibitive. Thermal degradation or ground disposal appear to be the most practical methods at present, although chemical or biological treatment warrant some considerations.

In considering the practicality of any disposal method, the specific pesticide types must be taken into consideration, as well as the proximity of surplus stocks to a potential disposal site. There is the additional problem of the disposal of pesticide and herbicide containers generated by disposal operations. Suitable methods for the disposal of empty containers will vary with the method developed for the disposal of the contents (i.e., thermal degradation, ground disposal, etc). Therefore, the problem of container disposal can be addressed concurrently with, or subsequent to, the development of methods for disposal of the pesticides themselves. The primary consideration in determining the best method, or methods, of destruction is, once again, the impact of such operations on the environment. Each pesticide, or group of pesticides, must be considered separately from the standpoint of quantity requiring destruction, specific destruction method, and environmental impact.

Thermal Degradation. Thermal degradation is a disposal technique whereby pesticides are thermally decomposed in a burner. Degradation products from pesticides depend on the specific type or formulation and may include HCl, CO, CO_2, SO_2, H_2S, NH_3, Cl_2, and various oxides of nitrogen. The use of this method requires carefully controlled conditions of temperature and contact-time, as well as some means of removing objectionable gases from the effluent. Consideration must be given to the secondary disposal of residues in scrubbing liquids and ash.

The literature contains various reports of work on the thermal degradation of pesticides. Two basic areas are of interest. The first concerns determination of thermal degradation or combustion products for various pesticides. The second concerns the incineration of pesticides in small laboratory, prototype, or full-scale burners of various types.

Kennedy *et al.* (1969)[6] reported that temperatures near 900°C resulted in complete incineration of both reagent-grade and commercial-grade samples of a wide variety of organochlorine, organophosphate and carbamate insecticides, and phenoxy acid herbicides. Stojanovic *et al.* (1970)[7] reported on the thermal degradation products of 16 different pesticides when they were exposed to temperatures ranging from 180 to 310°C. Within this temperature range, incomplete breakdown was observed for all materials, and a variety of breakdown products, some identified and others unidentified, were noted for each pesticide. For example, at 230°C dieldrin produced chlorinated benzoic and phthalic acids; at 250°C carbaryl produced 1-naphthal; at 250°C malathion produced diethy esters of succinic and maleic acids; at 275°C DDT produced DDE; paraquat at 310°C produced a mixture of paraquat and a variety of unidentified degradation products; and so on. Although these studies resulted in the detoxification of many of the pesticides, the results are inconclusive because all pesticides were not exposed to all temperatures and many of the degradation products were not identified. Additional studies reported by Stojonavic *et al.* (1969, 1970)[7,8] were concerned with the volatile products from burning (900°C) analytical-grade and commercial formulations of 20 different pesticides. In these studies many of the expected gaseous effluents were observed. However, for each pesticide many of the gases were not identified, making the studies inconclusive. It is interesting to note that, for each of the pesticides, analytical grade materials and commercial formulations did not produce the same complement of gaseous effluents. For example, at 900°C, analytical grade malathion produced CO, CO_2, SO_2, H_2S, O_2, and four unidentified gases, while the commercial formulation of malathion produced CO, CO_2 and three unidentified gases.

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Similarly, 2,4-D at 900°C yielded CO, CO_2, Cl_2, HCl, and O_2 when the analytical-grade material was used, while CO, CO_2, and three unidentified gases were produced by using the commercial formulation. In addition to the burning tests of single analytical-grade or commercial formulations (Stojonavic *et al.* 1969, 1970)[7,8], other studies reported by Stojonovic *et al.* (1970)[8] showed that combinations of pesticides produced gaseous complements different from those of the individual pesticides. For example, malathion and 2,4-D, when mixed and burned at 900°C, produced CO, HCl, H_2S, and six unidentified gaseous effluents. Thermal degradation of other specific pesticides has been reported. Brown *et al.* (1966)[9] listed thermal breakdown products for Bidrin and Azodrin, while Whaley *et al.* (1970)[10] listed 14 theoretical compounds resulting from the thermal decomposition of DDT.

Stojonovic *et al.* (1970)[8] reported on the evaluation of various commercial incinerators to determine their potential for meeting the following requirements: have primary and secondary combustion chambers; be capable of temperatures of ≥900°C; provide proper fuel-air combustion ratio and proper retention time; have a liquid and dust-handling capability; create turbulence sufficient for complete mixing of pesticides and fuel; be capable of handling large quantities; be resistant to corrosive and explosive chemicals; and be adaptable to various scrubbing mechanisms. A single commercial model, the CONSUMAT Model V-18 (Waste Combustion Corporation, Richmond, Virginia), was selected for testing, but eventually proved too large for laboratory evaluation of gaseous effluents. Therefore, a 1/3 scale model was designed for laboratory testing. A commercial formulation of malathion (containing 57% active ingredients, 30% aromatic petroleum, and 13% inert ingredients) was used as a test material, and various flow rates for pesticide, fuel (butane), and primary and secondary combustion chamber air supplies were studied to determine optimum operating parameters. CO_2 and SO_2 were the only effluent gases monitored during the studies.

Studies of the thermal destruction of DDT in an oil carrier were reported by Whaley *et al.* (1970)[10]. Complete combustion of DDT was achieved in "blue flame" laboratory incinerators. The chlorine component of DDT was reduced to hydrochloric acid gas which was removed from the effluent by alkali scrubbers. Design criteria were presented for commercial DDT/oil incinerators. Additional studies by Lee *et al.* (1971)[11] reported on the thermal destruction of DDT dusts in a pilot-scale incinerator. The DDT dust was blended with inert carrier dust and the residual product from complete combustion of DDT, hydrochloric acid gas, was removed from the effluent by water-alkali scrubbers. Basic cations in the inert dust were found to neutralize part of the hydrochloric acid gas. Design criteria were presented for commercial-scale DDT/dust incinerators.

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Montgomery *et al.* (1971)[12] have reported on the construction and operation of an incinerator specifically designed to decompose chlorinated hydrocarbons, including DDT. Putnam *et al.* (1971)[13] reported the use of oxidizing agents and binders to aid in the combustion of pesticides.

Research on the determination of combustion products of pesticides and the incineration of pesticides has continued at Mississippi State University under grants provided by the US Department of Agriculture and the Mississippi State Government. Work on the thermal degradation of pesticides has also been supported by US Department of Agriculture grants to Pennsylvania State University. Other on-going research in these areas was not elucidated in the literature search conducted.

Ground Deposition. A variety of methods are presently used for the disposal of pesticides by ground deposition; none of which are entirely satisfactory from the standpoint of environmental pollution. The basic drawback to this method of disposal is the inability to determine, let alone control, the ultimate fate of the pesticides. Deposition in sanitary landfills or other special excavations is seldom undertaken with adequate knowledge of the hydrologic and geologic situation involved, and the extent of translocation of the pesticides is not known. Deposition in a geologic stratum known to be impervious or inactive, access to which may be gained by means of a deep well below the existing aquifer, may preclude the problem of translocation, but really only involves the "storage" of pesticides, the ultimate fate of which cannot be known.

The degradation of pesticides subsequent to deposition is due to chemical or biological activities which take place in the soil, with the latter being the more significant. Considerable information has been published concerning the biological degradation (largely microbial) of pesticides. Two general areas are of interest: the biological degradation of pesticides *in vivo* as demonstrated by laboratory and field tests; and the isolation of microbial enzymes which are capable of degrading pesticides *in vitro*.

Biological degradation has been implied in many instances where the effects of soil on the decomposition of pesticides have been studied. In many cases biological activity is assumed because sterilized soils generally show a lower rate of degradation than non-sterilized soils; or because there is a period of time, following deposition of the pesticide, before significant degradation occurs. This latter phenomenon is generally considered a period of adaptation for the soil microorganisms. Various papers have reported these types of non-specific biological degradation in soil for a variety of pesticides

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as follows: microbial degradation of aromatic compounds (Gibson, 1968)[14]; degradation of diazinon and Zinophos® (Getzin, 1967)[15]; the interactions between soil-borne microorganisms and DCPA, a herbicide (Tweedy *et al.* 1968)[16]; biochemical transformations of anilide herbicides in soil (Bartha, 1968)[17]; decomposition of tordon herbicide in soils (Youngson *et al.* 1967; and Moffat, 1968)[18, 19]; biodegradation of benzene hexachloride in submerged soils (MacRae, 1967)[20]; the disappearance of pyrazon, a herbicide, from soil (Frank and Switzer, 1969)[21]; degradation of organochlorine insecticides by microbes (Chacko, 1966)[22]; decomposition of lindane in soil (Yule, 1967)[23]; degradation of dieldrin by soil microorganisms (Matsumura and Boush, 1967)[24]; accelerated degradation of herbicides in soil by the addition of microbial nutrient broths (McClure, 1970)[25]; transformation of solan, a herbicide, in soil (Bartha, 1969)[26]; microbial degradation of parathion (Griffiths and Walker, 1970)[27]; degradation of malathion in soil (Konrad, *et al.* 1969)[28]; and decomposition of carbaryl by a soil bacterium (Tewfik, *et al.* 1970)[29]. Getzin and Rosefield (1968)[30] reported the degradation of organophosphorous insecticides by heat-labile substances in the soil.

Other studies have identified specific microorganisms capable of metabolizing various pesticides. Murray *et al.* (1969)[31] reported studies of the degradation of urea herbicides by *Aspergilli niger*, *Aspergilli sydowi*, and *Aspergilli tamarii*. Bollag *et al.* (1967)[32] reported the ability of *Flavobacterium perigrinum* and *Arthrobacter* sp. to degrade the herbicide, MCPA. The ability of *Pseudomonas* sp. to degrade another herbicide, TCA, was shown by Kearney *et al.* (1969)[33]. Bollag and Alexander (1971)[34] have reported on the dehalogenation of chlorinated aliphatic acids by *Micrococcus denitrificans*. Sethunathan *et al.* (1969)[35] have reported the dehydrochlorination of BHC by *Clostridium* sp. Matsumura and Boush (1966)[36] found that malathion was metabolized by *Trichoderma viride* and *Pseudmonas* sp. found in soils which had been heavily treated with insecticides. Additional studies by Matsumura and Boush (1968)[37] showed that *Trichoderma viride* was capable of metabolizing several organophosphorous, carbamate, and organochlorine insecticides. Caserjesi (1967)[38] reported the ability of three species of *Trichoderma* to degrade pentachlorophenol. Kaufman and Blake (1970)[39] reported on the degradation of atrazine by a variety of soil fungi, including *Aspergillus* spp., *Fusarium* spp., *Penicillium* spp., and *Trichoderma viride*. Mick and Dahm (1970)[40] reported the metabolism of parathion by *Rhizobium* spp. fungi. *Chlorella pyrenoidosa proteose* was shown to degrade parathion (Zucherman *et al.* 1970)[41]. Focht and Alexander (1970)[42, 43] reported that a species of *Pseudomonas* utilized diphenylmethane, a DDT analog, as a sole source of carbon. Evans *et al.* (1971)[44, 45] have identified many of the metabolites resulting from the degradation of the herbicides 2,4-D and CPA by a species of *Pseudomonas*. Diazinon was shown to be degraded in soil by *Arthrobacter* sp. and

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Streptomyces sp. (Gunner, 1968)[46]. Sethunathan and Pathak (1971)[47] demonstrated that *Arthrobacter* sp. degraded diazinon applied to rice paddy water. Loos *et al.* (1967)[48,49] showed that *Arthrobacter* sp. was capable of degrading 2,4-D in soil. Laboratory cultures of *Arthrobacter* sp. and *Pseudomonas fluorescens* have been shown capable of degrading atrazine (Sobieszczanski, 1969)[50]. Clark and Wright (1970)[51] demonstrated the ability of *Arthrobacter* sp. to degrade the herbicide, IPC, in laboratory tests. Burns and Audus (1970)[52] reported the breakdown of paraquat in soil by *Lipomyces starkeyi*, and Horvath (1971)[53] reported the metabolism of another herbicide, 2,3,6-trichlorobenzoate, by *Brevibacterium* sp. Moe (1970)[54] reported the metabolism of the herbicides IPC and CIPC by *Pseudomonas striata*, and Lode (1967)[55] reported the decomposition of TCA by several strains of *Arthrobacter*. Laboratory studies using propanil have shown that *Fusarium solani* utilized the herbicide as a sole source of organic carbon (Lanzilotta and Pramer 1970)[56] and that an acylamidase extract of the same fungus was active against the herbicide (Lanzilotta and Pramer 1970)[57]. Anderson and Lichtenstein (1970)[58] reported the ability of *Mucor alternans* to degrade DDT, and to a lesser extent dieldrin, as well as the effects of nutritional factors on the ability of this species to degrade DDT (Anderson *et al.* 1971)[59]. Langlois *et al.* (1970)[60] reported metabolic pathways for the degradation of DDT by *Escherichia coli*, *Enterobacter aerogenes*, and three species of *Bacillus*. The partial hydrolysis of dieldrin by *Aerobacter aerogenes* was reported by Wedemeyer (1968)[61], and Liv and Bollag (1971)[62] reported the metabolism of carbaryl by the soil fungus *Gliocladium roseum*. Miyamota *et al.* (1966)[63] reported several metabolites in laboratory studies of the decomposition of Sumithion ® by *Bacillus subtilis*. This same species has also been shown to be highly effective in the laboratory in inactivating fenitrothion, parathion, and methyl-parathion (Yasuno *et al.* 1965)[64]. Tu *et al.* (1968)[65] reported the conversion of aldrin to dieldrin by various species of *Trichoderma*, *Fusarium*, *Penicillium*, and *Bacillus*.

Various *in vitro* studies with microbial isolates have been reported. A bacterial enzyme extracted from *Arthrobacter* sp. has been shown to degrade 2,4-D (Bollag *et al.* 1968; Tiedje and Alexander 1969; Loos *et al.* 1967; Tiedje *et al.* 1969)[66,67,68,69]. Cornette *et al.* (1971)[70] reported on the detoxification of Phosdrin ® by enzymes isolated from *Bacillus megaterium*. Extracts from *Geotrichum* sp. caused the nearly complete degradation of DDT and DDE (Ledford and Chen, 1969)[71]. Wedmeyer (1966, 1967)[72,73], Mendel *et al.* (1967)[74], and Plimmer *et al.* (1968)[75] reported the dechlorination of DDT by *Aerobacter aerogenes*, and Langlois (1967)[76] reported the same phenomenon for *Escherichia coli*. French and Hoppingarner (1970)[77] reported on the dehydrochlorination by membranes isolated from *Escherichia coli*. Enzymes from *Arthrobacter* sp. were shown capable of degrading chlorinated phenols and phenoxyacetates (Bollag *et al.* 1968; Tiedje and Anderson, 1969)[66,67]. An acylamidase, which readily hydrolyzes

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Karsil, and other related compounds was isolated from *Penicillium* sp. by Sharabi and Bordeleau (1969)[78]. Degradation of urea herbicides by cell-free extracts of *Bacillus sphaericus* has been reported by Wallnofer and Bader (1970)[79] and Englehardt *et al.* (1971)[80]. An enzyme complex, capable of degrading 2,4-D, has been isolated from *Arthrobacter* sp. by Tomati and Peitrosanti (1970)[81]. Bollag and Alexander (1971)[34] found that an enzyme preparation from *Micrococcus dentrificans* was capable of dehalogenation of chlorinated aliphatic acids.

Studies of the effects of moisture, pH, temperature, and adsorption on the chemical degradation of various insecticides deposited in soil have been reported by Roeth *et al.* (1969)[82]; Getzin and Shanks (1970)[83]; Matano and Ito (1967)[84]; Obien and Green (1969)[85]; Rotini and Levi-Minzi (1970)[86]; Foschi *et al.* (1970)[87]; Skipper *et al.* (1967)[88]; Lichtenstein *et al.* (1970)[89]; Graetz *et al.* (1970)[90]; Zimdahl *et al.* (1970)[92]; Baily *et al.* (1970)[92]; Lopez-Gonzalez and Valenzuela-Calahorro (1970)[93]; Plimmer *et al.* (1967)[94]; Konrad *et al.* (1967)[95]; Hance (1969)[96]; Gershon and McClure, Jr. (1966)[97]; Wiese and Basson (1966)[98]. The photodecomposition of various pesticides in soil and water, when exposed to sunlight or artificial UV radiation, has been reported by Henderson and Crosby (1967)[99]; Crosby and Tutass (1966)[100]; Crosby and Tang (1969)[101]; Crosby and Leitis (1969)[102]; Smith and Grove (1969)[103]; Plimmer and Hummer (1969)[104]; Mosier *et al.* (1969)[105]; Smith (1968)[106]; Hall *et al.* (1968)[107]; Plimmer *et al.* (1970)[108]; Kuwahara *et al.* (1969)[109]; Rosen *et al.* (1969)[110]; Miller and Narang (1970)[111]; Benson (1971)[112]; Zabik *et al.* (1971)[113]; and Ivie and Casida (1971)[114].

Various Federal and state agencies are conducting or supporting research relative to the deposition of pesticides in soils. The US Department of Interior, Bureau of Sport Fisheries and Wildlife, and Office of Water Resources Research, is supporting continuing research in the states of Rhode Island, Missouri and Alabama concerning the chemical, physical, and biological factors affecting pesticides in soil and water. The US Department of Agriculture, Agriculture Research Service, is supporting research in these same general areas in at least eight states. The Cooperative State Research Service of the US Department of Agriculture is providing funds for the support of research on various aspects of biological and chemical degradation of pesticides in soil and water systems in at least 23 states, including Hawaii. The state governments of Arkansas, Alabama, California, Colorado, Mississippi, New Jersey, Oklahoma, Washington, and Wisconsin are supporting continuing research in the areas of biological and chemical degradation of pesticides in soil and water systems. The Department of Defense is supporting continuing research by the US Air Force on the isolation of bacterial enzymes capable of decomposing pesticides.

The Office of Solid Waste Management, US Environmental Protection Agency, and Oregon State University are supporting on-going research in Oregon on the biological degradation of pesticides deposited in soil.

Chemical Treatment. The chemical decomposition of pesticides is a complex problem, due to the diversity of the chemical structures of pesticides. There is no single chemical reaction that will detoxify all pesticides. The situation is complicated by the fact that most, if not all, of the pesticides in question exist as emulsifiable concentrates, oil solutions, dusts, and other formulations. The constituents of these formulations may adversely affect chemical reactions that would otherwise readily decompose the pure pesticides.

The literature contains a great deal of information on chemical reagents which readily react with and neutralize pesticides. Kennedy *et al.* (1970)[115] reported the chemical detoxification of various organophosphorous insecticides. DDVP, parathion, schradan, and Systox® were completely destroyed by treatment with a mixture of metallic sodium and liquid ammonia. Phosphatase enzymes and enzyme-active household detergents were not effective. Wolverton *et al.* (1971)[116] reported that a solution of dipropylene glycol monomethyl ether and monoethanalamine effectively and rapidly decontaminated sulfur- and non-sulfur-containing organophosphorous insecticides. Similar results have been reported elsewhere (Anonymous, 1971)[117] using a solution containing 75% dipropylene glycol monomethyl ether and 25% monoethanolamine. Chemical degradation of certain organochlorine insecticides was reported in studies by Leigh (1969)[118], in which chlorine, potassium permanganate, and potassium persulfate were used, with various degrees of effectiveness, to detoxify aqueous solutions of lindane, DDT, heptachlor and endrin. Chau *et al.* (1970)[119] reported the rapid degradation of p,p'-DDT by using chromous chloride as a reducing agent. Kamiya *et al.* (1961)[120] reported the effectiveness of chlorinated lime in decomposing parathion and methyl parathion. Granular activated charcoal has been reported (Anonymous 1969)[121] to effectively remove dieldrin from deionized water. The use of a caustic rinse formulation, consisting of water, detergent, and caustic soda (lye) has been reported as (Anonymous 1965, 1970)[122,123] effective in the decomposition of organophosphorous insecticides. Gomma *et al.* (1971)[124] reported studies in which chlorine dioxide, chlorine, and potassium permanganate were evaluated for removal of the herbicides diquat and paraquat from waters. Chlorine dioxide was the most effective. Kennedy *et al.* (1969)[6] reported chemical treatment of a variety of herbicides and insecticides, using strong acid or alkali solutions. All treatments were not completely effective in decomposing the various pesticides. Studies by Faust *et al.* (1969)[125] reported unsuccessful attempts to remove diquat and paraquat

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from water by chemical coagulation with aluminum hydroxide. Gomma *et al.* (1969)[126] reported studies of hydrolysis of diazinon and diazoxon under various conditions of pH. Both materials were hydrolyzed rapidly under acidic conditions, with the rate for diazoxon being more rapid than that for diazinon.

Various Federal agencies are conducting or supporting research in the area of chemical decomposition of pesticides. The US Department of Agriculture is supporting work at the Pennsylvania State University on various methods for the detoxification of pesticides and pesticide containers, including chemical aspects. The Office of Water Programs, US Environmental Protection Agency, is supporting continuing research on chemical detoxification of pesticides at Aerojet General Corporation in California, the University of Texas at Austin, and the Midwest Research Institute in Missouri. The Office of Solid Waste Management, US Environmental Protection Agency, and Oregon State University are supporting research on the chemical decontamination and recycling of empty pesticide containers in Oregon.

CONCLUSIONS

A significant problem exists with regard to the disposal of DA surplus pesticides of all types. Although the exact qualitative and quantitative nature of the problem cannot be immediately defined, it is reasonably certain that large quantities of organochlorine insecticides and phenoxy acid herbicides will require disposal by destruction.

The specific destruction method, or methods, to be utilized must be tailored to minimize contamination of the environment.

Various types of thermal degradation or ground deposition are the methods with the greatest potential for handling large quantities of organochlorine insecticides and phenoxy acid herbicides. Chemical treatment has disposal potential on a small-scale basis, and may be applicable to the decontamination of empty pesticide containers.

RECOMMENDATIONS FOR FUTURE STUDY

Although considerable effort has been, and is being, expended in studying various methods for the chemical, biological, thermal, and ground disposal of pesticides, additional research is required in the

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following areas to provide information necessary for the development of safe, practical, environmentally-sound destruction methods:

1. An evaluation of methods for the small-scale disposal of pesticides and empty pesticide containers generated by the use of organochlorine, organophosphate, and carbamate insecticides, and phenoxy acid herbicides in routine pest control operations at DA installations.

2. A determination of thermal degradation temperatures and products of single and mixed military standard formulations of organochlorine insecticides and phenoxy acid herbicides as a basis for conducting studies to determine the most suitable techniques, hardware, and monitoring systems for incineration and methods for the secondary disposal of ash and scrubbing liquids.

3. The development of criteria for the ground disposal of organochlorine insecticides and phenoxy acid herbicides by deposition in sanitary landfills or other special excavations, or by deposition in chemically- or biologically-active soils.

4. An evaluation of methods for the decontamination and reuse, or decontamination and disposal of empty pesticide containers generated by incineration, ground deposition, or other disposal operations.

5. An evaluation of commercial pesticide disposal techniques and facilities to determine their applicability to DA needs in any of the areas mentioned above.

Those areas concerning evaluation of small-scale disposal of pesticides and empty containers and evaluation of commercial disposal techniques and facilities are recommended for study by USAMEERU. The remaining areas are considered to involve studies beyond the initial research capability of USAMEERU and are recommended for investigation on a contract basis. Details concerning research approach and resource requirements for USAMEERU investigations are shown in Appendix B. Technical areas of consideration for contract investigations are presented in Appendixes C and D. Since methods for the disposal of empty pesticide containers will vary with the method developed for disposal of the pesticides themselves, the problem of container disposal should be addressed subsequent to the development of the best methods for disposal of the pesticides themselves.

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APPENDIX A

PESTICIDES THAT POSE SIGNIFICANT OR CONTROVERSIAL DISPOSAL PROBLEMS

FSN	ITEM	UNIT PACKAGE
	INSECTICIDES	
6840-253-3892	Insecticide, DDT, 5% solution	5 gal can
6840-242-4217	Insecticide, Lindane, 1%, dust	2 oz in 3 oz bottle
6840-270-8262	Insecticide, Chlordane, 72% water Emulsifiable Concentrate	5 gal pail
6840-543-7825	Insecticide, Chlordane, 5% dust	25 lb pail
6840-285-4307	Insecticide, DDT, Lindane, indoor fogging, 10% DDT and 2% Lindane	5 gal drum
6840-246-6432	Insecticide, DDT, 25% water Emulsifiable Concentrate	5 gal drum
6840-264-6692	Insecticide, DDT, 75% water Dispersable Powder	20 lb pail
6840-264-9043	Insecticide, Dieldrin, 18% water Emulsifiable Concentrate	5 gal drum
6840-242-4213	Insecticide, Lindane, 12% water Emulsifiable Concentrate	5 gal drum
6840-242-4219	Insecticide, Lindane, 1% Dust	25 lb pail
6840-766-9631	Insecticide, DDT, Pyrethum Aerosol	12 oz dispenser
	HERBICIDES	
6840-833-1217	Herbicide, Amitrole (90%) Powder Form	24 lb pail

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APPENDIX A (Cont)

FSN	ITEM	UNIT PACKAGE
	HERBICIDES (Cont)	
6840-926-9094	Herbicide, Cacodylic Acid (blue) Liquid Form	55 gal drum
6840-577-4204	Herbicide, Dalapon, Powder (85%)	50 lb drum
6840-905-4304	Herbicide, Dicamba, 49%, Liquid Form	1 gal bottle
6840-815-2799	Herbicide, Diquat, 35.3% Liquid Form	5 gal drum
6840-965-2071	Herbicide, DSMA, 63%, Powder Form	100 lb drum
6840-810-6920	Herbicide, Fenuron, Pellets (25%)	50 lb bag
6840-514-0644	Herbicide, Monuron, Powder (80%)	50 lb drum
6840-629-1638	Herbicide, Picloram-Silvex Salt Liquid Form	5 gal drum
6840-926-9093	Herbicide, Picloram-Silvex Salt (White), Liquid Form	55 gal drum
6840-822-4810	Herbicide, Silvex	5 gal drum
6840-814-7334	Herbicide, Simazine, Powder (80%)	5 lb bag
6840-664-7060	Herbicide, 2,4-D, Amine Salt	5 gal can
6840-577-4194	Herbicide, 2,4-D, Low Volatile Ester	5 gal drum
6840-577-4195	Herbicide, 2,4-D, Low Volatile Liquid Ester	55 gal drum

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APPENDIX A (Cont)

FSN	ITEM	UNIT PACKAGE
	HERBICIDES (Cont)	
6840-825-7792	Herbicide, 2,4-D, 2,4,5-T mixture Low Volatile Liquid Ester	55 gal drum
6840-582-5440	Herbicide, 2,4,5-T, Low Volatile Liquid Ester	5 gal can
6840-577-4201	Herbicide, 2,4,5-T, Low Volatile Liquid Ester	55 gal drum
6840-926-9095	Herbicide, 2,4-D and 2,4,5-T (Orange)	55 gal drum

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APPENDIX B

RESEARCH APPROACH AND RESOURCE REQUIREMENTS

TITLE: Evaluation of Environmental Health Aspects of Chemical Methods for the Disposal of Surplus Pesticides and Empty Pesticide Containers

REFERENCE:

a. AR 420-76, November 1971, Facilities Engineering: Pest Control Services.

b. TM 5-632, December 1971, Military Entomology Operational Handbook.

BACKGROUND:

Pest control operations conducted annually throughout the world by the Department of the Army (DA) generate pesticide wastes which require disposal and which can generally be categorized as follows: excess finished pesticide sprays of various types; unused, unserviceable surplus pesticides; and various types of pesticide containers associated with both the aforementioned categories.

Pest control operations require the preparation of finished pesticide sprays made from emulsifiable concentrate or wettable powder formulations; or the use of pre-mixed oil solution or dust formulations of pesticides. Although the specific amount of formulation to be prepared should be tailored to the job, it is not always possible to estimate the amount required and portions of finished sprays or premixed formulations remain at the completion of the operation. These excess materials become a problem since the dispersal equipment must be drained and cleaned for proper maintenance. Oil solutions or dusts can be retained for future use, but this is not an advisable practice because it creates an additional storage problem or involves possible contamination by returning the materials to their original containers. Water emulsions or water-dispersed powders cannot be retained for future use.

The conduct of pest control operations requires the stocking of various quantities of a large number of military standard pesticides. Many of these items become surplus due to restrictions placed upon usage, deterioration of the pesticides while in storage, or deterioration of the containers.

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Empty pesticide containers are generated as a result of the use of the contents in various pest control operations. The number of empty containers from any given installation or facility varies with the magnitude of the annual pest control program. Some activities generate only a few containers while others generate large numbers. On a worldwide basis, the number of empty containers generated by DA pest control operations is considerable.

TM 5-632 and AR 420-76 provide information on the disposal of obsolete or deteriorated pesticides, recommending ground disposal in a sanitary landfill which has been approved by the installation surgeon, safety officer, and facilities engineer. No guidance is provided concerning routine disposal of excess finished sprays or pre-mixed formulations. AR 420-76 indicates that up to 50 gallons of obsolete or deteriorated pesticide may be disposed of in the ground during an unspecified time period. Such an all-inclusive recommendation, without specification as to type of pesticide or formulation, or rate of deposition (i.e., gallons/day), raises considerable question concerning the overall environmental impact of such activities when viewed on a worldwide basis. Specific guidelines for the disposal of empty containers are not available and empty pesticide containers are probably disposed of in the same manner as the pesticides themselves. The environmental impact of ground disposal of pesticide containers is unknown, especially where containers are not decontaminated prior to burial, or where thorough hydrologic and geologic data concerning the disposal site are not available.

OBJECTIVE:

To conduct laboratory and field evaluations of the effectiveness of various chemical methods for the conversion of military standard pesticide formulations to non-toxic materials, and the environmental health and practical aspects of the employment of these various chemical methods.

RESEARCH APPROACH:

This study will evaluate methods for the chemical detoxification of pesticides and will include: an information search; laboratory studies of the chemical detoxification of pesticide standards; laboratory studies of the chemical detoxification of military standard pesticide formulations, finished pesticide sprays, and empty pesticide containers; and field studies of the environmental health and practical aspects of utilizing a chemical detoxification method.

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A search of published and on-going research will be conducted to find chemical reagents which will detoxify pesticides. The basic chemistry of pesticides will be reviewed to determine other suitable chemical reagents. Liaison will be established and maintained with various pesticide manufacturing firms (Table 1) to obtain detailed technical information relating to the disposal of pesticides by chemical and other methods. On the basis of information obtained from these various sources, a series of chemical reagents will be selected for testing.

Initial laboratory tests will be conducted to determine the effectiveness of the various chemical reagents in detoxifying analytical grade or technical grade standards of the pesticides listed in Table 2. These materials are representative of the types of chemical compounds currently used in military standard pesticide formulations. Each pesticide will be exposed, in replicate tests, to a chemical reagent, and the effectiveness of the reagent will be measured in terms of percent decomposition of the pesticide. The tests may involve preliminary treatment of the pesticide standards to place them in a medium (solvent) suitable for the chemical reaction. Appropriate controls will be included in all tests. Variables of the test will be the type of chemical reagent, the contact time between pesticide and reagent, and the reagent concentration. After the appropriate contact times, the reaction medium will be analysed for the pesticide and reaction products. If unidentified reaction products, or products of unknown toxicity, are observed, bioassays will be conducted to determine that the reaction has, in fact, produced only non-toxic materials. The general scheme for the laboratory studies is shown in Figure 1. Data will be analysed by three-way analysis of variance (Figure 2) to determine the most suitable reagent, reagent concentration, and contact time.

Laboratory tests will be conducted using chemical reagents that have been determined to be effective in the studies with analytical or technical grade pesticides. However, the actual military standard formulations (Table 2) of the pesticides will be used in these studies to determine the effects of the formulation constituents on the completeness of the decomposition. The tests with the formulations may involve preliminary treatment (Figure 3) to achieve a medium suitable for the chemical reaction. All other aspects of the tests with the formulations, including variables considered and analysis of data, will be identical to the tests conducted with analytical or technical grade standards.

Field studies will be conducted at a Department of the Army installation operating a pest control program of sufficient magnitude to provide pesticide

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APPENDIX B (Cont)

TABLE 1. List of Insecticide Manufacturers

American Cyanamid Company, Agricultrual Division, P.O. Box 400, Princeton, New Jersey 08540

Chemagro Corporation, P.O. Box 4913, Hawthorn Road, Kansas City, Missouri 64120

Chevron Chemical Company, Ortho Division, 920 Hensley Street, Richmond, California 94804

CIBA Agrochemical Company, Research and Development, P.O. Box 1105, Vero Beach, Florida 32960

Diamond Shamrock Chemical Company, Biochemicals Division, 300 Union Commerce Building, Cleveland, Ohio 44115

Dow Chemical Company, The, Agricultural Products Department, Midland, Michigan 48640

FMC Corporation, Niagara Chemical Division, 100 Niagara Street, Middleport, New York 14105

Geigy Chemical Corporation, Geigy Agricultural Chemicals (Division), P.O. Box 430, Yonkers, New York 10702

McLaughlin Gormley King Company, Inc., 1715 S.E. Fifth Street, Minneapolis, Minnesota 55414

Mobil Chemical Company, Industrial Chemicals Division, 401 East Main Street, Richmond, Virginia 23208

Monsanto Company, Agricultural Division, 800 North Lindberg Boulevard, St. Louis, Missouri 63166

Olin Mathieson Chemical Corporation, Insecticide Products Department, Colin Chemicals Division, 745 Fifth Avenue, New York, New York 10022

Shell Oil Company, Shell Chemical Company (Division), 110 West 51st Street, New York, New York 10020

Stauffer Chemical Company, Agricultural Research Center, P.O. Box 760, Mountain View, California 94040

Union Carbide, Olefins Division, 270 Park Avenue, New York, New York 10017

Velsicol Chemical Corporation, 341 East Ohio Street, Chicago, Illinois 60611

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APPENDIX B (Cont)

TABLE 2. Representative Pesticide Chemicals Used in Military Standard Formulations

Pesticide	Type of Chemical Compound	Military Standard Formulation*
DDT	diphenylethane	5%OS, 25%EC, 75%WP
Lindane	chlorinated cyclohexane	1%D, 12%EC
Dieldrin	chlorinated cyclodiene	18%EC
Chlordane	chlorinated cyclodiene	5%D, 72%EC
2,4-D/2,4,5-T	chlorinated phenoxy acids, esters, and amine salts	Numerous EC and OS Formulations
Malathion	phosphorodithioate	57%EC, 95%C
Diazinon	phosphorothioate	0.5%OS, 2%D, 48%EC
Propoxor	carbamate	1%OS
Carbaryl	carbamate	80%WP

*OS = oil solution, EC = emulsifiable concentrate; WP = wettable powder; C = concentrate

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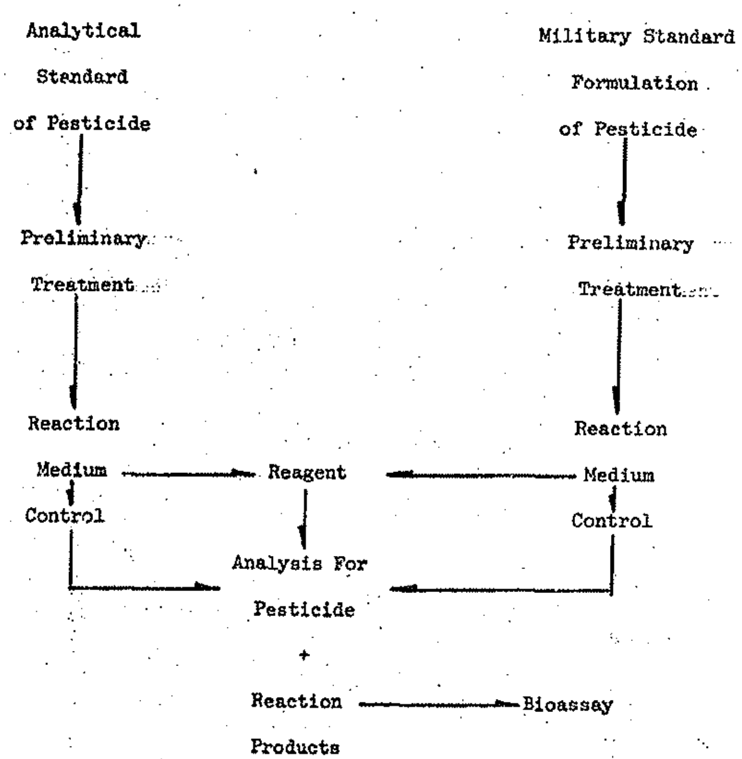

Figure 1. Laboratory Evaluation of Chemical Reagents

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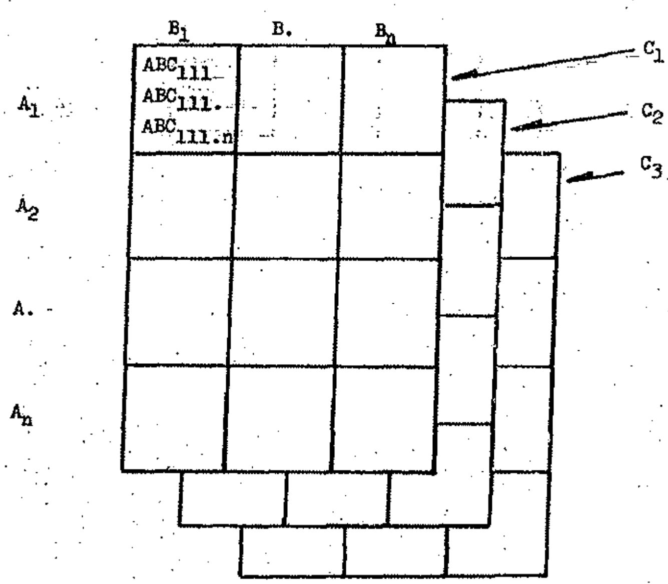

A-Classifications = Reagents (A_n = Control)
B-Classifications = Pesticide-Reagent Contact Time
C-Classifications = Reagent Concentration
$ABC_{111.n}$ = Replicate Values as % Pesticide Reacted

Figure 2. Treatment of Data by Three-Way Analysis of Variance

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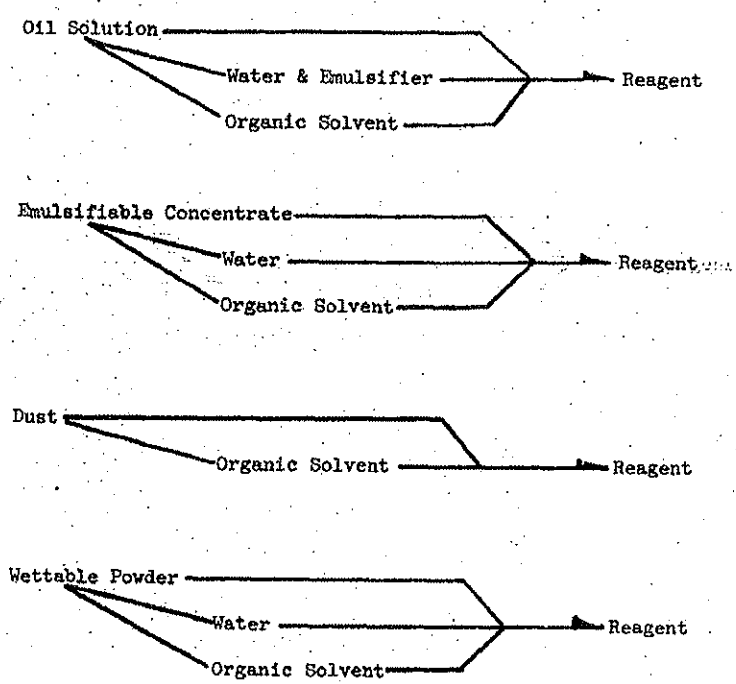

Figure 3. Preliminary Treatment of Formulations

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formulations, finished sprays, and empty pesticide containers of the quantities and types required for testing. The installation will be selected on the basis that is is qualitatively typical of DA pest control operations. Chemical reagents selected as a result of the laboratory tests will be used to determine their suitability under field conditions. Specific details concerning decontamination procedures, or requirements for special equipment or facilities, will be worked out with Facilities Engineer personnel at the installation as a part of establishing and conducting the test. The experimental design and analysis of data for the field tests will be the same as those for the laboratory tests discussed above, with the exception that all treatments and sampling will be conducted in the field, with field samples returned to the laboratory for analysis; and with the exception that additional sampling techniques, such as the physical removal and analysis of portions of metallic pesticide containers, may be required. Additional field studies concerning the ultimate disposal of decontaminated containers and chemically-treated pesticide formulations are planned. The details of these studies will depend largely on the results of the initial laboratory and field tests which will provide information on the effectiveness of the various chemical reagents, the nature of the various chemical decomposition products, and the requirements for the safe disposal of the latter.

RESOURCE REQUIREMENTS:

a. Personnel by Discipline (man-months):

(1) Entomological	12
(2) Chemical	14
(3) Microbiological	2
(4) Statistical	2
(5) Administrative	3
TOTAL	33

b. Funds ($000):

(1) Supplies and Equipment (consumables plus gas chromatograph and minor items of equipment)	20.0

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APPENDIX B (Cont)

(2) Travel (visits to other laboratories for meetings to maintain currency with new developments; field testing)	5.0
(3) Salaries, benefits, base support, and distribution of general laboratory supplies and equipment.	65.0
TOTAL	90.0

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APPENDIX C

TECHNICAL CONSIDERATIONS IN THE THERMAL DEGRADATION OF PESTICIDES

PROBLEM:

A serious problem exists concerning the disposal of surplus military standard pesticide formulations. Thermal degradation of the pesticides by incineration is one solution to the problem. Although incineration is not presently used by the Department of the Army for disposal of surplus pesticides, it represents an efficient and potentially complete means of disposal. In order to incinerate surplus military pesticides, certain background technical and environmental health data are required. It is necessary to know what temperatures are required for pyrolysis or complete combustion, the nature of the decomposition products or combustion products in the gaseous effluent, and the nature of any residue remaining in the ash. Beyond this, it is necessary to know which pesticide formulations can or cannot be incinerated, and which type or types of incinerators and associated scrubbing and monitoring apparatus are most suitable. Additional information is required concerning the technical and environmental health aspects of the secondary disposal of undesirable effluents and ash from the incineration process, as well as the disposal of empty containers which may be generated by the overall process.

OBJECTIVE:

The objective of this study is to develop environmentally-sound methods for the thermal degradation of surplus pesticides by determining the thermal degradation temperatures and products of the formulations in question, and by determining design and operational criteria for incineration hardware. Military standard pesticide formulations, and analytical standards of the respective active ingredients, will be used in determining the optimum temperatures for pyrolysis or complete combustion, and to determine the respective degradation products. Similar laboratory tests will be conducted with military standard formulations to determine the effects of the various formulation constituents (i.e., additives, diluents, etc.) on the outcome of the thermal degradation. The laboratory tests will be conducted using single analytical standards and single military standard formulations, as well as specific mixtures of analytical standards and mixtures of military standard formulations. The tests using mixtures of pesticides will be conducted, since the effects of the pesticides on each other, from the standpoint of completeness of degradation or nature of the degradation products, is not known. Incineration studies will be conducted using several model or full-scale pieces of equipment whose operational and design features will enable them to thermally decompose various types of formulations (i.e., oil solutions, dusts, wettable powders, concentrates, etc.) and to remove undesirable gases from the effluent. Burning tests will be conducted using single military standard pesticide formulations, and specific mixtures thereof, to determine the completeness of thermal decomposition and the nature of the degradation products in both the effluent and the ash. Mixtures of the formulations will be used because the effects of the various formulations on each other, from the standpoint of completeness of combustion or nature of the combustion products, is not known.

EXPECTED RESULTS:

It is expected that these studies will provide basic information concerning optimal temperatures for the complete thermal degradation of specific military standard pesticide formulations, as well as information concerning the nature of the effluents and residue in the ash when military standard pesticide formulations are incinerated either singly or in various combinations. The information from these studies will then be used to determine energy requirements for incineration of specific pesticide formulations, or mixtures thereof, requirements for scrubbing apparatus to remove undesirable gases from the effluent, requirements for monitoring systems that are sufficiently responsive to preclude the release of undesirable gases or vapors in the event of liquids and residues in the ash; and will provide sufficient design and operational criteria data to permit the implementation of model or full-scale incinerator studies to determine specific requirements for the thermal destruction of the various military standard pesticide formulations. It is expected that the incineration studies will provide sufficient design and operational criteria to permit initiation of an environmentally-sound program of thermal destruction of surplus pesticides by: utilization of existing hardware that meets the requirements; modification of existing hardware to meet needed requirements; or design and construction of new hardware.

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APPENDIX D

TECHNICAL CONSIDERATIONS IN THE DISPOSAL OF PESTICIDES BY GROUND DEPOSITION

PROBLEM:

A problem exists concerning the disposal of surplus military standard pesticides. Ground deposition is one possible solution to the problem. At the present time, some surplus military pesticides are disposed of in small quantities by deposition in sanitary landfills for which adequate geologic and hydrologic data may not be available. Even in the presence of background geologic and hydrologic information for a particular landfill, the ultimate fate of pesticides deposited therein is unknown. Therefore, certain information is needed in order to develop requirements for efficient, environmentally-sound ground disposal sites for use by the Department of the Army. It is anticipated that ground deposition would be utilized on a small-scale, local-level basis for the disposal of relatively small quantities of pesticides generated by local programs. The utilization of natural sites for the ground deposition of large quantities of surplus pesticides may not be feasible at present. However, biological degradation in artificial, contained-earth sites may be a consideration. Since military standard pesticides represent a variety of chemical structures and formulations, a single set of disposal-site criteria may not apply.

OBJECTIVE:

The objective of this study is to determine environmentally-sound methods of disposing of pesticides by ground deposition. Ground deposition usually subjects the pesticides to biological or chemical degradation, with the former being the more significant. Situations where biological or chemical degradation do not occur are not desirable, since the pesticides would merely be stored in the ground without assurance that movement would not occur. Even in the presence of these degradation processes, and with hydrologic and geologic information available, there is no assurance that translocation would not occur, due to some change in meterologic or geologic factors, when pesticides are deposited in a natural setting.

EXPECTED RESULTS:

It is expected that these studies will provide basic information concerning the geologic, hydrologic, microbial, and chemical requirements

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for an environmentally-sound site for the disposal of pesticides, including information on the useful life of ground disposal sites, the requirements for altering or diluting pesticides formulations prior to deposition, and what proportion of a given pesticide evaporates, is detoxified, or remains unchanged. These criteria would provide a basis for selecting existing natural disposal sites, or designing and constructing artificial disposal sites where translocation could be minimized, if not eliminated, and rate of deposition of pesticides could be maximized by selection and fostering of microbial populations in the soil.

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The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides

December 2006

Submitted by

[redacted] Ph. D.

b6

for

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14. ABSTRACT
Early in 2006, the Department of Veterans Affairs (DVA) requested that the Department of Defense (DoD) provide: "an official compilation of locations and dates outside of Vietnam where the Department used herbicide agents, including Agent Orange, as well as locations and dates where DoD personnel were likely exposed to these agents." The intent of this request was to obtain information that may be important in evaluating the merits of many veterans' disability claims. Various estimates have circulated on the Internet as to the number of sites where veterans may have been exposed to Agent Orange and "other herbicides" used in Vietnam. There is, however, significant confusion by veterans and by the Department of Veterans Affairs as to the distinction between "commercial herbicides" used by the DoD and "tactical herbicides" used by the DoD. The belief that commercially available herbicides were simply purchased from the chemical companies and deployed directly to Vietnam is incorrect and contrary to historical records. Tactical Herbicides were herbicides developed specifically by the United States Department of Defense to be used in "combat operations." The history of the military development and use of tactical herbicides dates to World War II. During the Korean Conflict, the DoD developed the first major tactical herbicide, Herbicide Purple, although never deployed. Subsequently, for Vietnam the DoD developed, tested, evaluated, and deployed five additional tactical herbicides, Herbicide Pink, Herbicide Green, Herbicide Blue, Herbicide Orange, and Herbicide White. This report discusses the history of the development of the tactical herbicides, how they differed from commercial herbicides, and where they were tested, evaluated, stored, used (in the case of Korea in 1968) OUTSIDE of Vietnam. Additionally, the report discusses the final disposition of Herbicide Orange after Vietnam. The report contains 32 leaflets identifying different locations or multiple locations involved in same projects (e.g., Leaflet 19 identifies 5 locations in Texas), or the multiple use of a specific location (e.g. Eglin Air Force

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INSTRUCTIONS FOR COMPLETING SF 298

Base, Florida). A total of 40 distinctly different locations are identified. For each leaflet, a description of the activity is given, an assessment is made of the activity and the individuals involved in the project, and sources of the information are documented.

15. SUBJECT TERMS

tactical herbicides, agent orange, Herbicide Orange, Herbicide Blue, Herbicide White

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The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides

ABSTRACT

Early in 2006, the Department of Veterans Affairs (DVA) requested that the Department of Defense (DoD) provide: "***an official compilation of locations and dates outside of Vietnam where the Department used herbicide agents, including Agent Orange, as well as locations and dates where DoD personnel were likely exposed to these agents***." The intent of this request was to obtain information that may be important in evaluating the merits of many veterans' disability claims. Various estimates have circulated on the Internet as to the number of sites where veterans may have been exposed to Agent Orange and "other herbicides" used in Vietnam. There is, however, significant confusion by veterans and by the Department of Veterans Affairs as to the distinction between "commercial herbicides" used by the DoD and "tactical herbicides" used by the DoD. The belief that commercially available herbicides were simply purchased from the chemical companies and deployed directly to Vietnam is incorrect and contrary to historical records. **Tactical Herbicides were herbicides developed specifically by the United States Department of Defense to be used in "combat operations."** The history of the military development and use of tactical herbicides dates to World War II. During the Korean Conflict, the DoD developed the first major tactical herbicide, Herbicide Purple, although it was never deployed. Subsequently, for Vietnam the DoD developed, tested, evaluated, and deployed five additional tactical herbicides, Herbicide Pink, Herbicide Green, Herbicide Blue, Herbicide Orange, and Herbicide White. This report discusses the history of the development of the tactical herbicides, how they differed from commercial herbicides, and where they were tested, evaluated, stored, used (in the case of Korea in 1968) **OUTSIDE** of Vietnam. Additionally, the report discusses the final disposition of Herbicide Orange after Vietnam. The report contains 32 leaflets identifying different locations or multiple locations involved in same projects (e.g., Leaflet 19 identifies 5 locations in Texas), or the multiple use of a specific location (e.g. Eglin Air Force Base, Florida). A total of 40 distinctly different locations are identified. For each leaflet, a description of the activity is given, an assessment is made of the activity and the individuals involved in the project, and sources of the information are documented.

The History of the Development of Tactical Herbicides

INTRODUCTION

The period of use of tactical herbicides in the Vietnam War, 8 January 1961 – 7 January 1971, is a story that begins many years before Vietnam, and it is really a history of the Department of the Defense's efforts to develop vegetation control methods that would have military applications. In 1943, the Department of the Army contracted the University of Chicago to study the effects of a new series of organic compounds, especially 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-triclorophenoxyacetic acid (2,4,5-T) on cereal grains and broadleaf crops. From that research came the concept of military applications of small quantities of such compounds to destroy enemy crops. Subsequently, in early 1945, the Army tested 2,4-D and 2,4,5-T formulations at the Bushnell Army Air Field in Florida. That site is now a FUDS (**F**ormerly **U**sed **D**efense **S**ite) location for the Department of Defense. Although not used in World War II, the concept of vegetation control was not forgotten. In 1952, the Department of Army's Chemical Corps Biological Laboratories at Camp Detrick, Maryland, initiated a major program to develop both the aerial spray equipment and herbicide formulations for potential deployment in the Korean Conflict. Again, although not used in the Korean Conflict, the equipment that had been developed and tested, and the formulated chemicals were both stored on the Island of Guam until the end of the Conflict, after which the equipment was sent to Utah and the drums of herbicide were sent to Camp Detrick. Camp Detrick (now Fort Detrick) continued working on developing deployment systems and herbicidal materials through the 1950s.

<u>The Period from 1945 to 1959: Supporting the Initial Deployment of Herbicides for the Early Years of the Vietnam War</u>

The Tactical Herbicide Spray Systems (fixed-wing, helicopter, and herbicides) developed during this period were available to be tested in Vietnam in 1961. Their successful use during the period from 8 October 1961 through 18 March 1965 (the Initial Program Development Phase) resulted in the United States Department of Defense approving a major combat role for Tactical Herbicides from 29 March 1965 to 7 January 1971 (the Operational Phase). As noted above, the Initial Program Development Phase depended heavily on the limited research into both aerial spray systems and tactical herbicides that the United Army Chemical Corps had carried out from the end of World War II (1945) through 1959. The Leaflet Series from Site 1 to Site 9 provide both the history and successes of these research projects. For each site, an "**Activity Description**" is given to place in context what was occurring at the time and the intent of the project. The "**Assessment**" section of each Leaflet is intended to provide details about the human element, including who was involved and what they did with respect to the herbicides being evaluated, i.e. potential exposures. The section on "**Sources**" provided the information that was described and assessed.

The Period from 1963 to 1967: Developing the Spray Systems and Multiple Herbicides for Supporting Combat Operations in Vietnam

The second period was the period in which new spray equipment and new formulations of tactical herbicides were developed and thoroughly tested in different geographical locations that were applicable to the subtropical and tropical conditions encountered in Vietnam. This research supported the "Operational Phase" of the Army Chemical Corps and the Air Force Operation RANCH HAND deployment of tactical herbicides in the combat environment of Vietnam. The Leaflet Series from Site 10 through Site 21 describe the development of various aerial spray systems at Eglin Air Force Base, Florida, and the Dugway Proving Ground, Utah, for the Army Chemical Corps (helicopters and a proposed fixed-wing Defoliant System), and the Air Force C-123U modifications for RANCH HAND combat spray missions. In addition, this series of Leaflets describes the continual efforts of the Army Chemical Corps Laboratories at Fort Detrick to develop and test new tactical herbicides, including fine-tuning the rates of applications required to control the vegetation encountered in Vietnam and throughout Southeast Asia.

The Use of Tactical Herbicides in Korea in 1968, and the "Camille" Incident in Mississippi in 1969

The only "military use" of tactical herbicides "outside" of Southeast Asia was in 1968 when the Korean and US Governments agreed to provide Herbicide Orange and Herbicide Blue for vegetation control adjacent to the Demilitarized Zone in Korea. Leaflet 22 describes this activity and the involvement of Korean and US military personnel. Leaflet 23 describes the incident in August 1969 at Gulfport, Mississippi where hundreds of drums of Herbicide Orange and Herbicide Blue were destroyed or lost due to the damaging winds of Hurricane "Camille." This Leaflet also assesses the involvement of personnel from the Army Corps of Engineers and the Air Force Logistics Command in the cleanup operations.

The Period from April 1972 – March 1977: Disposal Options for the Surplus Herbicide Orange Remaining After the Vietnam War

This time period was the period in which the military evaluated various options for the destruction of the surplus Herbicide Orange that was returned to the United States in April 1972 from Vietnam (Operation PACER IVY), or was in storage at the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi in 1969. In August 1966, the United States Air Force Logistics Command took over the responsibility for managing the growing and continued procurement requirements for tactical herbicides in Southeast Asia. With the abrupt cessation of the use of Herbicide Orange in Vietnam in April 1970, the 7th Air Force in Vietnam was given the task of consolidating the remaining Herbicide Orange stocks in Vietnam (Operation PACER IVY), and transferring those stocks to Johnston Island, Central Pacific Ocean. The responsibility for maintaining those "surplus" stocks of Herbicide Orange and disposing of them in an environmentally and publicly acceptable manner was given to the Air Force Logistics Command. Leaflet Series 24 to 30 describe the many options for the final disposition of Herbicide Orange. The importance of identifying these options, and hence the preparation of the Leaflets, was because of the active involvement of Active Duty military personnel. Moreover, the Leaflets provide a unique view of the history of the disposal of Herbicide Orange.

The Period From May 1977 to December 2004: Operation PACER HO and Site Monitoring and Reclamation of the Storage Sites at NCBC and Johnston Island

After reviewing the technical and scientific data obtained from the studies of the various options for the disposition of Herbicide Orange, and weighing of the costs in both economic and environmental terms, the Department of Defense made the decision to destroy all of the remaining stocks of Herbicide Orange by at-sea incineration. The operation to dispose of the "surplus" Herbicide Orange at the Naval Construction Battalion Center, Gulfport, Mississippi, and Johnston Island, Central Pacific Ocean was named Operation PACER HO. The Air Force Logistics Command used the term "PACER" to describe the operational movement of materiel. The "HO" referred to "Herbicide Orange". Leaflets 31 and 32 describe Operation PACER HO for both the inventories at the NCBC and at Johnston Island. The importance of documenting this military operation is because hundreds of Active Duty military personnel were involved in the activity. With the completion of the removal of the drums of Herbicide Orange at the NCBC and Johnston Island, the responsibility for monitoring the residues and environmental impacts of those toxic residues was done by Active Duty military. In February 1989 and December 2004, final corrective measures at the NCBC and Johnston Island, respectively, were completed under the Department of Defense Environmental Restoration Program.

The Distinction Between Tactical and Commercially Approved Herbicides Used in the Vietnam War

There exists significant confusion as to how herbicides were selected by the military to be used in the defoliation program in the Vietnam War The belief that commercially available herbicides were simply purchased from the chemical companies and deployed directly to Vietnam is incorrect and contrary to historical records.

The Military Development and Deployment of Tactical Herbicides

Tactical Herbicides were herbicides developed specifically by the United States Department of Defense to be used in "combat operations". The history of the military development and evaluation of tactical herbicides was described in the previous section. The testing of large volume aerial systems in 1952 and 1953 using Air Force B-29, B-50, and C-119 aircraft, and spraying a mixture of 2,4-D and 2,4,5-T, proved that military aircraft and tactical herbicides could be potentially used in a combat environment. The mission to develop additional tactical herbicides and new delivery technology was assigned to the US Army Chemical Corps, and specifically to the Crops Division of the Biological Warfare Laboratories (subsequently, the Plant Sciences Laboratories) at Fort Detrick, Maryland. The program involved the evaluation of thousands of compounds for herbicidal activity. In addition, the US Army with the active participation of the Air Force and Navy continued engineering development of delivery technology. When the Air Force accomplished prove-out and acceptance testing of the large-capacity (1,000 gallons) spray system (known as the MC-1 or Hour-glass Spray System) it was immediately sent to Guam, along with 5,000 drums of a concentrated mixture of technical butyl esters of 2,4-D and 2,4,5-T called "Purple", although neither the Spray Systems or the herbicides were used. After the close of the Korean Conflict, Fort Detrick scientists were involved in 1957 with tests showing the herbicidal activity of cacodylic acid (an organic arsenical) on rice and grasses, and with the evaluation of aerial application tests with mixtures of 2,4-D and 2,4,5-T at Fort Ritchie, Maryland (1956), Dugway, Utah (1959), and Fort Drum, New York (1959) (see Leaflets 6, 7, and 8).

In early 1961, the US military initiated Project AGILE, a project designed to provide technical information on the chemical means of controlling vegetation that could be applied to military operations in South Vietnam. The tactical problem to which research was directed was the development of chemicals that could rapidly control a broad range of botanical species. Once again the Department of the Army's Plant Sciences Laboratories at Fort Detrick, Maryland was given the responsibility, but this time the goal was to determine the technical feasibility of defoliating jungle vegetation in South Vietnam.

In late 1961, a test program for evaluating tactical herbicides for vegetation control in South Vietnam was approved for the Air Force. With the full concurrence and support of the Republic of Vietnam and the Vietnamese Air Force, a project under the code name operation RANCH HAND was initiated. Operation RANCH HAND was the USAF operation responsible for the tactical fixed-wing aerial application of herbicides from UC-123 Aircraft. Operation RANCH HAND began 7 January 1962, and terminated 7 January 1971, exactly nine years to the day from the arrival of the first RANCH HAND aircraft at Tan Son Nhut airport. The military justification, and hence the mission for the deployment of tactical herbicides by RANCH HAND, was to improve combat visibility in enemy controlled or contested jungle areas in order to expose infiltration routes, base camps, weapon placements, and storage sites of the Viet Cong and the regular Armed Forces of the Democratic Republic of Viet Nam. Tactical herbicides were also used along lines of communication, riverine transportation routes, around base perimeters, and also for crop destruction.

The first tactical herbicides selected for evaluation in Vietnam were Purple, the 2,4,5-T formulations of Pink and Green, and the powder form of cacodylic acid identified as "Blue". None of these products were commercially available; thus, following the publication of "military specifications", for the formulation, packaging, labeling of drums (including a 10-inch colored band around the center of the drum identifying the tactical herbicide), and shipment, these herbicides were purchased by the Defense Federal Supply Center (later the Defense Supply Agency), Richmond, Virginia via competitive bids. The United States Air Force Logistics Command took responsibility for the arrangements of the shipment of these tactical herbicides to the Republic of Vietnam.

Recognizing the continuing mission in Vietnam for tactical herbicides, the Plant Sciences Laboratories maintained an active program of testing and evaluating chemicals for potential use in Vietnam. Three major "Defoliation Conferences" (1963, 1964, and 1965) were sponsored by Fort Detrick. Plant Sciences Laboratory personnel simultaneously conducted field tests in Puerto Rico, Thailand, New Brunswick, and in the States of Alabama, Arkansas, Florida, Georgia, Hawaii, Maryland, and Texas. With the exception of Texas and Puerto Rico, only personnel from the United States Department of Agriculture (USDA) identified and visited the test sites, the responsibility for the testing protocol and spray operations rested with US Army or US Air Force personnel. The USDA had no regulatory authority over the selection or use of herbicide formulations developed by the Department of the Army. These field tests resulted in the selection of a liquid formulation of cacodylic acid (Herbicide Blue), a picloram-2,4-D formulation (Herbicide White), and a 50:50 mixture of an n-butyl formulation of 2,4-D and 2,4,5-T (Herbicide Orange). Following publication of "Military Specifications", these new "Tactical Herbicides" were purchased directly by the Department of Defense for use in Vietnam. These new tactical herbicides had a 3-inch colored band around the center of the drum, in addition to a brief description, the Transportation Control Number (TCN) and final destination in Vietnam.

Operation RANCH HAND involved modifications of standard military aircraft and development of sophisticated aerial spray equipment. It also required a military cadre of highly trained air and ground-support crews. The training of aircrews, development of the interface between the aircraft and the spray equipment, and test and evaluation of the aerial spray systems were the responsibilities of the USAF Air Development Test Center and the Air Force Armament Laboratory, Eglin AFB, Florida.

The Air Force Armament Laboratory at Eglin AFB, Florida, the Air Force Environmental Health Laboratory, at McClelland AFB, California, the Air Force Occupational and Environmental Health Laboratory, Kelly AFB, Texas, the Plant Sciences Laboratory at Fort Detrick, and the United States Army Environmental Hygiene Agency, Aberdeen, Maryland, were responsible for determining physical properties, efficacy, toxicology, safe handling procedures, and actions to be taken for spills, environmental contamination, and disposal for all of the tactical herbicides.

Helicopters were used in the test phases of the tactical herbicide spray operations (1961 –1965), and were owned and operated by the Vietnamese Air Force. In September 1961, the Air Force Special Air Warfare Center, Eglin AFB, Florida, provided Army H-34 helicopters, spray systems, and aircrew training to the Vietnamese Air Force for tactical herbicide operations. Later the US Army and Marines used specially designed equipment developed by the US Navy at the Medical Field Research Laboratory, Camp LeJeune North Carolina, that could temporarily be attached to UH-1 helicopters for conducting spray projects around base perimeters and in other limited areas. The Department of the Army assigned a Chemical Office (J3-09) to the Military Assistance Command, Vietnam (MACV) to coordinate "operational aspects and plans" involving the use of the tactical herbicides by US and Vietnamese military units. In 1966, the US Army deployed the first (of 22) Army Chemical Corps units to South Vietnam. These units were responsible for the storage, handling, mixing, and application of riot control agents (tear gas), burning agents, and herbicides by the US Army. Men serving in these units performed duties associated with storage, preparation, and the ground and helicopter applications of vegetation control chemicals, as well as equipment cleaning and maintenance. The training of the Army Chemical Corps personnel to handle herbicides was the responsibility of the Army Chemical Corps Training Center at Fort Leonard Wood, Missouri.

The Defense Supply Agency (DSA) procured all tactical herbicides. DSA provided the 55-gallon drums and arranged for all transportation (primarily by rail) of the drums from the chemical companies manufacturing the herbicides to the port of embarkation. The chemical companies were selected on the basis of competitive bids and DSA provided the specifications (developed by the Army Chemical Corps) required to be met by the manufacturer.

Summary

The Herbicide Purple, Herbicide Pink, Herbicide Green, Herbicide Orange, Herbicide Blue, and Herbicide White were developed as "Tactical Herbicides". The United States Army's Plant Sciences Laboratories at Fort Detrick, Maryland, were responsible for the spraying, testing, and evaluating of tactical herbicide candidate formulations at numerous sites throughout the United States, and in Puerto Rico, Canada, and Thailand. The Plant Sciences Laboratories were also responsible for establishing the "Military Specifications" for those herbicides selected to be used as "Tactical Herbicides". The ground and aerial spray equipment were developed by the Department of Defense to support tactical combat military operations in Southeast Asia. The Department of Defense provided the training for the Air Force aircrews, ground based personnel, and the Army Chemical Corps personnel that had responsibility for handling and spraying of the tactical herbicides. The selection and use of the tactical herbicides were exempt from USDA regulatory oversight, or from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

The Role of the Armed Forces Pest Management Board

On 17 November 1956, Department of Defense Directive 5154.12 established the Armed Forces Pest Control Board (AFPCB) [subsequently The Armed Forces Pest Management Board (AFPMB)]. The purpose for establishing the AFPCB was to provide oversight of the DoD's pest management programs on its more than 600 world wide military installations. At the time the Board was established, the Department was using millions of pounds of commercial pesticides on these installations. The DoD Directive required that the Board be composed of members from the Army, Navy, Air Force and selected Defense Agencies (a total of 20 members). The Board was also to have 24 liaison members and 25 non-DoD Agency representatives. The Board established 8 Standing Committees: Environmental Impact, Equipment, Quarantine, Medical Entomology, Pesticides, Real Property Protection, Stored Products, and Training, Certification, and Manpower. In August 1961, the Department of Defense, via a Memorandum of Understanding, established with the USDA a support program that among other responsibilities provided the research, recommendations, and specifications of pesticides that were suitable and met the need for DoD use.

The Armed Forces Pest Control Board required all DoD agencies to use pesticide formulations that had "Federal Specifications", with the labeling and use directions approved by the Pesticides Regulation Branch of USDA (now EPA), and in full compliance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). As previously noted the "Tactical Herbicides" were required to meet "Military Specifications". There are four distinct "types of specifications". These are: (1) Purchase descriptions; (2) Army, Navy, and Air Force Specifications; (3) Military Specifications; and; (4) Federal Specifications. Purchase descriptions are merely descriptions of the material desired and are used for filling small needs or for materials that are needed on an emergency basis. They are issued by all government agencies and are of a temporary nature. Army, Navy, and Air Force Specification cover items specific to one of these military services (e.g., a biocide for ship hulls). Military Specifications are complete documents and are used when the need for the material is confined to a specific military operation (e.g., the Tactical Herbicides used in combat operations in Vietnam). The AFPCB adopted the policy for the Department of Defense to recommend that any pesticide formulation that has uses in civilian agencies be issued as a "Federal Specification". These types of pesticide are to be issued by the General Services

Administration (Tactical Herbicides were the responsibility of the Defense Supply Agency).

By 1966, the AFPCB strictly controlled the kinds and forms of pesticides available under "Federal Specifications" and on the military supply list. New pesticides, before being considered by the Board, had to be recommended by the US Department of Agriculture, the Fish and Wildlife Service, or the Public Health Service, and the proposed use had to have been approved by all three of these organizations. In February 1967, the Federal Committee on Pest Control (FCPC) was established. All Federal pest control activities were placed within the purview of the Committee. The Committee was composed of two members from each of the Departments of Agriculture; Defense; Health; Education, and Welfare; and Interior. Before a pesticide was approved for use in the United States, or by a Federal Agency, it had to be reviewed by the FCPC. The DoD's "Tactical Herbicides" were exempt from this approval and oversight process. However, all other herbicides used by the Department of Defense were required to meet this approval process. The significance of this action was that herbicides used in 1967 to 1970 on the more than 600 military installations managed by the Department of Defense required approval by both the AFPCB and the FCPC (after 1970, the registration and oversight of commercially available pesticides was the responsibility of EPA). This requirement applied to herbicides used in Vietnam that were NOT TACTICAL HERBICIDES. Thus, herbicides used on Allied Bases in Vietnam around buildings, in equipment storage sites, and along interior roads came under the requirements of the AFPCB. The responsibility for the purchase and application of commercial pesticides on these installations was the Base Civil Engineer, NOT the Army Chemical Corps. Tactical Herbicides were NOT approved for these uses. The insecticides used in Operation FLYSWATTER (the aerial application of insecticides to control mosquitoes in Vietnam) were under the Military's Disease Prevention Program and were approved by the AFPCB.

With the establishment and functioning of the AFPCB, anytime a DoD Military Base, e.g., Eglin AFB, Florida, Andersen AFB, Guam, or Osan AB, Korea, requested the use of a herbicide to control plant pests, the selection of the herbicide must have been approved by the Board. Locally purchased pesticides were to be approved by the Command Entomologist. Moreover, the application of the herbicide had to be done by a Board "certified" (trained) applicator, and with equipment that had been approved by the USDA, and under the supervision of the Base Civil Engineer. The Department of Agriculture's Agricultural Research Service (ARS), and the Cooperative State Research Service (CSRS) provided critical support to the development of pesticides that were subsequently recommended and approved for use by the AFPCB. The Board DID NOT work with the chemical companies manufacturing the pesticides, rather, these materials were evaluated by ARS, the various State University Experiment Stations, and the State and Federal Extension Services. In addition, AFPCB depended upon CSRS and its University-based research and extension system to prepare and publish manuals on pesticide use, plans for certification of pesticide applicators, and the disposal of old pesticides and pesticide containers. The final statements on safety and environment precautions on the use of herbicides commercially available to the military were determined by the agencies of the Public Health Service, and when necessary by the United States Army Environmental Hygiene Agency.

To ensure that military installations were identifying and controlling pests detrimental to military personnel, property, projects, and programs, the AFPCB had a cadre of military and civilian personnel via supporting Agencies and Laboratories (e.g., the Epidemiology Division of the School of Aerospace, Brooks AFB, Texas; USAF Occupational and Environmental Health Laboratory, Kelly AFB, Texas; and the Public Health Service) that routinely conducted Pest Surveys, Staff Visits, Training Programs, and Conferences on identifying and controlling pests. Reports of these visits, programs, and conferences were published by the Board and widely circulated to other military installations.

Summary

Under the Directives 5154.12 and 4150.7, the Department of Defense gave the Armed Forces Pest Control Board/Armed Forces Pest Management Board the authority to set pest management policy *"applicable for all Department of Defense pest management activities in any unit, at any time, in any place, even when conducted by contract operations."* The significance of this Directive is that any herbicides used after 1961 on DoD's more than 600 installations must have been approved by the Board, and must have met USDA's regulatory requirements, and all the requirements of FIFRA. The exception to these Directives was the development of the "Tactical Herbicides" sprayed in combat military operations in Vietnam, or by Department of State approval as used in Korea adjacent to the Demilitarized Zone in 1968.

Implications

Herbicides used in Operation RANCH HAND for defoliation and crop destruction projects, and by the US Army Chemical Corps for vegetation control on perimeters, cache sites, and similar militarily-important targets were classified as "Tactical Herbicides" and were formulated, tested, evaluated, and assigned "Military Specifications" by the Department of Defense. They were not subject to regulatory oversight by the Department of Agriculture, the Armed Force Pest Control Board, or the Federal Committee on Pest Control. However, the insecticides used in Operation Flyswatter were subject to the AFPCB, as were all other pesticides used for control of pests within the boundaries of the military installations in Vietnam.

There were no documents that indicated the herbicides used in Guam, or CONUS military installations were "tactical herbicides", rather, the available documents confirmed that all pesticides use in these locations and other US Department of Defense installations world wide were those commercially available and approved by AFPCB.

Supporting Literature

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28175 USDA Pesticide Situations for 1964-1965 (1965)

35132 Federal Committee on Pest Control (FCPC, 1967)

37972 Non Standard Herbicides (1967)

40103 Report of Staff Visit to Japan and Korea (1968)

40234 How Agriculture Stretches Your Defense Dollar (1967)

40654 Restriction on 2,4,5-T to SEA (1967)

42605 USDA Moves to Tighten Pesticide Labeling Regulations (1963)

44355 Pesticides and Pest Control Equipment (1968)

50641 Herbicides, Pest Control, Agents, and Disinfectants (1969)

57235 Interim Guidelines for Disposal of Surplus Herbicide and Containers (1970)

57625 Insecticide Dispersal Equipment for Navy and Marine Corps Aircraft (1971)

61764 Statement on Use and Disposition of Pesticides (1971)

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96815 DoD Certification of Pesticide Applicators (1977)

118307 Medical Pest Management Survey, Korea, USAF OEHL (1983)

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168230 Contingency Pest Management Pocket Guide (1986)

171960 Military Pest Management Training Manual (1999)

Tactical Herbicides Deployed in Vietnam/Southeast Asia

DESCRIPTION

Herbicide Purple, 1962 – 1965: Purple was first formulated by the Army Chemical Corps at Fort Detrick, Frederick, Maryland in the mid-1950s time period. It was first used in the Camp Drum, New York defoliation tests in 1959 (*see Leaflet Site 8*). The formulation was a brown liquid soluble in diesel fuel and organic solvents but insoluble in water. One gallon of Purple contained 8.6 pounds active ingredient (acid equivalents) of 2,4-D and 2,4,5-T. The percentages of the Purple formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	30%
iso-butyl 2,4,5-T	20%

Herbicide Green, 1962: Green was a single component formulation consisting of the n-butyl ester of 2,4,5-T. It was used in limited quantities in 1962. The formulation was a light brown liquid soluble in diesel fuel but insoluble in water. One gallon of Green contained 8.16 pounds active ingredient of 2,4,5-T.

Herbicide Pink, 1962 –1964: Pink was a formulation of 2,4,5-T used extensively in the early RANCH HAND operations and in the defoliation test program in Thailand in 1964 (*see Leaflet Site 13*). One gallon of Pink contained 8.16 pound active ingredient 2,4,5-T. The percentages of the Pink formulation were:

n-butyl 2,4,5-T	60%
iso-butyl 2,4,5-T	40%

Herbicide Orange, 1965 – 1970: Orange was a reddish-brown to tan colored liquid soluble in diesel fuel and organic solvents but insoluble in water. The first shipment of Herbicide Orange arrived in Vietnam in March 1965. One gallon of Orange contained 8.62 pounds of the active ingredient 2,4-D (4.21 pounds) and 2,4,5-T (4.41 pounds). The percentages of the Orange formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	50%

Herbicide Orange II, 1967-1968: The same as Orange but with the substitution of the isooctyl ester of 2,4,5-T for the n-butyl ester of 2,4,5-T.

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Herbicide Blue (Liquid), 1966 – 1971: In 1961, the first Blue (95 drums) that was shipped to Vietnam was a powdered formulation that required water. In February 1966, the first Liquid Blue arrived in Vietnam. Herbicide Blue was a clear yellowish-tan liquid that was soluble in water, but insoluble in diesel fuel. One gallon of Blue contained 3.1 pounds of the active ingredient cacodylic acid. Blue contained both the cacodylic acid as the free acid and the sodium salt of cacodylic acid. The percentages of the formulation were:

cacodylic acid	4.7%
sodium cacodylate	26.4%
surfactant	3.4%
sodium chloride	5.5%
water	59.5%
antifoam agent	0.5%

Herbicide White, 1966 – 1970: White was a dark brown viscous liquid that was soluble in water but insoluble in diesel fuel or organic solvents. Herbicide White first arrived in Vietnam in January 1966. One gallon of White contained 0.54 pounds of the active ingredient 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2.00 pounds of the active ingredient of 2,4-D. White was formulated to contain a 1:4 mixture of the triisopropanolamine salts of picloram and 2,4-D. The percentages of the formulation were:

triisopropanolamine salt of picloram	10.2%
triisopropanolamine salt of 2,4-D	39.6%
inert ingredient (primarily the solvent, triisopropanolamine)	50.2%

The studies reported in the Leaflets describe how the tactical herbicides and the spray equipment were developed, tested, evaluated for use in Vietnam. The outcome of this process was that the tactical herbicides were sprayed at the rate of 3 gallons per acre in Vietnam. These were formulations and concentrations that greatly exceeded how the commercial components of these tactical herbicides (2,4-D; 2,4,5-T; picloram; and, cacodylic acid) were formulated and used in the United States in brush and weed control, and in forestry management.

Search Strategy for Historical Documents on Tactical Herbicides

SOURCES

The Department of Army research on tactical herbicides was conducted primarily by the Army Chemical Corps' Plant Sciences Laboratory, Fort Detrick, Frederick, Maryland and it predecessors. A search was conducted of more than a thousand documents of the Army Chemical Corps at the National Archives in Greenbelt, Maryland.

The United States Armed Services Center for Unit Records Research (CURR), The Department of Army, Springfield, Virginia was contacted with the assistance of the Deployment Health Support Directorate, Deputy Under Secretary of Defense (Installations and Environment), Department of Defense, Washington, DC. CURR provided numerous leads on important documents.

The Defense Technical Information Center (DTCI), Fort Belvoir, Virginia, is the "premier provider of DoD technical information." DTIC is the repository of the documents submitted by the military to its predecessor, the Defense Documentation Center (DDC). A DTIC search resulted in the identification and acquisition of numerous DDC documents.

The Armed Forces Pest Management Board's Defense Pest Management Information Analysis Center, and Literature Retrieval System, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC. The Literature Retrieval System is an online collection of scientific papers comprising more than 102,000 documents in searchable PDF format for research purposes only. The Literature Retrieval System was an excellent source of information.

The [redacted] Collection on Agent Orange, Specially Collections, The National Agricultural Library, Beltsville, Maryland, This is a collection of more than 7,000 documents collected by Dr. [redacted] from 1969 – 1987 on the issues associated with the use of herbicides in Vietnam and Southeast Asia. Many of the documents are technical reports of research conducted by the military on the use and disposal of tactical herbicides. Included are technical reports by Dr. [redacted] on the fate of the tactical herbicides in the environment. Approximately 1,600 documents are retrieval in a searchable PDF format.

The Office of Air Force History, Bolling Air Force Base, Washington DC, and the Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base Ohio were additional sources for information on tactical herbicides, Operation RANCH HAND Operations Operation PACER IVY and Operation PACER HO.

DOD TACTICAL HERBICIDE SITES

Site 1

Location: Bushnell Army Air Field, Florida

Dates⟶ February – April 1945

Activity Description: The purpose of this research was to determine means of accomplishing defoliation of tropical vegetation by application of a chemical agent. The herbicidal agents evaluated included the acids of 2,4-D and 2,4,5-T as 2% formulations in tributyl phosphate and diesel fuel. A total area of 382 acres (155 ha) was aerially sprayed, some areas receiving multiple applications.

Assessment: During the three-month period, a team (five military officers) from Camp Detrick, Frederick, Maryland, conducted preliminary screening of tropical plants obtained from the Plant Introduction Garden, Coconut Grove, Florida. Following the initial evaluations, aerial spray tests were conducted on "grids" of the natural vegetation adjacent to the runways on the Bushnell Army Air Field. Observations were made over the three-month period. The herbicides were formulated at Camp Detrick and transported to Bushnell Army Air Field.

Sources: Carpenter, JB (June 1945): The Effects of VXA and VKS on Natural Vegetation: Preliminary Trials. Special Reports No. 23 & No. 14, Special Projects Division, Chemical Warfare Service, Camp Detrick, MD, 17 June 1945. *The document declassified 30 Oct 1961, but subject to export control*

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DOD TACTICAL HERBICIDE SITES

Site 2

Location: USDA Station, Brawley, California

Dates⟶ July—August 1951

Activity Description: By the early 1950's, the herbicides 2,4-D and 2,4,5-T were being extensively evaluated by the United States Department of Agriculture (USDA) for their weed control properties. However, much of this work provided evidence that these same herbicides were detrimental to broadleaf crops, i.e., beans, soybeans, peppers, tomatoes, etc. Hence, the US Army Chemical Corps' Biological Laboratories at Camp Detrick, Frederick, Maryland, initiated studies to determine application rates that could be used in tactical operations as anti-crop agents. Formulations of 2,4,D and 2,4,5-T were evaluated on small field plots of various agronomic crops in an effort to evaluate the anti-crop effectiveness of small droplet sprays of these herbicides.

Assessment: The Army Chemical Corps established a project agreement with Division of Weed Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, USDA, to conduct studies on the toxicity to agronomic crops of various 2,4-D and 2,4,5-T formulations. The rates varied from 0.5 pounds (lbs) of active ingredient of the herbicide per acre (A) to 8 lbs/A. USDA personnel at the USDA Research Station at Brawley, California conducted all of the studies. Camp Detrick personnel provided project oversight and the formulations to be tested.

Source: Weintraub RL, Minarik, CE (1952): Field Plot Experiments with Plant Inhibitors, the 1950–51 Crop Season. Special Report No. 156, Chemical Corps, Biological Laboratories, Camp Detrick, Frederick, Maryland, August 25, 1952. *The Document declassified 17 April 1962 but subject to export control.*

DOD TACTICAL HERBICIDE SITES

Site 3

Location: Eglin Air Force Base, Florida (Test Ranges 52 and 57)

Dates→ November – December 1952, March – April 1953

Activity Description: In preparation for the potential use of tactical herbicides for use as anti-crop agents, the Air Force Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, tasked the Air Force Armament Center, Eglin Air Force Base, Florida, with the requirements for the design and procurement of a Large Capacity Spray System to used in the B-29, B-50, and C-119 bomber aircraft.

Assessment: In late 1952, a mixture of technical butyl 2,4-D (50%) and technical butyl 2,4,5-T (30%) and technical isobutyl 2,4,5-T (20%) was aerially sprayed from altitudes of 100-1000 feet at an airspeed of 200 mph. Tank size varied between 125-640 gallons. Spray systems were tested for B-29, B-50, and C-119 aircraft. The total spray area was 8,700 acres. This is first documented use of the Purple formulation. In the 1953 tests, the ester formulation was aerially sprayed from a B-29 and a C-119 aircraft from altitudes of 1,000-2,000 feet. Tank size was 1,000 gallons in both aircraft. 8,500 gallons of herbicide were released at a rate of 0.34 lbs/A on 8,000 acres of both test areas. A small number of Air Force, Army, and contractor personnel were involved in the operations. The formulation was furnished by the US Army Chemical Corps, Camp Detrich, Frederick, Maryland.

Source: Acker RM, Hartmeyer RW, Heatherly JE, and Bullard WE (1953): Anticrop Aerial Spray Trials, Phase III. Special Report No. 184, US Army Chemical Corps' Biological Laboratories, Camp Detrick, Frederick, Maryland, February 15, 1953. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49572*

Ward JF (August 1953): Evaluation of Production Model of Large Capacity Spray System for B-29 and C-119 Aircraft. Technical Report No. 53-33, Air Force Armament Center, Eglin AFB, Florida. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD17563*

DOD TACTICAL HERBICIDE SITES

Site 4

Location: USDA Experimental Fields, Gallatin Valley, Bozeman, Montana

Dates→ July – August 1953

Activity Description: In 1951, the US Army Chemical Corps evaluated the phytotoxicity of 2,4-D and 2,4,5-T on broadleaf crops. The question remained as to whether the phenoxy herbicides were equally phytotoxic to narrow leaf grain crops. Thus, a preliminary series of field evaluations were conduced of various 2,4-D and 2,4,5-T formulations as anti-crop agents against wheat. The tests were conducted at the United States Department of Agriculture (USDA) Research Center in the Gallatin Valley near Bozeman, Montana.

Assessment: The objective of these experiments conducted on wheat was to determine the feasibility of applying very small amounts of candidate anti-crop agents from a spray boom mounted on a light aircraft. The tests took place in July 1953 on 139 acres of hard red spring wheat. Four chemical agents were formulated by the Crop Division's Biological Laboratories, Camp Detrick, Maryland, and consisted of various mixtures of n-butyl, isobutyl and amyl formulations of 2,4-D and 2,4,5-T. The mixture of concentrated butyl 2,4-D and 2,4,5-T [50% butyl 2,4-D, 25% butyl 2,4,5-T, and 25% isobutyl 2,4,5-T – Herbicide Purple] was applied at rates from 0.03 to 4.18 lbs/A in four replications of plots within the 139 acres of wheat. The mixtures were sprayed from an altitude of 30 feet. Total quantity for all formulations of 2,4-D and 2,4,5-T was less than 55 gallons. Personnel involved were from either the USDA or from Camp Detrick.

Source: Acker RM, Hartmeyer RW, Bullard WE, and Heatherly JE (February 1954): Field Development of Chemical Anticrop Agents. Special Report No. 200, Crops Division, US Army Chemical Corps' Biological Laboratories, Camp Detrick, Maryland. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49571.*

Site 5

Location: Area B, Fort Detrick, Frederick, Maryland

Dates→ June – July 1953

Activity Description: Experiments were conducted on field grown crops to determine the feasibility of using an experimental spray tower mounted on a pickup truck to simulate aerial spray applications of chemical anti-crop agents. In addition, since anti-crop agents were to be deployed from a bomber aircraft, it was essential to obtain crop yield data when sprays were applied under simulated tactical operational conditions.

Assessment: The tests were conducted on Area B, Camp Detrick, Maryland, The Purple mixture of technical butyls of 2,4-D/2,4,5-T was applied to 1-acre plots of soybeans and sweet potatoes at a rate of 0.05 lbs/A. The chemical mixture was sprayed from a 20-foot tower mounted on a pickup truck. The agent was applied in the evening under inversion conditions, and with a wind velocity between 2 and 3 mph and a direction parallel to the crop rows. Chemical Corps personnel were responsible for both the spray operations and the preparation and handling of the tactical herbicide.

Source: Acker RM, Hartmeyer RW, Bullard WE, and Johnson WB (January 15, 1954): Field Development of Chemical Anticrop Agents, Series 2, Response of Field Grown Crops to Chemical Anticrop Agents Released from an Experimental Spray Tower. Special Report No. 201, Chemical Corps, Biological Laboratories, Camp Detrick, Frederick, Maryland. *Document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49420.*

DOD TACTICAL HERBICIDE SITES

Site 6

Location: Fort Ritchie, Cascade, Maryland

Dates→ April 1956 – September 1957

Activity Description: In 1956 and 1957, 577 chemicals were screened for the best available tactical defoliants, desiccants, and vegetation control agents. Selection of suitable agents was determined by evaluating environmental conditions, spray techniques, and formulations that increased the effectiveness of the defoliants and desiccants.

Assessment: Selected coniferous and deciduous trees native to the Fort Ritchie Reservation, Cascade, Maryland, were selected for treatment with 5, 60, 500, and 1,000 parts-per-million (ppm) applications of various 2,4-D and 2,4,5-T formulations. All applications were done by hand application. Sprays with the technical butyl esters of 2,4-D and 2,4,5-T were found to be most effective as defoliants. The applications of the tactical herbicides and the preparation of the formulations were the responsible of the personnel from the Biological Warfare Laboratories, Fort Detrick, Maryland.

Source: Preston WH, Downing CR, Hess CE (July 1959): Defoliation and Desiccation. Biological Warfare Laboratory Technical Report Number 16, Crops Division, Director of Biological Research, Army Chemical Corps Research and Development Command, US Army Biological Warfare Laboratories, Fort Detrick, Frederick, Maryland. *The document declassified July 1971 but subject to export control. Available from the Defense Documentation Center, Accession Number AD31980.*

DOD TACTICAL HERBICIDE SITES

Site 7

Location: Dugway, Utah

Dates→ May 1951 – March 1959

Activity Description: Ten projects of chemical anti-crop agents were conducted on the Dugway Proving Ground, including tests with formulations of 2,4-D and 2,4,5-T, between 7 May 1951 and 23 March 1959.

Assessment: The series of tests were all conducted from a variety of platforms, including balloons, an experimental spray tower, light aircraft, and jet aircraft, and with a range of volumes from low volume to large capacity spray tank volumes. Studies were conducted on the effects of altitude and airspeed on the droplet behavior of chemical anti-crop agents. The formulations, including the butyl ester formulations of 2,4-D and 2,4,5-T, were prepared by the US Army Chemical Corps, Fort Detrick, Frederick, Maryland. Personnel were from the Chemical Corps or on detail from the United States Air Force.

Sources: King DW, Ward RM (1961): Summary and Evaluation of Chemical Spray Trials, Technical Report 61-1B, Volume 2, Bibliography, C-E-I-R, Inc., Dugway Field Operations, Dugway, Utah, 31 August 1961. *Document declassified 19 October 1964.* (Summaries included for Special Report 149, 7 May 1951; Special Report 151, 20 December 1951; Special Report 184, 15 February 1953; Special Report 201, 15 January 1954; Special Report 200, February 1954; Special Report 225, November 1954; Special Report 227, 14 January 1955; Special Report 232, June 1955; Summary Report E-47-2, 2 December 1957; Summary Report E-47-3, 23 March 1959). *All documents subject to export control. Summary document available from the Defense Documentation Center, Accession Number AD354205.*

DOD TACTICAL HERBICIDE SITES

Site 8

Location: Fort Drum, New York

Dates→ May – October 1959

Activity Description: The basic consideration in aerial applications of liquid sprays for vegetation control is to secure maximum deposition of the delivered agent on the selected target. In the summer of 1959, a 2,4-D/2,4,5-T formulation was evaluated for its operational use in defoliating or killing trees growing in an area of about four square miles in an impact zone (an area receiving explosive ordnance) at Camp Drum, New York.

Assessment: Thirteen drums (715 gallons) of the concentrated butyl esters of 2,4,D and 2,4,5-T (Herbicide Purple formulation) were aerially applied by helicopter over 2,560 acres of Fort Drum's deciduous forested area in the summer of 1959. The area selected for treatment was an area isolated from combat maneuvers. The tests were conducted by US Army Chemical Corps personnel, and the Purple Herbicide formulation was surplus herbicide from an inventory manufactured in 1953-1954 period for potential use in the Korean Conflict. The rates of deposition and the flow rate calculations were instrumental in subsequent defoliation tests in both the Continental United States and in Southeast Asia.

Sources: Brown JW (1962): Section VI. Vegetation Control, Camp Drum, New York. IN: Vegetational Spray Tests in South Vietnam. US Army Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0476961.*

Minarik CE (1964): Crops Division Defoliation Program. IN Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0427874.*

DOD TACTICAL HERBICIDE SITES

Site 9

Location: Eglin AFB, Florida, Test Area C-52A and Hardstand 7

Dates→ March 1962 – January 1971

Activity Description: The training of the aircrews, the development of the interface between the aircraft and the spray equipment, and the test and evaluation of the entire aerial spray system were the responsibilities of United States Air Force's Air Development Test Center (ADTC), at Eglin Air Force Base (AFB). For ten years (1961-1971), the Air Force Armament Laboratory at Eglin AFB provided the scientific, engineering, and technical support for Operation RANCH HAND in Vietnam. One of the most important aspects in the development of aerial spray systems was testing of the equipment under the most realistic conditions possible. An array of test grids was developed where the aircraft and equipment could be monitored and evaluated using the actual herbicides that were deployed for use in Vietnam. The goal was not to test the effectiveness of the herbicides, but rather the effectiveness of the aircraft and spray equipment in disseminating a concentration of herbicide that would be effective in defoliating jungle vegetation.

Assessment: During the 10-year period, four test grids, each uniquely arrayed to match the needs of either fixed-wing, helicopter, or high performance jet aircraft, were established and operated within the boundary of Test Area C-52A. During the years of its operation, an area of less than 1 square mile of the Test Area received 15,455 gallons of Herbicide Purple (281 drums) and 18,975 gallons of Herbicide Orange (345 drums), 4,400 gallons of Herbicide Blue (80 drums). Spray equipment tests and evaluations of the more than 400 missions over the Test Area were generally scheduled and conducted with environmental conditions optimal for spray operations. The total estimated flight time spent dispensing herbicides over the four test arrays was 235 hours.

The program terminated in the spring of 1971, and Test Area C-52A was set-a-side as a unique research site for the environmental impacts of tactical herbicides and the associated dioxin. In 1978, following the conclusion of many ecological and environmental studies, the entire area was fenced and restricted from public access. The decision by the ADTC to allow natural attenuation to clean the ecosystem of chemical residues prevented a major reclamation operation of an area of more 400 acres.

In support of the test and evaluation programs on Test Area C-52A, ADTC established a herbicide storage and aircraft loading site at Hardstand 7, an asphalt and concrete aircraft parking area located west of the North-South Runway on the main Eglin AFB Airdrome. Hardstand 7 was the herbicide-loading site for the approximately 400 aerial missions in support of the aircraft and spray equipment tested on the Test Area. In 1974, 130 drums of Herbicide Orange were removed from the Hardstand to the Naval Construction Battalion Center, Gulfport, MS for final disposition

In the first years of the tests programs on Test Area C-52A, numerous US Army Chemical Corps personnel were involved in the operations. By 1963, Air Force Armament Laboratory military, civilian, and contractor personnel were involved in the handling and test operations. Hundreds of military and civilian personnel were involved in the Eglin AFB Test Programs, and subsequent ecological studies over the years from 1963 to 1983.

Sources: More than 25 technical reports on test operations and ecological studies involving Test Area C-52A and Hardstand 7 are available in the Special Collection on Agent Orange at the National Agricultural Library, Beltsville, MD.

Young AL, Thalken CE, Ward WE (1975): Studies of the Ecological Impact of Repetitive Aerial Applications of Herbicides on the Ecosystem of Test Area C-52 A, Eglin AFB, Florida. *Available from the Defense Documentation Center, Accession Number AD-A032773.*

Two recent articles have been published that summarize the test programs and ecological studies on Test Area C-52A and Hardstand:

Young AL, Newton M (2004): Long Overlooked Historical Information on Agent Orange and TCDD Following Massive Applications of 2,4,5-T-Containing Herbicides, Eglin Air Force Base, Florida. *Environ Sci & Pollut Res* 11(4): 209-221.

Vasquez AP, Regens JL, Gunter JT (2004): Environmental Persistence of 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin in Soil Around Hardstand 7 at Eglin Air Force Base, Florida. *J Soils and Sediments* 4(3): 151-156.

DOD TACTICAL HERBICIDE SITES

Site 10

Location: Fort Ritchie, Fort Meade, Maryland

Date → 1963 – 1964

Activity Description: The search for effective defoliants prior to Vietnam focused primarily on the effectiveness of the phenoxy herbicides 2,4-D and 2,4,5-T. Thus Herbicide Purple was the earliest formulation that was considered appropriate for use in Vietnam. However, the Crops Division of the US Army Biological Laboratories continued its search for other potential defoliants that could be used in Vietnam. This effort was both an in-house program at Fort Detrick, and a contractual program managed by Fort Detrick. By the early 1960s, the knowledge and experience in synthesizing and evaluating various chemicals with herbicidal properties was located primarily with the Chemical Companies that were developing new pesticides for agricultural use. Thus, in 1963, the Army Chemical Corps sponsored the first of three "Defoliation Conferences". The First Defoliation Conference was held at Fort Detrick on 29-30 July 1963. At this Conference, the major pesticide producers in the United States were invited to participate. The concept was that the companies through contractual agreements would synthesize new potential compounds and that Fort Detrick would screen these compounds for the necessarily biological activity.

The screening program by Fort Detrick was carried out in three phases: primary screening on 14 day-old Black Valentine beans at 0.1 and 1.0 pounds per acre (lbs/A); secondary screening of the most promising chemicals sprayed in the greenhouse at 1, 5, and 10 lbs/A on maple, spruce, pine, locust, privet, pin oak, hemlock, and elm seedlings; and, the third phase consisted of field screening. Some initial field screening occurred at Fort Detrick. Subsequent field screening was conducted at Fort Ritchie and Fort Meade in Maryland, geographically not far from Fort Detrick, but on Military Reservations sufficiently large to permit spraying individual trees or small plots in areas isolated and restricted from public access. The field screening was used to answer the question: "At what rate are certain compounds effective, if not effective at 5 or 10 lbs/A?"

Assessment: The 1963 tests at Fort Ritchee consisted of spraying various rates of picloram, 2,4-D, Herbicide Orange, diquat, endothal, and combinations of each of these on 108 individual trees consisting of ash, elm, and locust. The 1963 field tests at Fort Meade consisted of spraying 24 plots, each 225 square feet, with cacodylic acid, Dowco 173, and butynediol at 10, 25, 40, 55, 70, 85, and 100 lbs/A on 15 species of trees, including scrub pine, maples, oaks, American chestnut, sweet gum, tulip poplar, quaking

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aspen, and vaccinium. The 1963 tests confirmed the selectivity and effectiveness of a combination of picloram-2, 4-D (subsequently later labeled Herbicide White), and a water-soluble sodium formulation of cacodylic acid (subsequently later labeled Herbicide Blue). The 1964 field trials continued the evaluation of various "new" compounds that were sprayed on 105 plots, each 225 square feet, with 52 different compounds and formulations at 5 and 10 lbs/A.

Because the trees and plots at Fort Ritchie and Fort Meade were spread over a considerable area, and the terrain was frequently very rough, the spray system consisted of 3-gallon tank sprayer with a 20-foot hose and a 9-foot stainless steel wand having a 20-inch boom with three No.2 Whirljet nozzles. The compounds and formulations were carefully weighed to the desired rates in the laboratory at Fort Detrick, and then poured into the tank sprayer with just enough diluent to cover a plot or an individual tree. The sprayers were outfitted with pressure gauges so that each tree could be sprayed at 30 lbs pressure. Spraying was done from a large tank truck so that the spray was directed down on the foliage to more closely simulate aerial spraying. All personnel involved in the handling and spraying of the chemicals were military and civilians assigned at Fort Detrick.

Sources: Mattie VZ (1964): Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0427874.*

Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567.*

Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001.*

DOD TACTICAL HERBICIDE SITES

Site 11

Location: Dugway Proving Ground, Dugway, Utah

Date ⟶ September – October 1964

Activity Description: The objectives of the tests conducted on the Dugway Proving Ground during September and October 1965 were to determine the performance reliability, maintenance requirements, and suitability of the Army Interim Defoliant System for the US Army OV-1 (MOHAWK) aircraft.

Assessment: Six dissemination trials of the E44 Interim Defoliant System were conducted using two E44 spray tanks mounted under the wings of a US Army OV-1 (MOHAWK) aircraft. For each trial, Herbicide Orange was released at the deposition rate of 3 gallons/acre over an area of approximately 17 acres. In six trials, 935 gallons (17 drums) of Orange were disseminated on the test area. The trials were conducted by the US Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland, under an agreement with the US Army Test and Evaluation Command. The US Army Chemical Corps and the Dugway Proving Grounds provided all the personnel and tactical herbicides for the tests and evaluations.

Sources: US Army Test and Evaluation Command (1965): Integrated Engineering/Service Test of an Interim Defoliant System. Part I. Service Test, USATECOM Project No 5-4-3001-02. US Army Aviation Test Board, Fort Rucker, Alabama. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD466566.*

McIntyre WC, Sloane HS, Johnson KR, Taylor WS (1965): Final Report of Integrated Engineering/Service Test of an Interim Defoliant System. US Army Test and Evaluation Command, Dugway Proving Ground, Dugway, Utah. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD363013.*

DOD TACTICAL HERBICIDE SITES

Site 12

Location: Georgia Power Company Right-of-Way, and Tennessee Valley Authority Power Line Right-of-Way

Date → May 1964 – October 1965

Activity Description: The successful screening of candidate defoliants at Fort Ritchie and Fort Meade prompted Fort Detrick personnel to seek additional sites where a more extensive evaluation could be conducted on Herbicide Orange, Picloram-2,4-D (Herbicide White formulation), and with various combinations of the commercial herbicides diquat and dicamba. The objective of the field tests was to evaluate these formulations under field conditions against the standard tactical herbicide "Purple".

The Crops Division arranged with Georgia Power Company and Tennessee Valley Authority for the use of 65 acres of right-of-way through the swamps of Georgia, and additional 65 acres of right-of-way in the mountains of Tennessee. The test sites selected in Georgia were characterized by swamp forest vegetation with a long, hot, growing season and ample water available for active growth. Typically, the level of water in the swamp was between 6 and 24 inches. Sections of the right-of-ways for the Valdosta-Thomasville Power Line and the Bonaire Power Line near Macon were selected for treatment. In Tennessee, a section of the 200-foot right-of-way provided by the Tennessee Valley Authority was in a mountainous area and on a power line between Hiwassee Dam, North Carolina, and Coker Creek, Tennessee.

Assessment: The aerial spray tests conducted on these transmission line right-of-ways were by helicopter. In Georgia, six plots, each 60 by 2,640 feet, were treated on the Valdosta-Thomasville line, which had a 60-foot right-of-way. On the Bonaire line, with 200-foot wide right-of-way, seven plots were established each 200 feet wide and 700 feet long. At both locations, Herbicides Orange and Purple were applied at 10 lbs/A. The proposed Herbicide White formulation was applied at 4 lbs/A picloram and 11 lbs/A 2,4-D. In the aerial tests in Tennessee, the plots were difficult to mark because of the mountainous terrain, and thus the right-of-way (approximately 3 acres between adjacent powerline towers), served as the tests plots. The Orange and Purple Herbicides were applied at 4, 8, and 33 lbs/A. The proposed White formulation was sprayed at rates of 6.25, 11.50, 19.10, and 25.5 lbs/A. The plots in Georgia were sprayed on 20-23 May 1964. The plots in Tennessee were sprayed 17 June and 2-3 July 1964.

The Bell G-3 helicopter used in all tests was equipped with two 60-gallon saddle tanks and a 24-foot boom rigged amidship. Twenty-four D-8 nozzles without swirl plates were placed on 1-foot centers along the boom. The helicopter sprayed a 50-foot swath at an altitude of approximately 60 feet above the ground. All applications were made either just after sunrise or just before sunset when wind velocities were between 0 and 3 mph. Observations on all the plots in both Georgia and Tennessee were made over a period of one year. The Companies provided the helicopter and operators. The herbicide formulations and on-site personnel were provided by Fort Detrick.

Sources: Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567.*

Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001.*

DOD TACTICAL HERBICIDE SITES

Site 13

Location: Pranburi Military Reservation, Thailand

Date ⟶ April 1964 – April 1965

Activity Description: The objectives of the Thailand tests were to (1) determine minimal rates and volumes of Herbicide Purple, component 2,4,5-T butyl and isobutyl esters (Herbicide Pink), Dinoxol (31.6% butoxyethanol ester of 2,4-D and 30.3% butoxyethanol ester of 2,4,5-T), and Herbicide Blue applied at different seasons of the year for effective defoliation; and, (2) evaluate the effectiveness of other selected defoliants, desiccants, and herbicides applied singly or in combination mixtures at different seasons of the year on representative vegetation of Southeast Asia.

Assessment: The test site locations were established on the Pranburi Military Reservation. Arrangements were made with Thai governmental authorities to use the facilities of the Ministry of Communications Airport at Hua Hin (25 miles from the test site) as a base of operations for the twin engine Beechcraft (C-45) used for test applications. Survey and preparations of two test sites were initiated in August 1963. Lanes were cleared to mark boundaries of a series of 10-acre test plots for a total of 1450 and 2000 acres of treatment at the two test sites, respectively. The trials began on 2 April 1964 and continued through 8 September 1964 with duplicate 10-acre plots treated with each chemical mixture using three 100-foot swaths per plot flown at a height of 30 to 50 feet above treetops. Evaluations of vegetative responses to chemical treatments were made at periodic intervals, and primarily by photographic techniques. Observations continued for one year after treatment.

During the period from April through September 1964, approximately 115 gallons of Herbicide Purple, 46 gallons of Herbicide Pink, 21 gallons of Dinoxol and 15 gallons of Herbicide Blue were aerially sprayed on 170 acres of Pranburi Military Reservation, Thailand. Five civilians and 5 military personnel from Fort Detrick, Maryland, conducted the spray operations and subsequent research. Approximately 25 Thai civilian workers were involved in the preparation of the test sites, and 4 US civilian workers were involved in evaluating the results of the spraying through the end of September 1964. The names of the US personnel are listed in the source document.

Source: Darrow RA (1965) OCONUS Defoliation Test Program, Semiannual Report, 1 April – 30 September 1964. ARPA Order No. 423, US Army Biological Laboratories, Fort Detrick, Maryland. *Document declassified October 1977, but subject to export control. Available from the Defense Documentation Center, Ascension Number AD360646.*