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DDT: A REVIEW OF SCIENTIFIC AND ECONOMIC ASPECTS OF THE DECISION TO BAN ITS USE AS A PESTICIDE

ENVIRONMENTAL PROTECTION AGENCY

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DDT

A REVIEW OF SCIENTIFIC AND ECONOMIC ASPECTS OF THE DECISION TO BAN ITS USE AS A PESTICIDE

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Birds
eggshell thinning
reproduction
carcinogenicity in mice
tumor production in mice
carcinogenicity in humans
" in mammalian species
DDT metabolites
persistence
drift
vaporization
soil erosion
cotton
insecticide use patterns
insect control costs
economics of minor uses of DDT
military use
sweet potatoes
sweet peppers
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DDT

A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide

Prepared for:

Committee on Appropriations

U.S. House of Representatives

U.S. Environmental Protection Agency
Washington, D.C. 20460
July, 1975

This report has been prepared by the U.S. Environmental Protection Agency at the direction of a committee of Congress and has not been reviewed by other Federal Agencies. Mention of trade names does not constitute endorsement.

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I.
INTRODUCTION

REASON FOR STUDY

At the request of the Appropriations Committee, U.S. House of Representatives, the Environmental Protection Agency has undertaken a review of the 1972 decision cancelling many of the registrations of DDT. The specific language of the request is contained in both the 1974 report of the Appropriations Committee and the November 6, 1973 Congressional Record (H 9619):

> "The Agency was also directed to initiate a complete and thorough review, based on scientific evidence of the decision banning the use of DDT. This review of DDT must take into consideration all of the costs and benefits and the importance of protecting the Nation's supply of food and fiber."

To this end, the Agency assembled a team of scientists and economists to review the relevant scientific and economic data.

HOW UNDERTAKEN

This review centered on the key findings of the Administrator in his Decision released June 14, 1972 (Appendix IA). The initial assemblage and evaluation of the information was under the direction of the Criteria and Evaluation Division, Office of Pesticide Programs. Comments and suggestions for the final report were given by scientists at offices elsewhere in EPA.

The review was divided into four major areas for purposes of conducting the review by multidisciplinary teams and for presentation of findings:

1. Fish and wildlife effects
2. Human effects
3. Residues in the environment and man
4. Economic aspects

The following methodology was used in reviewing various aspects of the Administrator's Decision:

1. Ascertain the Administrator's findings in his 1972 Opinion (Factual Findings Section).

2. Review the information available to the Administrator in support of these findings at the time of his decision.

3. Conduct information searches using relevant data banks for more recently published articles and current research projects in EPA and elsewhere.

4. Evaluate available scientific studies and data on DDT in light of the key findings of the Administrator in his 1972 Opinion to determine which of the following best describes the current data situation: a) no new data since the decision in 1972; b) new data confirm (or deny) 1972 findings.

WHAT THE REPORT DOES AND DOES NOT DO

The aim of this report was to provide a detailed review of the literature and data relating to the findings which supported the 1972 decision, and to impacts it had on social, economic, and environment variables since it became effective January 1, 1973. The review was of the data supporting the various findings of the Administrator rather than of the overall decision itself, which involved weighing of various social, economic and environmental factors.

DDT REGULATORY HISTORY: A BRIEF SURVEY

A brief survey of the regulatory history involving DDT is presented in Appendix IB. The summary covers the period from early actions by USDA to restrict DDT use in the late 1950's to EPA actions since 1972, such as those involving temporary registration for use against the pea leaf weevil (1973) and applications for emergency use of DDT against the tussock moth in forests (1974) and against the tobacco budworm on cotton (1975).

II.

SUMMARY

A. FISH AND WILDLIFE EFFECTS

B. HUMAN EFFECTS

C. DDT RESIDUES IN THE ENVIRONMENT AND MAN

D. ECONOMIC ASPECTS

SUMMARY

This summary consists of an introductory survey and a matrix summarizing results in tabular form for each major review area: fish and wildlife effects, human effects, residue monitoring, and economic (benefit) aspects. The matrices summarize results of the review, finding-by-finding in the 1972 order. The detailed analyses that led to the results summarized in Part II are presented in Part III, arranged in the same order.

FISH AND WILDLIFE EFFECTS

Voluminous literature published in this area since the DDT hearings has allowed a more complete picture of DDT's effects in this area than was available at the time of cancellation. Reproductive, behavioral, lethal, and sublethal effects on fish and wildlife have been reviewed in detail based on the additional literature and data. Also, EPA personnel conducted intensive on-site field interviews with persons involved in research on fish and wildlife effects to obtain most recent data and results, as a supplement to the nearly 500 articles that have been published in this area and reviewed since the cancellation.

New data were available in the case of most findings on fish and wildlife effects and none of the findings of the Administrator could be denied on the basis of new data. Certain behavioral effects on wildlife that were not known in 1972 have been established since that time.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Fish and Wildlife Effects

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	
DDT can be Concentrated and Transferred in Freshwater and marine plankton, insects, molluscs, other invertebrates, and fish.			X		
	Experimental evidence has demonstrated the propensity of DDT to bioaccumulate in aquatic organisms and to be transferred upward in the food web.		X		An absorption-diffusion uptake mechanism has been proposed for the midge; uptake by algae is also passive.
	Residue data collected in the environment demonstrate that DDT is ubiquitous in aquatic organisms at levels exceeding those occurring in the physical environment.		X		Residue determinations on organisms from natural habitats provide most credible evidence. Since the DDT ban, residues have generally declined. Declines are especially evident in salt water molluscs and Lake Michigan fish.
DDT Affects Phytoplankton Species Composition and the Natural Balance in Aquatic Ecosystems.			X		
	DDT decreases photosynthesis by different species of phytoplankton.		X		Exposure to DDT has resulted in reduction of oxygen production of near 90%; distorting of cell organelles also resulted from DDT exposure.
	DDT can adversely affect phytoplankton growth rate.		X		Ability to tolerate NaCl was reduced after exposure to DDT.
DDT Can Have Lethal and Sublethal Effects on Useful Aquatic Freshwater Invertebrates, including Arthropods and Molluscs.			X		
	Experimental laboratory data have shown that DDT is highly toxic to many aquatic invertebrates.		X		
	Experimental data have demonstrated that very low levels can result in reproductive failure and other sublethal effects.		X		DDT has been found to result in a decrease in fructose diphosphatase activity in quahog clams, indicating possible interference with gluconeogenesis. It has also been shown to result in reduction of sodium and potassium concentrations in shrimp hepatopancreas.
	DDT has resulted in acute kills of aquatic invertebrates in the environment.		X		Few new data are available, with the exception of preliminary data from the Tussock Moth Spray Program in the Pacific Northwest. In one study stream, the treatment resulted in almost total elimination of the aquatic insect fauna and no significant recovery was detectable a month later.
	DDT has been shown to affect higher trophic levels as a result of starvation following kills of prey invertebrates.	X			

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Fish and Wildlife Effects (continued)

Administrator's Findings	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
			New Data:		
		No New Data	Confirms 1972 Finding	Denies 1972 Finding	
DDT is Toxic to Fish.			X		
	Experimental laboratory data have shown that DDT will kill most fish species at very low levels.		X		Recent acute toxicity data are sparse, primarily because additional data would be redundant. A chronic study on fathead minnows showed that they are particularly susceptible during the first 2-1/2 months of life and during the spawning stage.
	DDT has been responsible for fish kills.		X		New reports of fish kills are lacking except for incomplete data obtained from the Tussock Moth Spray Program which showed 643 sculpins were killed in one study creek following DDT application.
DDT Can Affect the Reproductive Success of Fish.			X		
	DDT can be highly concentrated in fish and stored in lipids, particularly in the eggs. This can result in increased fry mortality during the stage when the fry are utilizing the yolk.		X		In some cases recent data are more comprehensive. Egg residues have been correlated with increased fry mortality, both experimentally and in the environment.
	Experimental results have shown that DDT can result in delayed maturation of lake trout.	X			
DDT Has a Variety of Sublethal Physiological and Behavioral Effects on Fish.			X		
	DDT differentially affects the normal utilization of some amino acids.	X			
	DDT inhibits thyroid activity in fish.	X			
	DDT has been shown to alter the temperature regime selection of fish.		X		Also has been shown to affect the amount of activity at the selected temperature. Cold and warm water temperature shock has resulted in death after altered temperature selection resulting from DDT exposure.
	DDT can affect the impulse transmission in the lateral line of fishes.	X			
	DDT can affect learning processes of fishes.		X		Hypersensitivity can result from DDT exposure.
	DDT has been shown to disrupt cellular energy.		X		Exposure to DDT has resulted in decreased enzyme (ATPases) activity in kidneys and gills, sites intimately involved in osmoregulation. Exposure to DDT has resulted in abnormalities in the ionic makeup of blood.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Fish and Wildlife Effects (continued)

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation: No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	Remarks
	DDT alters other "natural" behavior.		"X"*		Exposure to DDT has resulted in changes in exploratory behavior, locomotive display patterns, and schooling behavior.
	DDT can cause developmental effects.		"X"*		Exposure to DDT resulted in increased pectoral ray asymmetry.
Birds Can Mobilize Lethal Amounts of DDT Residues.			X		
	DDT residues present a hazard to birds during stress periods.		X		During migration or food deprivation when fat reserves are utilized, DDT residues are relocated through the bloodstream and accumulated in the brain causing death.
	Residues have been found in areas of little or no previous DDT use.		X		DDT residues up to 4.12 ppm have been found in Australian birds in areas far from any pesticide use.
	Assessment of cause of death is sometimes difficult because of the many pesticides present in the environment.		X		DDE residues up to 78 ppm were found in sick and dead eagles along with dieldrin, PCB's and mercury.
DDT is Concentrated in and Transferred Through Terrestrial Invertebrates, Mammals, Amphibians, Reptiles and Birds.			X		
	DDT is ubiquitous at all trophic levels in the terrestrial system.		X		DDT has been found in virtually all terrestrial organisms.
	Some species near the top of the trophic levels are adversely affected by DDT.		X		Osprey, eagle, sparrowhawk, peregrine falcon and other piscivorous birds are still affected by DDT in behavior and reporductive success but some are now showing some signs of recovery.
	Residue body burdens in some speices are declining.		X		Migratory songbirds in Florida are displaying a declining mean DDT residues in ppm from 1964 to 1973. Osprey have increased from 4 to 26 fledged young per year off Long Island, New York, associated with declining residues of DDE.
DDE Can Cause Thinning of Bird Eggshells and Thus Impair Reproductive Success.			X		
	Museum shells and collected shells showed marked thickness decline after introduction in 1940's.		X		Shells now show pattern of returning to nearer normal thickness since suspension of use and reduction of residues.
	Correlations between degree of shell thinning and amount of residues in eggs and birds.		X		Numerous confirming studies.

*Newly found effects.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Fish and Wildlife Effects (continued)

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
			New Data:		
		No New Data	Confirms 1972 Finding	Denies 1972 Finding	
Laboratory studies showed the phenomenon to reproducible.			X		Confirming studies show that less than 1 ppm DDE diet causes thinning of shells.
DDE affects calcium metabolism.					Biochemical mechanism found; DDE inhibits calcium ATPase ("the calcium pump") in the avian shell gland.
			"X"*		Breeding behavior and nest attentiveness adversely affected by DDE.
Widespread reproductive failures in many avian species in U.S.			X		Fewer reproductive failures since suspension. Some avian populations returning to near normal reproduction.
No other chemical found to cause the degree of thinning caused by DDE.			X		More chemicals tested. None cause thinning like DDE.

---

*Newly found effects.

HUMAN EFFECTS

Prior and current literature and data on carcinogenicity of DDT are reviewed. The review indicates that DDT is a carcinogen in mice, and a potential carcinogen in man. Valid epidemiological studies of human effects of DDT are still lacking. Adequate laboratory studies in species other than the mouse are still lacking. NCI studies involving the carcinogenicity of DDT and its metabolites in rats are scheduled to be completed during the next year. The extent of acute human health risk due to use of DDT substitutes was reviewed, indicating no large increase in incidents due to the cancellation. However, data do not permit detailed evaluation of previous DDT use patterns. Acute and chronic health effects of DDT substitutes are being evaluated under EPA's Substitute Chemical Program on a continuing basis. Efforts have been made to protect against acute health effects by user awareness training and worker reentry standards.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Human Effects

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data:		
			Confirms 1972 Finding	Denies 1972 Finding	
DDT is a Potential Human Carcinogen.			X		The potential of DDT to produce cancer in man has to date only been evaluated on the results obtained from mouse studies. There are no adequate human studies which document DDT as an actual carcinogen in man.
	- Experiments demonstrate that DDT causes tumors in laboratory animals.		X		The production of hepatic tumors by DDT given by the oral route has been demonstrated and confirmed in several strains of mice.
	- There is some indication of metastasis of tumors attributed to exposure of animals to DDT in the laboratory.		X		Liver cell tumors have been produced in both sexes, and in CF mice were found to have metastasized to the lungs.
	- Responsible scientists believe tumor induction in mice is a valid warning of possible carcinogenic properties.		X		Specific chemicals have been observed to produce tumors in mice as well as in the rat, dog and monkey. In specific cases a chemical was observed to produce carcinomas in man as well.
	- Not all chemicals show the same tumorigenic properties in laboratory tests in animals.		X		The mouse for specific chemicals has been found to serve as a reliable indicator of the carcinogenicity of a chemical in other species and man, although the target tissue may be different. Therefore, carcinogenic effects in mice can be valid when dealing with these carcinogens; however, carcinogenic effects can vary greatly depending on the compound tested.
	- There are no adequate negative experimental studies in other mammalian species.	X			Studies in rats have been inconsistent as to dose-response. The groups were small in number and the histopathology employed was inadequate to draw definite conclusions. The one hamster study cited in this review was inconclusive, as a positive control was not incorporated. Further, information as to carcinogenicity (e.g., spontaneous tumor incidence; response to known carcinogens) is not extensive with this species. Studies performed with the dog and monkey were of too short duration and utilized too small a sample size to yield any reliable statistical information. NCI studies now underway on carcinogenicity of DDT and its metabolites could be completed during the next year (rats and mice).

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT
Human Effects (continued)

Administrator's Finding: Lines of Evidence or Nature of Finding/Subfinding	Current Data Situation			Remarks
	No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	
- There is no adequate human epidemiological data on the carcinogenicity of DDT, nor is it likely that it can be obtained.	X			No additional well-defined data were obtained from the community studies program except residue data. The early studies cited utilized small experimental groups (35 or less) over relatively short periods of time (1-11 years) as compared to that which is required (20-30 years) or greater, to test a potential carcinogen of the potency of DDT in man. Medical follow-up in the case of Hayes' controlled dose studies was limited to 4 years with only 2 subjects in each dose group. In addition, the majority of studies utilizing occupational high exposure groups were uncontrolled. Small sample size, lack of data on the age of first exposure to DDT (which could be critical in development of a carcinoma) along with other limitations make such studies inconclusive. Moreover, since DDT is ubiquitous, there is no completely unexposed human control group.
HUMAN EFFECTS OF DDT SUBSTITUTES				Definitive conclusions as to the extent of acute human health impacts of the use of DDT substitutes cannot be drawn on basis of available data. Data series do not permit quantitative analysis of human health effects in use patterns impacted by the 1972 decision, e.g., cotton. However, there is indicated some acute hazard to humans involving the use of DDT substitutes, such as the organophosphates.
- Many poisonings have been attributed to the use of Methyl parathion.		X		EPA's pesticide episode review system still lists methyl parathion as one of the most frequently reported pesticides involving human poisonings.
- Untrained users of Methyl parathion are frequently not sufficiently careful in its use despite lable directions.		X		As indicated by EPA's Project Safeguard, highly toxic organophosphates could be used safely with training and following label directions. Reentry standards also offer some potential to protect against premature entrance into treated areas. Such standards were promulgated by EPA in 1974. Other substitutes are used as well in most cases.
- Methyl parathion can be used safely.		X		
- Training programs are useful in averting the negligent use of Methyl parathion.		X		
- Methyl parathion is a substitute for most crop uses of DDT.		X		
- Ultimately, parathion is dangerous to users and presents a risk to them.	X			EPA pesticide applicator certification and training program will contribute to reduced risk of toxic DDT substitutes.
- An opportunity to train users will minimize the risks.	X			

DDT RESIDUES IN THE ENVIRONMENT AND MAN

DDT is ubiquitous in the environment due to its past use and chemical and physical characteristics. Soil residues will continue to decline slowly. Residues in food commodities and in man have declined in recent years. Future declines will be at a slower rate.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

DDT Residues in the Environment and Man

Administrator's Findings: Lines of Evidence or Nature of Finding/Subfinding	Current Data Situation			Remarks
	No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	
DDT Can Persist in Soil for Years and Even Decades. Degradation of DDT in the soil environment is highly variable but typically is very slow. "Half-life" values of 10 years or more are commonly found.		X		The use of DDT for agricultural and forestry purposes has contaminated a substantial portion of our nation's productive land. Total soil residues of DDT and its metabolites will only decline very slowly and substantial portions will still be present after extended periods of time.
Because of Persistence, DDT is Subject to Transport from Sites of Application.				
- DDT can be transported by drift during aerial application.	X			Drift of DDT has ceased to be a problem since cancellation of all uses in 1972, except possibly in the use of DDT against the tussock moth.
- DDT can vaporize from crops and soils.		X		The significance of vaporization of DDT resides from soil, especially the more volatile DDE component, is still poorly defined. Of special importance is the relative role that volatilization may play in causing low level residues in domestic animal feeds grown on DDT contaminated farmland.
- DDT can be attached to eroding soil particles.		X		Loss of DDT from terrestrial to aquatic sites due to soil erosion will continue to occur for many years into the future.
DDT is a Contaminant of Fresh Waters, Estuaries and the Open Ocean, and it is Difficult or Impossible to Prevent DDT from Reaching Aquatic Areas and Topography Adjacent and Remote from the Site of Application. DDT residues are ubiquitous in the aquatic environment, especially in aquatic sites fed by agricultural watersheds. Contamination of estuarine areas by way of major river systems has occurred and coastal areas are generally polluted with low levels of DDT. The open oceans contain considerably less DDT, but minute levels can be found worldwide, even in the polar regions.		X		A gradual decline in residue levels of aquatic organisms can be expected as the bioavailability of DDT is decreased due to the combined factors of dispersion, degradation, and sedimentation. Excessive residue levels, as noted in fish from the Great Lakes in the 1960's are no longer frequent occurrences. With the exception of data on fish from the Great Lakes, most available residue data are not applicable to prediction of long term trends with regard to the degradation of DDT in aquatic environments.
DDT Can Persist in Aquatic Ecosystems. DDT and its metabolites DDE and DDD are commonly found in water, sediment and aquatic life. A dynamic equilibrium exists with the main storage reservoir being the bottom sediment.		X		Residues of DDT and its metabolites can be expected to persist for an extended period of time. Bioavailability, however, can be expected to decrease as a result of dispersion degradation and sedimentation especially in areas where bottom sediments are not subject to continued disruption. Good "baseline" data from which future trends can be compared and/or predicted are not yet available for many types of aquatic areas.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

DDT Residues in the Environment and Man (continued)

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
			New Data:		
		No New Data	Confirms 1972 Finding	Denies 1972 Finding	
The Accumulation in the Food Chain and Crop Residues Results in Human Exposure.	DDT and its metabolites DDE and DDD are commonly found in human foods, especially meat, fish and dairy products.		X		Gradual declines of total DDT residues in certain major food commodities began as early as 1965, but declined rapidly only after 1970. For meat and poultry, these declines had stabilized by FY 1973. Levels of the metabolite DDE have increased relative to DDT over the last several years indicating that much of the current DDT residual is coming from pesticide treatments applied prior to DDT's cancellation in 1972. Due to the persistence of these compounds, residues will continue to occur for many years, even after cessation of DDT use.
Human Beings Store DDT.	DDT and its metabolites DDE and DDD are found to store in human adipose tissue. DDT residues are found in human populations world-wide with higher residues usually associated with DDT use in underdeveloped countries.		X		DDT residues in human adipose tissue have tended to decline in recent years (1971-1973), while the percent of DDT stored as DDE has moved up only slightly. During this same period, significant declines in residues in human food were noted. However, since FY 1973, levels of DDT and its metabolites in food have leveled off so that no precipitous change in human tissue levels can be expected in the near future. Human serum levels of DDT in samples from occupationally exposed individuals showed a pronounced downward trend between 1971 and 1973 suggesting decreased exposure during the period.

ECONOMIC ASPECTS

Cotton was the major use of DDT prior to the cancellation, accounting for more than 80 percent of domestic DDT use. DDT was used on about one-sixth of U.S. cotton acreage in 1971 and 1972 (one-fourth of cotton farms). Insecticides are an important input to cotton production, contributing to improved yields, although they account for only about four percent of total production costs for the average cotton grower. Insecticides range to near 15 percent of costs in some regions.

Alternative insect controls, chemical and non-chemical, are available although there are pest resistance problems in some areas for certain pests, and, at times, market scarcities of supplies.

Costs of growing cotton were affected in the Southeastern United States where DDT was used prior to the cancellation. Costs were increased by about $7.75 million per year on the average in 1973 and 1974. Nationally this impact amounted to an increase in costs of slightly over $1.00 per acre treated with insecticides (all types), equalling an increase in cotton production costs per acre of about 0.5 percent. This cost impact was within the range of estimates in the hearing record (cost impacts up to $54 million per year). This cost impact was quite significant in the most affected region as production costs were increased by more than $600 per farm on the average for about 10,000 farms. Insecticide costs in this region were increased by about $6.00 per treated acre, over the 1971/72 average of about $15.50 per acre in 1971/72. Farms in this southeastern U.S. region that use insecticides average about 70 acres treated per farm. Effects on costs elsewhere were much less significant.

The cost impact of $7.75 million translates into a nominal impact on the consumer of cotton, i.e. 2.2 cents per capita per year. The cost impacts of the cancellation are not expected to generate large regional or national impacts on cropping patterns for cotton and other major agricultural crops, based on a recent analysis. Studies are in progress in EPA to evaluate possible cotton yield effects of DDT and other cotton insect pest management options as well as cost impacts which were the prime focus of studies reported in this review due to data limitations.

Minor use DDT cancellations have resulted in increased insect control costs of more than $400,000 per year (estimate for 1973), a nominal impact nationally. Production and yields of minor use crops have not been seriously affected. Temporary uses of DDT have been permitted in certain emergency or special cases such as the tussock moth and the pea leaf weevil. Studies are underway to better evaluate benefits of DDT and alternative controls in forest uses under an EPA/USDA interagency agreement.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Economic Aspects: Cotton

Administrator's Finding	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	
COTTON General economic context of DDT cotton cancellation since 1972					Cotton was the major DDT use accounting for more than 80 percent of domestic use. DDT was used on about 17 percent of cotton farms in the U.S. prior to the cancellation (16,700) and about 25 percent of the cotton acreage (1971-72 averages). DDT was used only in the S.E. U.S. immediately prior to the cancellation (S. Atlantic Region - Md., Del., Va., W. Va., N.C., S.C., Ga. and Fla.; and the East S.Central Region - Ky., Tenn., Ala., Miss., Ark. & La.). DDT was used on more than half of the cotton farms and cotton acreage in the S. Atlantic Region in 1971/72, but less than one fourth of the cotton farms and acreage in the East S. Central Region. Insecticides are an important input in the cotton industry, but less than 5 percent of the cost of growing cotton in the U.S. In the S.E. U.S. where DDT was used, costs of insecticides ranged up to 14 percent of the budget for growing cotton as of 1971/72. Economic well-being of the U.S. cotton grower is much more a function of other factors than changes in pesticide regulatory policy. The cotton farmer, from year to year, is hard hit by such factors as bad weather, late plantings leading to pest infestation problems and declining prices which battered the industry in 1974. This outcome followed a banner year in 1973, when prices were the highest in history and the 15 cents per pound government payment to growers was in effect. The unfavorable economic outcome for cotton growers in 1974 has lead to greatly reduced cotton plantings in 1975. The cotton industry has been able to meet market needs since 1972, especially in 1974 as prices declined sharply when the crop came to market.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Economic Aspects: Cotton (continued)

Administrator's Finding: Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation: No New Data	Current Data Situation: New Data: Confirms 1972 Finding	Current Data Situation: New Data: Denies 1972 Finding	Remarks
AVAILABILITY OF ALTERNATIVES TO DDT				
DDT is useful for the control of certain cotton insect pests.		X		In the DDT Hearing Admission No. 2 the USDA considered DDT essential to control the following insect pests: budworm, boll weevil, cotton bollworm, cotton fleahopper, fall armyworm, garden webworm, Lygus bugs, mirids, thrips, and cutworms. However, the 1972 Annual Conference Report on Cotton Insect Research and Control only recommended DDT for the bollworm, budworm, and cutworm.
Cotton pests are becoming resistant to DDT.		X		The 1972 Annual Conference Report on Cotton Insect Research and Control (USDA) stated many cotton pests are resistant to DDT. Also, hearing testimony stated DDT was not effective for the control of the boll weevil and that cotton pests, including the bollworm, are partially or totally resistant to DDT. The trend in use of DDT was downward since 1964, presumably due in part to developing pest resistance.
Methyl parathion and other organophosphate chemicals are effective for the control of cotton pests.		X		Alternative pesticides are registered by EPA and recommended by the states for all cotton insect pests and are effective in most areas. However, there may be cases where effectiveness of some alternatives is limited to development of pest resistance due to heavy or consistent use of chemicals in the past or extreme pest infestation outbreak conditions. The 1975 Annual Conference Report on Cotton Insect Research Control (USDA) recommended EPA registered insecticides for the control of the various cotton pests. Integrated pest management programs are minimizing the impact of the DDT decision by pest detection and improved use of DDT alternatives, including non-chemical controls.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Economic Aspects: Cotton (continued)

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data		
			Confirms 1972 Finding	Denies 1972 Finding	
By Using Methyl Parathion or Other Means of Pest Control, Cotton Producers Can Generally Produce Satisfactory Yields at Acceptable Cost.			X		Impacts of DDT Decision on Cotton Insecticide Costs - Comparison of 1971/72 and 1973/74 pre and post-cancellation periods The comparison of two year averages for the periods immediately prior to and following the 1972 decision provides the basis for making judgements of impacts on costs of growing cotton. Data on the individual years are not available. Insecticide expenditures nationally increased from $64.6 million per year in 1971/72 to $102.9 in 1973/74 (from $10.07 $13.65 per acre treated with an insecticide, or by $3.58). Of this $38.3 million increase in insecticide costs, an estimated $6.1 million was due to the DDT cancellation (about one sixth). In addition, the cancellation led to an estimated increase in application costs of $1.6 million for an overall total of $7.75 million. This amounts to an average increase of about $1.04 per acre for all cotton acres treated in the U.S., 1973/74 average (7.563 million acres). This impact translates into a rather nominal impact on the consumer, i.e., about 2.2 cents per capita/year for 1973/74. These cost impacts are well within the estimates in the record at the DDT hearings (up to $55 million per year). Impacts in the two affected regions are much more significant. In the South Atlantic, increased insecticide and application costs, for a total of $6.0 million. This equalled about $630 per farm, based on the estimated number of farms that would have been treated with DDT in 1973/74 if it were available (about 10,000 farms). This is a significant increase in costs, and is at a difficult time for cotton growers because of economic conditions of the industry and the economy generally. The increase in the East South Central was much less significant (about $1.0 million for insecticides plus $0.75 million for application costs for a total of $1.75 million). This would be less than $200 per farm on 9,000 farms. Supplies of some DDT alternatives were not plentiful in 1973/74, as costs increased sharply, particularly in the South East U.S. cotton area.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Economic Aspects: Cotton (continued)

Administrator's Findings:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data Confirms 1972 Finding	New Data Refutes 1972 Finding	
					Evaluation of Impacts of the DDT/Cotton Cancellation on U.S. Agriculture 1975 An analysis has been made of impacts of the DDT/cotton cancellation on U.S. agriculture for the year 1975, utilizing EPA's linear programming model for U.S. agriculture. This analysis evaluates impacts of changes in costs of production upon acreages, total production and prices of cotton and other major agricultural crops for the year 1975, as a typical year during the post-cancellation period. The analysis indicated that the DDT cotton cancellation had minor impacts on acreage production, costs, and returns for cotton and other major crops.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT

Economic Aspects: Minor Uses

Administrator's Finding:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation			Remarks
		No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	
DDT is useful for controlling insects that attack the following: beans (dry, lima, snap), sweet potatoes, peanuts, cabbage, cauliflower, and brussels sprouts, tomatoes, fresh market corn, sweet peppers, pimentos, onions, garlic, and commercial greenhouse plants. The use of DDT is not necessary for the production of these crops.			X		A review was made of the yield and cost impacts of the minor uses contested at the hearings, which included these crops. No review was made of the commercial greenhouse use. DDT was not widely used for these crops at the time of cancellation (2.4 percent of U.S. acreage in 1971). Tomatoes and cabbage had the largest percentage uses (9 and 16 percent of U.S. acreage respectively in 1971). Yield/acre and total production in US for these crops have been maintained since the cancellation. The only crop with 1973/74 yield/acre noteably below the 1968/72 average was cauliflower for which there was no reported DDT use in 1971. Insecticide costs for contested minor crops were estimated to increase nominally (by about $460,000) due to the DDT cancellation based on the year 1973. This would translate into a rather small impact on the consumer. Costs to growers in some local areas could have been affected significantly but no such effects are reported, aside from problems with the pea leaf weevil, discussed below.
Adequate substitute chemicals, namely, methyl parathion and other organophosphates--for the most part--exist for...crops except: sweet potatoes in storage, heavy infestations of corn borer, attacking sweet peppers grown on the Del Marva Peninsula, and onions attacked by cutworms.			X		These uses have been cancelled, but since the hearing substitutes have been registered for sweet potatoes (stored) and sweet peppers. Cost impacts from use of alternatives to DDT for sweet peppers were estimated at $76,000 over the Del Marva area, or about $19.00 per acre (4,000 acres). In 1972, DDT cost to farmers was $6.51 per acre on 1,100 acres. The onion use was limited to a few acres in California, and substitutes are available. Lack of alternative controls for the pea leaf weevil had led EPA to authorize temporary registration of DDT against this pest in Washington and Idaho. Testing of alternative controls in connection with these registrations has led to registration of alternative controls for 1975.

SUMMARY

REVIEW OF DATA ON FINDINGS SUPPORTING ADMINISTRATOR'S ORDER ON DDT
Economic Aspects: Minor Uses (continued) and Forest Use

Administrator's Finding:	Lines of Evidence or Nature of Finding/ Subfinding	Current Data Situation: No New Data	New Data: Confirms 1972 Finding	New Data: Denies 1972 Finding	Remarks
DDT is Used for Exterminating Bats and Mice by the Military. a) Fumigation and Non-Chemical Methods can Guard Against Bat Infestations. b) Warfarin is Effective for Exterminating House Mice.		X			Data requested from the Armed Forces Pest Control Board have not yet been received and evaluated, but probably not a great economic impact.
DDT is Considered Useful to Have in Reserve for Public Health Purposes in disease Vector Control.			X		A very minor use of DDT in this country; it was not cancelled; substitutes are available.
The Administrator found that potential benefits outweighed possible hazards.					

FOREST USES

1. The forest use of DDT was not contested in the DDT hearings, but since 1972 has been the subject of emergency use requests.

2. DDT had been used extensively against forest insect pests through the mid 1960's when its use was phased out as a matter of policy by USDA and USDI because of environmental concerns.

3. An emergency request by USDA to use DDT against the Tussock Moth in 1973 was denied by EPA, but a similar request was granted in 1974. Evaluation of the impacts of that action are in process. Some environmental damage occurred to fish, wildlife and domestic stock, according to preliminary data.

4. Benefit evaluations of past forest pest control efforts have been limited by data and methodology. The Forest Service is presently engaged in a major research effort on the biology and control of the gypsy and tussock moths. EPA has recently entered into an interagency agreement with the Forest Service to evaluate the environmental and economic consequences of the cancellation of DDT for control of these pests. This will be a major study with $250,000 from EPA and $70,000, Forest Service, and should considerably enhance our ability to estimate forest pest losses and the benefits of various control strategies, with and without DDT.

III

DETAILED REVIEW OF SCIENTIFIC AND ECONOMIC ASPECTS

III

A. FISH AND WILDLIFE EFFECTS

INTRODUCTION

In drafting the Fish and Wildlife Effects Section, we have located, obtained, and reviewed nearly 500 scientific publications. Also, we contacted approximately sixty individual scientists by telephone and visited more than twenty key scientists with unpublished current information. We reviewed their data, verified their protocols, and obtained written and unwritten "personal communications" and clearance for quotation in this report. In this manner, we feel that the review is quite comprehensive and current as of January 1975.

Many articles collected and reviewed are not cited in this report because: 1) the sample size of the experiment was too small to allow valid conclusions; 2) the data were for foreign species; 3) the data were confused with high residues of other pollutants; 4) the data were not pertinent because they were for nonwildlife species; 5) the data were obsolete or represented excessive duplication of quoted experiments; 6) they were negative data about noneffects, i.e., lack of effects where positive findings would not be expected, in view of other studies; 7) they were old data and had been discussed in the DDT Hearings previously.

Residue and concentration values are cited as reported by the original authors, although available analytical techniques may not always be as precise as indicated.

BIOACCUMULATION IN AQUATIC ORGANISMS

Administrator's Finding: DDT can be concentrated and transferred in freshwater and marine plankton, insects, molluscs, other invertebrates and fish.

This issue is concerned with the evidence that DDT is concentrated and incorporated into body tissues of aquatic organisms at levels much greater than those occurring in the physical environment and that these high levels may be transferred upward through the food web, with the highest level consumers receiving the greatest pesticide load.

Arguments used to support this issue are:

1. Experimental evidence has demonstrated the propensity of DDT to bioaccumulate in aquatic organisms and to be transferred upward in the food web.

2. Because of the persistence and mobility of DDT in the environment and its lipophilic properties, DDT is widely available to and biologically concentrated by aquatic organisms. Residue data collected in the environment demonstrate that DDT is almost ubiquitous in aquatic organisms in levels exceeding those occurring in the physical environment.

Data as of 1972

Experimental data presented at the hearing showed that DDT can be biologically concentrated by a variety of aquatic organisms at all trophic levels. Phytoplankton, the dominant oceanic vegetation and primary food source for marine animals, concentrates DDT from seawater into its cell membranes. Waterfleas *(Daphnia)*, a food source for many freshwater fish species, accumulated 9.0 ppm in tissues after three days exposure to 80 pptr. This represents a bioconcentration factor of 112,500 times the exposure level. Rainbow trout exposed to 1.0 ppm DDT (wet weight) in food and 10 pptr in water for 84 days contained 2.3 ppm as whole body residues. Exposure to food alone resulted in residues of 1.8 ppm (a concentration factor of 1.8 X) and exposure to water alone yielded residues of 0.72 ppm (a concentration factor of 72,000 X). In fish fed 1 mg/kg DDT/day, 73% of the DDT residues were present 90 days after the fish were transferred to clean food.

The ability of DDD (TDE), a metabolite of DDT, to concentrate and be transferred up the food web is demonstrated by studies at Clear Lake, California. DDD was applied directly to the lake between 1949 and 1957 to control a gnat at levels calculated to be 0.143 ppm in the water. During the 1950's, many western grebes were found dead; body fat residues were about 1600 ppm. Residues in fish from the lake ranged from 40 ppm in carp to 2,500 ppm in visceral fat of brown bullheads. Since fish are the primary diet of grebes, it is obvious that DDD levels in fish were transferred upward to the grebes. As of 1969, residues in grebe body fat were about 350 ppm. Egg lipid residues were about 124 ppm in 1969 and 305 ppm in 1970. In addition to causing mortality among the grebe population, reproduction was very seriously impaired and resulted in drastic population declines. Similar environmental concentration and transfer, where the source was agricultural runoff from onion fields, was found at Tule Lake, California. The western grebe, a stationary marsh resident that preys on the Tule chub, exhibited monthly fluctuations in residues ranging from 1.2 to 3.7 ppm in the organs and from 2.3 to 142.8 ppm in adipose tissue.

DDT residues in the low parts per trillion were found in all of the Great Lakes. Lake Michigan had the highest concentrations. Whole body residues found in some Michigan fish are: bloater-chub, 8.61 ppm; lake herring, 6.71 ppm; Kiyi chub, 13.28 ppm; yellow perch, 3.2 ppm; lake trout, 6.96 ppm (lake trout eggs, 4.44 ppm); white-eye chub, 7.50 ppm; coho salmon, 3 - 4 ppm in the summer of their second year, rapidly increasing to 12 ppm in late summer as they increased feeding. Whole body residues found in fishes in southern waters were: Mississippi --small-mouth buffalo, 8.43 ppm, and carp, 13.02 ppm; Texas--gizzard shad (a plankton feeder), 4.17 ppm, channel catfish, 7.27 ppm, and blue catfish, 3.98 ppm; Alabama--carp, 3.40 ppm, and large-mouth bass, 2.44-5.15 ppm, mullet, 1.56-2.16 ppm; Arkansas--carp, 2.03-2.09 ppm, small-mouth buffalo, 3.10-7.20 ppm, flathead catfish, 3.26 ppm, and channel catfish, 2.31 ppm; Florida--channel catfish, 57.0 ppm. DDT also has been found to concentrate in marine organisms, including marine mammals such as seals and whales. DDT residue data generally showed lower levels in organisms in the lower trophic levels and higher levels in organisms higher in the food web.

Data since 1972

Data collected and published since the hearing fully substantiate that DDT is virtually ubiquitous in aquatic ecosystems and that most aquatic organisms (plant and animal) concentrate it from the physical environment and transfer it through the food web. Residue determinations on wild organisms provide the most credible evidence, while laboratory studies supply additional relevant data and give some insight as to mechanisms.

Concentration of DDT by bacteria *(Aerobacter aerogenes* and *Bacillus subtilis)* has been documented by Johnson and Kennedy (1973). The bioconcentration factor did not change significantly with an increase in the water concentration of DDT (0.5-5.0 ppb), but was dependent upon the concentration of bacteria in the water. Uptake was rapid, with 80-90% of the residue being concentrated within the first 30 minutes of the 24-hour test period. With a water concentration of 0.64 μg/l and a bacterial concentration of 200 μg/l, *A. aerogenes* concentrated DDT about 1800 times. At a similar water concentration and a bacterial concentration of 174 μg/l, *B. subtilis* had a concentration factor of about 3,200 times. No evidence was found that DDT was degraded during the tests. Patil, Matsumura, and Boush (1972), in a study of the transformation process of DDT in marine systems, took samples of seawater, ocean and estuarine bottom sediments, surface films, algae and plankton, treated them with radiolabeled DDT at the collection site, and incubated them for 30 days in the laboratory. The authors believed that the most significant observation was that DDT is not metabolized in plain seawater. Most of the strong degradation activity was found to be associated with the metabolism of DDT by algae, plankton, organisms associated with surface films, and microorganisms. In general, DDD (TDE) was the principle metabolite.

The removal of dissolved DDT and DDE from water by phytoplankton has been documented by several authors using a number of species. Rice and Sikka (1973) found that *Skeletonema costatum* removed 93% of the compound from the water; *Cyclotella nana*-73%; *Isochrysis galbana*-57%; *Olisthodiscus luteus*-38%; *Amphidinium carteri*-44%; and *Tetraselmis chuii* removed 33% of the available DDT when these organisms were exposed to concentrations of 1 ppb in the medium. Sodergren (1971) determined that when *Chlorella pyrenoidosa* was exposed to near saturation levels of DDE, the cells assimilated 82% of the DDE. No difference in uptake was found between living and dead cells, indicating that uptake is a passive process. An inverse relationship between cell density and bioaccumulation factors was noted by these authors. Very rapid initial uptake of DDT by *Euglena gracilis* followed by neither excretion nor degradation after 5 days has been documented by de Koning and Mortimer (1971). Slight metabolism of DDT to DDE was recorded for diatoms *(Nitzschia sp.)* by Miyazaki and Thorsteinson (1972) and conversion of up to 12% was found for several species of phytoplankton by Rice and Sikka (1973).

Parrish (1974) studied accumulation and loss of DDT by American oysters *(Crassostrea virginica)* which were exposed continuously to a concentration of 0.01 ppb DDT for 56 weeks. Maximum residue concentrations, based on body weight, (µg/g) occurred after 8 weeks of exposure, but absolute amounts of toxicant accumulated (µg) occurred after 56 weeks of exposure. After 8 weeks, whole body residue concentrations (wet weight) averaged 0.46 µg/g (ppm), a concentration factor of 46,000 times the exposure level. Total body residues averaged 1.0 µg. After 56 weeks, average residue concentration was 0.37 µg/g and the total residue average was 7.0 µg per oyster. Residues based on body weight decreased between 45% and 81% during early July and late October, apparently as a result of spawning, and increased following these periods. Neither growth nor mortality of exposed oysters was significantly different from that of control oysters at the 0.01 confidence level. Bedford and Zabik (1973) exposed freshwater mussels *(Anodonta grandis)* to concentrations of 0.14-0.62 ppb DDT and found that they concentrate it about 2400 fold in lake water. Residue concentrations were highest in the digestive and reproductive tissue and lowest in the muscle, mantle, and gill tissues.

Sodergren and Svensson (1973) tested mayfly nymphs *(Ephemera danica)* in a flow-through system at a concentration of 761 pptr (parts per trillion) for a period of 9 days and found accumulation factors (concentration in organisms/water concentration) ranged from 440 to 6250. p,p'-DDT added to the system was rapidly metabolized, the principle metabolite being p,p'-DDE. Accumulation appeared to follow a kinetic equation of the first order. In experiments with the midge *(Chironomus tentans)* Derr and Zabik (1972) found that exposure of 0.07-2.2 ppb through the life cycle from egg to adult resulted in accumulation of residues in excess of 20,000 times the water concentration. Accumulation was dose dependent with DDE residues increasing exponentially with increased concentration at a given exposure time. At any given water concentration, accumulation increased with exposure time. The process of egg deposition eliminated 11.6-30.9% of the adult female DDE residues. In a subsequent paper utilizing the same organisms, Derr and Zabik (1974) found no difference in the amount of DDE accumulated by live and dead fourth instar larvae. However, the amount of DDE concentrated by the larvae was increased by manipulation of water hardness. The authors proposed an adsorption-diffusion mechanism to account for the mode of uptake and biological concentration capabilities of the midge.

Reinert, Stone, and Bergman (1974, unpublished) studied accumulation from water and food by lake trout (*Salvelinus namaycush*) in the laboratory to determine how fish from Lake Michigan accumulate high concentrations from the environment where water concentrations are generally less than 0.01 ppb. Groups of yearling trout were exposed to concentrations of p,p'-DDT ranging from 0.006 to 0.01 ppb in the water and from 1700 to 2300 ppb in the food. After 90 days, the fish exposed only through the water had accumulated body residues of 422 ppb DDT, fish exposed only through the food contained 464 ppb DDT, and those fish exposed through both food and water contained 798 ppb DDT. Maximum DDT uptake from the food only was noted after 120 days and was 712 ppb. After exposure to DDT stopped, elimination of DDT was monitored. Elimination proceeded very slowly and after 125 days, the residues of DDT had not significantly declined. This rapid uptake and slow elimination clearly illustrate why high body residues of DDT are maintained by some fishes.

Jarvinen, Hoffman, and Thorslund (1974 unpublished) subjected fathead minnows to nominal concentrations of 0.05 and 2.0 ppb DDT in water, with some groups being exposed to 50 μg/g DDT (^{14}C labeled) in the diet. The study lasted 266 days, through a complete life cycle. In general, residues peaked by 56 days for fish exposed to the low DDT water concentration and fed clean food and for controls with DDT contaminated food, and by 112 days for the rest of the exposed fish. Residue levels rapidly decreased during the spawning period (112-224 days) and rose again after termination of spawning activity. After 266 days, fish exposed to control water, but with DDT contaminated food, had a body burden 2.4 times those exposed to low DDT water concentration but fed clean food. Fish exposed to the low water DDT concentration plus DDT contaminated food had residues 3 times those exposed to the same DDT concentrations but fed clean food. Residues from fish exposed to the high DDT water concentration and fed DDT contaminated food were about 2 times greater than in fish exposed to the same DDT water concentration but fed clean food. The percentage of total tissue residues attributable to the DDT food source remained relatively constant after 28 days exposure at about 35% for fish exposed to 2.0 ppb DDT in water plus DDT food, and 60% for fish exposed to 0.5 ppb DDT in water plus food. Bioconcentration factors were 1.2 times from the diet and over 100,000 times from the water. Total DDT residues were separated into DDT, DDE, and TDE. DDE was the principal metabolite found after 14 days exposure, indicating that DDT was rapidly metabolized. In the elimination portion of the study, there was virtually no DDT elimination for the 0.5 ppb DDT water exposed fish up to 56 days, but fish exposed to this water concentration plus contaminated food had a rapid elimination within the first 28 days followed by slower elimination. At 56 days, more than 50% of the total tissue residues were lost and the body burden was equal to that of the fish fed clean food.

Several studies applying DDT to either small natural ecosystems or laboratory model ecosystems have been performed. Vaajakorpi and Salonen (1973) applied DDT to a small pond in order to determine the fate of this compound in the aquatic system. They noted that the maximum residues in the living organisms were attained after the water residues started to decline. Fifty-nine days after DDT introduction, the water concentration was <0.01 ppm while concentrations in perch, carp, and pike were over 1 ppm. Mesentary adipose tissue taken from the perch showed the highest DDT concentration at 23.8 ± 6.60 ppm. Using a laboratory model ecosystem, Metcalf (1972) found that DDT was accumulated by the mosquitofish *(Gambusia affinis)* to a level 84,500 times that found in the environment.

Residue studies on wild organisms have shown that DDT is virtually ubiquitous in marine organisms, from plants and invertebrates up through the tertiary carnivores such as marine mammals. Levels of the pesticide burden in body tissues offer ample proof that DDT is concentrated and transferred up the food web (Bjerk, 1973).

DDT residues have been found in plankton from widely separated regions of the oceans. Residues up to 34 ppb have been reported in plankton from the Gulf of Mexico and the northern Caribbean (Giam et al, 1973). Williams and Holden (1973) reported total DDT residues of 107 ppb in plankton taken from waters north of Scotland. This same study indicated that residue concentrations declined seaward, implying a connection between runoff and open ocean DDT levels.

Bjerk (1973) analyzed liver and muscle tissue from cod *(Gadus morrhua)* taken from Norwegian fjords. DDT residues in the liver ranged from 3.5 to 95.6 ppm on a wet weight basis (means ranged from 11.7 to 25.2 ppm). Residues in the muscle tissue ranged from 0.005 to 0.023 ppm. Deichmann et al (1972) found that DDT residues in the abdominal fat of the great barracuda *(Sphyraena barracuda)* in Florida waters ranged from 0.03 to 107.7 ppm in young adult fish (1.14-4.99 kg) and from 3.48 to 28.77 ppm in older fishes (12.5-18.35 kg). Ripe gonads contained DDT concentrations of 0.02-4.73 ppm, with lean females containing the most. About 75% of the DDT was eliminated during the height of the spawning period, along with most of the abdominal fat. Castle and Woods (1972) analyzed white croakers *(Genyonemus lineatus)* taken from the Los Angeles-Long Beach Harbor area during the fall of 1971. DDT residues ranged from 6.36 to 18.56 ppm in fillets without skin and from 9.44 to 30.64 ppm in fillets with skin attached. Means were 10.82 and 18.23 ppm, respectively. During 1971-1972, Giam et al (1974) collected groupers of the genera *Epinephelus* and *Mycteroperca* from six sites in the Caribbean and the Grand Bahamas. Total residue values in the muscle tissue ranged from very low levels (1-6 ppb) in the Grand Bahamas up to 139 ppb in *Mycteroperca interstitialis* from off the Texas coast. Kelso and Frank (1974) analyzed whole body residues of three species of fish collected from Lake Erie during 1972. Total DDT residue averages ranged from 0.01 to 0.11 ppm in yellow perch *(Perca flavescens)*, 0.02 to 0.27 ppm in white bass *(Morone chrysops)*, and 0.01 to 0.26 ppm in small-mouth bass *(Micropterus dolomieui)*.

Plankton and trout samples collected in the Atlantic Ocean by Harvey, Bowen, Backus, and Grice (1972) contained DDT residues at every level of the marine food chain examined. Most zooplankters had residues of less than 1 ppb. Mesopelagic fish and invertebrates had concentrations ranging from 3 to 12 ppb. The white tip shark *(Carcharinus longimanus)* a top carnivore, had liver residues of 100 ppb. Sargassum (a brown algae), the only representative of the primary producer level, had residues of about 0.5 ppb. In the Gulf of Maine, Zitko, Hutzinger, and Choi (1972) found residues of DDT in sea raven muscle tissue of 0.24 ppm; liver tissue of the white shark *(Carcharodon carcharias)* had 63 ppm. Numerous species of marine fish contained low concentrations (0.01-0.48 ppm) of DDE. Residue analyses of invertebrates and fishes taken from Guatemalan estuaries, where pesticide usage has been heavy, showed DDT levels as high as 45 ppm (Keiser, Amado, and Murillo, 1973). The molly *(Poecilia sphenops)*, an important food fish, had the highest levels. The mullet *(Mugil* sp.*)* had residues as high as 36.56 ppm. Offshore fishes and shrimp had residues much lower than the estuarine fishes. Shaw (1972) analyzed eight marine fishes in California and found that liver residues for five species approached or surpassed the FDA residue action levels. Edible tissue residues were highest in the sablefish *(Anoplopma fimbria)* at 6.3 ppm. In Hawaii, Bevenue et al (1972) studied residues in various aquatic systems. They found that residues in canal water were about 0.03 ppb and residues in the sediments (dry weight basis) were 600 ppb. Residues in the biota of the Ala Wai Canal (wet weight basis) were: algae, 85 ppb; small fish, 460 ppb; plankton and detrital feeding fish, 606 ppb; and carnivorous fish, 864 ppb. Ratios of residues in these organisms to water concentration were: algae, 2833; plankton and detrital feeders, 20,200; and carnivores, 28,800. Smith et al (1974) monitored DDT levels in Utah fish. DDT was detected in 85% and DDE in 95% of the fish muscle tissue analyzed. Levels ranged from 0.011 to 0.175 ppm DDT and 0.007 to 0.112 ppm DDE. In Iowa rivers, Johnson and Morris (1974) found that total DDT levels in fish eggs ranged from 103 to 715 ppb.

Fairly complete and consistent monitoring records have been kept in some areas. From these, some trends can be determined. Butler (1973) analyzed molluscs in fifteen coastal states between 1965 and 1972. In many areas where the continuity of sample collections was adequate, DDT apparently reached maximum levels in 1968-1969. A pronounced decline has been evident both in size and incidence of DDT residues in molluscs since that time. The percentage of samples containing negligible residues (0.011 ppm) during the last year of monitoring compared to earlier years increased 85% in 12 of the 15 states monitored. In California, New York, and Virginia, the incidence of DDT residues increased but the number of samples containing more than 0.1 ppm declined by about 46%. The data demonstrated that the decline in DDT residues in molluscs has been nearly universal on the Atlantic, Gulf of Mexico, and Pacific coasts. In Maine, levels of DDT residues in Sebago Lake salmon have dropped from 17.2 ppm (wet weight) in 1964 to 1.42 ppm in 1973 (DeRoche, 1973). MacGregor (1974) analyzed monitoring data for marine organisms in the ocean off southern California. He found that between 1949 and 1970, total DDT residues increased in the biota. The major source was apparently wastes discharged into the Los Angeles sewer system by a major manufacturer of DDT. As measured in myctophid fish, p,p'-DDT and p,p'-DDE increased for several years until metabolism, excretion, and dispersion equalled input, at which point the levels stabilized. The more persistent, less easily metabolized p,p'-DDE continued to increase throughout the period studied. The amount of DDE decreased with distance from the sewer outfall. Total accumulated residues of DDT dropped steadily from 4.56 ppm to 4.14 ppm between 1970 and 1973, a percentage decrease of almost 10%.

Data obtained from Dr. Virginia Stout (personal communication, 1975), National Marine Fisheries Service, Seattle, indicated several trends. Residues of DDT and metabolites in edible portions of commercially important offshore Pacific coastal fish show a north-south gradient, with the higher residues generally occurring in California waters as compared to waters of the State of Washington. No time-trend conclusion can be made as the residues appeared to be relatively stable within broad limits during 1970-1973. Non-fish samples were limited, but showed relatively low residues. It should be noted that many fish had residues in excess of those which laboratory studies have shown to cause shell-thinning in certain birds, and in some cases approach the 1-10 ppm DDE residues found in anchovies eaten by brown pelicans during their extreme reproductive failures in the late 1960's off the California coast.

Off Long Island, along with increasing reproductive success of fish eating birds and dropping DDT residues, upward trends in populations are evident in the blue crab *(Callinectes sapidus)* for which concentrations of a few parts per billion are toxic to the larvae. This species almost vanished from Long Island's Great South Bay from the late fifties to the early seventies. However, it began to reappear and in 1974, was once again a plentiful and important food resource (Puleston, 1975).

Dr. Robert Reinert, Bureau of Sport Fisheries and Wildlife, Ann Arbor, Michigan, has monitored DDT residues in Lake Michigan since the late 1960's. Reinert (personal communication, 1975) found that highly contaminated fish in Lake Michigan are currently showing a downward trend which began in the mid-1960's, corresponding to the beginning of reduced DDT use. The trend became more evident when DDT uses were cancelled in Michigan. Since the nationwide ban on DDT in 1972, the downward trend has continued through 1974. Concentrations of DDT in whole fish for years 1969-1974 are presented in Table IIIA.1. Residues in bloaters (*Coregonus hoyi*) dropped from 9.94 ppm in 1969 to 1.34 ppm in 1974. Lake trout (*Salvelinus namaycush*) levels dropped from 19.93 ppm in 1970 to 9.96 ppm in 1973. Coho salmon (*Oncorhynchus kisutch*) dropped from 11.82 ppm in 1968 to 4.48 ppm in 1973.

Numerous reports of DDT residues found in marine mammals have been published in the last few years. Harbor seals *(Phoca vitulina richardii)* from off the West Coast of the United States were examined by Anas (1974) for DDT residues in the blubber. Off San Miguel Island, blubber residues ranged from 380.7 ppm to 2,350.0 ppm with a geometric mean of 610.7 ppm. The lowest residues were in seals captured off Alaska with blubber concentrations ranging from 6.8 ppm to 27.8 ppm DDT. Harbor seals from eastern Canadian waters were found to contain total DDT residues of 0.38-139.15 ppm in the blubber, from a trace to 2.77 ppm in the muscle, and up to 0.47 ppm in the cerebrum (Gaskin et al, 1973). Harp seals *(Pagophilus groenlandicus)* from these same waters were found to have blubber residues up to 50.0 ppm DDT. In European waters, Koeman et al (1972) reported residues in the common dolphin *(Delphinus delphis)*. In the blubber, DDT ranged from 1.8 to 38 ppm, DDE values were 1.8 to 117 ppm, and DDD from 0.67 to 22 ppm. Total DDT residues found in British grey seal *(Halichoerus grypus)* blubber ranged from 5.59 ± 3.57 ppm to 10.71 ± 3.21 ppm. In nine seals, mean DDT residues and their standard deviations were reported for different tissues including: liver, 1.42 ± 1.38 ppm; heart, 0.32 ± 0.25 ppm; brain, 0.19 ± 0.12 ppm; and blubber, 12.55 ± 6.23 ppm (Heppleston, 1973).

Table IIIA.1

DDT Residues in Lake Michigan Fish

Data given as whole body residues (wet weight)
with 95% confidence intervals in parentheses

Year	Species	Number of Fish	Average length (mm)	Total DDT (ppm)
1969	Bloaters	120	270	9.94 (0.33)
	Lake trout	--	--	--
	Coho salmon	11	621	11.82 (2.69)
1970	Bloaters	28	263	9.87 (1.44)
	Lake trout	18	613	19.19 (3.27)
	Coho salmon	13	651	14.03 (1.29)
1971	Bloaters	60[a/]	264	6.24 (1.13)
	Lake trout	20	579	13.00 (1.76)
	Coho salmon	15	674	9.85 (1.41)
1972	Bloaters	120[a/]	255	4.33 (0.48)
	Lake trout	9	648	11.31 (3.26)
	Coho salmon	10	693	7.17 (1.09)
1973	Bloaters	160[b/]	250	2.09 (0.26)
	Lake trout	30	602	9.96 (1.36)
	Coho salmon	29	620	4.48 (0.34)
1974	Bloaters	130[b/]	253	1.34 (0.052)

a/ Composite samples, 5 fish/sample

b/ Composite samples, 10 fish/sample

Source: Reinert, personal communication,
Great Lakes Fishery Laboratory
US Fish and Wildlife Service,
Ann Arbor, Michigan, 1975.

Female California sea lions giving premature birth were found to contain DDT mean residues in the blubber 8 times higher (924 ppm) than those females which carried pups to full term (103 ppm). Similarly, mean PCB residues in the blubber were 6.5 times greater (112 ppm as opposed to 17 ppm) in those females giving premature birth. Dieldrin residues, when detected, were low. High mortality among premature pups was observed (DeLong et al., 1973).

Pearce et al (1973) provided data on chlorinated hydrocarbon levels in blubber and liver of three species of seals from the Gulf of St. Lawrence, Canada. Up to 6.33 ppm DDE was found in blubber of the harp seal, 3.5 ppm in the hooded seal, and 24.6 ppm in the gray seal. Harbor seals from the Bay of Fundy contained 24.6 ppm DDE; those from the Gulf of Maine contained 33.6 ppm DDE. Marine phytoplankton represent the primary stage in the pelagic food web (0.007-1.09 ppm) and several species of fish such as herring and mackerel (0.09-0.67 ppm) form a secondary stage which in turn are consumed by seals.

Conclusion

The evidence supporting the finding that DDT can be concentrated in aquatic organisms and transferred upward through the food web is irrefutable. Experimental data have shown that most aquatic organisms will concentrate residues of DDT in their tissues far in excess of levels occurring in the surrounding medium and that residues can be transferred upward to predator organisms. Monitoring data of DDT residues in wild populations demonstrate overwhelmingly that they are ubiquitous in aquatic organisms and occur in tissues at levels much higher than levels present in the physical environment. Monitoring data are also beginning to show downward trends in tissue residues of DDT as a result of the ban on its use in this country.

EFFECTS ON PHYTOPLANKTON

Administrator's Finding: DDT affects phytoplankton species composition and the natural balance in aquatic ecosystems.

This issue is concerned with two main, interrelated, facts: 1) DDT decreases photosynthesis by different species of phytoplankton; 2) DDT can adversely affect phytoplankton growth rate.

Data as of 1972

It has been shown that DDT can, in vitro, decrease the incorporation of carbon by phytoplankton, thus decreasing the amount of oxygen evolved by these same plants. An example of this photosynthetic reduction has been illustrated by the effect of DDT upon *Cyclotella* sp., a diatom.

Reduction of phytoplankton growth rate has been shown for the diatoms *Skeletonema* sp. and *Cyclotella* sp. Actual reduction in the number of living cells has been observed after exposure of *Scenedesmus quadricauda* to 0.1 ppb and 1.0 ppb of DDT. After 8 days, the numbers of cells were reduced by 25% and 51% respectively.

Data since 1972

Exposure of the freshwater algae *Scenedesmus quadricauda* to 5 ppm DDT for 95 minutes resulted in the reduction of oxygen production by about 90% compared to the control culture. Exposure to 10 ppm DDT for this same period caused nearly a 98% drop in oxygen evolution compared to the controls (Pritchard and Dines, 1972). Work by these same scientists has shown that if these algae are exposed to 5 ppm or 10 ppm DDT in the dark, then placed in a lighted situation, photosynthesis will proceed for only 30 minutes before complete cessation.

MacFarlane et al (1972) have demonstrated that exposure of the marine diatom *Nitzschia delicatissima* to as low as 9.4 ppb DDT resulted in a significant reduction in photosynthetic efficiency and a reduction in the amount of chlorophyll "a" in the cells. Exposure to 220 ppb DDT reduced photosynthesis by as much as 82%. Chloroplast size was reduced and the shape distorted after exposure to 9.4 ppb DDT.

In studying the green algae *Chlorella pyrenoidosa*, Cole and Plapp (1974) reported at a cell concentration of 1 mg algae/ml and a DDT concentration of 1 ppm, photosynthesis had been inhibited 69.4% after 7 days.

While studying the effect of DDT on community structure, Mosser et al (1972) found that a concentration of 10 ppb DDT resulted in a marked change in the ratio of the diatom *Thalassiosira pseudonana* to the green algae *Dunaliella tertiolecta*. This altered ratio of the two species within the same system could change the relative abundance of foods for grazing zooplankton.

Another factor affecting phytoplankton production is phytoplankton's ability to withstand environmental changes. The bluegreen algae, *Anacystis nidulans*, is, under normal conditions, able to withstand waters of relatively low salinity without showing adverse effects. When exposed to 0.3 ppm DDT, this species lost the ability to tolerate even a 1% (by weight) solution of NaCl. This effect may result from the interference by DDT with Na^+ and K^+ ATPases, compounds intimately involved in sodium transport (Batterton et al, 1972). This loss of ability to tolerate low salinity conditions could be of major importance in estuarine regions where rivers wash into marine areas.

Conclusion

Information presented during the Administrative Hearings process and made available since the end of those hearings has clearly demonstrated that DDT can have severe detrimental effects on several types of phytoplankton: both marine and freshwater species. These effects can have a significant impact upon microscopic aquatic plants, which are a major source of the world's oxygen.

LETHAL AND SUBLETHAL EFFECTS ON AQUATIC INVERTEBRATES

> *Administrator's Finding: DDT can have lethal and sublethal effects on useful aquatic invertebrates, including arthropods and molluscs.*

This issue is concerned with the fact that DDT can result in both acutely lethal and chronic sublethal effects on aquatic invertebrates. These effects include direct mortality, reproductive failure, altered ecosystem species composition, and effects on higher trophic species.

Arguments used to support this issue include:

1. Experimental evidence demonstrates that DDT is highly toxic to many aquatic invertebrates.
2. Experimental data have demonstrated that very low levels can result in reproductive failure and other sublethal effects.
3. DDT has resulted in acute kills of aquatic invertebrates in the environment.
4. DDT has been shown to affect higher trophic levels as a result of starvation following kills of prey invertebrates.

Data as of 1972

The evidence presented in the DDT hearings contains considerable data which demonstrate that DDT is extremely toxic to aquatic invertebrates and that very low levels can have adverse sublethal effects.

Experimental data, based on both static and flow-through tests, show that aquatic arthropods are extremely sensitive to DDT at levels below about 5 ppb. Examples of 48-hour median lethal concentrations to freshwater arthropods are: *Daphnia pulex*, 0.36 ppb; *D. magna*, 4.4 ppb; scud, 2.1 ppb; caddisfly (one species), 3.4 ppb; and mayfly (one species), 0.3 ppb. Similar examples for marine species (96-hour exposure) are: sand shrimp, 0.6 ppb; grass shrimp, 2.0 ppb; and hermit crabs, 6.0 ppb. Additional data on grass shrimp showed that no shrimp exposed to 2.0 ppb were killed at 10°C, but that over 75% were killed at 30°C. Temperature also affects toxicity of DDT to other invertebrates. It is seven times more toxic to the scud at 5°C than at 21°C, and twice as toxic to *Daphnia* at 5°C than at 21°C.

Adult hard clams (*Mercenaria mercenaria*) and snails tend to be less susceptible to DDT. However, shell growth rate in the oyster was reduced by 50% at concentrations of 7 ppb.

Exposure at sublethal levels may result in additional effects, such as immobilization and reproductive impairment. Exposure for 21 days at sublethal levels has been shown to result in immobilization of aquatic insect larvae. Mayfly and stonefly larvae exposed to sublethal amounts of DDT in one experiment failed to emerge as adults. In another study, *Daphnia* held at a 1.0 pptr concentration of DDT in a flow-through system for 10 days resulted in a 40% decrease in reproduction when compared with controls. This type of effect could reduce species numbers and affect higher trophic levels.

DDT use has been shown to be responsible for kills of aquatic invertebrates in field situations, with additional effects on higher trophic levels. When applied at 1 lb/acre to Connecticut forests for control of gypsy moth, a variety of forest stream insects were killed in great numbers. Exposure of the stream invertebrates was a result of drift, inadvertant aerial application over streams, and runoff water containing soil, leaves, and other organic matter to which DDT was adsorbed. This type of organic matter also serves as a food source for aquatic invertebrates. Two to 4 years may be required subsequent to a kill for complete recovery of the populations. It was noted that less desirable species were first to repopulate. Similar results were found after spraying DDT at the rate of 0.75 lbs/acre for spruce budworm control in Canada. Studies in Maine and Canada found that losses of insects in this manner caused significant trout and salmon mortality as a result of starvation.

Data since 1972

Experimental data developed since the hearing on acute effects are in agreement with those presented in the hearing. Sanders (1972) using intermittant flow bioassays, found that the scud *(Gammarus fasciatus)* had a 96-hour LC_{50} of 0.80 ppb and that the glass shrimp *(Palaemonetes kadiakensis)* had a 96-hour LC_{50} of 3.5 ppb. At 120 hours, the values were 0.60 ppb and 1.3 ppb, respectively. Sanders also studied various life stages of the crayfish *(Orconectes nais)* and found that 96-hour LC_{50} values were 0.30 ppb for 1-day-old crayfish, 0.18 ppb for those 1-week-old, 30 ppb for those 10-weeks-old, and 100 ppb for mature crayfish. Calabrese (1972), using static tests in which water was totally replaced every two days, found that DDT at a concentration of 50 ppb caused over 90% mortality of oyster larvae and almost completely prevented growth. Muirhead-Thomson (1973) found a marked differential effect in predator invertebrates such as dragonfly naiads (agrionid and libelluid) and *Nepa* as compared to prey organisms such as mayfly naiads *(Baetis* sp.*)* and *Simulium* larvae. Many dragonfly naiads could survive an exposure to 20 ppm DDT for 1 hour, and live long enough to produce adults, while concentrations as low as 50 ppb for 1 hour could proudce near 100% mortality in *Baetis* naiads and *Simulium* larvae. Exposure to concentrations of 20 ppb for 1 hour resulted in 82% and 80% mortality for *Baetis* naiads and *Simulium* larvae, respectively. This author also observed that, when DDT was used as an emulsifiable concentrate formulation, concentrations produced a progressive immobilizing effect on the naiads during the 1-hour exposure. This effect continued well into the holding period in clean water but a high proportion of the naiads eventually recovered. The effect was not noted when the wettable power formulation was used.

New data on reproductive effects also substantiate previous data. Schoettger exposed *Daphnia* to 10, 30, and 100 pptr of p,p'-DDT in a flow-through system and found significantly reduced population numbers (USDI, 1973). Reproduction was inhibited 10% and 40% by 10 and 100 pptr, respectively. Derr and Zabik (1972) studied the effects of p,p'-DDE residues on the egg viability of the aquatic midge, *Chironomus tentans*. Egg masses were held in a 30 ppb concentration of DDE and in control water for about 1 month until the adults emerged. The adults were allowed to mate and egg masses from exposed and control females were subjected to 4 treatments: 1) DDE contaminated eggs placed in clean water; 2) DDE contaminated eggs placed in 20 ppb DDE contaminated water; 3) uncontaminated eggs placed in 20 ppb DDE contaminated water; and 4) uncontaminated eggs placed in clean water. There was significant reduction in the number of adults emerging from aquaria containing DDE contaminated egg masses, but the presence of 20 ppb DDE in water with uncontaminated eggs did not result in a significant reduction. Neither did the combination of DDE treated water and DDE contaminated eggs show significant differences from DDE contaminated eggs in clean water. Egg masses obtained from DDE exposed females were of a less gelatinous consistency and had a shriveled appearance compared to control eggs. It was also found that about 30-34% of an adult female burden of DDE residue was lost to the extruded egg mass, indicating that a significantly high amount of residue in the adult was transferred to the eggs.

Other sublethal chronic effects of DDT have been demonstrated experimentally. Engel, Neat, and Hillman (1972) maintained quahog clams *(Mercenaria mercenaria)* in concentrations of 2 ppb in flowing sea water for 30 weeks. DDT was found to reduce the glucose-6-phosphate dehydrogenase content of gill tissue to negligible levels and to cause a consistent decrease in fructose diphosphatase activity, which indicate that this chemical may interfere with gluconeogenesis. Nimmo and Blackman (1972) determined that concentrations of sodium and potassium were lowered in the heptopancreas of shrimp *(Penaeus aztecus* and *P. duorarum)*, exposed to concentrations of 0.05 and 0.10 ppb of DDT for a period of 30 days. For shrimp held at 0.1 ppb, significant differences ($P \leq 0.01$) occurred in sodium in all samples while significant differences ($P \leq 0.05$) did not occur in potassium levels until the 20th day. Significant differences in both of the cations were found in shrimp exposed to 0.05 ppb DDT only on the 20th day of exposure. By the 30th day, differences were no longer significantly different. The authors noted that the experimental levels were equivalent to amounts of DDT which had been shown to enter the Gulf of Mexico.

The only recent field information pertaining to effects of DDT on aquatic invertebrates is contained in an interim report by the Interagency Monitoring Committee and unpublished data submitted by Steven G. Herman, The Evergreen State College, Olympia, Washington. This information was generated through monitoring of environmental effects resulting from the use of DDT in the forests of the northwestern United States for tussock moth control during 1974. Herman (personal communication, 1975) monitored three streams, two within the spray boundaries and a control in a non-spray area. In the control stream, numbers of riffle-dwelling insects in all major taxa increased steadily throughout the study period. One stream in the spray area received a very light DDT deposit (equivalent to 0.0-0.023 lb/acre). Insects in this stream were little affected, with the exception of blackfly larvae *(Diptera, Simuliidae)* which suffered drastic reduction, but recovery began in 2-3 weeks post-spray. The other stream in the spray area received the equivalent of 0.0-0.6 lb/acre DDT. The treatment resulted in almost total elimination of the aquatic insect fauna and no significant recovery was detected a month later. Information contained in the interim report by the Interagency Monitoring Committee consists of "casual field observations" by environmental monitoring personnel in the field. No hard data are contained therein. However, the qualitative observations are in agreement with Herman that adverse effects on the aquatic invertebrates were substantial.

Conclusion

Data presented in the hearing record and obtained subsequently are in substantial agreement that DDT can produce lethal and sublethal effects on freshwater and marine invertebrates. Experimental data and data derived from monitoring the effects of DDT use in the field demonstrate that many aquatic invertebrates are killed, with subsequent recovery of populations being a slow process; that reproductive impairment and other sublethal effects may have serious adverse effects on populations; and that higher trophic levels can be seriously affected as a result of starvation.

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DDT TOXICITY IN FISH

Administrator's Finding: DDT is toxic to fish.

This issue is concerned with the fact that DDT can be acutely toxic to fish. This may occur immediately or sometime after initial exposure.

Two central arguments support this finding: 1) Experimental laboratory data show that DDT will kill most fish species at very low levels; 2) DDT has resulted in numerous fish kills.

Data as of 1972

The evidence presented in the DDT Hearings is replete with experimental data demonstrating acute toxicity to both freshwater and marine fish. DDT levels which produced statistically calculated 50% mortality were normally below about 30 ppb, with the more sensitive species being killed at less than 1 ppb. Examples of 96-hour median lethal concentrations to freshwater fish are: fathead minnows, 32 ppb; bluegills, 16 ppb; goldfish, 27 ppb; juvenile striped mullet, 0.9 ppb; larger mullet, 3.0 ppb; Atlantic silversides, 0.4 ppb; killifish, 1.0 ppb; and bluehead, 7.0 ppb.

Experiments with brook trout have shown that DDT can significantly increase mortality during the spawning period caused by natural stress factors (i.e., starvation, cold, and physiological changes). DDT also has been shown to cause delayed mortality occurring when residues are mobilized during periods of stress. For example, when rainbow trout fed at the rate of 1 ppm wet weight and held in a water concentration of 10 pptr for 140 days, were later fasted and subjected to 28 days of forced swimming to simulate their spawning run, DDT was mobilized into the brain at the rate of 0.1 ppm/day. At the end of 28 days, 80% of the treated fish had died.

Fish kills resulting from DDT use have been documented on numerous occasions. For example, dead and dying fish have been observed when heavy rainfalls followed applications of DDT to Mississippi cotton fields. Top predator fish are absent from this otherwise favorable habitat. Attempts to restock Wolfe Lake in Mississippi with large-mouth bass were unsuccessful. In addition, carefully monitored DDT programs for the spruce budworm in Canada have resulted in almost total kills of some year classes of salmon, with severe economic losses to the commercial fisheries.

Data since 1972

Acute toxicity data developed since the hearings in 1972 are sparse, primarily because additional data would be redundant. Korn and Earnest (1974) tested small (14-83 mm standard length) striped bass (*Morone saxatilis*) in intermittently flowing sea water with a mean salinity of about 28 parts per thousand. The 96-hour LC_{50} value was 0.53 µg/l (ppb). These authors noted that DDT levels in bay water in Tiburon, California, an important striped bass habitat, were found to vary from 3-21 μg/l. Earnest and Benville (1972) determined acute toxicity values to the shiner perch *(Cymatogaster aggregata)* and the dwarf perch *(Micrometrus minimus)* held under both static and intermittent conditions. The 96-hour median lethal concentration for the shiner perch was 7.6 ppb in the static system and 2.6 ppb in the intermittent flow system. Similar values for the dwarf perch were 4.6 ppb and 0.26 ppb, respectively. It should be noted that the static values are less reliable than those from the intermittent flow system because of the small sample size and test conditions. Gardner (1973) approximated 24-hour LC_{50} values for small brook trout *(Salvelinus fontinalis)* at about 30 ppb for p,p'-DDT and about 45 ppb for p,p'-DDE in a flow-through system. These values were approximate due to small sample size.

Jarvinen, Hoffman, and Thorslund (1974, unpublished) studied chronic effects of DDT on fathead minnows *(Pimephales promelas)* during a period of 266 days, including the reproductive phase of their life cycle. They found that two separate mortality periods occurred, indicating increased susceptibility to DDT at both the fry stage up to 73 days of age and at the spawning stage when highly colored males were most susceptible. Fish that died during the spawning period were in relatively poor condition and were not observed to feed. The authors suggest that these fish probably utilized their fat reserves, which resulted in a release of stored DDT into the blood where it could become toxic. This agrees with results showing that the fish that died had predominately lower lipid values than live fish at the same time. It was also observed that fish fed DDT contaminated food had a greater mortality rate, which lasted longer before reaching a plateau, than did fish exposed at a corresponding DDT water concentration but fed clean food.

Reports of fish kills resulting from DDT use since 1972 are presently lacking except very incomplete data obtained from the Tussock Moth Spray Program in 1974. Herman (personal communication, 1975) noted that 643 sculpin fry were found dead in one stream within 72 hours after DDT drift reached the stream. The interim report by the Interagency Monitoring Committee stated that fish populations in index areas "did not appear" to be adversely affected by the spray project. It was also noted, however, that fish in one of the streams were observed gorging themselves on large numbers of dead and dying insect larvae.

Conclusion

Data presented in the hearing record and developed subsequent to the hearing demonstrate that DDT is highly toxic to fish on an acute basis and that use of DDT has resulted in fish mortality in the field.

DDT EFFECTS ON FISH REPRODUCTION

Administrator's Finding: DDT can affect the reproductive success of fish.

This issue is concerned with the fact that concentrations of DDT which may show no adverse effects on parent fish may significantly increase the mortality of the eggs or fry and thus result in reproductive impairment. Because DDT is highly lipophilic, residues are concentrated in the yolk of the eggs, eventually utilized by the fry, and can result in their death. DDT has also resulted in delayed maturation of lake trout.

Arguments supporting this issue can be delineated as follows:

1. DDT can be highly concentrated in fish and stored in lipids, which results in greater concentrations being stored in the eggs. This can result in increased fry mortality during the stage when the fry are utilizing the yolk, which is high in lipid content where DDT is stored.

2. Egg residues have been correlated with increased fry mortality, both experimentally and from the field.

3. Experimental results have shown that DDT can result in delayed maturation of lake trout.

Data as of 1972

Evidence presented in the hearings indicated that DDT was responsible for the death of lake trout fry hatched from eggs taken from Lake George, a tributary of Lake Champlain. It has also been implicated in excessive mortality of Lake Michigan coho salmon fry, and salmon eggs from a Maine lake exhibited lowered hatchability when DDT levels reached 3 ppm in the eggs. In 1969, residues of DDT in sea trout in the Laguna Madre (Texas) were correlated with residues in menhaden, a major food of the trout. Reproductive impairment had been observed since 1964 as evidenced by a decline from 30 to 0.2 juvenile trout per acre. After residues in menhaden declined, the sea trout populations returned to 1964 levels.

Experimental results have shown that DDT at 2.95 ppm in the eggs of lake trout induced fry mortality and that brook trout fry reacted similarly. Brown trout were somewhat less sensitive. In addition, DDT fed to fish can result in delayed maturation. In one study, 3-year-old lake trout failed to spawn after being fed DDT.

Data since 1972

Additional evidence has been published since the hearings supporting the argument that DDT can impair fish reproduction. Dacre and Scott (1971) reported that an unusually high mortality (44.6%) occurred in rainbow trout *(Salmo gairdneri)* eggs and fry obtained from Lake Taupo in New Zealand. Total DDT residues in the fry were 4.63 ppm. This level is above that which previous studies have shown result in fry mortality in other species. Smith and Cole (1973) subjected male and female winter flounder *(Pseudopleuronectes americanus)* to five test treatments: 1 ppb DDT + 1 ppb dieldrin; 2 ppb DDT; 2 ppb dieldrin: an acetone control equal in amount to the highest concentration administered with an insecticide treatment; and an unaltered seawater control. Length of exposure was variable, but was based upon previous experimentation and was generally sufficient to duplicate gonad levels found in a previous field study. In three spawnings the percentage of fertilization differed markedly from that of the control matings (mean = 97.8%). Eggs containing 4.60 ppm DDT and 0.01 ppm dieldrin had 40% fertilization, while 12% fertilization occurred in eggs containing 0.17 ppm DDT and 1.74 ppm dieldrin. There was no fertilization in eggs with no detectable DDT but with 1.74 ppm dieldrin. However, in two other spawnings, eggs which contained 3.70 and 2.39 ppm DDT, but no dieldrin residues, had 99 and 80% fertilization, respectively. Similarly, eggs which had 0.61 ppm dieldrin and a small amount of DDT (0.39 ppm) had over 99% fertilization. The relations between DDT concentration in the eggs and mortality by the end of the 4th day of development indicated dose-dependent effects. Mortality in eggs with DDT concentrations of 1.62 ppm or greater was frequently associated either with failure to gastrulate or with abnormal gastrulation where the blastulae, instead of undergoing involution as in normal gastrulation, exogastrulated and development ceased. At hatching, there was a much higher incidence of severe vertebral deformities in the larvae treated with DDT than in those from the untreated adults. The mean incidence of deformed larvae was 39% with a range of 2 to 77%. No abnormal gastrulation occurred in the controls and incidence of vertebral deformities was less than 1% in both the control larvae and the larvae from adults treated only with dieldrin. Bone erosion and hemorrhaging at the vertebral junctures were often observed in conjunction with the vertebral deformities when DDT in the eggs equalled or exceeded 2.39 ppm.

Jarvinen, Hoffman, and Thorslund (1974, unpublished) exposed fathead minnows *(Pimephales promelas)* to two DDT concentrations in the water, one in the diet, and combinations of water and diet for 266 days through a reproductive period of their life cycle. Fish were held in aquaria at nominal concentrations of 0.5 and 2.0 ppb DDT, while clams used as food received water containing a nominal concentration of 2.0 ppb DDT. Water was supplied by a proportional diluter, with flow rates adjusted to maintain dissolved oxygen levels at greater than 65% saturation. The DDT concentration contained in clam tissue fed to fish was 50 µg/g. Presence of DDT in the food did not significantly alter embryo hatchability, but hatchability was significantly reduced ($P=0.05$) in the 2.0 ppb concentration. In addition, there was no survival of fry beyond 5 days in the 2.0 ppb DDT concentrations, with or without DDT contaminated food. When groups of fry spawned from adults under these conditions were transferred immediately to clean water, the fry from adults exposed to DDT in both food and water experienced about 2 times greater mortality than those from adults exposed in water only. These data agree with egg residue which show almost 2 times greater residue levels in fry from adults in the former group. Fry survival was not significantly different from controls at the 0.5 ppb concentrations.

Conclusion

Data presented in the hearing record and developed subsequent to the hearing are in substantial agreement that DDT has the potential to adversely affect the reproductive success of a number of fish species and that it has, in fact, contributed to reproductive impairment for some species in the wild.

SUBLETHAL EFFECTS ON FISH

Administrator's Finding: DDT has a variety of sublethal physiological and behavioral effects on fish.

This issue addresses all sublethal physiological and behavioral effects on fish including:

1. DDT differentially affects the normal utilization of some amino acids.

2. DDT inhibits thyroid activity in fish.

3. DDT has been shown to alter the temperature regime selection of fish.

4. DDT can affect the impulse transmission in the lateral line of fish.

5. DDT can affect learning processes of fish.

6. Some fishes can avoid DDT containing waters.

7. DDT has been shown to disrupt cellular energy utilization.

Data as of 1972

Information presented during the DDT Hearings addressed this issue as a series of sub-issues, or topics.

After laboratory exposure to DDT, rainbow trout were exercised, leading to abnormal utilization of 14 of 19 amino acids.

DDT stimulated at low levels, and at near lethal doses suppressed, normal operation of the thyroid gland in some fishes. This gland regulates metabolic rate and other important body functions.

Exposure of some fishes to DDT has led to their selecting temperature regimes which proved lethal to the selecting fish. This temperature selection has been related to fish kills in nature.

DDT can, under some conditions, affect the impulse transmission in the lateral line of fishes. The lateral line is one of the primary sensory systems in most fishes.

The ability to learn required responses and to demonstrate "natural" behavior can be inhibited by DDT.

The ability of some fishes to avoid waters containing DDT has been demonstrated. In the case of the sheepshead minnow (*Cyprinodon variegatus*) this avoidance of DDT can lead to deflection from spawning areas.

The action of ATP and its enzymes are affected by DDT. This ATPase activity is one of the main driving forces of cellular synthesis, and, in fish, NaKMg ATPase is deeply involved in osmoregulation.

Data since 1972

Information published recently has further documented the effect of DDT upon temperature selection in fishes. Javaid (1972a, 1972b) has determined that exposure to DDT can alter both temperature selection and the absolute amount of fish activity at the resulting selected temperature. He found that when exposed to DDT, Atlantic salmon *(Salmo salar)* selected lower than acclimation temperatures (0-10 ppb DDT), and higher than acclimation temperatures (10-100 ppb DDT). Cold temperature shock was noted for Atlantic salmon and brook trout *(Salvelinus fontinalis)*. DDT exposed Atlantic salmon displayed decreased activity when compared to control fish. Rainbow trout *(Salmo gairdneri)* showed selection only for higher than acclimation temperatures, and exhibited symptoms of warm temperature shock which were followed by death. The mechanism affecting changed temperature selection was postulated to be altered metabolic rate.

These effects on fish by DDT also have been noted by Peterson (1973) and Gardner (1973), but the mechanism postulated by Peterson was destabilization of the nervous system by action on neuron membrane function.

Several behavioral alterations have been tied to exposure to DDT. Hansen (1972) found that when mosquitofish (*Gambusia affinis*) had been exposed to 5, 10, or 20 ppb DDT they selected waters of significantly greater ($P=0.05$) salinity than did the control fishes.

DDT avoidance by mosquitofish (Hansen et al, 1972) was found to occur only when the fish could choose between uncontaminated and contaminated waters, and then only when the DDT concentration was above the 24-hr LC_{50}. When presented with a choice between two contaminated waters, the fish either did not discriminate or they chose the water with the higher DDT level.

Exposure to DDT at near the 96-hr LC_{50} for 24 hours caused Atlantic salmon parr *(Salmo salar)* to become hypersensitive to external stimuli and temporarily improved their ability to learn a conditioned response (Hatfield and Johansen, 1972a). Exposure to this level of DDT for 24 hours did not seem to affect the ability of Atlantic salmon parr to escape predation by brook trout *(Salvelinus fontinalis)* (Hatfield and Johansen, 1972b).

The effect of DDT upon "natural" behavior of fishes has also been documented. Exposure of goldfish *(Carassius auratus)* to 10 ppb of p,p'-DDT for 4 days has resulted in the disruption of normal, nonrandom exploratory behavior (Davy et al, 1973) and the alteration of normal spontaneous locomotive display patterns (Davy et al, 1972). The changes in the pattern of locomotive display may be due to DDT's effect on short-term memory.

After a 7-day exposure to 1 ppb DDT and subsequent placement into clean water for 3 days, the normal swimming and schooling behavior of goldfish was significantly affected (Weis and Weis, 1974). The treated goldfish swam faster ($P<0.001$), turned more often ($P<0.005$), and occupied a greater area ($P<0.02$) than did control fish. When disturbed, the goldfish schools scattered further and regrouped more slowly than did control schools. This change in schooling lessens the protective advantage of schools.

Investigations into the disruptions by DDT of processes involved in cellular energy utilization and transfer have provided more than ample evidence that DDT is capable of interfering with adenosine triphosphate phosphohydrolases (ATPases).

Concentrations of 10^{-5}M DDT have resulted in 23% inhibition of NaKMg ATPase, 15% reduction of NaK ATPase, and 34% reduction of Mg ATPase in rainbow trout gill microsomes. Further inhibition was reported for 10^{-4}M DDT. Inhibition of NaKMg and Mg ATPases was higher when DDD was used instead of DDT (Davis et al, 1972).

The effect of DDT on mucosal ATPases (Na^+, K^+, and Mg^{2+}) has been investigated by Janicki and Kinter (1971a, 1971b). Inhibition of these ATPases, which are involved in sodium transport suggests that DDT may interfere with the osmoregulatory ability of fishes. More recent work by Weisbart and Feiner (1974), although it does not prove a connection between DDT and osmoregulation, did find abnormalities in the ionic makeup of blood plasma from goldfish exposed to 0.035 ppm DDT.

Not specifically addressed by the Administrator is the finding that p,p'-DDT can cause developmental defects in fish. Fry of grunion *(Leuresthes tenuis)*, after being exposed to p,p'-DDT at a concentration of less than 1 ppb, showed evidence of significant pectoral ray asymmetry. When eggs taken from relatively polluted waters off California (a region of relatively high past DDT input) were not exposed to further DDT, their fry showed significantly greater pectoral fin ray asymmetry than did fry from a nonpolluted area (Valentine and Soule, 1973).

Conclusion

The Administrator's findings concerning the sublethal physiological and behavioral effects of DDT on fish have been supported by investigations published since those findings, although data on avoidance suggests that this phenomenon may not occur at environmental levels. Additional behavioral and developmental effects of DDT have been illuminated which further reinforce the conclusion that DDT can cause changes in fishes that are less immediately noticeable than death, but may lead to an inability of those affected fish to successfully compete in the aquatic environment, thus having the same ultimate effect.

BIOACCUMULATION IN TERRESTRIAL ORGANISMS

> *Administrator's Finding: DDT can be concentrated and transferred through terrestrial invertebrates, mammals, amphibians, reptiles, and birds.*

The 1972 opinion of the Administrator, EPA, listed among the findings a major heading, Activity in Food Chain and Impact on Organisms. Basic findings indicated that DDT is concentrated in organisms and transferred through food webs, and more precisely, that DDT can be concentrated in and transferred through terrestrial invertebrates, mammals, amphibians, reptiles, and birds These statements infer that most wild vertebrates are exposed to DDT and metabolites in their diet and these contaminants are bioaccumulated in the tissues. Kinetics, or movement and change, describes the action and metabolism of chemicals entering the animal body. In the body, chemicals can make changes or be changed, accumulate in tissues, and ultimately leave through excretion, lactation, deposition in eggs, or placental transfer to unborn young. The pattern of events may be somewhat variable, depending upon whether exposure is at sublethal levels or sufficient to cause death of the organism.

Data as of July 1, 1971

A vast body of information on DDT residue accumulation was presented in exhibit and transcript form during three years of intensive administrative inquiry into the uses of DDT. Experimental studies as early as 1947 showed that poultry fed diets containing DDT accumulated DDT in their eggs and tissues, particularly in fat. A similar residue accumulation in wild birds was first demonstrated in 1958 when death of birds followed DDT applications. The early literature on food web relationships on land involved contaminated soil and leaves → earthworms → robins trophic level movement. Fish-eating birds, (such as ospreys and pelicans) and flesh-eating avian predators (hawks, owls, eagles), absorbed concentrations which affected reproduction, behavior, and sometimes resulted in death. Very minute residues, some in the parts-per-trillion range, may be lethal to the larvae of marine organisms. Wild mammals accumulated DDT residues from food and were affected variously depending upon their ability to metabolize or excrete the parent material and metabolites. Residues in a wide variety of organisms confirmed the world-wide distribution of DDT and metabolites through contamination of soil, air, and fresh and marine waters.

Conclusion

Data published since cancellation of most DDT uses have corroborated and provided a more substantial data base to confirm earlier findings. Recent data can be summarized as follows:

1. DDT and metabolite residues continue to be found world-wide in all trophic levels of the terrestrial ecosystem.

2. Certain species (fish-eating birds and raptors) at the top of the food web are still affected adversely as evidenced by behavioral changes or reproductive failure.

3. Widespread agricultural and forestry uses of DDT in North America and northern Europe have declined markedly since the mid-1960's. Concurrent with reduced application, there has been a gradual decline of residue body burdens in certain nontarget species, e.g., songbirds and ospreys. Slight, but encouraging, recovery of some nearly decimated local nesting populations has been observed.

4. Means of transport for this persistent pesticide point towards ultimate deposition in the ocean environment. Residues in ocean waters may already have peaked.

Data since July 1, 1971

Bioaccumulation in Invertebrates and Lower Vertebrates

The effects of organochlorine insecticides on earthworms have been reviewed (Davey, 1963). Results reported vary, but establish that worms are more tolerant of DDT than arthropods, with little risk of causing worm population reductions. However, consumption of DDT-residue laden worms by birds or insectivorous mammals is of concern. In the case of robins, die-offs have resulted from this route of exposure. DDT concentrations in worms increased from 0.15 ppm when soil residues were 1 ppm to about 45 ppm where soil levels were 64 ppm (Davis, 1971).

Worms in soils containing 1 ppm DDT accumulated the maximum amount of DDT residues from the soil (from 1-4 ppm DDT) after about 1 month followed by a slight loss, and then reached an equilibrium at 3-4 ppm DDT plus DDE in 5 or 6 months (Edwards and Jeffs, 1974).

Almost all micro- and macroarthropod forest litter taxa analyzed by Klee et al (1973) metabolized the two major isomers of DDT (o, p'-DDT and p,p'-DDT) into p,p'-DDE after introduction into the food chain via resistant carrier *Collembola*. Manley (1971) pointed out that p,p'-DDE accumulates very little in microarthropods compared with macroarthropod predators.

The effects of pesticides on soil microflora have been studied extensively, but those on soil protozoa have been neglected. Predatory protozoa play an important role in ecosystems such as soil, water, rumen fluid, and sewage by regulating bacterial populations (Alexander, 1969). Any effect a pesticide has upon these protozoa may be reflected in the bacterial population of the particular ecosystem. *Euglena* and *Paramecium* concentrated DDT in their cells 964 times when exposed to 1 ppm aqueous mixture of the insecticide without obvious adverse effects. Applications of p,p'-DDT to a garden soil at rates of 5 and 50 ppm inhibited soil protozoa (MacRae and Vinckx, 1973).

Dindal and Wurzinger (1971) showed that the terrestrial snail, *Capaea hortensis*, accumulated high whole body levels of DDT wet weight residue after 3 hours exposure (24 ppm) but were reduced and stabilized after 1 day at 11 ppm. This invertebrate serves as a food source of concentrated pesticide to vertebrate predators. Snails and slugs as nontarget organisms accumulated DDT residues at concentrations equal to or considerably higher than the surrounding environment. The concentration factor varied from 0.14 to 17.93 times that of the surrounding terrestrial ecosystem.

Gish (1970) reported that snails in two agricultural areas of the United States averaged 3.5 ppm total DDT residues. Slugs in the same sites contained up to 200 ppm, and earthworms up to 50 ppm. Earthworms in other sites sometimes contained 500 ppm. Thus snails in some agricultural areas, particularly in the United States, are likely to have suffered reduced shell growth as evidenced by Roman snails (*Helix pomatia*) treated with various amounts of p,p'-DDT from 2 weeks of age to hibernation (Cooke and Pollard, 1973). Relatively low doses of DDT significantly reduced shell and operculum weight whereas higher doses of DDT did not cause this response. Residues varied from 7.2 to 160 ppm, depending on the rate of exposure.

Snakes collected near Texas land treated with DDT and in untreated areas were analyzed for residues. All snakes contained some residues from a trace to over 1000 ppm DDE. The mean total residues from the pesticide use area were 14 to 386 times greater than in the nonuse area. Insecticide residues were higher in semiaquatic snakes than in terrestrial species. In a female cottonmouth, total residues in brain (1.4 ppm) and muscle (0.4 ppm) were 308 and 1080 times less, respectively, than those in fat. Residues (396 ppm) in the fat of embryos from this snake were similar to the maternal fat,but whole yolk residues were only 28.5, indicating placental transfer (Fleet et al, 1972). Crocodile eggs from Rhodesia were found with residues of 1.75 ppm total DDT (Billing and Phelps, 1972).

Bioaccumulation in Birds

Because of its persistence in the environment, widespread application, and dissemination through food and water, DDT is found virtually all over the world in both terrestrial and aquatic ecosystems. By 1958, there were indications that DDT and its metabolites might be associated with declines in avian populations at the top of food chains. Even small migratory songbirds, not at the highest trophic level, carry body burdens of DDT and metabolites. Such migrants are conspicuously obese, especially in the autumn, when subcutaneous and abdominal fat depots comprise 30% or more of body weight. Analyses of 10 species of migratory songbirds killed when they flew into television towers in Florida showed a progressive decline of contaminants in their fat from 1964 to 1973. In 1969, the mean for 5 species was 17.8 ppm but in 1973 the mean was only 2.06 ppm. This decline is apparently associated with the decreased usage of DDT in the United States during the same time (Johnston, 1974a).

Osprey, or fish hawk, population size has been carefully monitored for many years. A significant decrease in bird numbers in many East Coast nesting colonies had been noted for more than 20 years. Now an important reproductive increase has been documented on Gardiners Island off Long Island, New York. The number of fledged young dropped from about 600 in 1948 to a low of only 4 each in 1965 and 1966. This increased to 18 in 1973 and 26 in 1974. Eggs (unhatched and overdue) collected in the mid-1960's contained 11.3-13.8 ppm total DDT. One such egg collected in 1974 contained only 3.59 ppm total DDT and a dead 3-day-old chick, 1.34 ppm (Puleston, 1975).

Six osprey and two eagle eggs were collected and analyzed from the Gulf of Bothnia near Finland. Eagle eggs contained about 175 ppm and osprey eggs about 15 ppm DDE. The higher amounts in eagle eggs were suspected from 1) the longer life-span of the eagle and 2) its higher position on the food chain (Koivusaari, 1972).

In 1971 only one-fifth of 113 hen sparrowhawks in a 500 km^2 area in Scotland hatched all their eggs successfully, two-fifths had at least one egg disappear, in one-fifth all eggs vanished, and another fifth failed to nest. Some causes of failure were thin eggshells, egg breakage, and embryonic death. These factors contributed to a reduced potential young output of 61 percent. Significant organochlorine residues were found in all ten eggs taken from the area. DDE varied from 48-441 ppm, dieldrin from 10.0-110.6 ppm, and PCB from 32-159 ppm. The proportion of occupied sparrowhawk sites increased between 1967 and 1971, but the proportion of pairs producing young and the mean brood size in successful nests remained consistently low (Newton, 1973).

There were some 160 peregrine falcon eyries in Ireland in 1955. Those which successfully fledged young decreased from 36 in 1967 to 14 in 1970 (Chambers and Norris, 1971). Changes in land use, afforestation, and road building may be partially responsible. Residues (wet weight) in tissue samples (48 birds of 13 species) were p,p'-DDE (0-1.85 ppm) and dieldrin (0-0.71 ppm). In 1970, peregrine falcon eggs contained 9.8 ppm p,p'-DDE.

A preliminary note on organochlorine residues in eggs of fish-eating birds on the Florida west coast showed that the eggs contained DDE ranging from 2.46 for a brown pelican to 20.9 ppm (oven dry weight) for a snowy egret. Other species showed DDE egg residues in ppm as follows: black skimmer - 4.5; least tern - 3.17; laughing gull - 11.7; white ibis - 8.74; great egret - 10.36; and great blue heron - 20.0 ppm (Lincer and Salkind, 1973).

Residues of p,p'-DDE in double crested cormorants ranged from 8.63-29.4 ppm (wet weight), in herring gulls from 2.83-5.67 ppm, and black ducks averaged 1.50 ppm. Sampling sites were from the Bay of Fundy, Canada (Zitko and Choi, 1972).

Cormorants in The Netherlands increased from 800 breeding pairs in 1962 to 1500 in 1971. Spoonbills declined from 500 pairs in 1950 to 150-200 pairs in 1971. Purple heron increased to 900 in 1971. Heron declined from 8500 in 1935 to 3750 in 1964. Sandwich terns reached a low of 650 pairs in 1965 and then increased to 2900 pairs by 1971. Chlorinated hydrocarbons were believed responsible. Early in the 1960's, the common tern population greatly declined from approximately 10,000 pairs to a few thousand. Little tern declined until the last nests were unsuccessfuly reared in 1957. There was no breeding in 1972. Kingfishers declined 80% in the last 25 years from 250-500 to 50-100 pairs in 1970. Persistent pesticides may have a lethal effect on such piscivorous birds as those referred to above at the top of a food chain. Population declines, in most cases, are of a local or temporary nature (Rooth and Jonkers, 1972).

The use of organochlorine insecticides has been restricted almost exclusively to terrestrial areas. Nevertheless, several recent investigations have revealed substantial concentrations of residues in vertebrates in marine environments.

Herring gull eggs from Norway varied from 0.2-5.4 ppm DDE and common gull eggs from 0.2-3.5 ppm. DDT occurred from 0.1-0.3 ppm in only herring gull eggs. There were only slight differences evident in eggshell thickness (Bjerk and Holt, 1971).

Swan and pochard eggs from two locations in Denmark were collected and examined. Swan eggs from one site contained mean values of 0.151, 0.333, and 1.02 ppm of DDT, DDE, and PCB, respectively. The DDT was believed to come from the Baltic Sea. Swan eggs from the second site contained 0.335 ppm DDE and 3.34 ppm PCB; pochard eggs contained 2.015 ppm DDE and 40.7 ppm PCB. This high PCB content may be attributed to the pollution from an adjacent town. Pochards are higher on the food chain and contain more residues than swans (Bloch and Kraul, 1972).

Levels of chlorinated hydrocarbon pesticides were determined in Rhodesian animals. Pesticide residues were widespread, the highest levels being from agricultural regions. Residues ranged from none found to 43.41 ppm total DDT in a black flycatcher liver (Billing and Phelps, 1972).

Quail from Alabama soybean fields with a previous history of insecticide application had DDT residues averaging 17.0 ppm in their meat, while quail from soybean fields with little or no previous insecticide application averaged 1.68 ppm in their meat (Causey et al, 1972).

Laying Japanese quail were given 9 mg/kg/day of p,p'-DDT. Egg production, egg weight, and eggshell thickness were not altered. The mean total residue level in control birds never exceeded 1 ppm. The p,p'-DDT metabolite reside in treated birds ranged from 27 ppm in the liver to 444 ppm in fat. The DDE residues ranged from 8 ppm in the liver to 82 ppm in fat. DDD was highest in the liver at 15 ppm. DDT and metabolites in eggs and fat reached a peak at 6 weeks (McBlain et al, 1974).

DDT and its metabolites were studied in a diverse Arizona ecosystem downwind from an area of insecticide application. Soil residues ranged from 3.6 to 6700 ppb and samples of Harlequin and Gambel's quail livers ranged from 500 to 2800 ppb (Laubscher et al, 1971).

Bioaccumulation in Mammals

The ubiquitous nature of DDT and metabolite bioaccumulation in mammalian tissues is illustrated by the following examples:

DDT was analyzed in the brain tissues of shrews, voles, and mice from DDT contaminated Canadian forest areas. Residues occurred in low, but detectable, amounts in brain tissue. The average concentrations for shrews, voles, and mice were 0.039, 0.024, and 0.027 ppm, respectively. Shrews, which are at a higher trophic level, accumulated higher residues than voles or mice (Sundaram, 1972).

Residues of DDT and its metabolites ranged from 6-929 ppb in white-footed mice and up to 2770 ppb in cotton rats from the Tucson-Nogales area of Arizona (Laubscher et al, 1971). Deer fat samples ranged up to 107 ppb, rabbits to 235 ppb, and packrats to 2.9 ppb from the same region.

Two species of shrew, *Blarina brevicauda* and *Sorex cinereus*, were studied in a 4.05 hectare old-field ecosystem treated with 0.92 kg/ha ^{36}CL-ring-labeled DDT in 1969. The mean radioactive DDT levels in *Blarina* liver (10 ppm), muscle (10 ppm), brain (4 ppm), and fat (135 ppm) were the same in 1970-1971. Consumption of slugs may have caused DDT peaks in fat of 243 ppm in 1970 and 236 ppm in 1971. *Sorex*, unlike *Blarina*, had increasing DDT from 1969 to 1971. Mean levels of DDT residue in muscle (4 ppm) and viscera (3 ppm) were not influenced by sex, but by breeding condition (Forsyth and Peterle, 1973).

Five short-tailed shrews, *Blarina brevicauda*, were fed earthworms containing about 16.55 ppm DDT for 3 weeks, and five were fed DDT-free earthworms. After 4 weeks, the DDT-exposed shrews had a mean DDT level of 7.59 ppm in liver and 14.70 ppm DDT in fat. No DDT was found in control shrews (Braham and Neal, 1974).

Samples of rabbit and deer meat from Alabama soybean fields subjected to varying degrees of insecticide use were analyzed. DDT and its metabolites were the only insecticides occurring consistently, averaging 3.00 and 2.47 ppm, respectively, for deer and rabbits from treated fields. Fields with little or no history of insecticide use averaged 0.10 and 0.05 ppm DDT, respectively, for deer and rabbits (Causey et al, 1972).

Residues of DDT and its metabolites from Mississippi deer collected in 1970 ranged up to 1.29 ppm (Baetcke et al, 1972).

DDT was sprayed in 1964 at 1 lb/acre on a 525,000 acre area in Idaho with the periphery of 41,000 acres receiving 0.5 lb/acre (Benson and Smith, 1972). Deer were analyzed in 1964 and 1969. In 1964, total adipose tissue DDT was <0.1 ppm in control animals, but deer from the sprayed area had a mean of 19.36 ppm. The mean level of p,p'-DDE in exposed deer was 17 times higher than controls and 350 times higher than controls for p,p'-DDT. Adipose pesticide residues in deer from an unsprayed area in 1969 differed little from those in 1964 (mean of 0.08 versus 0.05). The mean total DDT of animals in 1969 from the sprayed region was only 0.18 ppm compared to 19.36 ppm in 1964.

Chlorinated hydrocarbon insecticide residues were measured in wild mink by Franson et al (1974). Total residues of DDT and related compounds in the adipose tissue ranged from 0.27-9.51 ppm. Of the total, p,p'-DDE comprised 23-80%, p,p'-DDT 4-50%, p,p'-DDD 6-41%, and p,p'-DDT 2-34%.

Total DDT in fish fed to mink ranged from 0.12 to 18.23 ppm. No clinical signs were observed on mink with this diet although reproduction was lessened. Two months of feeding 10 ppm PCB's plus 10 ppm DDT produced a highly significant reduction in growth and, after 4 months, loss of weight (Aulerich et al, 1973).

Badgers in the Netherlands contained up to 0.50 ppm DDE, 0.13 ppm DDD, and 0.13 ppm DDT. The badgers were not threatened by this degree of pesticide contamination (Keij and Kruizinga, 1972).

Black bear were analyzed for pesticides in Idaho. The highest p,p'-DDE level found in any bear was 2.055 ppb; total DDT was only 2.89 ppb. The lowest amount was 0.320 ppb total DDT. Bear meat had little or no significant pesticide residues to endanger the health of people (Benson et al, 1974).

Analysis of 30 British bats from 1963 to 1970 showed 100% contained DDE in the liver (0.30-53.7 ppm), and 82% contained DDT (1.3-28.6 ppm). The mean levels of these materials in the liver were 10.68 and 4.62 ppm, respectively. Pipistrelles were very sensitive, and when fed DDT, none died at less than 45 mg/kg, half died between 45-90 mg/kg, and all died when fed more than 90 mg/kg. Mortality began when liver and whole body residues of DDT plus DDE reached 43 and 45 ppm, respectively (Jeffries, 1972).

Five samples of adult Australian bats (88 animals) had a mean of 15.9 μg total DDT in their bodies while two samples of juvenile bats (28 animals) contained only 8.8 μg total DDT/bat. One wild bat contained 56 μg total DDT. The DDT levels in these bats are a cause for concern particularly since this was not an area of extensive DDT use (Dunsmore et al, 1974).

Livers from Rhodesian herbivores were analyzed for DDT and its metabolites. Elephants and impalas showed traces of DDD, DDE, and DDT; total DDT in waterbuck liver reached a high mean of 0.24 ppm (Billing and Phelps, 1972).

TOXICITY OF DDT TO BIRDS

Administrator's Finding: Birds can mobilize lethal amounts of DDT residues.

Some wild birds have been affected adversely by mobilized DDT and its metabolites. The residues are absorbed from their diet and bioaccumulated into tissues. The identification of lethal and sublethal toxic residue limits has been well documented under controlled conditions. Of particular importance is the movement or mobilization of residues through the body. Sex, age, and stress conditions (migration, cold weather, starvation, etc.) are proven contributing factors affecting both residue limits and species tolerance. While it is difficult to assess the impact in field populations, the identification of abnormal toxicant levels (consistent with those established under laboratory conditions) justifies the assertion that DDT and its metabolites are responsible for increased avian mortality and, at sublethal levels, may cause mutagenicity. Birds can contain concentrations in amounts sufficient to prevent carrying out normal functions; death can be caused if conditions favor mobilization of stored residues to sites of action or target areas such as the brain. Only the presence of toxic residues, consistent with levels known by controlled study to be associated with lethality, can justify the conclusion that a certain chemical agent is responsible for mortality.

Data as of 1972

Birds are endangered when DDT and DDD residue levels reach 30 or more ppm in the brain. Birds store DDT in their fat. Under stress, body fat is utilized, DDT enters the bloodstream, and hence, finds its way to the brain. The brain does not tend to lose its fats and accumulates DDT from other body parts. Death from mobilization can occur more than 4 months after DDT intake has ceased. DDT and DDD body residues as low as 10.10 ppm can concentrate to 41.27 ppm in the brain.

Heavy application of DDT in forests (up to 5 lbs/acre) have eliminated or reduced local bird populations in Pennsylvania, Maryland, and Texas. Many birds died when elms were treated for Dutch Elm disease in urban areas. DDT has proven lethal to ducks, pheasant, and black birds exposed to treated rice; songbirds feeding in treated vegetable plots; and thrushes in apple orchards.

Data since 1972

DDT residues are hazardous to birds during stress periods. DDT stored in fat deposits can be metabolized and eliminated very slowly without apparent ill effects as long as the organism does not utilize fat reserves for energy. Deprivation of food was used to simulate the stress situation encountered on long migratory flights. Prior to their semiannual migrations, birds build up large fat reserves to be used as energy sources for their long flight. Robins wintering in colder areas are often exposed to conditions requiring mobilization of fat reserves (Sodergren and Ulfstrand, 1972). Fat metabolism proceeds at an accelerated rate and residues are relocated via the bloodstream. When the carcass loses some fat, levels of organochlorine residues, in terms of fresh weight, decrease. Consequently, due to the remaining low fat content, residue levels, in terms of fat weight on a ppm lipid basis, increase. Although the fat content decreases in the breast muscles, the residue levels, in terms of both fresh and fat weight, increase.

Van Velzen et al (1972) evaluated in cowbirds the lethal mobilization of DDT and the effects of food deprivation on the distribution and loss of DDT, DDD, and DDE. Cowbirds were fed 100 ppm DDT for 13 days, followed by a full ration of untreated food for 2 days. The following 4 days, the ration was reduced to 6 grams food/bird/day and then for 10 days untreated food was presented. During the 4 days of food restriction, 7 of 20 birds died. No birds died when fed 100 ppm DDT or when the ration was reduced, indicating that neither weight loss nor dosage alone was sufficient to cause mortality. Also, 2 male kestrels died after 14 and 16 months on a diet containing 2.8 ppm DDE (Porter and Wiemeyer, 1972). The kestrels died during the season weight loss and depletion of fat reserves caused by the stress associated with reproduction and molting.

When fat reserves are utilized, there is an increased concentration of DDT and its metabolites in the fat tissues, as well as a corresponding increase in other tissues because DDT is generally lipophilic and found in lipid-rich organs and tissues. Bobwhites fed 100 ppm DDT for 10 weeks had a much higher quantity of liver lipids than birds not fed DDT (15.4 versus 12.9 percentage dry weight) (Haynes, 1972). This increase in liver lipids is enhanced by an accelerated mobilization of lipids from the adipose tissue during food deprivation. Mobilization is known to be affected both by substances toxic to hepatic cells and hormonal influences. Bobwhites, deprived of food after DDT administration, had liver lipids of 34.4 percentage dry weight for DDT-fed birds compared to only 20.6 percentage dry weight for birds not given DDT. This increase in liver weight, liver residues, and percentages of lipid in the liver was also noted by Dieter (1974) for coturnix and Jefferies and French (1972) for pigeons.

During stress periods resulting in weight loss, toxicants stored in fat are released as lipids, are discharged into the blood, and are redeposited at other sites. When sufficient quantities of toxicants are present in the brain, death results. The brains of the 2 dead kestrels contained DDE residues of 213 and 301 ppm (wet weight) compared to 14.9 ppm for 11 adult males not dead after 16 months (Porter and Wiemeyer, 1972). Weight loss for birds on a DDT diet was much greater than for birds not given DDT. DDT-dosed cowbirds on full ration lost 0.2% body weight while untreated birds on full ration gained 2% (Van Velzen et al, 1972). Cowbirds, that died during weight loss, exhibited a rapid increase in the brain residues when compared to birds sacrificed immediately before food restriction (61 versus 5 ppm total DDT).

To better establish the role of DDT as the cause of illness and death in wild birds, the effects of various dietary levels of DDT on several species were studied by Hill et al (1971). Weight losses in farm-reared bobwhite quail were significant when concentrations of DDT reached 400 ppm in the diet (about 3%). The average wet weight of DDD + DDT residue levels in brain associated with death were: house sparrow, 43.2 ppm (with 32.6 ppm giving an indication of DDT poisoning); wild bobwhite, 31.3 ppm; farm-reared bobwhite, 28.4 ppm; cardinal, 26.7 ppm; and bluejay, 23.0 ppm. With the latter species, only 20-25 ppm appeared to implicate DDT as the lethal agent.

Comparison of stressed versus unstressed birds ascertained that stress was associated with increased brain and liver residues, but decreased carcass residues. Penned cormorants were fed daily 2, 5, and 10 mg of DDT, DDD, and DDE, respectively (Greichus and Hannon, 1973). At 9 weeks, food was cut in half for some birds, creating a stress situation. A marked increase in the proportion of DDE and a decrease in DDD and DDT was found in the brains of stressed birds compared to controls. Brain:carcass residue ratios were higher in stressed than nonstressed groups. Average brain concentrations of DDD ranged from 24-85 ppm wet weight in cormorants which died from the toxic effects of DDT, DDD, and DDE and from 0.4-29 ppm in survivors. Apparently, 30 ppm was diagnostic of lethality. DDT residues, in carcasses of cowbirds dying during weight loss, decreased from 119 to 97 ppm wet weight (Van Velzen et al, 1972). Cowbirds, sacrificed prior to food restriction, showed no such reduction in DDT residues. In contrast, DDD and DDE residues increased from 19 to 41 ppm and 8 to 18 ppm, respectively; birds sacrificed prior to food restriction showed no increase in residues. Stress caused a mobilization and redistribution of DDT residues from the carcass to the brain.

Sex and age also influence the quantity of DDT-related residues present in the system of birds. DDE residues were more variable and attained higher levels in male mallard and black ducks than in females of the same species (Heath and Hill, 1974). This may be due, in part, to the female's ability to eliminate some pesticide residue through eggs. Grocki and Johnston (1974) found that adult cuckoos had higher total DDT levels than first-year birds (1.55 versus 0.95 ppm lipid weight total DDT); an adult would have more time to accumulate pesticides than an immature bird.

An accurate assessment of the cause of wild bird abnormalities or death is extremely difficult because many pesticides are present in the environment. Body residues in these birds may not be uncommonly high and even less than the normal range of toxicity. DDE residues ranging from 0.16-78 ppm wet weight were detected in 39 bald eagles found sick or dead in 1969-1970 (Belisle et al, 1972). All 37 bald eagles found sick or dead in 1971-1972 contained DDE (Cromartie et al, 1975). Dieldrin, PCB's, mercury, and other foreign substances also were present emphasizing the difficulty in identifying cause of death. Belisle et al (1972) found one eagle containing a possible lethal level in the brain of 385 ppm DDE. A warbling vireo, found dying in tremors nearly four weeks after a field was sprayed with up to 0.75 lb/acre of DDT, had 459 ppm total DDT wet weight in the brain (Herman, 1975). DDE residues in the brains of 7 white-faced ibis found dead or dying in Texas in 1970 ranged from 0.1-0.7 ppm (Flickinger and Meeker, 1972).

A significant relationship between liver and whole body residues of DDE in dead guillemots occurred as 40% of their body weight was lost and depot fat mobilized in their livers contained 18.8 percent DDE (Parslow and Jefferies, 1973).

The incidence of abnormal chicks (feather loss, and eye, bill, and foot deformities) in 2,000 common and 800 roseate terns in Long Island increased from 0.1 to 1.3% from 1969 to 1970 (Hays and Risebrough, 1972). Median concentrations of DDE and PCB in the breast muscles of young terns were 2.1 and 25 ppm wet weight, respectively. The search for the causes of wild bird abnormalities is made difficult by the nature of the relationship between environmental teratogens and the incidence of observed effects. Exposure of a large population of organisms to comparable concentrations of a teratogen could be expected to produce abnormalities in only a few individuals. Concentrations of the chemical responsible could be as high in apparently normal birds as in those with obvious abnormalities. Increasing the level of exposure, however, would increase the probability and, therefore, the incidence of the effects. Within a given ecosystem, such as the marine ecosystem supporting the terns on Long Island, it may not be possible to relate the abnormalities to concentrations of any one or a combination of pollutants in the birds.

Biologists are constantly alert to new situations concerning pesticide-wildlife relationships. Of particular importance, is the continual monitoring on a yearly basis of wildlife species. This is an important action because when birds are subjected to heavy pesticide concentrations, their resultant death frequently goes unnoticed. Ducks collected in Iowa in 1969-1970 had higher total DDT residues in the fat than other tissues, ranging from 67-662 ppb wet weight (Johnson et al, 1971). The breast muscle contained from 6-97 ppb and the liver residues ranged from 8-247 ppb. Analyses of 5,200 mallard and black duck wings in 1969-1970 revealed DDE as the predominant organochlorine residue, ranging from 0.06-5.27 ppm (Heath and Hill, 1974). These concentrations alone, however, would not be hazardous to duck populations, but coupled with stress conditions could contribute to sickness or death.

Although almost all chukar, pheasant, and waterfowl samples taken in Utah from 1970 through 1971 contained pesticides, no pheasant or chukar breast muscle tissues exceeded the 5.0 ppm tolerance guideline for DDT + DDE residues established by the Food and Drug Administration for edible portions of fish (Smith et al, 1974b). Mourning dove breast muscles, collected in 1970-1971 in the Eastern United States, were found to contain DDT + DDE + DDD in all 145 samples tested. The average residue level was 0.068 ppm wet weight (Kreitzer, 1974). The amounts identified are not considered hazardous to higher order carnivores.

Birds sampled in areas of high pesticide use, as expected, contained higher residues than those from nonuse areas. Bobwhite quails collected in Alabama in 1968-1969 (McIntyre and Causey, 1971) from untreated fields contained an average of 1.68 ppm DDE fat basis (range of 0.55-3.10 ppm) while quail from nearby treated fields (DDT, Toxaphene, or methyl parathion) averaged 17.08 ppm DDT fat basis (range of 2.07-46.40 ppm). This concentration exceeds the 7 ppm tolerance guideline established by the Food and Drug Administration for commercial poultry. The same results were obtained from bobwhite in South Carolina in 1969-1970 (Percival et al, 1973) and from ring-necked pheasants in Idaho in 1969 (Messick, 1972).

When residues are detected in areas where there has been little or no pesticide use, it can be concluded that they were transported from other areas. A survey was made during 1970 and 1971 of organochlorine pesticide residue in the fatty tissues of two bird species (about 47 individuals) in Australia (Best, 1973). In areas far from human agricultural activity, total DDT was found in birds ranging from <0.01-4.12 ppm fat basis. It has been suggested that DDT levels above 2 or 3 ppm in the tissues may cause serious damage to bird populations.

Greichus et al (1973) examined cormorants and pelicans for pesticide residue concentration. The p,p'-DDE was the most prevalent contaminant, reaching 154.50 ppm wet weight in pelican fat and 107.64 ppm in cormorant fat. Penned cormorants approaching toxicosis had 20 μg/g of DDD in the brain. Stress conditions for cormorants (migration or disease) may cause a decrease in body lipid stores and it is quite possible that 20 μg/g of DDD could occur in the brains. Analyses of ten wild cormorants from South Dakota showed average concentrations of 0.56 ppm DDE in the brain, 9.12 ppm in the carcass, and 2.70 ppm wet weight in the liver (Greichus and Hannon, 1973). Carcass levels in these cormorants were 20 times greater than in penned birds, although brain concentrations differed little. This evidence suggested storage of residues in body fat as a means of adjusting to residue intake and maintaining low brain levels. Low brain residue levels indicated the wild birds were in no immediate danger.

Most species continually monitored exhibited a gradual decline in amounts of pesticide residues associated with decreased DDT use. When 319 migratory songbirds were sampled in Florida, all contained DDT in their fat deposits (Johnston, 1974a). There was a decline in DDT from 17.80 ppm in 1969 to 2.06 ppm lipid weight in 1973. The same result was evident in songbird species which contained 15.48 ppm in 1969 compared to 1.66 ppm in 1973 (Johnston, 1974b). Samples of Louisiana woodcock in 1971 had lower mean DDE residues (6.88 ppm) in the carcass than did the 1965 sample (17.90 ppm) (Clark and McLane, 1974). Starlings also showed a decline from residue levels of 1.9 ppm in 1967-1968 to 1970 values of 1.0 ppm (Martin and Nickerson, 1972). The decline in DDT residues in starlings in 1972 was not as great as that shown in the 1970 values but generally still decreasing (Nickerson, 1972). These declines are attributed to decreased usage of DDT in the United States.

Exposure to organochlorine pesticides remained relatively constant from 1965 to 1970 for golden eagles in the United States (Reidinger and Crabtree, 1974). DDE was the most prevalent residue ranging up to 84 ppm in the fat. Exposure was apparently through diet and not sufficient to warrant concern for direct nonsynergistic acute toxic effects. Sublethal effects are not precluded, however.

Conclusion

DDT residues present an intensified hazard to birds during stress periods including migration and partial food deprivation even with normally sublethal concentrations. Mortality occurred when birds were fed DDT simultaneously with food restriction. However, there was no mortality when the same DDT dosage or the same food restriction was applied separately indicating that neither weight loss nor dosage alone was sufficient to cause mortality. Under stress, body fat is utilized: DDT is mobilized and may be translocated via the bloodstream to the brain in sufficient amounts to cause death. Death from mobilization of stored DDT residues can occur long after the dosage has been eliminated.

An accurate assessment of cause of death in the field is extremely difficult because many pesticides are present in the environment. Birds carrying DDT residues may have traveled long distances from DDT contact points making it difficult, if not impossible, to relate the cause of death to one pollutant.

The conclusion reached from the new data agrees with the Administrator's prior decision: DDT is toxic to birds and can be mobilized from tissues in lethal amounts.

Administrator's Finding: DDE can cause thinning of bird eggshells and thus impair reproductive success.

Certain wild birds, in their natural breeding areas, are affected by DDT-related residues in the diet and bioaccumulated into tissues in such a way as to produce reproductive impairment. This impairment is associated with the production of eggs with shells thinner than the historical norms and results in such deleterious phenomena as cracking, crushing, egg-eating by the parents, and nest abandonment. These phenomena result in reduced reproductive success among natural populations, and in some cases, failure of large breeding colonies to reproduce the young needed to sustain the population. These effects can result ultimately in partial or complete loss of whole species.

The statement that DDT-related residues produce this eggshell thinning is based upon at least three lines of evidence: 1) museum eggshells of the affected species show that a marked decline in average thickness occurred during the late 1940's corresponding to the time DDT came into prominent use; 2) affected species have a negative correlation between the concentration of DDT-related residues in the egg, bird, or colony and the thickness of eggshells. These kinds of residue correlations along with shell thickness, population status, and reproductive failures are field research evidence; 3) controlled studies on this chemical effect on shell thickness have shown the phenomenon to be repeatable in the laboratory.

Data as of 1972

Testimony presented during the hearings included pro and con information regarding each of the three lines of evidence. Museum studies were presented by Dr. Joseph Hickey and others describing the decline in shell thickness of certain species in the US. Testimony was also presented showing a lack of change in certain other species. Testimony was presented showing a negative correlation between shell thickness and egg residues for some species and no correlation for others. Earlier laboratory studies, such as those of the University of Wisconsin and the Patuxent and Denver Wildlife Research Centers of the USDI, were presented which showed that dietary or single oral dosages of the DDT complex, particularly DDE, could cause shell thinning in some species but not in others. While several witnesses expressed the opinion that DDE-impaired calcium metabolism was responsible, no definitive biochemical mechanism was demonstrated, though several possible mechanisms were proposed. (Public Hearings on DDT, 1971-1972)

Data since 1972

Since the Administrative Hearings, more information has become available. An excellent, in-depth review of shell thinning in avian eggs has been written

(Cooke, 1973). Any serious student of the phenomenon should read this well-referenced 68-page review for a thorough grasp of the subject's history and an analysis of research to that time. Other recommended background reading is the most comprehensive American study of eggshell thickness ever conducted (Anderson and Hickey, 1972).

These reports document the decreased shell thickness certain American species have displayed since the late 1940's. Species of wild birds studied in North America not demonstrating any significant shell thinning included the golden eagle, great horned owl, gyrfalcon, rough-legged hawk, whooping crane, and mourning dove.

Species in North America showing recent decreases in shell thickness include the peregrine falcon, bald eagle, prairie falcon, osprey, red-tailed hawk, merlin, white pelican, brown pelican, double-crested cormorant, common egret, great blue heron, guillemot, herring gull, and ashy petrel.

The species showing thinning are generally among those at the top of food chains, such as fish-eaters, bird-eaters, and other flesh-eating birds. Herbivorous species such as pheasants, quail, and certain waterfowl have not displayed this shell thinning.

Numerous authors present graphs of shell thickness plotted against time. The decreases first appeared to have happened in the period 1946-1952, typically in 1947, continuing in many cases to the present. In certain cases, thickness increases toward historical norms have occurred very recently (Anderson and Hickey, 1972).

The degree of shell thinning in affected wild colony populations has varied from over 34% (with eggs collapsing as a result) for the California brown pelican (Keith, Woods, and Hunt, 1970) to none for many species. Within a given species there are geographical differences in average degrees of shell thinning.

There are many research papers giving negative correlation coefficients between the degree of shell thinning and the concentration of DDT-related residues for affected species (Blus et al, 1974; Faber and Hickey, 1973; Cade et al, 1971).

Blus et al (1972) have developed the mathematics for the relationship between DDE residues and shell thinning for several species. The relationship between the logarithm of the dose and the response is well known in toxicological theory. Blus et al extend this to the association between residue and response. His calculations show a concentration-effect relationship involving the logarithm of DDE (wet weight basis) in eggs and the thickness of the shells for affected species. The resulting regression is linear and similar for different species. However, he notes that this relationship operates on a different level for different species. For example, in the brown pelican, which seems to be extremely susceptible, a 15%

thinning is associated with DDE residues of 4-5 ppm. In contrast, the herring gull shows no thinning at 4-5 ppm and only 11% thinning at 80 ppm.

In certain cases, this shell thinning-DDE residue correlation led to population studies and on-site reproduction assessments. One set of studies concerned the brown pelican off the coast of California and Baja, California. A report, prior to 1972 (Risebrough et al, 1971), showed this population experiencing extremely low reproduction in association with thin shelled-egg production and abnormally high DDE residues. The residues resulted from the brown pelicans' diet of northern anchovies and other fish carrying high DDE residues.

Dr. Daniel Anderson (personal communication, 1974) is studying this population. His data demonstrate that a change has occurred since the 1960's for the islands of Anacapa and Coronados off the southern California coast. A significant drop in the average levels of DDE, DDT, and TDE in the anchovies began in 1971.[1/] A significant improvement in the reproductive success of the brown pelicans has occurred since 1971. For 1969, it was reported (Risebrough et al, 1971) that the colony was littered with eggs that had collapsed under the weight of the incubating adults. Shells of these eggs averaged 53% thinner than those collected before 1943. In 1969, a maximum of five young hatched from 1,272 nesting attempts. In 1970 and 1971, there was little improvement. More improvement occurred in 1972 and 1973. For 1974, Anderson has data showing that approximately 1,200 young were successfully hatched from the Island of Anacapa. This reproductive improvement was associated with a significant improvement in shell condition, as well as increased survival of eggs and reduced DDE residues. This reproductive success is attributed both to improved rate of reproduction and an increased number of breeding adults by 1974. The increase in number of breeding adults is thought to be brought about by possible recruitment of first breeders from more southerly populations as a response to an increased food supply (fish).

This increased reproductive success is not enough to be called "normal" for these pelicans. Anderson states it as a "chronic lower level of adverse effects" as opposed to the acute problem of almost total reproductive failure which had just previously occurred. The numerical data supporting this history have been evaluated and are to be published.

James O. Keith, of the Denver Wildlife Research Center, has also been involved in the on-site study of West Coast brown pelicans for many years.

[1/] Montrose Chemical Company, DDT manufacturer, installed a separate treatment system and no longer used the Los Angeles sewer system in 1971; this accounts for some of the lower DDT related residues thereafter.

He states (personal communication, 1975) that "the average productivity of brown pelicans in the Gulf of California during the last five years appears to be inadequate to maintain their population." Whereas existing data on mortality rates for the species suggest that a recruitment standard of from 1.2 to 1.5 young per adult pair is necessary (Henny, 1972) to maintain the population, production has averaged less than 1.0 young per pair in the Gulf. Average productivity was reduced primarily by two kinds of inadequate performance on the part of adult pelicans. In two of the [last] five years, only about one-half and one-third of the adults came to the colonies to breed; the remaining proportion of the adults did not produce young during those years. In addition, during every year a proportion of the adults (10 to 95%) deserted eggs or young sometime during production. Keith notes that, in addition to DDE residues carried by the adult pelicans, food availability was possibly related to this inadequate performance.1/ Keith's research on food deprivation and its effect on birds carrying DDE residues is reviewed elsewhere in this report.

Like Gress (1970), Keith noted erratic behavior in the field such as a tendency of breeding adults to leave normal nests unattended. He also noted that a tendency toward less intense courtship behavior than normal was correlated with higher DDE residues than occurred in "normal" pairs. Experimental evidence has substantiated this phenomena under controlled conditions and is presented elsewhere in this report.

Schreiber and Risebrough (1972) described the historical status of brown pelicans throughout the United States and its relationship to DDE residues. Risebrough (personal communication, 1974) was concerned about the biochemical mechanism by which DDE could cause thin shells.

Blus et al (1974) studied egg effects from 13 or more colonies of brown pelicans from South Carolina, Florida, and California in 1969 and 1970. They observed a 17% eggshell thinning in South Carolina which was associated with subnormal reproductive success. Since the DDT cancellation, there has been a significant decline in residues of DDE, DDD, and DDT in eggs (brown pelicans in South Carolina); at the same time, reproductive success of the pelicans returned to near normal for the first time in many years (Blus, personal communication, 1975). This is consistent with other findings for brown pelicans off the California coast (Anderson, personal communication, 1974) and ospreys in the Eastern US (Stickel, personal communication, 1974).

Controlled laboratory studies, both before and after the cancellation, have demonstrated the shell-thinning phenomenon to be reproducible. Chickens and related wild gallinaceous birds have shown little or no thinning upon exposure to DDT or DDE in the diet (Davison and Sell, 1972). On the other

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1/ Restricted food intake can lead to mobilization of DDE residues from body fat.

hand, waterfowl, such as the mallard (Davison and Sells, 1974) or black duck (Longcore et al, 1971; Longcore and Samson, 1973), ring doves (Haegele and Hudson, 1973), and sparrow hawks (Peakall et al, 1973) have shown significant shell thinning of a degree impairing reproduction even when the eggs are artificially incubated. Studies have not been performed in the laboratory with the same species showing reproduction problems in the wild, with the exception of the prairie falcon and sparrow hawk. The reason for this is the other species are not amenable to laboratory rearing practices.

To determine if mercury or lead compounds caused significant shell thinning or synergized the thinning caused by DDE, Haegele et al (1974) fed them singly and in combination with DDE, to mallard ducks. DDE alone caused 15% reduction in shell thickness; but neither mercury nor lead caused significant thinning or additive thinning, either alone or in combination with DDE. Furthermore, Haegele and Tucker (1974) orally administered fifteen common environmental pollutants to both coturnix and mallards to determine if pollutants, other than DDE, caused shell thinning. The chemicals tested included Aroclor 1254, 2,4-D, dieldrin, heptachlor, chlordane, parathion, sodium arsenite, Toxaphene, and tetraethyl lead. Results showed that several chemicals and pesticides caused temporary production (2-5 days) of thin-shelled eggs in association with treatment levels producing severe signs of intoxication. When the overt intoxication remitted, the next eggs subsequently returned to normal thickness, except for the DDE-treated groups where thinning persisted throughout the 18-day study, in the absence of signs of intoxication. These authors studied DDE-produced shell thinning in mallards which persisted in excess of a year after the birds were returned to normal, uncontaminated diets (Haegele, personal communication, 1974). Peakall et al (1975a) studied the prolonged nature of this thinning using the white Pekin duck. They concluded that recovery of shell thickness following cessation of exposure to DDE was less than half-way to normal in 27 weeks and that DDE residues in egg yolks produced at that time had decreased 40%. The authors noted that recovery would be slower in the wild for affected species since they lay far fewer eggs. Eggs are a major route by which female birds rid their bodies of DDE residues.

Some significance of shell thinning is shown by Longcore and Sampson (1973) who fed black ducks just 3 ppm wet weight p,p'-DDE. The ducks produced eggs with shells 22% thinner than normal. When the hens were allowed to incubate these eggs, the increase in total percentage of eggs with cracked shells was statistically highly significant (57.7%), four times the percentage of cracked control eggs (12%). Only 18.7% of the eggs laid by DDE treated ducks hatched, compared to 86% of control eggs. Most other studies utilized artificial incubation techniques and thus, in part, missed the cracking effect. These authors in prior years conducted the same study but artificially incubated the eggs and found that of the control eggs, 2.2% cracked and of the DDE group eggs, an unimpressive but statistically significant 11.0% cracked.

One major thrust of current laboratory shell-reproduction research has been to elucidate the biochemical mechanism by which DDE could cause thinning.

Previously, a number of mechanisms, all related to calcium metabolism, had been proposed. One by one, each proposed mechanism has been either dismissed as further experimental evidence became available, or been relegated to a minor role.

Such mechanisms proposed and studied include carbonic anhydrase inhibition, thyroid destruction via liver enzyme induction, premature oviposition, parathormone dysfunction hydroxylation of the steroid vitamin D causing poor calcium absorption from the gastrointestinal tract, hormonal changes, and numerous other theories. These were thoroughly discussed by Cooke (1973) and, more recently, by Mueller and Leach (1974).

In the last few months some very important breakthroughs have been made. The most popular theory of the early 1970's, carbonic anhydrase inhibition by DDT, has now been rather successfully refuted by Maren et al (1974). Carbonic anhydrase inhibition in the shell gland by DDE had been presumably demonstrated by previous authors and should have been responsible for reduced laying down of calcite ($CaCO_3$), the major constituent of eggshells. Previously, Pocker et al (1971) showed in assays that a false inhibition resulted from coprecipitation with insoluble DDT, thus occluding carbonic anhydrase from solution. Maren et al (1974), using DMF with ultrasonication to keep any carbonic anhydrase and DDT in suspension, demonstrated a lack of inhibition of anhydrase activity by DDE and DDT. Peakall et al (1975b) have now shown that DDE does not reduce blood calcium levels in either the Pekin duck or the ring dove, both of which are susceptible to shell thinning. Thus, the mechanism had to involve the function of the shell gland in laying down calcite rather than decreased calcium supply to the gland.

Finally, Miller et al (1975) reported that calcium ATPase present in the shell gland may act as a calcium pump to produce the active transport of calcium ions across the avian shell gland from the blood to the developing shell. Their experiments demonstrated that calcium ATPase in the shell gland of Pekin ducks is strongly inhibited by DDE both in vivo and in vitro. As little as 0.2 ppm DDE in the shell gland produced inhibition in the susceptible duck species. If this biochemical explanation is valid, one should expect little or no calcium ATPase inhibition in the shell gland of a DDE-treated chicken. In fact, this has been verified in recent weeks (Kinter, personal communication, 1975), thus finally explaining the difference between susceptible species and the nonsusceptible chicken.

Conclusion

Based upon previous data available to the Administrator and additional material which has since become available, we conclude:

1. Because there is a mass of information showing that the shell-thinning phenomenon was not a problem prior to the introduction of DDT into the environment, and because there is a corresponding remission in severe shell thinning in many affected species taking place across the nation since the cancellation,

we feel a clear-cut time relationship exists between thin-shell production, concomitant reproductive failures, and DDT use in North America.

2. There is a spatial relationship showing that the areas, colonies, and birds of susceptible species most exposed and carrying the highest residues have been the most affected.

3. Time and time again, negative correlations between the DDE content of eggs and parents versus thickness of shells produced have been shown. The only exceptions, to our knowledge, were the lack of correlation found by one mosquito abatement district manager on a few eggs and one graduate student who found yet another negative correlation coefficient, albeit a nonstatistically significant one (Switzer et al, 1971).

4. Controlled studies have shown repeatedly that many species are susceptible under laboratory conditions of exposure to environmental levels of DDE. However, chickens and related gallinaceous birds are generally refractory both in laboratory studies and their natural habitat. A plausible explanation for how thinning occurs in susceptible species but not in chickens or other non-susceptible species is the biochemical mechanism (calcium ATPase inhibition in the shell gland) previously discussed.

5. No other chemical has been shown to produce the degree and duration of shell thinning produced by DDE.

For all these reasons, we conclude, as did the Administrator, that DDE can cause thinning of bird eggshells, thus impairing reproductive success. This phenomenon has been so general and widespread as to, in our opinion, present serious environmental risk to the many avian species involved.

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III

B. HUMAN EFFECTS

CARCINOGENICITY OF DDT IN MICE

Administrator's Findings: 1) Experiments demonstrate that DDT causes tumors in laboratory animals. 2) There is some indication of metastasis of tumors attributed to exposure of animals to DDT in the laboratory.

Data as of 1972

In a published preliminary note, 18 male and 18 female (C57BL/6 x C3H/Anf) F1 mice and a similar number of (C57BL/6 x AFR) F1 mice were given single doses of 46.4 mg/kg bw p,p'-DDT by stomach tube at 7 days of age. The same absolute amount was given daily until the animals were 28 days of age; they were then transferred to a diet containing 140 ppm p,p'-DDT. Mice were killed at 81 weeks. In both strains, about 30% of the females died during treatment. Hepatomas (liver cell tumors) were found in 11/18 male and 4/18 female (C57BL/6 x C3H/Anf) mice compared with 8/79 male and 0/87 female controls, and in 7/18 male and 1/18 female (C57BL/6 x AFR) F1 mice compared with 5/90 male and 1/82 female controls. In addition, 6/18 (C57BL/6 x AFR) F1 females died with malignant lymphomas, compared to 4/82 controls (Innes et al, 1969).

A 5-generation experiment, originally devised to investigate the effects of DDT on behavior, provided animals for a carcinogenicity study. One test and one control group of BALB/c mice were taken from each of the 5 generations and their tumor incidence studied. A total of 683 received a diet containing 3 ppm p,p'-DDT and 406 a control diet. Lung carcinomas were observed in 16.9% of the treated mice and 1.2% of the controls (the incidence of lung adenomas is not reported, although the authors note an average incidence of 5% in their colony of mice). The incidence of lymphomas was 4.8% in treated and 1.0% in control mice; leukemias 12.4% and 2.6%, and other tumors 5.3% and 1.0%, respectively (Tarjan and Kemeny, 1969).

At this time, the multigeneration Lyon study was ongoing and preliminary data indicated that International Agency for Research on Cancer (IARC) also had observed an increased incidence of hepatomas in mice but no conclusive data were available for publication (IARC, Scientific Advisory Committee to EPA Administrator, personal communication, 1972). The committee agreed at this point that the unpublished evidence made available to them, indicated an overwhelming production of hepatomas in mice by DDT. However, they admittedly were in disagreement at this time, for lack of evidence, whether or not hepatomas signified eventual development of carcinomas. The presence, however, of lung carcinomas and malignant lymphomas (lymph gland tumors) in addition to the hepatomas signaled the ability of DDT to produce cancerous growths in other tissues and gave weight to the potential carcinogenicity of this chemical in other mammalian systems.

Data since 1972

A 2-generation dose-response study on the feeding of DDT to CF1 mice involving a total of 881 treated and 224 control mice has been reported (Tomatis et al, 1972). Dietary concentrations of 2, 10, 50, and 250 ppm technical DDT were administered for lifespan (approx. 18 months). In both parent (P) and offspring (F1) generations, there was excess mortality from week 60 onward among mice receiving 250 ppm DDT. Only the incidence of liver-cell tumors was affected by exposure to DDT, and in the two sexes, it ranged as follows:

Group	Male*	Female*
0 ppm	25/113	4/111
2 ppm	57/124	4/105
10 ppm	52/104	11/124
50 ppm	67/127	13/104
250 ppm	82/103	69/90

(* Number of animals demonstrating the appearance of the first tumor at any site.)

The excess of liver-cell tumors in mice of both sexes fed 250 ppm DDT over the controls was significant at the 1% level. The excess of liver-cell tumors in males fed 2, 10, or 50 ppm over the controls was significant at the 1% level in animals surviving more than 60 weeks. In females, all liver-cell tumors were found after 100 weeks of age, and the excess over the controls was significant at the 5% level only in the group fed 50 ppm DDT. Four liver-cell tumors, all occurring in DDT-treated mice, gave metastases. No remarkable differences were observed between P and F1 mice in this study.

These results were confirmed by a later study reporting the effect of DDT on 6 consecutive generations of CF1 mice. CF1 minimal inbred mice of 6 consecutive generations (parents, F1-F5) were fed technical DDT mixed into the diet at dose levels of 2, 10, 50, and 250 ppm for their lifespans. The experiment involved 3,987 mice, including DDT-exposed and negative and positive controls.

Exposure to all 4 levels of DDT significantly increased liver tumors (hepatomas) in males (50-55.9% in the 2, 10, and 50 ppm groups and 86% in the 250 ppm DDT groups, compared to 29.5% in male controls). In females, hepatoma incidence increased considerably only after exposure to 250 ppm DDT (65.5% compared to 4.7% in controls). Ten and 50 ppm DDT only slightly increased the incidence (9% and 13% respectively). No effect was seen at the 2 ppm level in females.

The average lifespan of males with hepatomas decreased in DDT-treated groups (84 wk at the 250 ppm DDT level, 101-104 wk at the 2, 10, and 50 ppm levels, as compared to 114 wk in controls). In females, only the highest dose level shortened the average lifespan of hepatoma-bearing mice (94 wk compared to 104 wk in controls). DDT did not alter tumor incidence at sites other than the liver, although an apparent, but not significant, increase in lung tumor incidence was noted at the levels of 2 and 10 ppm DDT. No progressive increase of hepatoma incidence from generation to generation was noted in DDT-treated mice. However, considerable variations in the incidence of tumors of the liver, lungs, and hematopoietic tissue were observed between the generations within each treatment group, including controls. One metastasizing hepatoma was found in controls and 13 were found in 4 DDT-treated groups. Malignant liver tumors, tentatively termed hepatoblastomas, also occurred, with a slightly increased incidence in the 10 and 50 ppm groups (3.9% and 3.1%, respectively, as compared to 0.9% in controls) and a significant increase in the 250 ppm group (7.1%). Ten of 56 tumors of this type found in DDT-treated mice metastasized to the lungs (Turusov et al, 1973).

In a 2-generation study, a total of 515 females and 431 male BALB/c mice were administered dietary concentrations of 0, 2, 20, or 250 ppm technical DDT for lifespan. Only liver-cell tumors were found in excess, and only the 250 ppm dose level was effective. In females, the survival rates were comparable in all groups, and liver-cell tumors were found in 0/131 control mice, 0/135 mice fed 2 ppm, 1/128 mice fed 20 ppm and 71/121 mice fed 250 ppm DDT. In males, early deaths occurred in all groups as a consequence of fighting and (at highest dosage level) because of DDT toxicity. In males surviving over 60 weeks of age, liver-cell tumors were found in 1/62 control mice, 3/58 receiving 2 ppm, 0/48 receiving 20 ppm, and 15/31 receiving 250 ppm DDT. Liver-cell tumor distribution was unrelated to the litter of origin. No metastases were found. The tumors grew after transplantation into syngenetic animals (Terracini et al, 1973a).

Confirmatory results were obtained in two subsequent generations of BALB/c mice fed DDT, although F1-F3 mice, exposed to DDT both in utero and after birth for lifespan developed more liver tumors than did P mice exposed to DDT only after weaning (Terracini et al, 1973b).

In a multigeneration study in A strain mice, DDT in 0.1 ml sunflower-seed oil was administered to 234 mice by stomach tube at doses of 10 ppm. In two control groups a total of 206 mice received either no treatment or sunflower-seed oil (0.1 ml) alone. Similar treatments were applied to the F0, F1, F2, F3, F4, and F5 generations. An additional 30 mice were given doses of 0.1 ml of a 50 ppm solution which adversely affected pregnancies, thus no subsequent generations were obtained at this level. Approximately 30-50% of the animals in the treated groups died before 6 months; all animals were killed after 12 months. Only lung adenomas were found. The incidences in F0-F5 generations treated with 10 ppm DDT were:

F0, 8/42 (19%); F1, 4/26 (15%); F2, 6/25 (24%); F3, 19/41 (46%);
F4, 16/37 (43%); F5, 8/63 (1[illegible]); controls F0-F5, 15/206 (7%).

Of the 30 mice receiving 50 ppm doses, 14 died before 6 months, and 3 of these (21.5%) had lung adenomas; of the 16 dying after this time, 8 (50%) had lung adenomas. The average number of lung nodules/mouse, about 7.2, was similar in both sexes, compared to 1.0-4.7 nodules/mouse in the 6 generations receiving 10 ppm doses and 1.0 nodule/mouse in controls (Shabad et al, 1973).

Diets containing 50 or 100 ppm p,p'-DDT were administered to groups of 30-32 CF1 mice of each sex for 2 years. The control groups included 47 mice of each sex. In males given 0, 50, and 100 ppm, liver tumors occurred in 13%, 37%, and 53% of the animals, respectively. In females, the corresponding incidences were 17%, 50%, and 76%. The ratio of liver tumors, characterized by simple nodular growths of solid cords of parenchymal cells, classified as benign tumors (type a), to tumors growing with papillary or adenoid growths with cells proliferating in confluent sheets with necrosis and increased mitosis (type b) was greater than 3:1 in the treated group; no type b tumors occurred in controls. The incidences of other tumors were comparable in control and DDT-treated mice. Metastases were found in one treated female (Walker et al, 1973).

In a subsequent study 30 male and 30 female CF1 mice were fed 100 ppm p,p'-DDT for 110 weeks. The animals were not autopsied until the ultra-abdominal masses reached a size causing the animals to become anorexic or clinically affected. In this experiment, 79% of the males and 96% of the females compared with 24% and 23% in the controls developed liver tumors within 26 months. The ratio of type a to type b tumors was about 1:1 in the DDT-treated mice (Thorpe and Walker, 1973).

Conclusion

As a result of additional studies concluded after 1972, the hepatocarcinogenicity of DDT by the oral route has been demonstrated in several strains of mice. Liver-cell tumors have been produced in both sexes, and in CF1 mice were found to have metastasized. An increased incidence of hepatic tumors has been observed with doses of DDT as low as 2 ppm.

TUMOR PRODUCTION IN MICE AS AN INDEX OF POTENTIAL CARCINOGENICITY IN OTHER SPECIES

Administrator's Findings: 1) Not all chemicals show the same tumorigenic properties in laboratory tests in animals. 2) Responsible scientists believe tumor induction in mice is a valid warning of possible carcinogenic properties.

Data as of 1972

Tomatis el al (1973) in a review of the literature containing over 350 references dating from 1937 through 1972 concluded that a positive correlation appears to exist between the capacity of a chemical to induce liver tumors in the mouse and its capacity to induce tumors at any site in the rat or the hamster. The strongest positive correlation was found when the chemical, given to the mouse during adult life, induces tumors of the liver in both sexes as well as tumors at other sites. However, the induction of liver tumors in the mouse by a chemical does not necessarily imply that the liver would be the target organ in the rat or the hamster.

Tomatis, in the same review, further indicated that among the 58 chemicals considered, seven are recognized or suspected human carcinogens (3N-benzopyrene 4-aminobiphenyl, benzidine, auramine, 2-naphthylamine, stilbestrol, and aflatoxin). With the possible exception of aflatoxin, there is no evidence that the target organ for man would be the liver. All were hepatocarcinogenic in the mouse and six were carcinogenic for the liver and/or other organs in the rat. In the hamster, four were tested and found carcinogenic.

Data since 1972

The chemical vinyl chloride when given by inhalation has been observed to produce lung adenomas and mammary carcinomas in mice and hepatic angiosarcomas and angiomas of the liver in mice and rats (Maltoni and Lefemine, 1975). Angiosarcomas of the liver have also been observed in workers employed in the manufacture of polyvinyl chloride resins (Creech and Johnson, 1974; Creech et al, 1974).

Current studies on carcinogenicity of DDT and metabolites in mice and rats at the National Cancer Institute are to be completed within the next 12 months.

Conclusion

Although the target tissue may be different, the mouse can, in specific cases, serve as a reliable and proven indicator of the carcinogenicity of a chemical in other species including man. However, although carcinogenic effects in mice are valid when dealing with certain chemicals, the results can vary greatly depending on the compound tested and may not always be a reliable basis for extrapolation to other species.

CARCINOGENICITY OF DDT IN OTHER MAMMALIAN SPECIES

Administrator's Finding: There are no adequate negative experimental studies in other mammalian species.

Data as of 1972

Rat

In two 2-year experiments started at an interval of 1 year, a total of 228 Osborne-Mendel rats received diets containing technical DDT (as a powder or solution in oil) at concentrations of 0 ppm (24 males and 12 females), 100 ppm (12 males), 200 ppm (24 males and 12 females), 400 ppm (24 males and 12 females), 600 ppm (24 males and 24 females), and 800 ppm (36 males and 24 females). Of the 192 rats exposed to DDT, 111 died before 10 months of treatment; only 14 rats given 800 ppm, 23 rats given 600 ppm, 14 given 400 ppm, 24 given 200 ppm, 6 given 100 ppm and 20 controls were alive at this time. Tumor incidences for each dose level were not given. Among the 81 rats surviving at least 18 months, 4 had low-grade hepatic-cell carcinomas (measuring up to 0.5-1.2 cm) and 11 showed nodular adenomatoid hyperplasia (nodules measuring up to 0.3 cm). No liver lesions were found in control rats (Fitzhugh and Nelson, 1947). Hepatic-cell tumors are reported by these authors to occur spontaneously in 1% of the rats in this colony, and nodular adenomatous hyperplasia is reported to be rare.

Two experiments on Osborne-Mendel rats reported from the same institution, exposed groups of 30 males and 30 females for at least 2 years to either 80 or 200 ppm DDT (recrystallized, purity unspecified) and compared them to two control groups of 30 animals of each sex. Undifferentiated bronchogenic carcinomas were seen in 8/60 rats fed 80 ppm DDT, in 2/60 controls and in none of the animals receiving 200 ppm DDT. Incidences of other tumors were similar in control and treated rats (Deichmann et al, 1967; Radomski et al, 1965). These results are inconclusive since carcinogenic effects were not seen at 200 ppm.

A group of 15 male and 15 female Fischer rats was given doses of 10 mg/rat DDT (unspecified composition) by stomach tube, 5 times/week, starting at weaning. Treatment lasted 1 year, and survivors were observed for a further 6 months; the average survival was 14.2 months. No hepatomas were found. No data are available on the occurrence of other tumors (Weisburger and Weisburger, 1968).

Hamster

Groups of 25-30 Syrian golden hamsters of each sex were fed a diet containing either 500 or 1000 ppm, p,p'-DDT in olive oil for 44 out of 48 weeks. Survivors at 50 weeks were 70/115 treated versus 59/79 control animals; all treated animals and 62/79 controls were dead by the 90th week. Eleven treated animals developed tumors at different sites (including 1 hepatoma), as did 8 controls (Agthe et al, 1970).

Dog

A total of 22 animals, approximately equally divided by sex, were fed either 0 (2 dogs), 400 (2 dogs), 2000 (4 dogs), or 3200 ppm (14 dogs) DDT. Only the control dogs, the 2 dogs given 400 ppm, and 2 of the dogs receiving 2000 ppm survived to the time of sacrifice (29-49 months). Functional liver damage but no tumors were observed (Lehman, 1952, 1965).

Monkey

Dietary concentrations of either 5 or 200 ppm technical DDT were given to rhesus monkeys (Durham et al, 1963). Seven and a half years after the beginning of treatment, 3/5 animals fed 200 ppm were alive and clinically well. In 2 additional groups totaling 6 animals receiving 200 ppm DDT (either technical or the p,p'-isomer), 3 were alive after 3.5 years. Animals which did not survive died from intercurrent diseases not related to carcinogensis.

Data since 1972

No studies, other than in mice, were reported concerning long-term DDT testing after 1972.

Conclusion

No studies have become available since 1972 to adequately demonstrate the presence or absence of carcinogenic effects of DDT in species other than the mouse.

With animals such as the dog and monkey, which live considerably longer than mice, the studies cited are of short duration, and too small a sample size to yield any reliable information relevant to carcinogenicity.

Although the evidence presented is limited in scope, it is apparent that DDT did not consistently enhance the growth of well-defined hepatic lesions in rats or hamsters. However, the experiments available using species other than the mouse are too limited to make definite conclusions.

CARCINOGENICITY OF DDT IN HUMANS

Administrator's Finding: There is no adequate human epidemiological data on the carcinogenicity of DDT, nor is it likely that it can be obtained.

Data as of 1972

In the first study, 40 men ranging in age from 39-50 years engaged in the manufacture or formulation of DDT were medically examined (Ortelee, 1958). Twenty-four workers had also been exposed to other pesticides. The length of exposure was less than 1 year for 2 workers, 1-4 years for 21 workers, and 5-8 years for 17 workers. Examination included a complete medical history, physical and neurological examinations, hemoglobin titre, white blood cell count and differential, plasma and erythrocyte cholinesterase determinations, and measurement of urinary DDA concentration. DDT intake was calculated from urinary DDA for 38 workers; in 10 cases it was 10-20 mg/man/day, 30 mg/man/day in 15 and 40 mg/man/day in 13. No evidence of neoplasia was found among the 40 workers at the time of investigation.

Another study was carried out on 35 workers with intensive occupational exposure exclusively to DDT (Laws et al, 1967). Ages ranged between 30 and 63 years. The range of exposure was 11-19 years. Investigations include medical histories, physical examinations, chest x-rays, blood and urine tests, and measurements of fat, urine, and serum concentration of DDT residues. On the basis of DDT storage and DDA excretion, the daily intake of DDT was estimated to be 3-6 mg/man in 3 workers with low exposure, 6-8 mg/man in 12 with moderate exposure, and 17-18 mg/man in 20 with high exposure. No cancer was reported in any of the workers.

A study involving 24 volunteers from a penitentiary was started in 1956 (Hayes et al, 1971). The average age was 34 years, and exposure to DDT lasted 21.5 months. Four men were used as controls, and technical DDT was given at daily doses of 3.5 mg/man to 6 men and 35 mg/man to 6 other men. Another group of 8 men received 35 mg/man day p,p'-DDT. Two men in each group were kept under supervision until 4 years after beginning of the study, and the remainder completed an additional year. However, no cases of tumors were recorded although adipose tissue concentration of DDT reached 280.5 ppm in the high dose group.

Autopsy studies have been performed attempting to correlate cancerous diseases to the amount of DDT stored in tissue (Hoffman et al, 1967). In one investigation, an average concentration of 9.6 ± 6.5 ppm total DDT and DDE in abdominal wall fat was reported among 292 patients with cancer; this did not differ significantly from an average of 9.4 ± 6.5 ppm among 396 patients with other diseases. Another study dealing with autopsy material from 38 persons aged over 36 years revealed that, of 19 patients with lower tissue levels of organochlorine (total DDT + dieldrin + heptachlor epoxide), 4 had malignant tumors, whereas the corresponding figure for 19 patients with higher levels was 9 (Casarett et al, 1968). In another investigation, the average level of DDT in fat tissues at autopsy was 21.96 ppm in 40 cases of carcinoma, 21.37 ppm in 5 cases of leukemia, 13.66 ppm in 5 cases of Hodgkin's disease, and 9.75 ppm in 42 control cases. Samples from 6 patients with brain tumors showed fat and brain levels of DDT residues comparable to those of controls. In patients with nonneoplastic liver diseases, fat and liver concentrations varied considerably throughout all groups, and, therefore, reliable statistical analysis of differences in group averages was not possible.

Data since 1972

Since the 1972 DDT Hearings, no additional human studies with DDT involving detailed medical followup over an extensive period have been published.

Conclusion

The epidemiological studies discussed are of too short duration and too limited sample size to permit conclusions regarding carcinogenicity. No additional studies have become available since 1972. The studies examining DDT residues in adipose tissue of terminal cancer patients are inconclusive since patients with nonneoplastic liver diseases also showed higher adipose tissue levels of DDT than controls.

The activity of hepatic microsomal enzymes varies greatly between different strains of the same animal species, different animal species and animals and man. Since DDT is metabolized by hepatic microsomal enzymes, its degradation in vivo may be affected by drugs and chemicals which induce drug metabolizing enzymes. Drugs such as diphenylhydantoin and phenobarbital have been shown to induce (accelerate) the hepatic metabolism of DDT in animals (Conney, 1967) and man (Edmundson et al, 1969; Schoor, 1970). In fact DDT, being an inducer, also could conceivably accelerate its own metabolism. Consequently, it is of importance to review the in vivo metabolism of DDT and evaluate the activity of its metabolites.

Metabolism in animals

DDT is metabolized in a variety of mammalian species by reductive dechlorination of TDE (Klein et al, 1964) and/or by dehydrochlorination to DDE (Mattson et al, 1953; Pearce et al, 1952). Both TDE and DDE are further degraded in the liver and kidney to more polar metabolites which are excreted in the urine or bile (Datta, 1970; Suggs et al, 1970; Judah, 1949; Pinto et al, 1965).

A considerable species variation exists in the rates of detoxification of DDT to TDE or DDE giving rise to variable storage levels of DDE in the adipose tissue (Ortega et al, 1956; Durham et al, 1963). An example is the higher ratio of DDE versus TDE in liver and perirenal fat after DDT administration to Swiss mice, compared to the corresponding values in hamsters (Gingell and Wallcave, 1974).

Conversion of DDT to TDE also has been reported to occur via rat intestinal flora (Mendel and Walton, 1966).

Storage in animals following continuous feeding

A comparative study with mice and hamsters showed that following a 6-week administration of a diet containing 250 ppm p,p'-DDT, levels of total DDT in both liver and fat were 7-8 times greater in mice than in hamsters, i.e., 56-70 ppm and 8-9 ppm in mouse and hamster liver, respectively, and 2400-2500 ppm and 290-310 ppm in mouse and hamster fat, respectively. It must be taken into consideration that food consumption in mice per kg body weight was 3 times greater than in hamsters. DDE residues in fat represented less than 1% in both species; in the liver, DDE represented about 20% of residues in mice and 2% of residues in hamsters, the DDE:TDE ratio being about 0.5 in mice and 0.02 in hamsters (Gingell and Wallcave, 1974).

Feeding rats 200 ppm p,p'-DDT for 140 days led to fat concentration of DDT in the order of 500 ppm in males and 1500 ppm in females; 10% of this was present as DDD. DDT and DDE concentrations in the liver were in the order of 13-25 ppm, with a DDT:DDE ratio of about 5:1 (Dale et al, 1962).

Metabolism and storage of DDT and its metabolites in man

Ingested DDT yields, following a reductive dechlorination, TDE, which is further degraded and readily excreted in the urine as DDA (Roan et al, 1971). DDT is also slowly converted, by dehydrochlorination, into DDE (Morgan and Roan, 1971), which is retained in adipose tissue (Abbott et al, 1968; Hayes et al, 1971; Wasserman et al, 1967). No increase in the urinary excretion of DDA was noted after the oral ingestion of DDE by human volunteers; however, such an increase was observed after ingestion of TDE or DDT (Roan et al, 1971). The observations of Laws et al (1967) of occupationally exposed people indicate that urinary levels of DDA are correlated to the levels of exposure to technical DDT and that DDT and its metabolites are stored in adipose and other tissues.

DDT is also excreted in human milk (Curley & Kimbrough, 1969; Quinby et al, 1965; Zavon et al, 1969; Hornabrook, 1973; Kroger, 1972; Ritcey et al, 1972; Newton and Green, 1972; Wilson et al, 1973) and transferred through the placenta (Curley et al, 1969; O'Leary et al, 1970; Zavon et al, 1969).

The ingestion of technical or p,p'-DDT during 21.5 months was studied in human volunteers. The concentration in adipose tissue after administration of technical DDT to man at a dose of 35 mg/man/day rose from a preexposure level of 4.1 ppm to 280.5 ppm after 21.5 months. After a recovery period of 37.8 months, 56.8 ppm DDT were still present. The concentration of DDE amounted to 8-11% of the total DDT in adipose tissue during the dosing period; its proportional concentration relative to that of DDT increased during recovery phase and represented 47% at the end of this period (Hayes et al, 1971). A high percentage of DDT is also stored as DDE in the general population (Durham, 1969).

Carcinogenicity

TDE (DDD)

Mouse: A group of 59 female CF mice was fed a diet containing 250 ppm p,p'-TDE for lifespan, and tumor incidences were compared to a control group of 98 males and 90 females. Hepatomas were found in 52% of treated and 34% of control males and only sporadically in females. Incidences of lung tumors were 86% in males compared with 54% in controls, and 73% in females compared with 41% in controls (Tomatis et al, 1974).

Rat: A group of 10 adult male Wistar rats was fed a low-protein, low-riboflavin diet containing 600 ppm o,p'-TDE and killed at intervals from

24-469 days. Testicular damage was observed from the second month onward. Of the 3 animals killed after 348 or more days, one rat had microscopic adenomatous nodules and 2 had tumors of the interstitial cells of the testes. These lesions are considered related to specific degenerative changes induced on the adrenal cortex by o,p'-TDE. (Lacassagne and Hurst, 1965).

DDE

Mouse: A group of 53 male and 55 female CF mice was fed a diet containing 250 ppm p,p'-DDE for lifespan, and tumor incidences were compared to those observed in a control group of 98 males and 90 females. Hepatomas were found in 74% treated males and 98% treated females compared with 34% and 1% in the controls. Incidences of other tumors were not increased (Tomatis et al, 1974).

Conclusion

The DDT metabolites, p,p'-DDE and TDE (DDD), were tested by oral administration to mice. An increase in hepatomas was observed with both metabolites; also an increase in lung tumors occurred with TDE. Hepatomas were not observed in rats with a high dose of 60 ppm o,p'-TDE although testicular damage was seen. It is interesting that, in a comparative feeding study, residues of DDE in rat livers were 10 fold greater (as a fraction of total liver DDT levels) than amounts observed in hamster liver (Gingell and Wallcave, 1974). These studies with DDT metabolites are limited and results are not conclusive. The fact that these metabolites and DDT accumulate in adipose tissue of animals and man, and the fact that they do have tumor producing potential, would suggest that the metabolites may act with DDT or other DDT metabolites in vivo to potentiate a tumor producing capability; or that the metabolites themselves may be the active tumorigens in mice.

> *Administrator's Findings (VI, Matters Relating to Methyl Parathion): A. Basic Findings 1) Many poisonings have been attributed to the use of methyl parathion. 2) Untrained users of methyl parathion are frequently not sufficiently careful in its use despite label directions. 3) Methyl parathion can be used safely. 4) Training programs are useful in averting the negligent use of methyl parathion. 5) Methyl parathion is a substitute for most crop uses of DDT. B. Ultimate Findings 1) Methyl parathion is dangerous to users and presents a risk to them. 2) An opportunity to train users will minimize the risks and keep down the number of accidents.*

Data as of 1972

The availability of efficacious alternatives to DDT which would not present undue or unreasonable risks to man was addressed in some detail in the Administrator's Decision to cancel DDT (particularly part V.B). The above findings were a key element in the decision leading to the cancellation. Methyl parathion was found to be the principal substitute for most crop uses of DDT. Though many poisonings were attributed to the use of methyl parathion, it was found that it can be used safely (Tr:6366; Tr:248). Many accidents connected with the use of methyl parathion are the result of untrained workers who are not sufficiently careful in its use (Tr:6406). Therefore, training programs were found to be useful in averting the improper use of the pesticide (Tr:3118).

Data since 1972

A source of information on acute (and chronic) effects of DDT substitutes is the reviews conducted by the Criteria and Evaluation Division, Office of Pesticide Programs, EPA, under the Substitute Chemical Program (SCP). The SCP was initiated under Public Law 93-135 of October 24, 1974, to "provide research and testing of substitute chemicals." The legislative intent was to prevent use of substitutes, which may be more deleterious to man and the environment than a problem pesticide (one that has been suspended, cancelled, deregistered, or in an internal review for suspected "unreasonable, adverse effects to man or his environment"). Fourteen substitutes for DDT are being studied under the SCP. Excerpts from the studies on DDT substitutes published thus far in this SCP series relative to acute human health hazards are presented in Appendix IIIB1.

These evaluations of occupational safety hazards associated with the SCP reviews are based on available state and federal accident monitoring systems. Analysis of the Pesticide Accident Surveillance System (PASS), shows that between 1972 and 1973 parathion and methyl parathion were associated with 78% of the reported episodes (Osmun, 1974).

A more recent analysis of data based on EPA's Pesticide Episode Reporting System (PERS) tends to confirm the impression developed in the SCP reviews (see Appendix IIIB2). That is, it appears that the above-named compounds together with methomyl and several registered substitutes have been associated with numerous reports of occupational poisonings (Appendix IIIB2). Yet, it appears that in many cases, these accidents were avoidable had label precautions been heeded. In fact, on the whole, there is no evidence in available state and federal accident monitoring systems which would indicate the DDT decision has increased the number of accidents associated with the use of substitute pesticides.

One must move with caution, however, in assessing available data. The most reliable accident data appears to be reported from two state sources -- California and Florida -- but, neither of the states were major DDT users. Thus, in order to evaluate the DDT decisions, we must return to the national data in the EPA's PASS and PERS. However, careful examination of all the episodes in these systems indicates that these data are not sufficient to rigorously evaluate impact of the DDT decision, in specific use patterns where DDT was used. Although the national reporting systems are being strengthened, for present purposes, they do not permit establishing incident rates by compound and crop or other use patterns. Until this is accomplished, precise evaluations will not be possible on the relative occupational safety of various pesticides.

Since the cancellation, there have been several EPA program actions taken to forestall and evaluate the possibility of adverse effects stemming from the use of acutely toxic pesticides. These are discussed below.

Immediately following the DDT cancellation, concern for the possibility of poisonings among former DDT users unfamiliar with the hazards of the more acutely toxic substitutes prompted the initiation of Project Safeguard (1972). Small acreage cotton growers were designated as a key target group in this effort. The program was organized jointly by EPA and USDA and funded by EPA (about $2 million) and USDA. The target area included Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. New Jersey was added to the project later because it was considered a "pocket problem" area.

Project Safeguard's first priority was contacting farmers but, dealers, applicators, formulators, and medical personnel were contacted also in an effort to produce an integrated safety program. Safeguard was successful in its efforts, its major strengths being: the ability to effectively reach small-acreage farmers and ancillary populations; the production of effective literature and media; and the spirit of cooperation fostered among various federal agencies, state governments, community groups, and industry. Some weaknesses existed in the program due to its short-term, rapid implementation nature. For example, some concern should be raised about the extent to which non-English speaking groups were sensitized to the danger. Despite these problems, Project Safeguard proved quite effective in getting pesticide safety information to the target audiences, to prevent an increase of pesticide poisonings (Cannon, 1974).

More recently EPA has taken an additional programmatic step to forestall accidents associated with agricultural use of toxic pesticides. In March

1974, the Office of Pesticide Programs, EPA, proposed promulgation of health and safety standards for field workers potentially subject to poisoning by toxic pesticides (EPA, 1974). These standards were based on a variety of inquiries designed to specify the problem, including a series of public hearings in various regions of the country. The thrust of these standards is the setting of a minimum unprotected worker re-entry standard (48 hours) for yields treated with specific toxic pesticides, e.g., ethyl and methyl parathion. Anyone entering the field prior to the conclusion of this safety interval is required to wear protective clothing. These worker re-entry standards are now in effect.

During FY 1975, two contract research efforts were initiated by EPA in order to examine acute toxicity safety standards more closely. The first was concerned with estimation of the extent to which soil, air, and plant surface residues are available for exposure of the field worker. This is a continuing study through FY 1976. The second study, now nearing completion, was concerned with the extent of health effects from ethyl parathion exposure of workers in peach orchards in Washington state. Preliminary indications in the peach study are that workers are suffering no ill effects from exposure.

EPA's applicator certification and training programs now in process of implementation will contribute to safer application of DDT alternatives.

The Administrator, in his decision, quite clearly took into account the acute health risks of DDT alternatives, specifically methyl parathion. Later in this report data will be presented on use patterns of pesticides on cotton which indicate that there were several other registered alternatives for most cotton pests and that increases occurred in the use of other alternatives. Use of Toxaphene/methyl parathion combinations on cotton increased greatly. However, ethyl and/or methyl parathion use actually declined slightly in 1973-1974.

Conclusion

At the present time, there is no basis in the available evidence to link the DDT decision to a precipitous increase in pesticide poisonings among those shifting to new or heavier reliance on the registered alternatives to DDT.

As will be seen later in this report, methyl parathion (and some of the other more acutely toxic insecticides) were already in general use prior to the cancellation, in the case of cotton the major DDT use. DDT was not generally used alone, but in combination with one or more of the chemicals which replaced it. For this reason, as of 1973, most farmers who had been using DDT had some knowledge of or working experience with acutely toxic DDT substitutes. However, dosage and frequency of applications may have increased in some areas, thus increasing risks to exposed persons. Some of the DDT substitutes are not highly acutely toxic, e.g. Toxaphene.

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III

C. MONITORING OF DDT RESIDUES IN THE ENVIRONMENT AND MAN

PERSISTENCE OF DDT IN SOIL

Administrator's Finding: DDT can persist in soils for years and even decades.

A typical degradation curve for DDT in soil leads to half-life values ranging from several years to a decade or more. The major DDT metabolite in soil, under normal conditions of aeration, is DDE. This compound is also highly persistent. Since DDT and DDE are strongly adsorbed to soil particles and are highly insoluble in water, they do not move readily from their site of application and therefore a substantial amount will remain at the site of application for long periods of time.

Data as of 1972

The high degree of persistence of DDT, under many typical environmental conditions, has been well established by many investigators. Precise prediction of the long-term disappearance rate, however, is very difficult since a large number of factors can affect soil persistence: 1) rate of application, 2) mode of application, 3) soil type, 4) soil fertility, 5) type of formulation, 6) topography, 7) climatic conditions, 8) cropping practices, and 9) soil pH.

Breakdown of DDT in soil can proceed by several routes depending in part on the redox potential of the soil matrix. Under aerobic conditions, slow conversion to DDE [1,1-dichloro-2,2 bis(p-chlorophenyl)ethylene] will normally occur. Under flooded anaerobic conditions, direct and rapid conversion to DDD (TDE), 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane can occur which, in turn, can be converted to more polar compounds such as DDA, [bis(p-chlorophenyl) acetic acid]. DDE is quite resistant to microbial attack and unless lost from the soil it can be stable for extended periods.

A study of DDT persistence in Oregon orchard soils indicated that 40% of the total amount originally applied remained at the end of 20 years (Tr:721-722). Another study in a Maine forest showed no significant decline of DDT after a 9-year period following aerial treatment for spruce budworm control (Tr:3523). The National Soil Monitoring Program showed that at least five states had soil residues averaging greater than 1 ppm DDT (Tr:3535).

Data since 1972

A number of studies related to time decline of DDT in soils have been reported. Some of the more significant reports are described:

Kuhr et al (1972) in a study on New York vineyard soil showed that after 24 years, 22% of applied DDT could still be recovered. Of this amount, 27% was present as DDE.

Another study (Chisolm et al, 1972) gave a half-life value of 15 years for DDT in a field experiment conducted in Nova Scotia on sandy loam soil. The authors also claimed that significant reductions in bean crop yields were associated with the high DDT residues.

Ware, Estesen, and Cahill (1974) reported an "almost imperceptible" decline in total DDT residues in Arizona soils over a 4 year period following the 1969 DDT state moratorium.

Additional studies on DDT residues in forest soils have become available on Canadian land sprayed for spruce budworm control (Yule, 1973). Treatments totalling 70 oz DDT/acre had been applied between 1956 and 1967. Samples were taken between 1967 and 1971. A projection of the average loss rate for DDT residues found on the plots give an estimated half-life in the order of 10 years.

Wiersma et al (1973) surveyed total DDT residues in soils from eight major US cities. Levels varied significantly among cities with the average level varying from a high of 5.98 ppm to a low of 0.35 ppm. Residue levels in lawn areas were significantly greater than in unkept urban areas.

A taiga forest, treated for control of mite encephalitis with 4.44 lbs DDT/acre, showed 7.4 ppm in the upper soil horizon after one year. After 14 years, this level decreased to 0.47 ppm (Konstantinov, 1972). Since the combined residues of TDE and DDE represented less than 10% of total residues, loss mechanisms other than microbial degradation are suggested.

Other new information relating to persistence concerns various environmental parameters which can affect the longevity and nature of DDT residues in soils. Collyard et al (1972) showed that DDT in soil can be degraded to TDE in the presence of cattle manure.

Albone et al (1972) demonstrated a new nonpolar metabolite from anaerobic microbial decomposition, bis(p-chlorophenyl)acetonitrile or p,p-DDCN. Jensen et al (1972) found up to 0.6 ppm of this product in aquatic bottom sediments from Lake Maeloren, Sweden.

Several studies involving in vitro microbial degradation under anaerobic conditions have been reported (Jensen et al, 1972; Pfaender, 1972; Albone, 1972; Zoro, 1974). In all cases, substantial amounts of TDE were formed which did not further degrade. Similar findings in natural ecosystems have not been reported. Striking differences in degradation rate of ^{14}C-labeled DDT in estuarine sediment in situ compared with laboratory incubated samples under hydrogen were noted by Albone et al (1972a). These observations are consistent with real life situations where only small conversions of p,p'-DDT to dehydrochlorinated products occur in many aquatic systems, even over a period of many years.

Also, the stability of DDT and related compounds was studied under alkaline conditions. Based on data developed, normally encountered environmental pH variations should have little if any effect on the dehydrohalogenation reaction (Smith, 1972).

The quantitative aspects of pesticide decomposition have recently been reviewed by Hamaker (1972) and it is clear that degradation processes of many pesticides, including DDT, cannot be defined in terms of simple reaction kinetics. Until superseded by better descriptions, the concept of Wheatley (1964) seems most appropriate where the logarithm of the half-life is related directly to time on a linear basis. This affirms much of the current field persistence data wherein high initial loss phases are succeeded by slower changes.

Base-line data for DDT in US soils have been established by the National Soils Monitoring Program. Therefore, future time-rate declines should be comparatively simple to establish by means of programmed resampling. The monitoring programs for FY 1969 and FY 1973 showed that DDT levels in soil have significantly decreased. The overall average decreased from 0.36 ppm to 0.23 ppm, and the geometric mean estimate, with 95% confidence levels shown in parenthesis, decreased from 0.015 ppm (0.017-0.013 ppm) to 0.010 ppm (0.011-0.008 ppm) (Carey, personal communication, 1975).

Conclusion

The preponderance of evidence clearly demonstrates that DDT is stable in soil under natural environmental conditions. While under certain conditions, transformations to the metabolites DDE and TDE can occur, these also resist further degradation.

Due to the severe restrictions placed on the use of DDT in recent years coupled with DDT's high degree of persistence a gradual leveling out of the residues of DDT can be anticipated. Future residue levels in crops grown in soils last treated with DDT in 1972 can be expected to remain at current or only slightly lower levels.

While average levels of DDT are expected to decline slowly, the ratio of DDE to DDT can be expected to increase. As noted elsewhere in this document, levels of DDE relative to DDT have increased constantly in many food commodities in recent years, reflecting the slow trend in soils away from parent DDT pesticide to the DDE metabolite.

TRANSPORT OF DDT FROM AERIAL APPLICATION SITES

DRIFT

Administrator's Finding: DDT can be transported by drift during application.

Pesticides drifting as minute particles, especially from aerial application, have caused widespread contamination of nontarget portions of the environment. Since about only 50% of an aerially applied pesticide reaches the target area, a substantial portion of the environment is exposed to such drift. Localized drift has contributed significantly to contamination of food and feed, whereas more distant movement has probably contributed substantially to the world-wide distribution of DDT.

Data as of 1972

Drift of DDT, when applied aerially, is "virtually impossible to prevent" (Tr:749). Even with the most up-to-date aerial application devices, up to 6% of an aerial spray can exist as particles with diameters of less than 50 microns (Tr:467; 502). These particles are known to be highly mobile and it is impossible to control their movement to nontarget sites.

Data since 1972

Insecticide application technology has not improved in the last several years so as to significantly reduce drift problems.

Conclusion

Problems encountered with the drift of DDT can be expected to recur if DDT were to again come into general use as a pesticide.

VAPORIZATION

Administrator's Finding: DDT can vaporize from crops and soils.

DDT, like many organic pesticides, tends to vaporize. DDT lost to the air can contribute to air pollution, soil residue declines, and to low-level crop residues by redeposition. Quantitative estimates of these various factors are extremely important with regard to predicting long-term changes in environmental residues of DDT and its metabolites.

Data as of 1972

DDT may substantially vaporize given the proper physical environment (Tr:727). Once vaporized, the pesticide can attach itself to suspended particulate matter (Tr:718) and be carried to the far reaches of the Earth (Tr:741-742; EDF-16; EDF-17). It has been estimated that up to 250,000 pounds per year can vaporize from southern cotton soils alone (Tr:7757).

Data since 1972

Additional data (Cliath and Spencer, 1972) are provided in support of the high relative volatility of p,p'-DDE as compared to DDT with the suggestion that the major pathway of loss is probably via this route. An attempt to modify the volatility of DDT residues in soil was by means of flooding and organic matter amendments (Spencer et al, 1974). Only minor changes in vapor concentration were noted but, regardless of treatments, DDE remained the major constituent to volatilize. Total DDE volatilizing from such treatments will ultimately be decreased, since TDE rather than DDE is the major product from flooded soil (anaerobic) degradation. The volatilization of DDT or DDE, as a major source of global atmospheric contamination, was discounted by Freed et al (1972) primarily on theoretical grounds.

The translocation of chlorine-36-labeled DDT in an old-field ecosystem was studied by Bandy (1972). The leaves of 10 herbaceous plant species carried DDT residues at one or more periods during the growing season. DDT vaporization from the soil, followed by condensation on the plant surfaces, is thought to be the mechanism of contamination. The exact role of volatilization versus root translocation in terms of low-level residues in feed and forage crops is worthy of additional study.

Plimmer et al (1970) and Moilanen and Crosby (1973) have shown that DDT can be photochemically converted to polychlorinated biphenyls (PCB's). The implications of this finding in light of additional environmental PCB burden is discussed by Maugh (1973). However, Harvey (1974) and Plimmer and Klingebiel (1973) discount the significance of this finding. Their reasoning is that PCB's derived from DDE would contain a much lower percentage of chlorine than those normally encountered in the environment.

Kerner et al (1972) report two new photoproducts of DDE from vapor phase photolysis. Physical properties of these products are not described, so that their lipophilic (bioaccumulative) potential cannot be estimated. Miller et al (1973) report that a triplet sensitizer, decyl bromide, can sensitize the photolysis of DDT by way of the intermediate TDE.

Several additional reports on measurements of particulate matter, rainfall, or fallout of DDT in various parts of the world are available: particulate matter (Lloyd-Jones et al, 1972; Prospero et al, 1972), rainfall (Edwards, 1973; Craig et al, 1973; and Hughes et al, 1972). None of these adds significantly to previous observations that low levels of DDT can indeed be transported by air to the far reaches of the world. Cramer (1973) proposed a model for the global transport and accumulation of DDT based on a low mean residence time in air and a low rate of transfer from land to air.

Sodergren (1972) measured fallout with silicone-impregnated nylon filter nets near Swedish agricultural areas. Levels ranged from 100 to 2,000 mg/m^3/month depending on the season. It could not be established whether the DDT originated within the local agricultural region, or had been transmitted from far away.

No additional air monitoring data are available on DDT.

Conclusion

Vaporization of DDT and DDE from soils is qualitatively well established. However, the contribution such volatilization makes to overall global dispersal has not as yet been determined. DDT may be deposited on plant surfaces and may be volatilized from the surface; these processes are dynamic in nature and will ultimately approach an equilibrium.

SOIL EROSION

Administrator's Finding: DDT can be attached to eroding soil particles

Runoff of soil particles has long been established as a primary route of chemical transfer from terrestrial to aquatic sites. Vast quantities of particulate matter are yearly carried by water to low-lying areas and, to a certain extent, on into the oceans. Some of our richest agricultural areas (delta lands) are associated with the end product of numerous such annual occurrences. Since DDT is extremely insoluble in water but readily adsorbed on soil particles, soil erosion is a major transport mechanism from agricultural areas into aquatic environments. Similarly, DDT can be transported by means of treated sewage sludge draining from sewer systems into aquatic sites.

Data as of 1972

Runoff is a major source of DDT contamination in aquatic environments, occurring particularly after heavy rainfall. DDT is strongly bound to soils (Tr:717) and erosion of soil particles has been established as the principal means of contamination of lakes, streams (Tr:729; R-107; R-26), rivers, and estuaries.

Data since 1972

A number of studies concerning aquatic sediment fractions as they relate to pesticide content of water systems have been described. Some of the most relevant studies are described below:

Bradley, Sheets, and Jackson (1972) found that over a 6-month period following DDT application to cotton plots, 2.83% of the DDT applied was present in runoff waters. Of this amount, 96% of the DDT was associated with the sediment fraction.

High residues in certain portions of bottom sediments from a Salinas River monitoring program (Routh, 1972) were found to be associated with a fine-particle, light-weight sediment as compared to a different textured material collected from other sampling sites. Sediments precipitated from the collected water samples contained about 5 times as much total DDT as bottom sediments from the same sites.

Ahr (1973) discussing long-lived pollutants in sediments from the Laguna Atascosa National Wildlife Refuge, Texas, suggests that environmental studies made by geologists are needed to assess the significance of sedimentary layers which may ultimately be relocated by post depositional, biological, or mechanical processes.

Contamination of cisterns with DDT-laden sediment is a frequent occurrence on the island of St. John in the Virgin Islands. Previously DDT was used extensively in agriculture on these islands (Lenon et al, 1972).

Schulze, Manigold, and Andrews (1973) determined that pesticide concentrations in western streams were always highest in water samples containing appreciable amounts of suspended sediments.

Several studies have been reported dealing with the adsorption of DDT on soil particles. For example, Weil, Duke, and Quentin (1973) determined the heat of adsorption of DDT to humic substances to be 2.5 kcal/mole. Biggar, Doneen, and Riggs (1966) reported on the adsorptive behavior of various insecticides, including DDT in solution, onto soils. The adsorption of ^{14}C DDT on coloring colloids in surface water also has been determined (Poirrier et al, 1972).

Finally, the ability of sodium humate to solubilize DDT is discussed by Khan and Schnitzer (1972). Such a phenomenon could possibly increase the total amount of DDT solubilized from bottom sediments and thereby make it more available to fish and other aquatic life.

Conclusion

All available evidence suggests that erosion is a significant source of transport for DDT via runoff of particulate matter. Continued long-term contamination of aquatic sites from agricultural soils can be anticipated since localized flash flooding of fresh plowed fields can never be controlled and such events can lead to significant losses of particulate matter. Some decline of the environmental burden of DDT can be expected from the continued sedimentary deposition of DDT residues into the upper soil horizons coupled with overlayering of fresh sediments containing smaller amounts of adsorbed DDT. This may lead to a partial decline of available DDT per unit area of surface.

CONTAMINATION OF THE AQUATIC ENVIRONMENT

> *Administrator's Finding: DDT is a contaminant of fresh waters, estuaries and the open ocean, and it is difficult or impossible to prevent DDT from reaching aquatic areas and topography nonadjacent and remote from the site of application.*

DDT residues are ubiquitous in the aquatic environment, especially downstream from tributary waterways draining either urban or agricultural areas. This contamination generally permeates the major river systems and the estuaries receiving land based runoff. Transport into remote ocean areas can take place in a number of ways including movement on suspended particulate matter; dissolved in ocean water; movement of plankton by ocean currents; and as an accumulated residue in free swimming fish. A final source of transfer is rainfall which can carry not only volatilized DDT from other water bodies but also DDT adsorbed on particulate matter directly from terrestrial environments.

Data as of 1972

DDT is commonly found in lakes, streams, ponds, estuaries, and ocean sediments (Tr:3808; Tr:5730; Tr:3699-3700). Although these levels are often quite low, DDT is concentrated and magnified in aquatic organisms (Tr:3714) and is being transported into the ocean (EDF-30). Residue buildup in fish and other aquatic organisms is also transferred to marine mammals and birds (Ref-1) and to remote sections of the world such as Antarctica (Ref-2).

Data since 1972

Leland et al (1973) found a strong relationship between quantity of adsorbed total DDT on Lake Michigan bottom sediments and organic content of sediment. DDT was the principal component of sediments except in the eastern edge of the South Basin where reducing conditions (anaerobic) are found. Here, the predominant form was TDE.

Oertzen et al (1972) calculated that 2.78×10^4 tons of DDT are introduced into the ocean each year by precipitation or runoff. Georgii (1973) calculates a similar amount.

Two reports stemming from the National Water Monitoring Program have been issued recently. One deals with pesticide levels in selected western streams over the period 1968-1971 (Schulze et al, 1973) and another with chlorinated hydrocarbons in sediments from tributary streams of San Francisco Bay (Law et al, 1974). Both authors show the ubiquity of DDT residues stemming from watersheds within the United States. Similar stream monitoring projects are underway in Canada. A recent report by Harris et al (1973) reviews results of a 1971 survey of streams draining agricultural, urban-agricultural, and resort areas of Ontario. Of these areas, the greatest total DDT transport was noted in the Muskoka River which drains a resort area where DDT was used for control of biting flies until 1966. A peak of 11.8 lbs total DDT/week was recorded in May with a May to October average of 1.9 lbs/week.

DDE contamination off the southern California coast (MacGregor, 1974), stemming primarily from sewage plant effluents from a DDT manufacturing plant, is approaching a maximum level where metabolism and dispersion of DDT equal system input. DDT was entering the coastal system from 1949-1970. A best fit accumulation formula, based on residue patterns in myctophid fish between 1950 and 1966, utilized 2%/year as the value of DDE degradation. This suggests half-life values for DDE numbering in decades.

Conclusion

Contamination of aquatic areas with DDT and its metabolites can be expected to remain for a considerable period of time. Much contamination is associated with aquatic sediments and therefore, the ultimate fate of DDT will depend on what happens to this material. For example, DDT-laden sediments can be overlayed with fresh uncontaminated sediments; or they may be resuspended at a later time only to be redeposited elsewhere.

Persistence of a chemical in an aquatic ecosystem implies a dynamic relationship between the various components within the system, slow degradation of the chemical in question, and a high retention index within the system. In the case of DDT and its significant metabolites, the bottom sediments act as the primary reservoir or storage compartment for excess quantities of DDT. These bottom sediments are composed of mineral fractions having a wide distribution of particle sizes along with organic matter including animal detritus and humic substances associated with eroded soil. DDT in excess of the water solubility (0.0012 ppm) is adsorbed onto these sediments and in turn is available for direct ingestion by bottom dwelling organisms or for resolubilization back into the aqueous phase. In turn, the DDT solubilized in the aquatic phase is available for direct incorporation to varying degrees into all trophic levels of the aquatic food web. Eventually, much of this DDT is recycled back to the sediment reservoir from which it can again become available.

PERSISTENCE IN AQUATIC ECOSYSTEMS

Administrator's Finding: DDT can persist in aquatic ecosystems.

DDT and its lipid-soluble metabolites, DDE and TDE, adsorb readily onto aquatic sediments and from this storage reservoir transfer to the benthos and free-swimming organisms including plankton, crustaceans, and fish. The aquatic phase, per se, can hold only a limited amount of the total DDT in many existing contaminated environments and serves mainly as a transfer mechanism between the sediment and aquatic organisms. Much DDT is constantly recycling, but with time is also slowly metabolizing. DDE, the main metabolite of DDT, is also persistent and capable of recycling in aquatic systems.

Data as of 1972

Persistence of pesticides in aquatic environments was recognized in the early phases of environmental concern over DDT. Residues in fish have been monitored since 1965 in the Great Lakes (Reinert, 1970). The National Estuarine Monitoring Program, established in 1965, was also concerned over the persistent chlorinated hydrocarbons, especially DDT, existing in our nation's estuaries. Numerous other incidents had clearly established that long-term residues of DDT and similar compounds could cycle through the aquatic environment. Model ecosystem studies reported by Metcalf (1972) clearly demonstrated the potential for DDT and its lipid soluble metabolites to penetrate into every component of an aquatic environment.

Because of the low water solubility of DDT (0.0012 ppm) and the frequent contamination of aquatic areas from local applications due to erosion and runoff associated with heavy rainfalls, excess DDT tends to be taken up on sediments, living organisms, and other particulate matter. Due to the highly variable nature of bottom sediments and more immediate concerns over residues in fish and drinking water (filtered water), most efforts aimed at defining problems in aquatic environments gave secondary emphasis to sediment analyses. However, a striking example of long-term persistence of DDT was given by Dimond et al (1972), where residues of DDT in stream bottom muds, plants, insects, mussels, and fish existed for a period up to 10 years following single applications of DDT. In animal samples, 60-85% was present as DDE whereas mud samples contained 35%, 45%, and 20% DDT, DDE, and TDE, respectively.

Data since 1972

Vind, Muraoka, and Mathews (1973) deposited a number of chlorinated hydrocarbons, including DDT, on diatomaceous earth and cultured them with marine microorganisms in seawater. No appreciable degradation occurred after one year. Degradation of p,p'-DDT in situ by estuarine sediments (Severn estuary) proceeded much more slowly than companion studies conducted under hydrogen in the laboratory (Albone et al, 1972). This is consistent with findings of substantial residues in these sediments resulting from agricultural runoff from the watershed serving this estuary.

Harvey (1974) concludes that the half-life of DDT in ocean water is only 10 days. However, his information source (Wilson, personal communication, 1975) has conducted more extensive tests where, during short exposure periods, solubilized DDT in seawater is found to be transferred to suspended material but not necessarily lost or extensively degraded. Rice and Sikka (1973) found that various organisms are able to remove dissolved DDT and DDE from seawater.

Patil, Matsumura, and Boush (1972) found, in laboratory incubation experiments using filtered sea water, that no significant degradation took place. On the other hand, particulate materials in the presence of sea water caused further degradation to both polar and nonpolar metabolites.

Conclusion

Persistence of DDT in aquatic ecosystems has been well documented and long-term studies support the conclusion that contaminated waters and sediments will purge themselves of DDT only after a long hiatus of DDT usage. In those contaminated areas, a gradual conversion of DDT to DDE and TDE can be expected. Residue levels of fish taken from the Great Lakes indicate that either there is a gradual loss of DDT and its metabolites from these areas or that the DDT laden sediments are being overlaid with fresh sedimentary deposits containing lower levels of DDT. Similar residue findings are noted with oysters taken from various coastal areas where, in general, residues have declined in recent years. There are few direct observations of residue declines in aquatic sediments over extended periods of time, so conclusions with regard to persistency have largely been based on indirect measurements of residues in aquatic organisms. The fate of DDT in the open ocean is not at all clear and the relative roles of sedimentation of residues into the deep abyss versus other forms of degradation are not well defined. The relatively high levels of DDT associated with coastal environments compared with the open ocean are closely associated with the increased biomass and particulate matter load existing over the continental shelf. The rate of diffusion of coastal residues into the deeper oceans is currently unknown. Data clearly show, however, that coastal area contamination with DDT can be expected for an extended period.

HUMAN EXPOSURE TO DDT RESIDUES

Administrator's Finding: The accumulation in the food chain and crop residues results in human exposure.

Aside from the effects of DDT on certain forms of wildlife and its persistence in various environmental components, the greatest concern over DDT has been its routine occurrence in staple human foods, especially meat and milk. High per capita US consumption of these commodities leads to relatively high residues in human tissues. Human exposure to DDT has been a constant occurrence since its early use on various food and feed crops. Efforts in the last decade have led to significant reductions of average DDT levels in all commodities including meat and dairy products. However, low-level residues of DDT and its metabolites are still commonly found in these commodities. Since DDT levels in meat and dairy products are dependent on levels in feed and forage fed to domestic ruminants, the limiting factor in a future residue decline in humans is directly associated with these items.

Data as of 1972

FDA data (Duggan and Corneliussen, 1972) indicate that DDT and its metabolites are the most commonly found pesticide in market basket samples. The average daily intake of total DDT residues per day in 1970 was calculated to average 0.0004 mg/kg of body weight, down from 0.0009 in 1965.

DDT and DDE residues are routinely found in dairy products and meats. Average levels in total diet samples were 0.047 ppm and 0.233 ppm respectively for these two commodities (Corneliussen, 1972). There is little doubt that food ingestion represents the primary route of human exposure in the United States (Tr:1987). Exposure by way of drinking water, inhalation, and dermal exposure, while not quantifiable, are not believed to be highly significant.

Data since 1972

The Food and Drug Administration (Corneliussen, personal communication, 1973) evaluated pesticides in FY 1973 samples of food and compared them with composite results for FY 1964-1969. Their report stated that "there has been a distinct decline in relative occurrence of DDT-related residues in all major commodity classes except that DDE (degradation product of DDT) remained constant in eggs and showed a slight relative increase in fluid whole milk. This phenomenon is likely a result of the environmental burden of DDT, since usage has been drastically limited. Continued occurrence of the DDT degradation products in foods of animal origin (particularly fish) is reasonably expected." Comparative analyses of baby foods (infant and junior) for FY 1973 versus FY 1964-1969 showed a decline in positive DDT findings but little change in DDE interceptions. These data are:

	% Samples Positive	
	FY 1973	FY 1964-1969
DDE	13.8	12.7
DDT	4.8	9.3

Total diet residue studies involving analysis of ready-to-eat foods in 12 food class categories taken from 30 markets in 28 different cities have been conducted by the Food and Drug Administration since 1965. Major sources of DDT food contamination lie in two specific categories: dairy products and meat, fish and poultry products. Data for Fiscal Years 1966 through 1971 are shown in Table IIIC.1 and Figures IIIC.1-6 (Pesticide Monitoring Journal: 1(2)2-12, 1967; 1(4)11-20, 1968; 2(4)140-147, 1969: 4(3)89-105, 1970: 8(2)110-124, 1974). These data show that DDT and its metabolites have been dropping gradually since 1965. Figures IIIC.1-6 represent statistically computed best fit plots for the raw data.

The residue declines are undoubtedly due to numerous factors, the most likely being increased public awareness and caution in pesticide usage, state restrictions prior to the 1972 Federal cancellations, and gradual phaseout of DDT in preference to less persistent materials.

Dietary intake values based on prorated food quantities of the various food commodity classes (based on typical diet of a 19 year-old boy) have also been summarized in Table IIIC.2.

Although a gap exists in the data for FY 1971 and FY 1972, a rapid decline in all members of the DDT family is evident, especially for DDT and TDE. From FY 1969 to FY 1973, respective declines of 86%, 89%, and 64% took place for DDT, TDE, and DDE.

A significant decline of DDT residues in poultry between 1968 and 1971 was reported by Spaulding (1972). Data tables for these studies follow (Stadelman, 1973):

DDT Residues in Poultry (ppm Fat Basis)

	Total Samples Analyzed				
	N.D.	0.01-0.1	0.1-0.5	0.5-3.0	3.0-5.0
1968	1	406	1781	465	13
1971	138	412	1062	192	0

Table IIIC.1

Total Diet Studies

FY 1966-1971

Parts Per Billion (Fat Basis)

	Dairy Products			Meat, Fish and Poultry		
FY	DDT	DDE	TDE	DDT	DDE	TDE
1966	40	75	15	299	253	139
1967	53	54	19	195	172	110
1968	30	63	19	103	116	62
1969	23	48	10	101	100	43
1970	17	16	6	52	71	29
1971	trace	36	--	36	60	11

Sources

Pesticide Monitoring Journal 1(2):2-12, 1967.
Pesticide Monitoring Journal 1(4):11-20, 1968.
Pesticide Monitoring Journal 2(4):140-147, 1969.
Pesticide Monitoring Journal 4(3):89-105, 1970.
Pesticide Monitoring Journal 8(2):110-124, 1974.

Table IIIC.2

Estimated Dietary Intake (micrograms/day)[a]

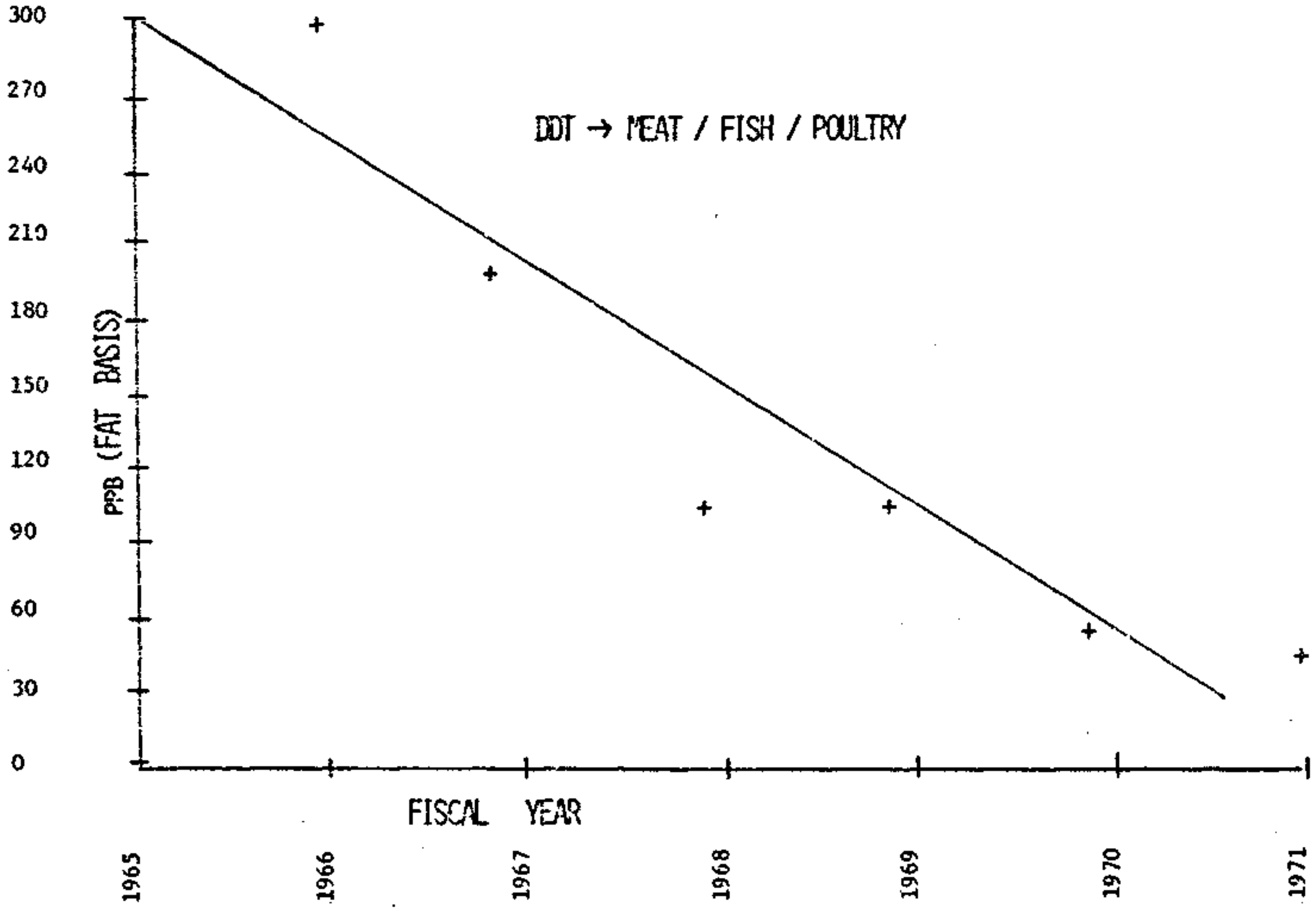
FY	DDT	DDE	TDE
1965	31	18	13
1966	41	28	18
1967	26	17	13
1968	19	15	11
1969	16	11	5
1970	15	10	4
1971[b]	--	--	--
1972[b]	--	--	--
1973[c]	1.88	4.98	0.72

Sources

[a] Duggan, R.E., and P.E. Corneliussen. Dietary intake of pesticide chemicals in the United States (III) June 1968-April 1970, 1972.
[b] Data for 1971-1972 not available.
[c] Corneliussen, P.E., Personal communication, Food and Drug Administration, 1975.

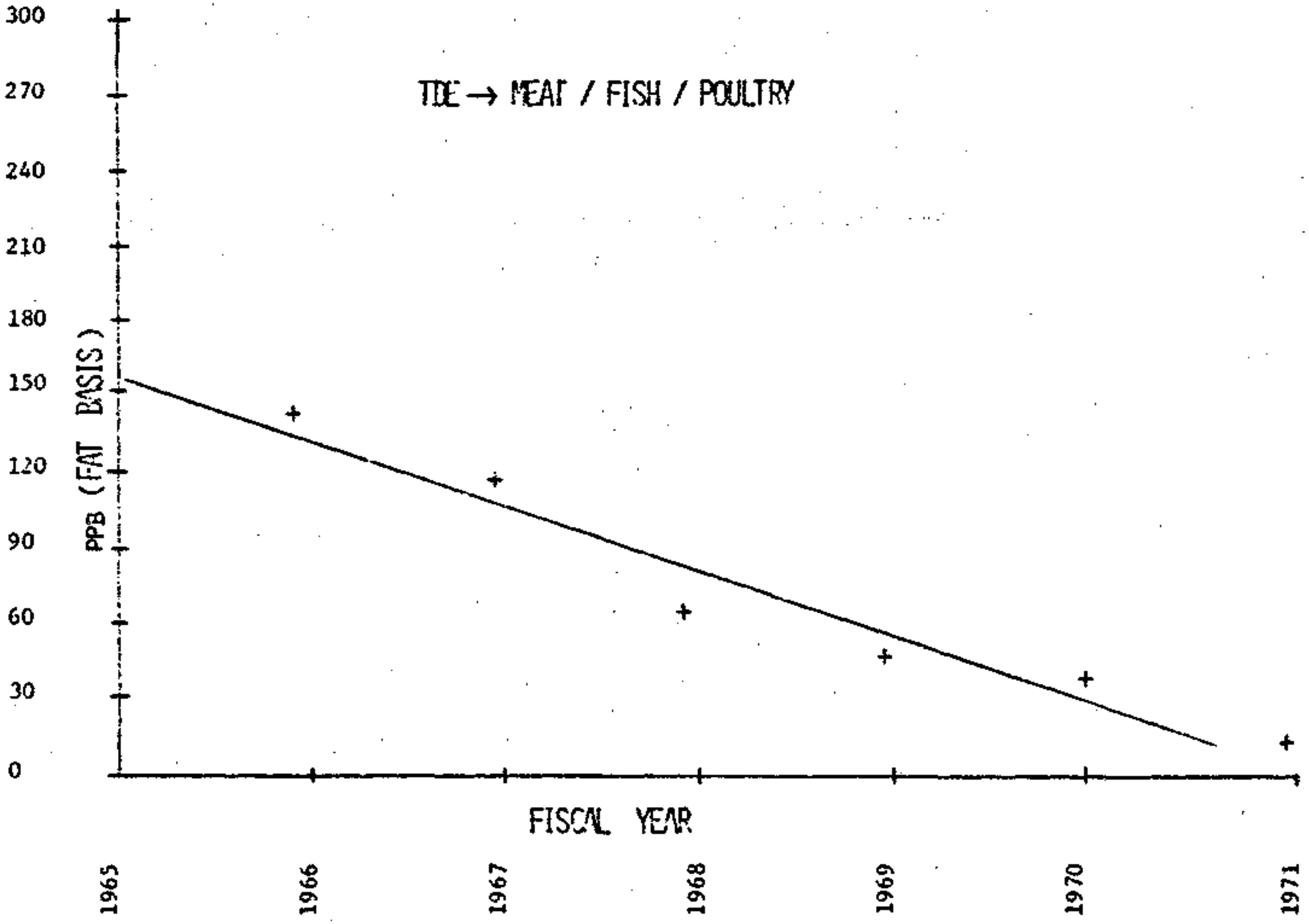
NOTE: Less precise values were reported for the period 1965-1970 in the first printing of the report.

Fig. IIIC.1



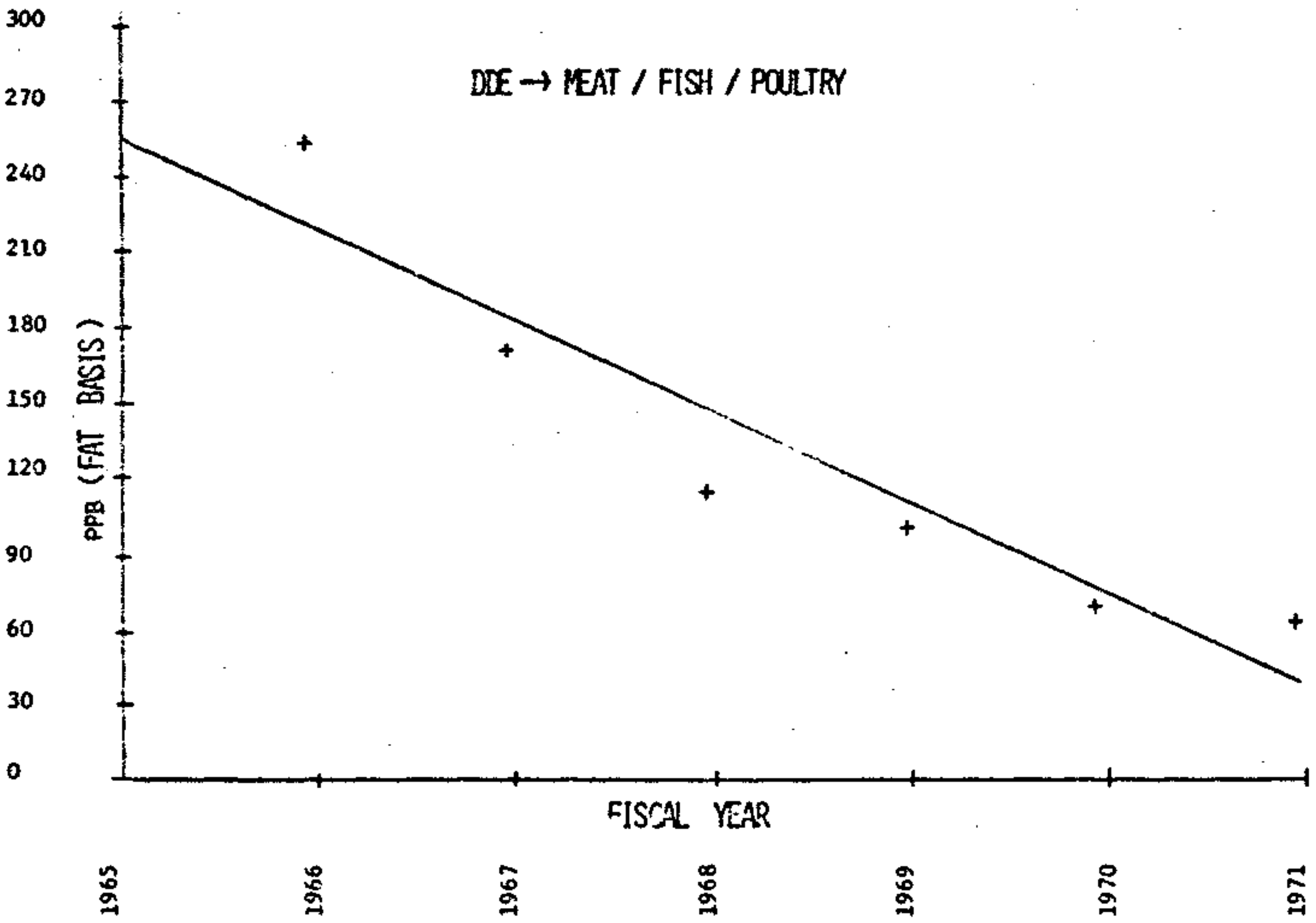
Source: Pesticide Monitoring Journal (See Table IIIC.1).

Fig. IIIC.2



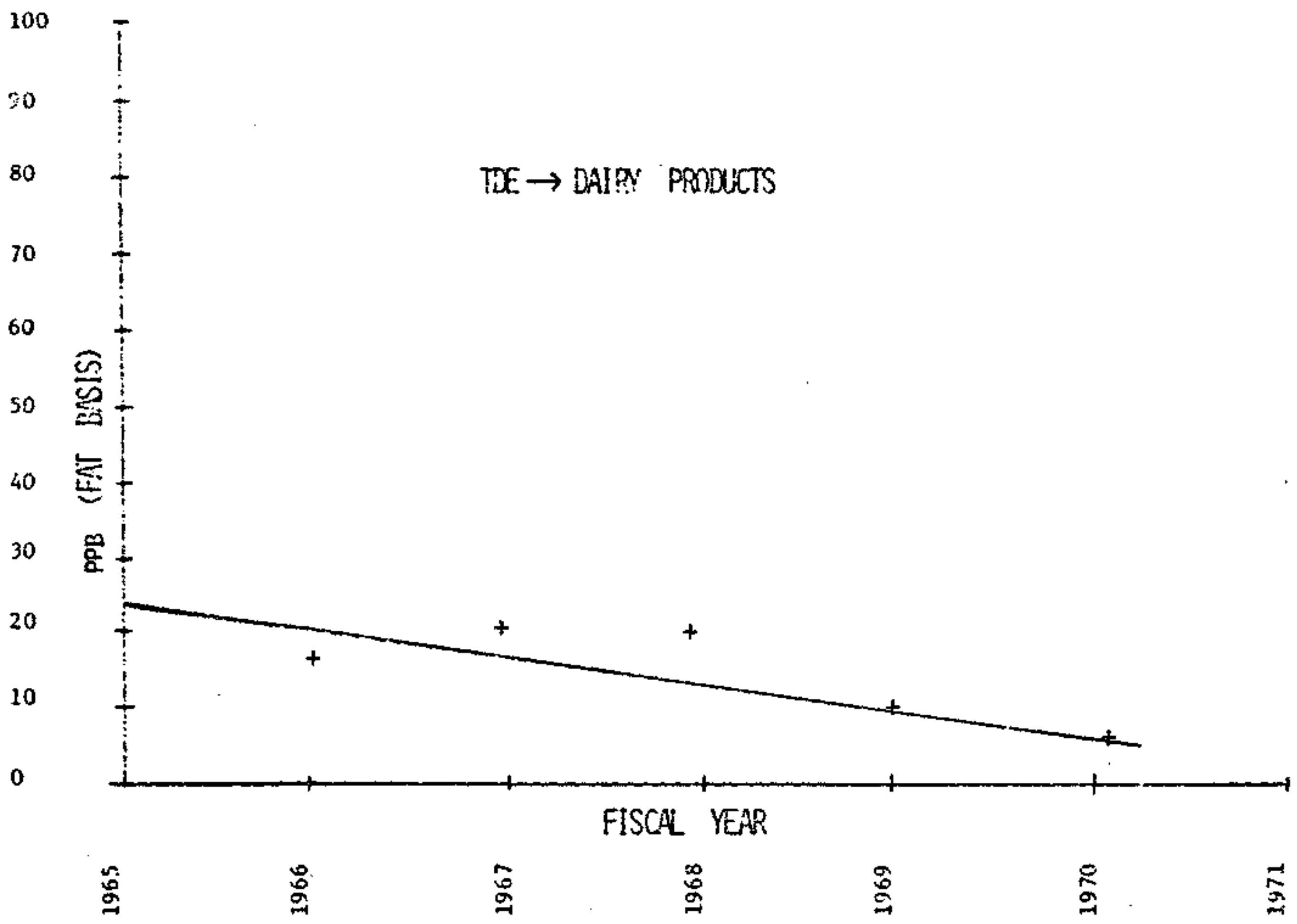
Source: Pesticide Monitoring Journal (See Table IIIC.1).

Fig. IIIC.3



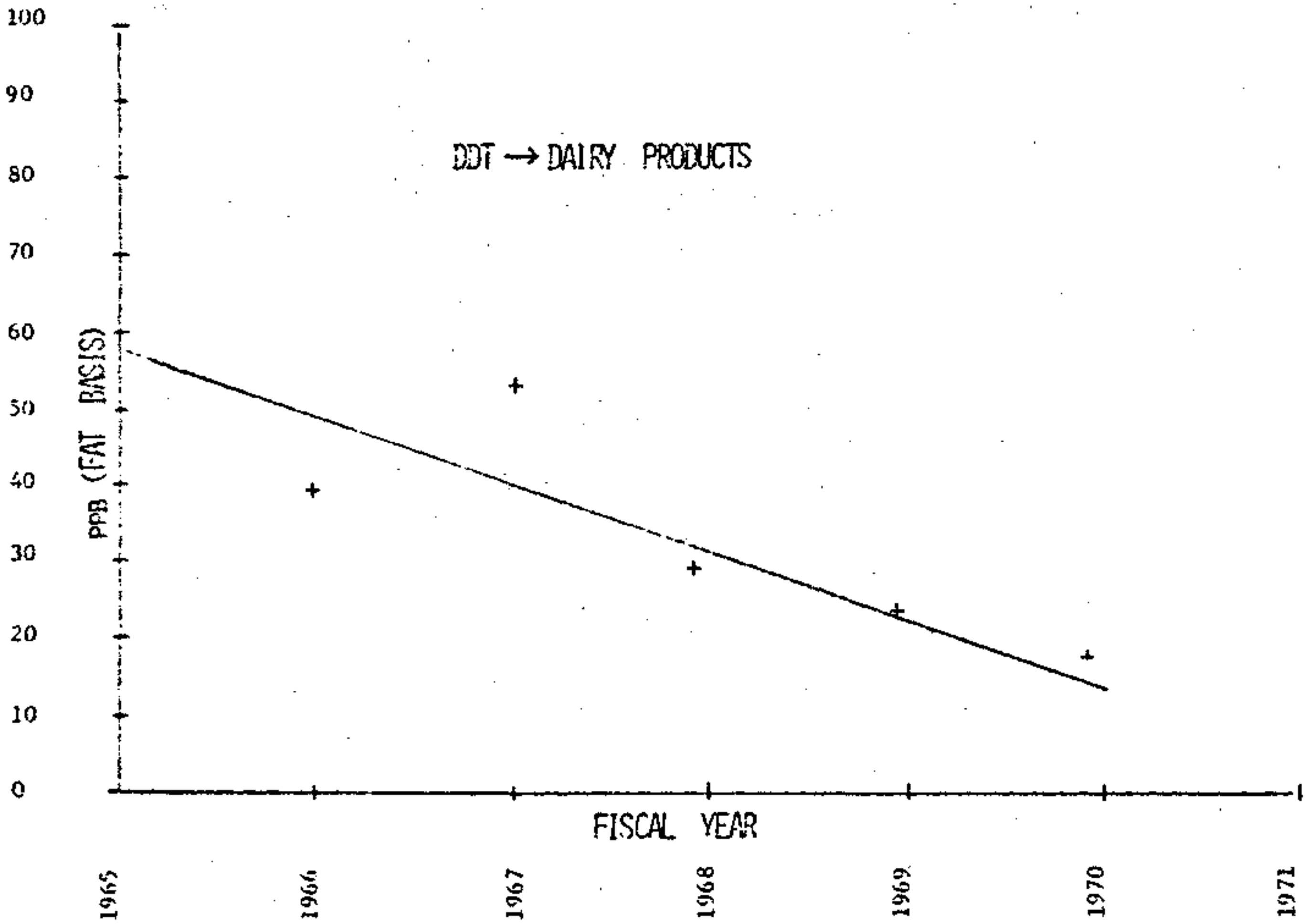
Source: <u>Pesticide Monitoring Journal</u> (See Table IIIC.1).

Fig. IIIC.4



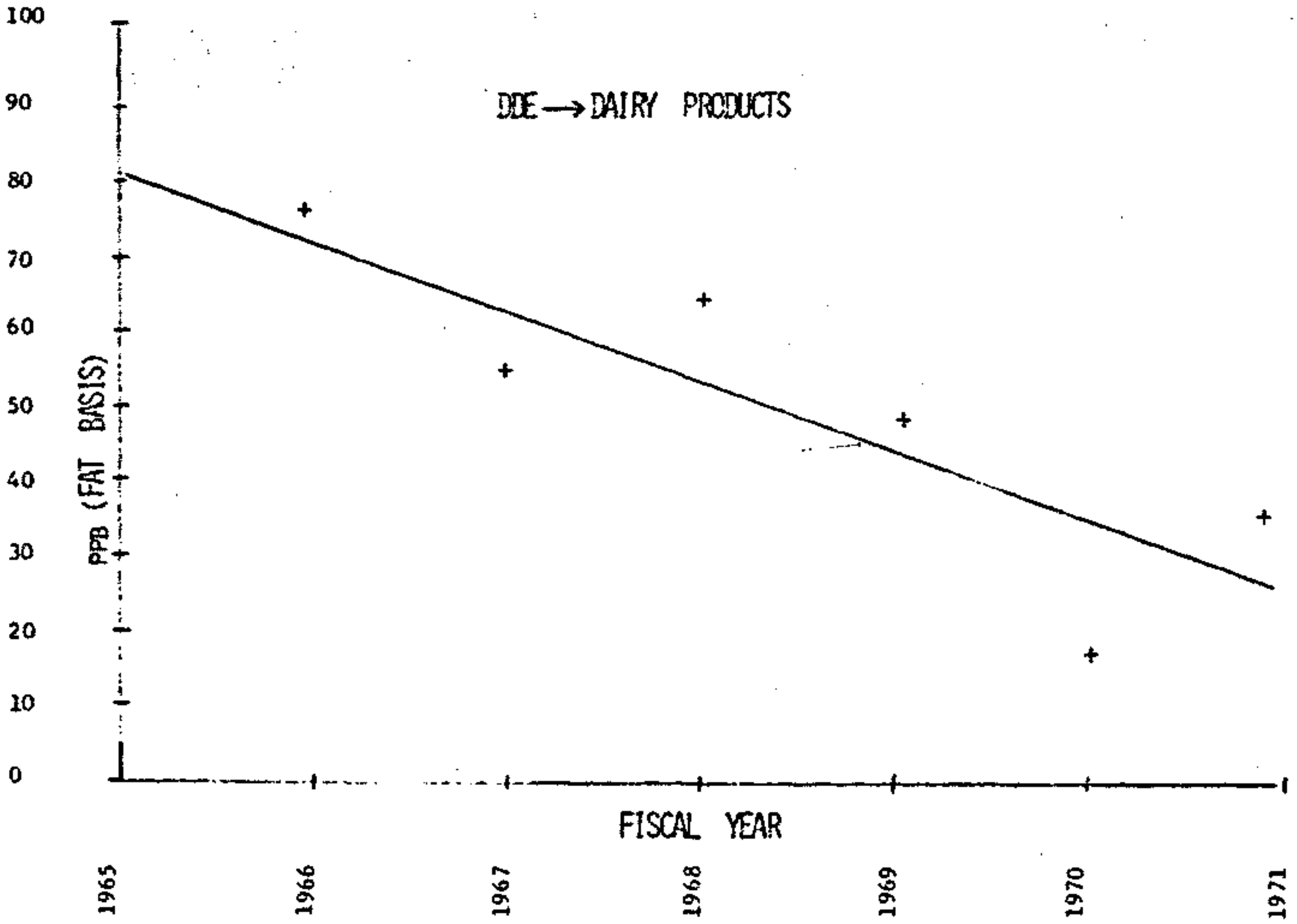
Source: *Pesticide Monitoring Journal* (See Table IIIC.1).

Fig. IIIC.5



Source: Pesticide Monitoring Journal (See Table IIIC.1).

Fig. IIIC.6



Source: Pesticide Monitoring Journal (See Table IIIC.1).

Similar declines were not noted between 1967 and 1973 for livestock except for the frequencies of high-residue samples greater than 1.5 ppm. These data along with a general discussion of the APHIS (Animal and Plant Health Inspection Service, USDA) residue monitoring program are given by Mussman (1975) and summarized below:

DDT Residues in Livestock (ppm Fat Basis)

	Percent of Samples			
	N.D.	0.01-1.5	1.5-3.0	3.0
1967	23.3	72.8	2.2	1.5
1973	26.1	72.7	0.6	0.6

A review of similar data from USDA, APHIS for calendar years 1972-1974 (Conrey, 1975) does not reveal additional trends for poultry or any other meat product. However, it must be remembered that many residue problems are identified and dealt with in various manners prior to a product's entering into interstate trade channels. A summary of 1972-1974 data is given in Table IIIC.3.

The USDA, APHIS conducted a special monitoring program exposing domestic ruminants to 1974 Tussock Moth spray residues and monitoring for DDT residues. The animals were grazing in and around the immediate understory of treated forests. However, sincere efforts were made not to treat open pasture land within the forest complex. A significant number of animals developed illegal residues and were quarantined to allow residue decline to occur. Young calves were released from quarantine on April 1, 1975 whereas older cows having a greater body pool of adipose tissue were not released until June 1, 1975, or later. Data available to date involve objective phase analyses of 358 samples entering interstate commerce. Only two of these samples were found to contain levels of DDT above the current tolerance. The total number of animals being held back for later slaughter is unknown (Spaulding, 1975).

Withdrawal of DDT use in Arizona agriculture in 1968 resulted in a drop in total DDT residue in green alfalfa from an average of 404 ppb in 1967 to 45 ppb in 1970. Residues in beef fat during the same period dropped from 0.97 to 0.49 ppm (Ware et al, 1971). Ware et al (1974) in a recent update of this work found still lower levels corresponding to about 30 ppb of DDT residues in alfalfa. Statistical analysis of data for the sampling dates between 1969 and 1972 showed that in three of four areas sampled, levels of total DDT in green alfalfa have stabilized at about 0.03 ppm.

Data on the decline of fish residues from samples taken in the Great Lakes have been reported elsewhere in this document. In summary, precipitous

Table IIIC.3

DDT Residues in Domestic Animals From Nationwide Meat and Poultry Inspection Programs

Species	No. Samples	Violations	Warnings	None Detected (%)	ppm Total DDT (Fat) 0.01-0.3*(%)	0.31-1.0**(%)	1.0 (%)
Cattle							
1972	202	0	0	59 (29)	135 (66)	8 (3)	9
1973	710	0	0	132 (18)	464 (65)	95 (13)	19 (2)
1974	1010	1	0	165 (16)	755 (74)	74 (7)	15 (1)
Calves							
1972	11	0	0	5 (45)	6 (54)	0	0
1973	84	0	1	3 (3)	73 (86)	4 (4)	4 (4)
1974	282	1	0	8 (2)	245 (86)	23 (8)	6 (2)
Horses							
1973	44	1	0	20 (45)	18 (40)	3 (6)	3 (6)
1974	266	0	0	53 (19)	176 (66)	25 (9)	12 (4)
Swine							
1972	129	0	0	64 (49)	58 (44)	6 (4)	1 (0.7)
1973	232	0	0	119 (50)	101 (43)	8 (25)	5 (0.2)
1974	329	0	0	84 (25)	229 (69)	1[illegible] (4)	1 (0.3)
Turkeys							
1972	206	0	0	39 (18)	155 (75)	10 (4)	2 (0.4)
1973	517	0	0	58 (11)	374 (72)	70 (13)	15 (2)
1974	734	1	0	75 (10)	610 (81)	46 (6)	3 (0.5)
Chickens							
1972	357	0	0	50 (14)	291 (81)	14 (3)	2 (0.5)
1973	531	0	0	89 (16)	393 (74)	46 (8)	3 (0.5)
1974	1034	0	0	66 (6)	925 (89)	38 (3)	5 (0.4)
Lambs							
1972	130	0	0	42 (32)	83 (63)	4 (3)	1 (0.7)
1974	99	1	0	24 (24)	58 (58)	7 (7)	10 (10)

*.01-0.5 (1972)
**0.51-1.0 (1972)

Source: Conrey, personal communication, 1975.

declines were noted with average residues in coho salmon (*Oncorhynchus kisutch*) declining from 11.8 ppm in 1968 to 4.48 ppm in 1973 (Reinert, 1975). An evaluation of fish residue data in ocean fish from a recent NOAA survey (Stout, 1975) for fish off the Pacific Coast showed a residue trend which generally declined with the northward progression of sampling from California to Oregon. In general, the residues were well within the current action limit except for samples taken off the coast of Southern California.

Butler (1973) described the results of a national program for monitoring estuarine molluscs in 15 coastal states for the period 1965-1972. "For most estuaries monitored, detectable DDT residues have declined in both number and magnitude in several species of estuarine molluscs in recent years. DDT pollution in many estuaries as judged by the magnitude of the residue in molluscs, peaked in 1958 and has been declining markedly since 1970."

The North Carolina Agricultural Experiment Station (1974) and Sheets (1973) found significant reductions in DDT and TDE levels in flue-cured tobacco between 1968 and 1972. These decreases are shown in Tables IIIC.4 and IIIC.5. In 1970, a decrease in use of DDT for tobacco occurred and since 1970, a certification that DDT and TDE would not be used has been necessary for tobacco producers to obtain price support. When reviewing these data, it should be remembered that a 2-year period normally occurs between time of tobacco planting and final sale of cured product at auction.

Domanski, Haire, and Sheets (1975) proposed that the low levels of DDT found in recent samples (1972) of auction market tobacco resulted primarily from existing environmental contamination rather than direct application. Recent experiments by the North Carolina Agricultural Experiment Station (1974) confirmed that tobacco produced with currently recommended cultural procedures will in general have residue levels similar to the 1972 survey of US auction market tobacco.

Residue levels found in the lower stalk portion correlated linearly with those in the soil and were in agreement with recent radiochemical DDT-uptake studies conducted by Rosa and Cheng (1974) Drift of airborne soil containing DDT was considered to be a possible contaminant source, especially for upper tobacco leaves.

Domanski and Guthrie (1974) reporting on residues of DDT in cigars found little difference in the residue levels between the years 1969, 1971, and 1972. However, Sheets (1974) found a decrease from 15.6 ppm in 1971 to 10.5 ppm in 1973.

Due to the variable time lag between harvest and marketing of finished tobacco products, it may take 5 years or more for the decline in DDT and TDE to manifest itself fully in such products.

Table IIIC.4

Frequency Distribution of DDT and TDE in Flue-Cured Tobacco
US Market

Concentration Range (ppm)	Samples within Range %		
	1968	1970	1972
0.0-0.099	0	0	0.9
0.1-0.49	0	11.6	63.9
0.5-0.99	0	27.7	15.7
1.0-2.99	0	31.3	12.0
3.0-9.99	1.2	15.2	7.4
> 10.0	98.8	14.3	0

Source: North Carolina Agricultural Experiment Station, 1974.

Table IIIC.5

Average DDT and TDE Residues in Flue-Cured Tobacco from the Auction Market
US, All Belts

Year	Average Conc. (ppm)
1968	53.0
1970	5.9
1972	0.85
1973*	0.21

*Additional information from limited survey.

Source: Sheets, 1973.

Conclusion

Between 1965 and 1970, levels of DDT and DDE in the two commodity groups, dairy and meat, fish and poultry, gradually decreased. Then, between 1970 and 1973 a precipitous drop occurred in residues of DDT and TDE with respective decreases of 86% and 89%. DDE on the other hand decreased only 27%. In FY 1973, these two commodity groups represented more than 95% of the total body burden of ingested total DDT residue with dairy products contributing about 30% of this amount.

Based on domestic ruminant monitoring data since 1972, no significant change has occurred in the residue profile through 1974. If current levels of DDT exposure to domestic ruminants are caused by ingestion of food and feed produced from soil having past, but no current exposure, to DDT, diminution of these levels cannot be expected to occur in the near future.

DDT residues in agricultural commodities other than dairy products and meat, fish, and poultry do not currently pose a significant problem with regard to direct human intake.

HUMAN STORAGE AND DDT RESIDUES

Administrator's Finding: Human beings store DDT.

DDT and its metabolites, DDE and TDE, are highly soluble in fatty substances. Thus, when humans are exposed to residues of DDT in food, a certain portion will be retained and stored in the body fat. The major source of this DDT is dairy and meat products ingested as part of the total diet. The source of this DDT in food is our nation's agricultural soils. Small quantities are taken up by plant materials. Thus, the simple food chain (soil → plant → domestic ruminant → human) accounts for most of DDT found in human tissues.

Data as of 1972

Adipose tissue data from the National Human Monitoring Programs (Yobs, 1971) yielded mean levels of total DDT, including metabolites, in the general population of 6.26 ppm in 1968 and 5.97 ppm in 1970. Significant differences were noted between black and white populations (TR:1984). Blood serum levels of DDT varied significantly with the socioeconomic background of the subject and "lowest values are found in the more affluent groups, and higher values in poor" (TR:2022).

Analysis of DDT in the human food chain using a system modeling approach was done by O'Neill and Burke (1972) for the DDT Advisory Committee. This approach revealed that a reduction of DDT levels in human fat to 25% of that existing at the time of cancellation of all DDT uses would take approximately 28 years.

Data since 1972

A comparison of 1970 thru 1972 National Human Monitoring data has been prepared by Kutz, Yobs, and Strassman (1974) and Kutz (1975) and is shown below. The geometric mean of DDT in human adipose tissue declined from 7.95 ppm in 1971 to 5.89 ppm in 1973, which may signal a downward trend. Since 1970, the percent of DDT residues found as DDE increased slightly (from 77.15% to 81.19%). Detailed analyses of FY 1970 data were described by Kutz et al (1974).

National Summary of Total DDT Equivalent Residues in Human Adipose Tissue

(total US population basis)

	FY 1970	FY 1971	FY 1972	FY 1973
Sample size	1,412	1,616	1,916	1,092
Frequency	99.3%	99.75%	99.95%	100.00%
Geometric mean	7.87 ppm	7.95 ppm	6.88 ppm	5.89 ppm
Percent DDT found as DDE	77.15%	79.71%	80.33%	81.19%

Total DDT equivalent = (o,p'-DDT + p,p'-DDT)

+ 1.114 (o,p'-DDD + p,p'-DDD +

p,p'-DDE + o,p'-DDE)

As part of an epidemiological study, Griffith (1975) monitored serum levels of p,p'-DDT, o,p'-DDT, p,p'-DDE and o,p'-DDE in a cohort of 382 exposed human subjects during 1971, 1972, and 1973. The data (Figure IIIC.7) clearly show that p,p'-DDT serum residue levels have decreased over the 3-year period 1971-1973 suggesting diminished exposure to DDT.

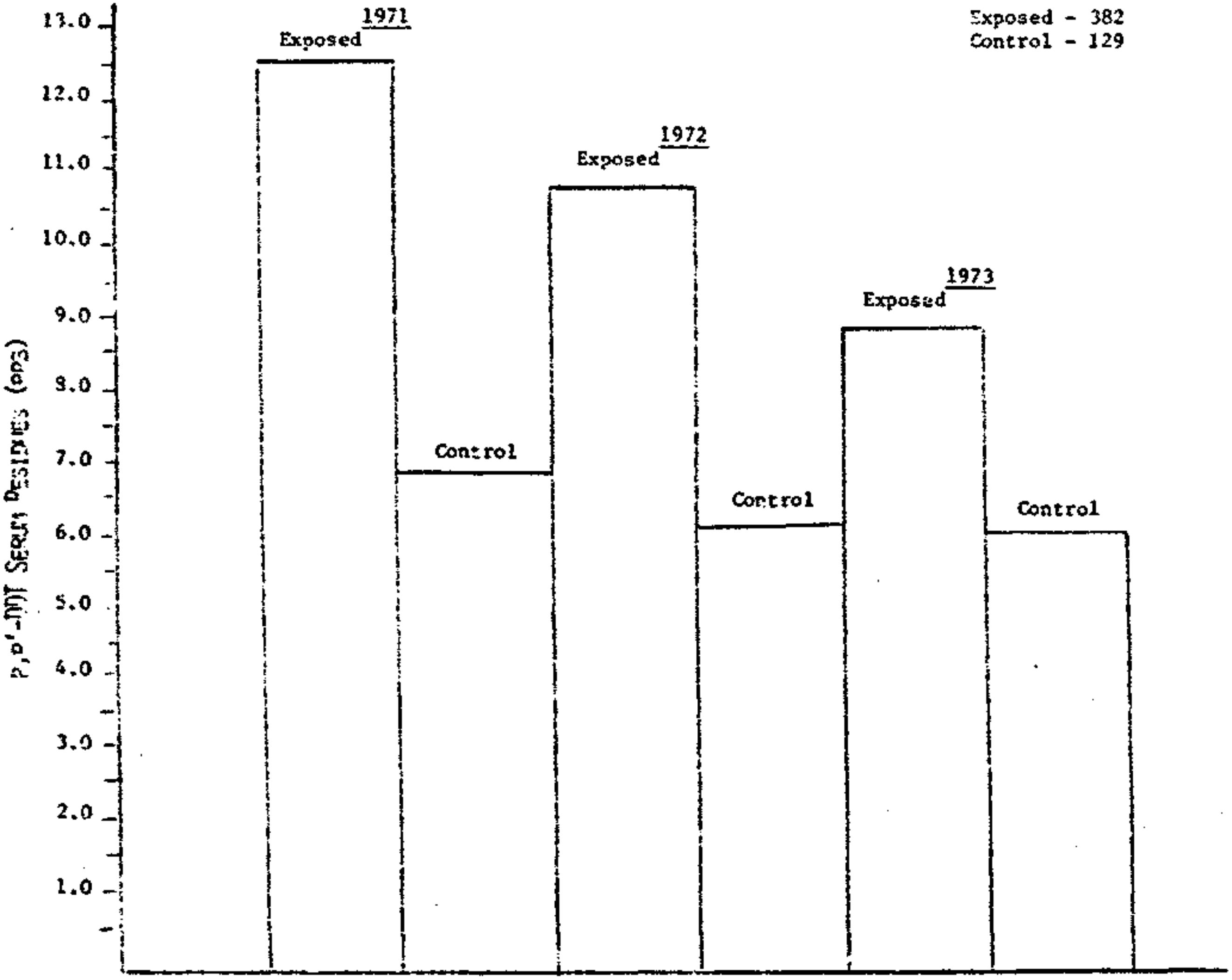
Residues of p,p'-DDE, on the other hand, do not show such a pronounced downward trend (Figure IIIC.8). It has been suggested by a number of investigators that serum p,p'-DDT levels reflect recent exposure to DDT, while p,p'-DDE levels seem to correlate well with long-term exposure and the storage capacity of the human body (Keil et al, 1972; Edmundson, 1970; Morgan, 1971 and Selby, 1968).

Conclusion

DDT residues in human adipose tissue have tended to decline in recent years (1971 to 1973), while the percent of DDT stored as DDE has moved up only slightly.

Fig. IIIC.7

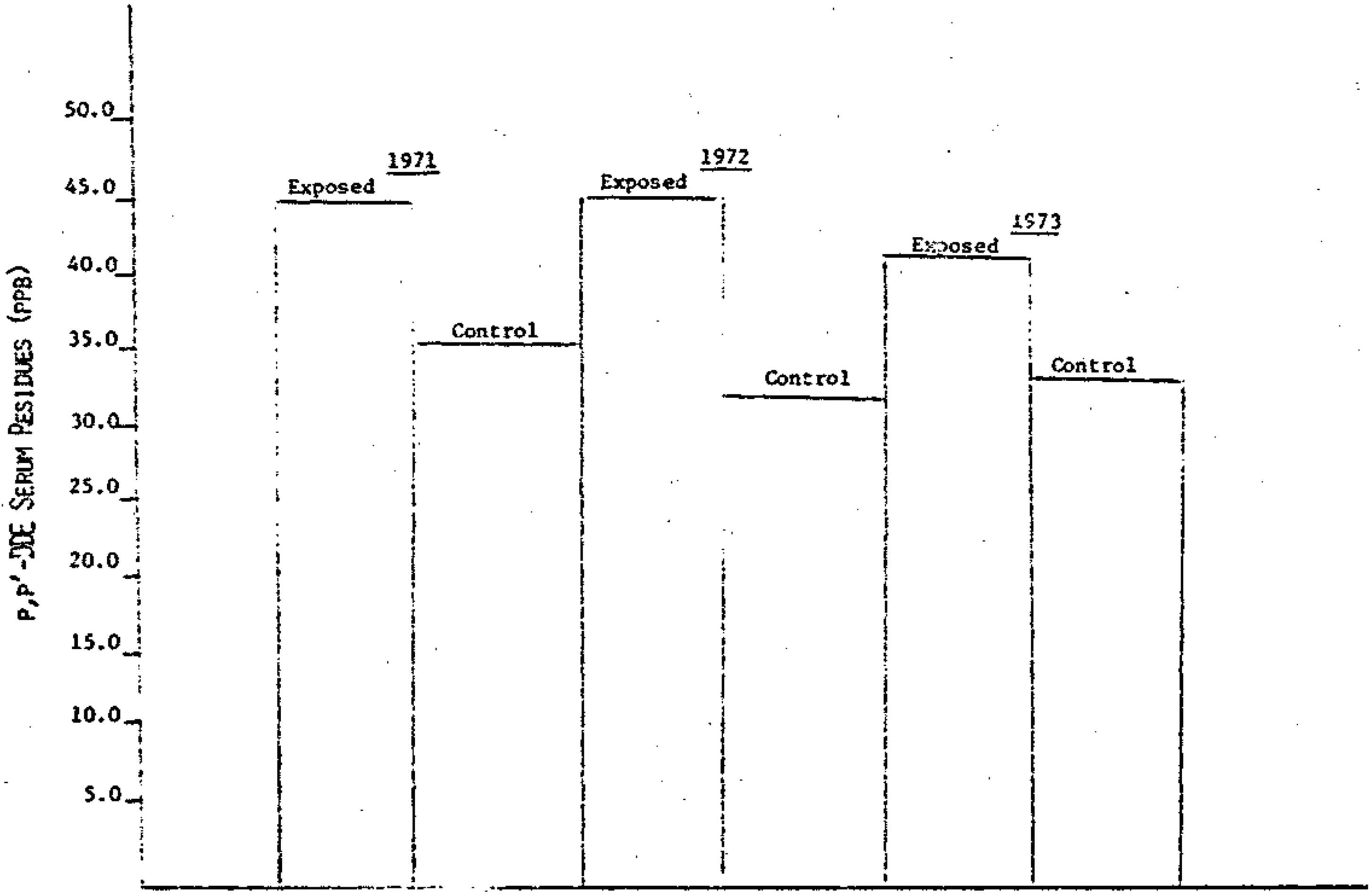
EPIDEMIOLOGICAL STUDIES PROGRAM
$\bar{X}$ Serum Residues of p,p'-DDT
1971-1973
Exposed - 382
Control - 129



Source: EPA, Office of Pesticide Programs, Human Effects and Monitoring Branch
Feb 1975.

Fig. IIIC.8

EPIDEMIOLOGIC STUDIES PROGRAM
$\bar{X}$ Serum Residues of p,p'-DDE
1971-1973
Exposed - 382
Control - 129



Source: EPA, Office of Pesticide Programs, Human Effects and Monitoring Branch, Feb 1975.

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III

D. REVIEW OF ECONOMIC ASPECTS

INTRODUCTION

> *Administrator's Findings: 1) The use of DDT is not necessary for production of cotton, beans, peanuts, cabbage, cauliflower, brussels sprouts, tomatoes, fresh market corn, pimentos, garlic, and commercial greenhouse plants but may be necessary to protect sweet potatoes in storage, sweet peppers against heavy corn borer infestations (in the Delmarva Peninsula only), and onions during an interim cancellation period. 2) Noncrop uses of DDT for moth proofing and to control bats and mice are proprietary uses for which DDT is not necessary.*

These are the Administrator's Ultimate Findings in Part V of his decision, Benefits. These ultimate findings on benefits were based on 12 Basic Findings which generally relate to economic matters. In view of these findings by the Administrator and the more recent regulatory actions involving emergency requests to use DDT against the tobacco budworm on cotton, the tussock moth and the pea leaf weevil, the following crop use patterns were reviewed for this report:

1. Cotton
2. Other crop uses
    - a) sweet corn
    - b) peanuts
    - c) cabbage
    - d) cauliflower
    - e) brussels sprouts
    - f) tomatoes
    - g) garlic
    - h) lettuce
    - i) potatoes
    - j) dry beans
    - k) lima beans
    - l) snap beans
    - m) sweet potatoes
    - n) sweet peppers
    - o) onions
3. Military uses
4. Public Health use
5. Forest use

Information available to the Administrator in 1972 was found in the testimonies of the DDT Hearing Record. Current information since the cancellation was located in a variety of sources.

Commodity specialists in the disciplines of agronomy, entomology, and economics were contacted in the USDA and the Land Grant Universities. Data sources, both public and private, were referred to and include USDA publications, Experiment Station and Extension bulletins, Tariff Commission Reports, EPA-contracted research projects, and others.

DDT PRODUCTION AND USE

In the early 1950's thirteen companies were involved in the manufacturing of DDT. Among the last firms to cease producing DDT were: Geigy Corporation (1966), Allied Chemical (1969), Olin Corporation (1969), Diamond Shamrock Corporation (1970), and Lebanon Chemicals (1971).

Domestic production reached a maximum of about 188 million pounds in 1963. By the late 1960's DDT output had declined by about one-third, e.g., 123 million pounds in 1969. Then production declined precipitously, to an estimated 60 million pounds per year in the early 1970's (Table IIID.1).

Domestic use peaked at near 79 million pounds in 1959, and declined to about 18 million pounds in 1971 (22 million pounds in 1972). More recent estimates of use are not available.

Export lagged behind domestic consumption up to 1958, and the maximum did not occur until 1963. From 1958 onward, the quantity of DDT exported continued to exceed domestic consumption.

Table IIID.1

Domestic Production, Consumption, and Exports of DDT in the United States, 1950-1972 (100% basis)

Year	Production	Domestic Consumption (1,000 lbs)	Exports
1950	67,320	57,638	7,898
1951	97,875	72,686	NA
1952	115,717	70,074	32,258
1953	72,802	62,500	31,410
1954	90,712	45,117	42,743
1955	110,550	61,800	50,968
1956	137,747	75,000	54,821
1957	129,730	71,000	61,069
1958	131,862	66,700	69,523
1959	156,150	78,682	76,369
1960	160,007	70,146	86,611
1961	175,657	64,068	103,696
1962	162,633	67,245	106,940
1963	187,782	61,165	113,757
1964	135,749	50,542	77,178
1965	140,785	52,986	90,414
1966	141,349	46,672	90,914
1967	103,411	40,257	81,828
1968	139,401	32,753	109,148
1969	123,103	30,256	82,078
1970	59,316	25,457	69,550
1971	63,134[a]	18,000[a]	45,134
1972	57,427[a]	22,000[a]	35,424

[a] EPA estimates based on Pesticide Review 1973, pp. 10, 11, 22, 23.

Source: USDA, ASCS. Pesticide Review 1973 and earlier years.

The major areas covered in this review are: the availability of alternative pest controls, chemical and nonchemical; impact of the cancellation on cotton production costs (1971-1972 average compared to 1973-1974 average); and impact of changes in cotton production costs on acreage, production, and prices of cotton and other crops in the US, by region, based on a representative year since cancellation. This latter analysis presents results in terms of the year 1975. Throughout the analysis, only cost impact is considered, as inadequate data were available to systematically evaluate possible impact of alternatives upon cotton yields throughout the areas where DDT was used.[1]

Before presenting results of the review, a brief summary of relevant background information is presented on the cotton industry.

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[1] Additional research is currently in progress in the Office of Pesticides, EPA, in cooperation with cotton specialists in the states addressing yield as well as cost impact in detail. Basic data on the entomology and economics of alternative cotton producing programs, including those with DDT, are now being received from the states but analysis will not be completed until well into FY 1976. Data are being obtained for 57 individual cotton growing regions, which will be utilized in an analysis of impact of yield and cost effects of the availability of DDT and other pest management options on the performance of the cotton and other sectors of agriculture (e.g., acreage, production, and price of cotton and other major agricultural crops).

As part of the cotton pest management study, states were requested to provide information on cotton yield differentials associated with alternative control techniques, including the use of DDT. As of July 1975, eight of the 14 states contacted have responded. This data is therefore incomplete at this time and the summary statements below provide tentative conclusions only.

In the Southeast, the two states responding indicate that growers would use DDT on cotton pests, principally for control of the tobacco budworm, bollworm, and the boll weevil, but yields would not change. Three western states expect very little DDT would be used if available. One state indicated cotton and alfalfa are frequently grown in adjacent fields and DDT would cause residue problems in the alfalfa. Yield improvements would not be expected except in the case of bollworm control. Three states in the Delta region have responded and two provide specific numerical information on yield improvements if DDT were available. Estimates of yield increases range from 3% to 14%, depending upon specific regional area. One Delta state does not expect any change in yields.

The yield information is obtained from the professional judgement of entomologists knowledgeable on the prevailing growing conditions in their respective regions and is based on actual field experience, experimental data, laboratory tests and other accumulated experience.

OVERVIEW OF THE COTTON ECONOMY

Cotton is one of our most important agricultural crops. It contributes \$3 to \$4 billion to cash receipts of farmers and is grown commercially on about 125,000 farms in the United States.[1] As many as one-fourth of these farms have less than 25 acres of cotton. The major cotton production regions of the US are shown in Figure IIID.1.

The cotton industry is one of the most intensive users of insecticides. As of 1971, nearly one-half the total insecticides used in agriculture were for protection of cotton. About two-thirds of the cotton acreage in the US is treated with insecticides. DDT was a major insecticide used in the cotton industry through 1972. Additional background on the use of DDT and other insecticides, as well as other aspects of the cotton economy, are discussed below (based on recent USDA evaluations, USDA, ERS, Cotton Situation, 1975 and other sources as cited).

The economic success of the cotton farmer is affected from year to year much more heavily by a number of other factors than by changes in regulatory policy on pesticides. Factors such as weather, government acreage allotment and price support programs, the market price of cotton, competition from other crops, limited input supplies, and costs of other inputs often have a major impact on cotton production costs and returns. Average total costs of producing an acre of harvested upland cotton in the US were estimated to be \$254.63 in 1974, of which insecticides accounted for only \$9.64 or about 3.8% (Table IIID.2) (Starbird et al, 1975).[2] Since 1972, the total costs of producing upland cotton have increased from \$193.48 to \$254.63 (by \$61.15 or about 32%). According to these USDA estimates, increasing costs of insecticides constituted a very minor part of the overall increase in cotton production costs (from \$7.74 to \$9.64 per acre or by \$1.90) (Table IIID.2). This is not to say that insecticide cost increases have been so nominal in all areas or that insecticides are unimportant factors contributing to cotton yields.

Costs of growing cotton varied significantly among the US cotton producing regions. In 1972, the latest year for which costs by region are available from USDA, total costs per harvested acre varied from \$95.49 to over \$500 per acre (Table IIID.3) (Starbird et al, 1972). Insecticide costs per acre also varied greatly. The regions with heaviest insecticide costs as of 1972 were:

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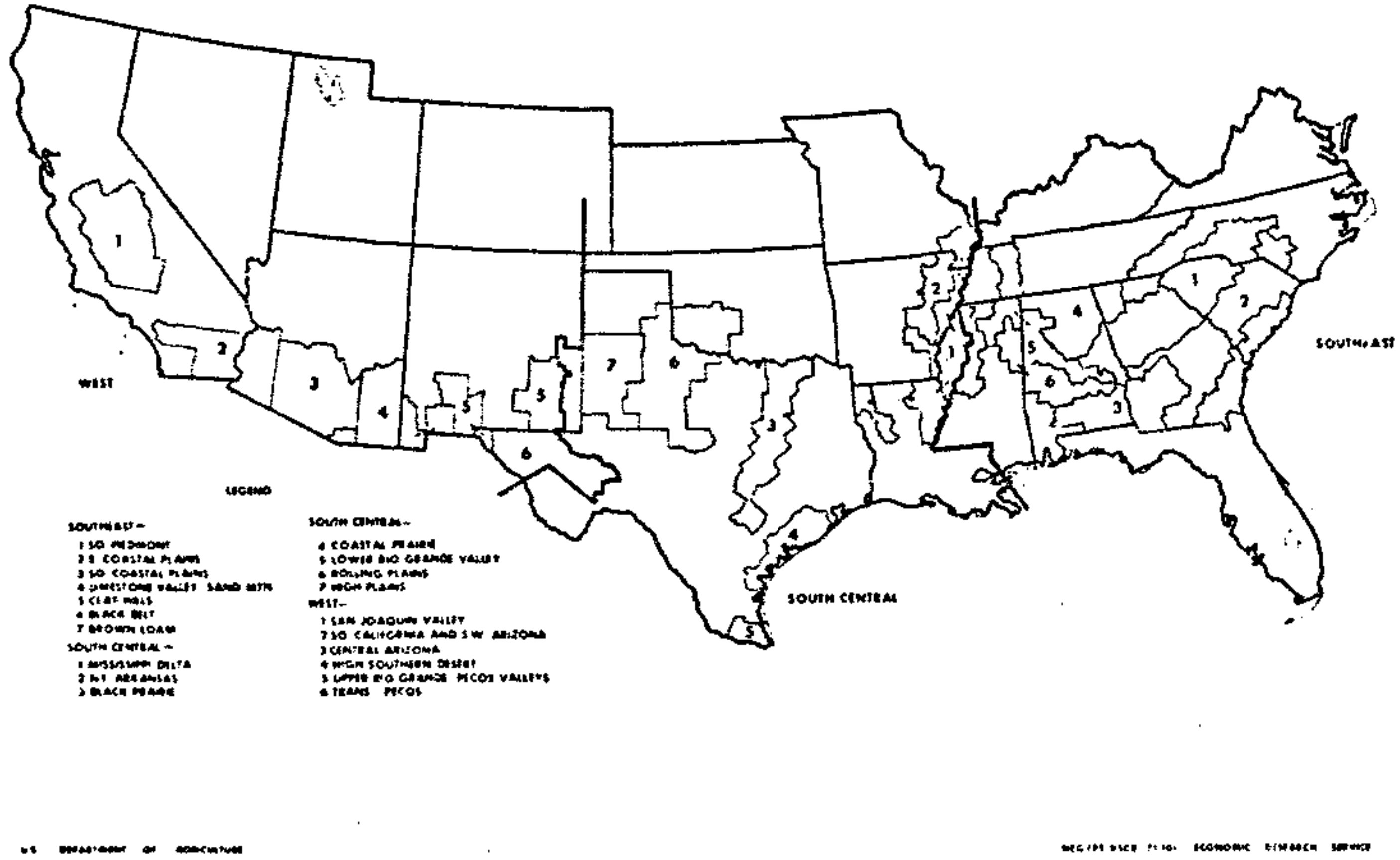
[1] There were estimates of as many as 150,000 farms with cotton allotments for the year 1972 (USDA estimate, based on ASCS & ERS data sources). However, as of 1974 the number of farms growing cotton on a commercial basis is about 125,000 (based on market research reports available to EPA).

[2] These preliminary USDA 1974 estimates of costs for insecticides are substantially lower than those presented later in this report, based on another data source. They are utilized here for purposes of indicating the importance of insecticides in the overall cost of growing cotton, as estimated by USDA.

Figure IIID.1

PRODUCTION REGIONS FOR COTTON



Source: Starbird, I.R., and B.L. French. Costs of Producing Upland Cotton in the United States, 1969, 1972.

Table IIID.2

Production Costs per Acre of Upland Cotton Harvested, United States, Selected Years, 1964-1974

	Average Cost per Acre Harvested				
Item	1964	1966	1969	1972	1974b/
Labor	42.40	27.83	21.97	23.33	27.49
Power & Equipment	34.04	37.28	42.46	43.50	56.90
Materials					
Seed	3.26	3.56	4.20	4.40	7.59
Fertilizer	11.44	12.67	10.90	10.96	17.56
Herbicides	1.59	3.72	4.56	6.18	7.70
Insecticides	5.69	6.42	6.79	7.74	9.64
Defoliants	1.00	1.00	1.17	1.48	1.85
Other Chemicals	0.30	0.25	0.20	0.52	0.65
Total Materials	23.26	27.62	27.83	31.28	44.99
Ginning, Bagging & Ties	19.11	19.82	18.44	23.34	25.28
Custom Services	7.74	8.90	9.91	11.28	14.39
Irrigation	8.37	9.19	7.86	11.12	13.71
Interest on Operating Capital	2.49	2.29	2.72	2.79	4.75
Total Direct Costs	137.46	132.94	131.18	146.83	187.51
Land	24.49	24.44	23.11	34.15	51.32
General Overhead	18.74	13.99	13.64	12.49	15.80
Total Cost per Acre Harvesteda/	180.69	171.38	167.93	193.48	254.63

a/ Totals do not necessarily add because of rounding.
b/ Preliminary.

Sources

Starbird, I.R., et al. Costs of Producing Upland Cotton and Selected Crops on Cotton Farms in the United States, 1972, 1975.
Starbird, I.R. Costs of Producing Upland Cotton in the US - Procedures, Results, and Implications, 1974.

Table IIID.3

Average Total Production Costs and Insecticide Costs per Acre for Upland Cotton, US by Region, 1969 and 1972

Regions	1969			1972		
		Insecticides			Insecticides	
	Total Cost (dollars)	Cost (dollars)	Percent of Total (percent)	Total Cost (dollars)	Cost (dollars)	Percent of Total (percent)
Southern Piedmont	179.61	11.51	6.41	NA	NA	NA
Eastern Coastal Plain	214.17	18.22	8.51	230.57	24.41	10.59
Southern Coastal Plain	202.60	16.19	7.99	226.40	31.96	14.12
Limestone Valley-Sand Mountain	165.49	8.06	4.87	218.46	15.86	7.26
Clay Hills	184.23	6.74	3.66	189.70	8.51	4.49
Black Belt	176.92	12.40	7.01	NA	NA	NA
Brown Loam	178.57	4.78	2.68	196.21	3.21	1.64
Mississippi Delta	185.98	10.92	5.87	210.11	10.31	4.91
Northeast Arkansas	165.33	2.41	1.46	179.33	3.39	1.89
Black Prairie	76.84	2.40	3.12	95.49	3.68	3.85
Coastal Prairie	109.57	3.27	2.98	160.15	11.43	7.14
Lower Rio Grande Valley	183.90	11.10	6.04	199.19	17.58	8.83
Rolling Plains	89.21	1.26	1.41	103.77	0.61	0.59
High Plains	126.00	0.53	0.42	150.94	0.72	0.48
San Jaoquin Valley	313.65	10.92	3.48	371.95	9.55	2.57
California & S. Arizona	414.94	35.99	8.67	487.73	38.32	7.86
Central Arizona	389.32	21.81	5.60	503.13	31.12	6.19
High Southern Desert	330.64	3.01	0.91	NA	NA	NA
Upper Rio Grande-Pecos Valleys	252.02	3.38	1.34	332.98	2.42	0.73
Trans Pecos	333.92	14.39	4.31	NA	NA	NA
United States	167.93	6.79	4.04	193.48	7.74	4.00

Sources

Starbird, I.R. and B.C. French. Costs of Growing Cotton in the United States, 1969, 1972.
Starbird, I.R. et al. Costs of Producing Cotton and Selected Crops on Cotton Farms in the United States, 1972, 1975.

Southern Piedmont, the Eastern Coastal Plain, Coastal Prairie, Lower Rio Grande Valley, and Southern California/Southwest Arizona. In these regions the costs of insecticides ranged up to 14% of total production costs compared with a national average of 4.0% in 1972. Later in this analysis additional cost data are presented for insecticides by chemical for purposes of estimating the cost impact of the DDT Decision on the average during 1973 and 1974 in comparison with the 1971-1972 average.

Competition from man-made fibers and declining demand, due to the unfavorable general economic conditions in the US and world markets during the last year have had significant impact on cotton prices (Figure IIID.2). Cotton prices received by farmers have declined sharply from the high of near $0.60 per pound which occurred about a year ago. The high market prices for cotton during the 1972-1973 and early 1973-1974 seasons generated very large plantings in 1974 (nearly 14 million acres compared with an average of 12.95 million acres for 1970-1974).

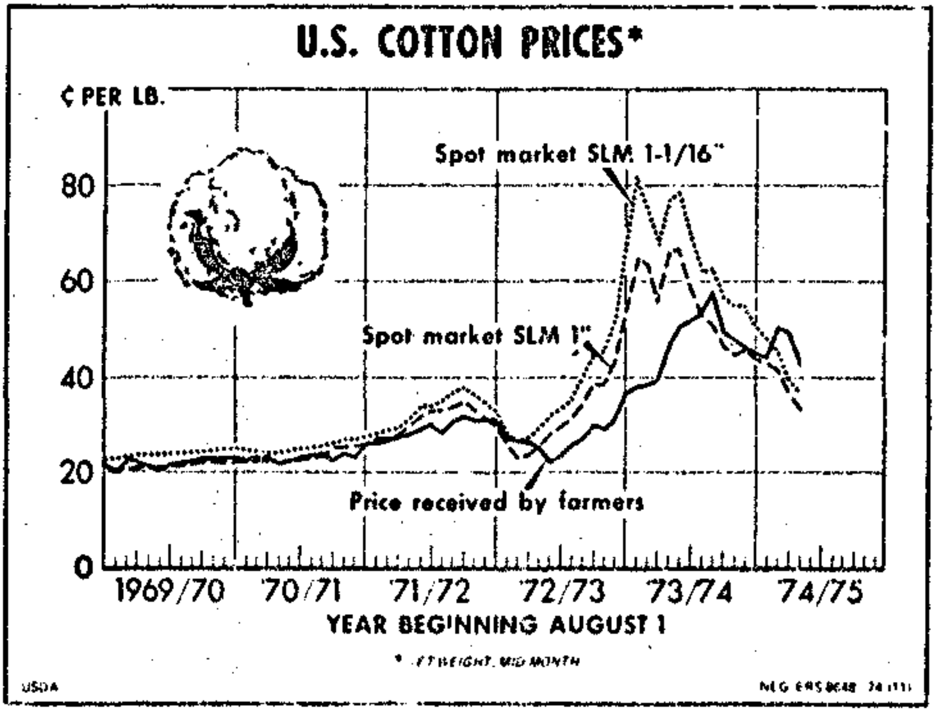
Although bad weather battered cotton producers all season long in 1974, particularly in the Southeastern and Delta areas, thus reducing yields, the 1974 crop totaled 11.7 million bales. In the face of declining demand, the crop precipitated dramatic price decreases. For example, the February price received by farmers in 1975 was only $0.32 per pound compared with $0.52 per pound in February 1974.

Improvement in the national market situation in cotton depends upon recovery of the economy and reduction in production in 1975, to adjust to needs in the domestic and export markets. The latter is expected to happen as prospective planting in 1975 is 9.5 million acres, down 22% from 1974, to the lowest level in many years.

The cotton commodity market in which one can contract for delivery at specified prices has been a disconcerting factor for the cotton farmer during the last 2 years. In 1974, 20% of the cotton crop was contracted compared with 75% in 1973 and only 15% in 1972. In 1973, farmers received attractive prices for cotton. Cotton was contracted at prices acceptable to farmers, and the $0.15 price support was in effect. However, cotton prices continued to increase throughout the 1973 season, and holders of the contracts were the beneficiaries, not necessarily the farmers. Farmers' anticipation of windfall gains in 1974 appear to have resulted in only 20% of the crop being sold under contract at future prices. However, since cash prices in 1974 were declining and farmers had not protected themselves by contracting at higher prices, 80% of the crop was on the open market at current lower cash prices.

The Federal Government's cotton program is a very significant factor affecting the cotton producer. The Agricultural Act of 1973 represented an important change in US agricultural policy. This Act reflects a trend away from government controls and guarantees to a more open market-oriented philosophy. Under free-market agricultural policies, farm markets tend to become more unstable. Annual prices can fluctuate, subjecting farmers to "shocks" in income.

Figure IIID.2



The Agricultural Act of 1973 first went into effect in the 1974 growing season, including new cotton allotment provisions. One important feature was the target price concept to replace the $0.15/lb lint price payment. Farmers would no longer automatically receive a price supplement. Instead, a target farm price floor was set for their crop. As long as the market price of cotton equals or exceeds the target price, no payment is made. Farmers receive per pound payment when cotton prices at the farm level fall below the target price, which for cotton was set at $0.38/lb lint. The farm price of cotton exceeded this level, and no payments were made to farmers for the 1974 crop.

The disaster provision of the law gives some income protection in the event of crop loss due to a natural catastrophe. The provision becomes effective if over one-third of the cotton crop grown on allotment acreage is lost. If, for example, a farmer has 100 acres of cotton allotment and the normal yield per acre is 500 lbs of lint, the farmer's normal yield is 50,000 lbs of cotton.1/ If one-half of the crop is lost, the farmer qualifies for disaster payments on 25,000 lbs of cotton. He receives a payment of one-third the current target price multiplied by the pounds of cotton lost if the loss is equal to or greater than one-third the normal yield.

In some circumstances the farmer can suffer a disaster to his crop yet not qualify for the disaster payments in the program. This can happen as follows. Consider the same farm as above with the 100-acre allotment. Now assume the farmer chooses to grow 200 acres of cotton, so that 100 acres under the allotment while the other 100 acres is not. Expected yield in this case is 100,000 lbs of lint. If 50,000 lbs of cotton are lost due to a disaster and the farmer produces only 50,000 lbs at harvest, he is not eligible for disaster payments. His disaster payment is based on 50,000 lbs of his normal yield. The cotton allotment applicable in this case assumes the farmer has received his normal yield and therefore does not qualify for disaster payments.

There are no restrictions on the number of acres of cotton planted. However, the risk to the farmer increases if he plants on nonallotment acres. In 1974, for every 100 acres of allotment cotton in the US, there were about 27 acres of nonallotment cotton grown. A combination of bad weather and insect damage in some areas such as the Southeast and the Delta appear to have resulted in yield reductions. However, as a result of growing a large amount of the crop on nonallotment acres, many farmers experiencing damage either did not qualify for disaster payments or received less than the full benefits of these payments.

1/ Although the allotment is stated in acres, the provisions of the cotton allotment program are based on normal yield. Normal yield is derived from a moving average of yields on each farm from previous years.

TRENDS IN COTTON ACREAGE, YIELDS, AND PRODUCTION IN THE US AND IN MAJOR PRODUCING REGIONS

Economic performance of the cotton industry since the DDT cancellation must be viewed within the context of trends during earlier years as indicated in Figure IIID.3 and Tables IIID.4, 5, and 6. These data indicate that cotton acreage, yield, and production vary greatly from year to year, that there are long-term trends in the cotton industry, and that results in 1973-1974 are not grossly out of line with past performance of the industry. The high degree of annual variability in the cotton market is typical of agricultural markets.

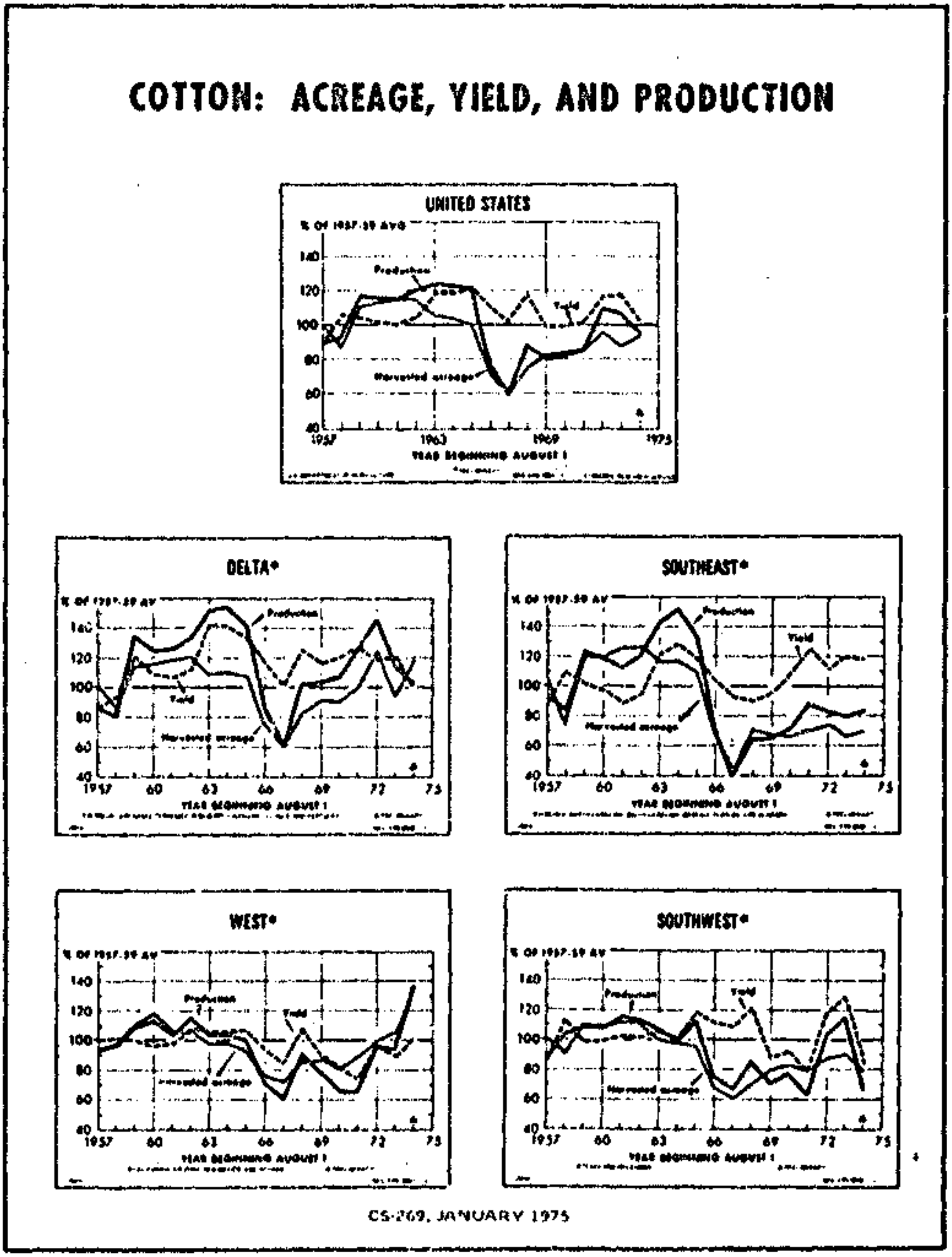
The cotton industry has been able to maintain its production to meet domestic and export needs since the DDT cancellation. Although production has declined slightly at the national level, it has been more than adequate to meet market needs, as prices declined very significantly in 1974. The record high prices for cotton in 1973 are not attributable to the DDT Decision.

The two regions of the United States in which DDT was used as of 1972 are the Delta and Southeast.[1/] DDT was used much more extensively in the Southeast Region (Va., N.C., S.C., Ga., Fla., and Ala.) than the Delta Region (Mo., Ark., Tenn., Miss., La., Ill., and Ky.). In the Southeast, it was used on about half the acreage compared with less than one-fourth of the acreage in the Delta. These insecticide use patterns will be discussed in more detail later in this report.

Cotton yields in Southeast Region in 1973 and 1974 are equal to or greater than yields during years immediately prior to the decision and are above the long-term average for the region (Figure IIID.3 and Table IIID.4). In the Delta Region, cotton yields increased slightly in 1973 over 1972 and were above long-term average yield. However, the Delta cotton yield declined from 555 lbs in 1973 to 406 lbs in 1974, the lowest yield in the last 14 years. Most of this decline is credited to floods and adverse weather conditions as discussed in USDA's analysis of the situation presented in its recent Cotton Situation reports (January and April, 1975). Changes in pesticide policy are not cited as a significant factor in yield reduction in USDA's 1974 cotton situations. Overall production in the Delta area did decline significantly in 1973 and again in 1974 as a result of reduced yield and acreage harvested. In the Southeast, production has been maintained in 1973 and 1974 at levels comparable to 1972 and prior years.

1/ Regions are defined in Figure IIID.3. Note that these USDA regional definitions differ from those for which production cost data were presented in Figure IIID.1 and Table IIID.2.

Figure IIID.3



Note: This chart, based on USDA estimates as of January, 1975, does not reflect more recent estimates reported in Tables IIID.4, 5 and 6, which are based on the <u>Cotton Situation</u> published in April, 1975.

Table IIID.4

Cotton Yield Per Harvested Acre, US by Region, 1961-1974

	Region				
Year	West	Southwest	Delta (lbs of lint)	Southeast	Total
1961	959	343	489	338	438
1962	1,356	339	510	363	457
1963	1,034	354	642	461	517
1964	1,035	338	643	488	517
1965	1,047	394	620	453	527
1966	918	375	532	392	480
1967	828	364	462	356	447
1968	1,047	404	569	342	516
1969	871	293	528	363	434
1970	798	306	546	410	438
1971	724	261	578	476	438
1972	937	399	539	427	507
1973	875	427	555	459	520
1974	983	280	406	451	443
Average Yield 1961-1974	937	348	544	413	477

West: California, Arizona, New Mexico, and Nevada.
Southwest: Texas and Oklahoma.
Delta: Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Illinois, and Kentucky.
Southeast: Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama.

Source: USDA, ERS. Cotton Situation, 1975.

Table IIID.5

Cotton Production, US by Region, 1961-1974

Year	West	Southwest	Delta	Southeast	Total
	Region (1,000 bales)[a]				
1961	2,813	5,145	4,485	1,840	14,283
1962	3,118	5,026	4,710	1,973	14,827
1963	2,822	4,744	5,407	2,321	15,294
1964	2,813	4,403	5,468	2,461	15,145
1965	2,707	5,030	5,051	2,150	14,938
1966	1,925	3,393	3,077	1,162	9,557
1967	1,651	2,958	2,179	655	7,443
1968	2,482	3,786	3,612	1,046	10,926
1969	2,104	3,138	3,691	1,057	9,990
1970	1,796	3,402	3,819	1,175	10,192
1971	1,780	2,791	4,468	1,438	10,477
1972	2,593	4,609	5,139	1,363	13,704
1973	2,550	5,126	3,990	1,308	12,974
1974	3,716	2,947	3,672	1,367	11,702
Average Production 1961-1974	2,491	4,036	4,198	1,523	12,247

West: California, Arizona, New Mexico, and Nevada.
Southwest: Texas and Oklahoma.
Delta: Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Illinois, and Kentucky.
Southeast: Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama.

[a] 480 lb net weight bales.

Source: USDA, ERS. Cotton Situation, 1975.

Table IIID.6

Cotton Acreage Harvested in the US by Region, 1961-1974

	Region				
Year	West	Southwest	Delta (1,000 acres)	Southeast	Total
1961	1,409	7,205	4,404	2,616	15,634
1962	1,418	7,112	4,434	2,605	15,569
1963	1,310	6,440	4,042	2,420	14,212
1964	1,306	6,250	4,080	2,421	14,057
1965	1,241	6,120	3,974	2,280	13,615
1966	1,006	4,348	2,774	1,424	9,552
1967	957	3,895	2,262	883	7,997
1968	1,138	4,505	3,049	1,468	10,160
1969	1,159	5,140	3,358	1,398	11,055
1970	1,079	5,346	3,355	1,375	11,155
1971	1,180	5,132	3,708	1,451	11,471
1972	1,328	5,544	4,578	1,534	12,984
1973	1,399	5,757	3,448	1,366	11,970
1974	1,814	5,059	4,344	1,453	12,670
Average Acreage 1961-1974	1,267	5,561	3,701	1,764	12,293

West: California, Arizona, New Mexico, and Nevada.
Southwest: Texas and Oklahoma.
Delta: Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Illinois, and Kentucky.
Southeast: Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama.

Source: USDA, ERS. Cotton Situation, 1975.

Trends in cotton yields since 1961 are presented by state in Tables IIID.7 and 8 for the Delta and Southeast regions. These data indicate a high degree of variability in cotton yields within the regions and from year to year at the state level. These data do not preclude the possibility of significant yield impact from the DDT Decision. However, yield reductions such as these have occurred at earlier times, due to other factors.

The Administrator's decision on the emergency request for the use of DDT against the tobacco budworm on cotton in Louisiana presents a review of pest problems and the impact of available controls on yields in the State of Louisiana, which is an important state in the Delta producing area. In that decision, the Administrator found that the State of Louisiana had "presented no substantial evidence - new or old - to support the premise that the tobacco budworm problem is new, that recognition of its occurrence and seriousness is new, or that the DDT mixture is the only insecticide that can be expected to prevent economically significant damage arising from a possible tobacco budworm outbreak this year." (EPA, 1975)

An unfavorable economic situation was faced by cotton producers in 1974 as seen in the basic cost/price relationships for that year. The 1974 US average yield of 443 lbs of lint per acre (Table IIID.4) and the estimated average production cost per acre of $254.63 (Table IIID.2) give a cost per pound of 57.5 cents. This cost compares with a cotton lint price of 45.9 cents per pound from August to January 13 (1974-1975) and an allowance of 10.4 cents for the value of the seed (a total of 56.3 cents per pound), to give an average net loss of 1.2 cents per pound (USDA, ERS, Cotton Situation and Starbird et al, 1972). This outcome has led to greatly reduced plantings in 1975 and probably hit some areas much harder than others (e.g., as a result of very low yields in some areas in 1974). Yields in the Southwest and Delta Regions were down markedly in 1974, while they were up in the West and in line with recent years in the Southeast (Table IIID.4).

AVAILABILITY OF ALTERNATIVES TO DDT

> *Administrator's Findings: 1) DDT is useful for the control of certain cotton insect pests. 2) Cotton pests are becoming resistant to DDT. 3) Methyl parathion and other organophosphate chemicals are effective for the control of cotton pests. 4) DDT is lethal to many insects beneficial to agriculture.*

Data as of 1972

On December 30, 1970, the USDA submitted a list of essential uses of DDT to the EPA, which was recorded by EPA as Hearing Admission Number 2. The USDA considered DDT essential to control the following pests: budworm, boll weevil, cotton bollworms, cotton fleahopper, fall armyworm, garden webworms, Lygus bugs, mirids, thrips, and cutworms.

Table IIID.7

Lint Yield Per Harvested Acre in the Delta Region, by State (Major States), 1[illegible]-1974

Year	Arkansas	Louisiana	Mississippi	Missouri	Tennessee	Region
			(lbs)			
1961	512	429	493	469	493	489
1962	512	464	512	582	494	510
1963	582	628	709	630	621	642
1964	605	544	732	564	640	643
1965	572	540	678	559	611	610
1966	418	602	653	408	475	532
1967	333	621	567	314	295	462
1968	502	636	660	495	432	569
1969	518	551	534	533	505	528
1970	470	555	658	431	483	546
1971	522	576	613	614	597	578
1972	488	509	599	520	543	539
1973	513	481	651	501	472	555
1974	368	445	459	356	298	406

Sources

USDA, ERS. Statistics on Cotton and Related Data, 1920-1973, 1974.
USDA, ERS. Cotton Situation, 1975.

Table IIID.8

Lint Yield Per Harvested Acre in the Southeast Region, by State (Major States), 1961-1974

Year	Georgia	South Carolina	North Carolina	Alabama	Region
			(lbs)		
1961	354	337	377	327	338
1962	369	373	327	371	363
1963	453	405	449	511	461
1964	467	496	470	512	488
1965	467	486	287	505	453
1966	398	442	290	392	392
1967	408	449	277	282	356
1968	322	352	310	362	342
1969	351	342	287	405	363
1970	373	349	464	453	410
1971	466	412	371	551	476
1972	395	435	337	470	427
1973	499	473	455	423	459
1974	480	456	440	431	451

Sources

USDA, ERS. Statistics on Cotton and Related Data, 1920-1973, 1974.
USDA, ERS. Cotton Situation, 1975.

Heavy dependence on DDT in cotton production was related to the control of the boll weevil and the bollworm. However, Dr. Brazzel of the USDA testified that DDT used for boll weevil control also destroys beneficial predators of bollworms (Tr:307, App. 1:159, 161). Also, evidence presented indicated that cotton insect pests are resistant to DDT and that methyl parathion was the most commonly used insecticide to control the boll weevil in every state but Mississippi (Tr:6332-6334, App. 5:1940).

Cotton entomologists participating in the DDT Hearings generally agreed that a successful boll weevil "diapause" control program, which tends to reduce insecticide use, would contribute to the effective control of the bollworms. This particular control program includes the destruction of cotton plant refuse after harvest and the use of insecticides prior to the boll weevil's diapause. Since this practice delays the use of insecticides until late in the growing season of the year, bollworm predator populations are given some protection.

Testimony at the 1972 Hearing presented DDT alternatives for the control of cotton pest infestations. Methyl parathion and carbaryl were two insecticides available for bollworm control and the merits of the boll weevil diapause program were stated. In addition, the possibility of future implementation of sex traps, sterilized insects, and trap crops were mentioned (Tr: 314 p. 15, App. 1:166-167 and Tr:191, App. 1:102).

Dr. Young of Mississippi State indicated that within 3 to 5 years the bollworm will have established a very strong resistance to DDT, as well as other insecticides (Tr:102, App. 1:13). Dr. Newsome of Louisiana State University contributed to this contention, since he believed that overuse of insecticides by cotton producers would hasten the development of cotton pest resistance mechanisms (Tr:102, App. 2:737).

Historically more insecticides have been used for cotton than for any other domestic agricultural crop. Insecticides have contributed to cotton production, but extensive use of insecticides has contributed to pest management problems due to development of resistance in pests.

Shortly after World War II, chlorinated hydrocarbons were successfully introduced as effective pest controls for cotton. However, many target pests proved to be very adaptive and developed a resistance to these pesticides (Adkisson, 1973).

The resistance problem was initially met with greater quantities of the chlorinated hydrocarbons by increasing the number of applications or the rate per acre. Also, cotton producers began to use new chemicals (e.g., organophosphates or carbamates) or they combined different chemicals to achieve either a broader spectrum of control or a higher probability of target pest decimation (NAS, 1974).

Both the increased quantity of insecticides as well as the use of different compounds have had a detrimental impact on populations of natural predators. Natural predator reduction contributed to larger infestations of the increasingly resistant primary pests and enabled secondary problem insects to achieve primary pest status (Adkisson, 1973).

In certain cotton producing regions, the chemicals used for boll weevil control enabled the bollworms to surpass the initial target pest in terms of importance. Also, the tobacco budworm has attained a high level of resistance to chlorinated hydrocarbons, organophosphates, and carbamates, which will hinder control in the future (Adkisson, 1973).

At the Annual Conference on Cotton Insect Research and Control in 1972,[1/] eight insect pests were declared resistant to DDT in one or more states (Table IIID.9). The bollworm and tobacco budworm were each determined to be resistant to DDT in several southeastern states, as of 1972 (Table IIID.10). DDT was recommended only for 3 of the 21 insects cited as cotton pests at the 1972 conference: bollworms, budworms, and cutworms (Table IIID.10). Alternatives to DDT were recommended for each of these three pests.

Data since 1972

Chemical alternatives

By 1975, the Annual Cotton Conference recommended several additional alternatives to DDT for the bollworm and budworm (Table IIID.11). However, only three chemicals were recommended for cutworms. This conference also cited numerous promising new future chemical controls for the bollworm, but only three for the budworm, and none for cutworms (Table IIID.11).

A review of EPA registration data indicates several alternatives to DDT for control of cotton insect pests for which DDT was considered essential by the USDA (Table IIID.12) (DDT Hearing Admission 2). There may be other alternative controls than those listed in Table IIID.12, which held registrations since 1972 or were recommended by the states. Alternatives to DDT are not equally efficacious or economically feasible in all areas due to pest resistance and other factors.

Under EPA's Substitute Chemical Program, a series of Minieconomic Reviews have been conducted on the efficacy and cost effectiveness of various chemicals for control of cotton insect pests. These reviews contain surveys of available literature and data on the capacity of substitute chemicals to control target pests and return a profit over costs when used by the grower.

[1/] The recommendations of the "Annual Conference" are based on the best available current research data known by representatives of the various cotton states and are generally followed in making recommendations to growers on controls for cotton pests.

Table IIID.9

Cotton Insect Pests Stated to be Resistant to DDT, 1972

Pest	States
Bollworm	Alabama, Arkansas, Arizona, California, Georgia, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, North Carolina, Texas
Cabbage looper	Arizona, Georgia, Tennessee, Texas
Cotton leafperforator	Arizona
Lygus bugs	Arizona, California
Southern garden leafhopper	California
Tobacco budworm	Alabama, Georgia, Louisiana, Mississippi, North Carolina, Texas, Arizona
Saltmarsh caterpillar	Arizona, California
Pink bollworm	Texas

Source: USDA, ARS. 25th Annual Conference Report on Cotton Insect Research and Control, Memphis, Tennessee, January 11-12, 1972.

Table IIID.10

Recommended Dosages of Technical Material in a Dust or Emulsion Spray for the Principal Insecticides Used for the Control of Cotton Insects[a] (1972)

Insecticide	Boll weevil	Bollworm or tobacco budworm	Cabbage looper	Cotton aphid	Cotton leaf perforator	Cotton leafworm	Cutworms	Fall armyworm
	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre
aldicarb(Temik)[b]	--	--	--	0.30-0.5	--	--	--	--
azinphosmethyl[c]	0.25-0.5	--	--	--	--	0.25-0.5	--	--
bacillus thuringiensis[d]	--	--	4 to 8x10^9	--	--	--	--	--
carbaryl	1.00-2.5	1.00-2.5	--	--	2.0	1.00-2.5	1.00-1.5	1.00-2.0
carbophenothion	--	--	--	0.20-1.0	--	--	--	--
DDT[h]	--	1.00-3.0	--	--	--	--	1.0	--
demeton	--	--	--	0.12-0.38	--	--	--	--
dicrotophos(Bidrin)	--	--	--	0.10-0.5	--	--	--	--
disulfoton[e]	--	--	--	0.50-1.0	--	--	--	--
endosulfan	--	--	1.0	--	--	--	--	--
endrin	0.5	0.30-0.6	--	--	--	--	0.20-0.4	--
ethion	--	--	--	0.20-1.0	--	--	--	--
EPN	0.5	1.0	--	--	--	--	--	--
malathion[c]	1.00-2.0	--	--	0.30-1.0	--	0.25-1.25	--	--
methyl parathion	0.20-1.0	1.00-2.0	1.0	0.25-0.5	1.0	0.12-0.38	--	0.25
Methyl Trithion[f]	0.5	--	--	0.20-0.5	--	--	--	--
monocrotophos (Azodrin)	0.60-1.0	0.60-1.0	0.60-1.0	0.3	--	--	--	-- --
parathion(ethyl)	--	--	--	0.10-0.5	--	0.12-0.25	--	--
phorate[g]	--	--	--	0.50-1.5	--	--	--	--
phosphamidon	--	--	--	0.12-0.5	--	--	--	--
Toxaphene	2.00-4.0	--	--	--	--	2.00-3.0	2.00-4.0	--
trichlorfon	--	--	--	--	1.00-1.5	--	1.00-1.5	0.50-1.0

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[a] For information on recommended insecticides for the following insects see source report: Beet armyworm, p. 46; darkling beetles, p. 56; field crickets, p. 72; seed corn maggots, p. 63; whitefringed beetles, p. 69; wireworms, p. 69; yellowstriped and western yellowstriped armyworms, p. 70.

[b] In-furrow granule treatment at planting.

(continued on next page)

Table IIID.10 (continued)

Insecticide	Cotton fleahopper	Garden webworm	Grass-hoppers	Lygus bugs & other mirids	Pink bollworm	Saltmarsh cater-pillar	Stink bugs	Thrips
	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre
aldicarb[b]	0.60-1.0	--	--	0.60-1.0	--	--	--	0.30-0.5
azinphosmethyl	0.10-0.25	--	--	0.10-0.25	0.50-1.0	--	--	0.08-0.25
carbaryl	0.50-1.5	1.25-2.5	1.2	0.70-2.0	2.00-2.5	2.0	1.25-2.5	0.35-1.0
diazinon	--	--	--	--	--	1.0	--	--
dicrotophos (Bidrin)	0.10-0.4	--	--	0.10-0.4	--	--	--	0.10-0.25
dimethoate	0.10-0.4	--	--	0.10-0.5	--	--	--	0.10-0.2
disulfoton[e]	--	--	--	--	--	--	--	0.50-1.0
endosulfan	--	--	--	--	--	--	1.0	--
malathion	0.70-1.0	1.00-2.0	1.00-2.0	0.70-1.0	--	--	--	0.40-0.7
methyl parathion	0.25-0.5	0.25-0.5	0.25-0.5	0.25-0.5	--	1.0	0.50-1.0	0.12-0.5
Methyl Trithion	0.5	--	--	--	--	--	--	0.12-0.25
monocrotophos	0.25-0.5	--	--	0.25-0.5	0.60-1.0	--	--	--
naled	--	--	0.25-0.5	--	--	--	--	--
parathion	0.25-0.5	--	--	0.5	--	--	0.50-1.0	--
phorate[g]	--	--	--	--	--	--	--	0.50-1.5
phosphamidon	0.50-1.0	--	--	0.50-1.0	--	--	--	0.25-0.5
Toxaphene	1.00-4.0	2.00-4.0	1.50-3.0	1.60-4.0	--	--	--	0.50-1.5
trichlorfon	0.25-1.0	0.50-1.0	--	0.25-1.5	--	1.00-1.5	1.00-1.5	--

[c] Azinphosmethyl and malathion may be applied ultra-low volume as technical material at 0.125-0.25 and at 0.5-1.2 lbs/acre, respectively.

[d] International units (1 to 2 quarts) per acre.

[e] In-furrow granule at planting. Seed treatment for cotton aphid and thrips control at 0.25 to 0.5 lb/cwt seed.

[f] Research indicates that higher dosages of Methyl Trithion than those registered are required in some areas.

[g] In-furrow granule treatment at planting. Seed treatment at 0.25 to 1.5 lbs/cwt seed.

[h] Pending the final decision by the Administrator of EPA recommendations for the use of DDT for the control of certain insects on cotton are included in this report.

Source: USDA, ARS. <u>25th Annual Conference Report on Cotton Insect Research and Control</u>, Memphis, Tennessee, January 11-12, 1972.

Table IIID.11

Recommended and Promising Controls for Bollworms, Budworms, and Cutworms Advocated by the 1972 and 1975 Annual Conferences on Cotton Insect Research and Control

Pest	1972 Recommended Controls	1975 Recommended Controls	Future Promising Controls in the Field
Bollworm	carbaryl endrin EPN methyl parathion Azodrin (monocrotophos) DDT	carbaryl endosulfan endrin EPN methyl parathion Azodrin (monocrotophos) Toxaphene Chevron Ortho 9006 (Monitor) chlordimeform methomyl	Orthene (acephate) Bay NTN 9306 carbofuran Cela S-2957 Lorsban (chorpyrifos) Ciba-Geigy CGA 18809 FMC 33297 Hoechst HOE 2960 Leptophor Zectran (mexacarbate) NPV San I 52, 159 Stauffer N-2596
Budworm	carbaryl endrin EPN methyl parathion Azodrin (monocrotophos) DDT	carbaryl endosulfan endrin EPN methyl parathion Azodrin (monocrotophos) Toxaphene Chevron Ortho 9006 (Monitor) chlordimeform methomyl	Bay NTN 9306 FMC 33297 NPV
Cutworm	carbaryl endrin Toxaphene trichlorfon DDT	carbaryl Toxaphene trichlorfon	

Sources

USDA, ARS. 25th Annual Conference Report on Cotton Insect Research and Control, Memphis, Tennessee, January 11-12, 1972.

USDA, ARS. 28th Annual Conference Report on Cotton Insect Research and Control, New Orleans, Louisiana, January 6-8, 1975.

Table IIID.12

Alternatives to DDT for Control of Cotton Insect Pests, 1974

Pest	Alternative	
Boll Weevil	aldicarb	malathion
	azinphosmethyl (Guthion)	methidathion
	carbaryl	methyl parathion
	dicrotophos (Bidrin)	monocrotophos (Azodrin)
	endosulfan	parathion
	endrin	Strobane
	EPN	Toxaphene
Cotton Bollworms (*Heliothis zea* and *Heliothis virescens*)	azinophosmethyl (Guthion	methomyl
	carbaryl	methyl parathion
	chlordimeform hydrochloride	monocrotophos (Azodrin)
	dicrotophos (Bidrin)	naled
	endosulfan	parathion
	endrin	Strobane
	EPN	Toxaphene
	methidathion	
Cotton Fleahopper	aldicarb	malathion
	azinphosmethyl (Guthion)	naled
	carbaryl	parathion
	carbophenothion	phosphamidon
	dicrotophos (Bidrin)	Strobane
	dimethoate	Toxaphene
	EPN	trichlorfan
Fall Armyworm	carbaryl	malathion
	endrin	methyl parathion
Garden Webworm	azinphosmethyl (Guthion)	methyl parathion
	carbaryl	parathion
	endrin	Strobane
	malathion	Toxaphene
Lygus Bugs	aldicarb	monocrotophos (Azodrin)
	azinphesmethyl (Guthion)	naled
	carbaryl	oxydemetonmethyl
	dicrotophos (Bihrin)	parathion
	dimethoate	phosphamidon
	endrin	Strobane
	malathion	Toxaphene
	methyl parathion	trichlorfan
Thrips	aldicarb	malathion
	azinphosmethyl (Guthion)	methyl parathion
	carbaryl	Monitor
	demeton	monocrotophos (Azodrin)
	dicrotophos (Bidrin)	parathion
	dimethoate	phorate
	disulfoton	phosphamidon
	endosulfan	Strobane
	endrin	Toxaphene
	EPN	
Cutworm	carbaryl	Strobane
	endrin	Toxaphene
	methyl parathion	trichlorfan

Source: EPA, *Summary of Possible Alternative Registered Pesticides for DDT Insecticides*, 1974.

Information on efficacy and cost effectiveness is exerpted from several reviews of alternatives to DDT in control of cotton pests and presented in Appendix IIID.1 of this report (parathion, methyl parathion, aldicarb, and malathion). Although current (1974) efficacy and cost effectiveness data are limited, there are indications that these chemicals can serve effectively to control the cotton pests once controlled by DDT combinations. Whether an alternative is effective in a given state or area depends greatly on how long the chemical has been used and at what intensity. Additional reviews of DDT alternatives are in progress under the Substitute Chemical Program.

Improved use of chemical and nonchemical alternative controls

Substantial economic and environmental benefits can be obtained by use of the least hazardous pesticides, and by their use only in line with economic thresholds of pest infestation, i.e., when the level of infestation actually justifies use. There has been a tendency to use insecticides on a regular schedule as part of a cotton growing program designed to insure against insect pest damage, with little or no regard for whether an infestation exists. Increasingly during recent years interested Federal Agencies, such as USDA and EPA, the states, and industry have promoted so-called integrated pest management programs, which are usually devoted to improved use of both chemical and nonchemical controls of cotton pests.

Integrated pest management (IPM) is a concept which will probably become more prevalent as a control of cotton pest infestations. It appears to be slowly gaining acceptance in many different regions of the country, even though many of the basic concepts are from 50 to 70 years old. Publicly run IPM programs have been encouraged in at least three states for 10 years or longer. These states are Alabama, Arkansas, and Texas.

The objective of the concept is to improve pest control systems. An IPM program normally has three goals:

1. Diagnosis of the pest problem (by scouting, also referred to as "field checking"; pest trapping; and/or other methods).

2. Determination if and when intervention (pest suppression) is required (mostly based on damage thresholds).

3. Suppression of the pest(s) by the most appropriate tool(s) available.

IPM programs vary from state to state, but most are oriented toward improved insect control by delayed chemical application. The delay of insecticide applications facilitates population growth of natural predator insects, which helps to control the pests. A number of programs have made progress in the use of the most appropriate tool(s) available, e.g., biological or cultural controls, as well as in improved pest diagnosis and suppression.

In states with publicly run IPM, program participants apply insecticides only on a recognized need basis, rather than treating according to a designated time schedule. This approach is not as sophisticated as some integrated pest management programs, but it has generally contributed to a 30 to 40% reduction in the number of insecticide applications.

Specifically, in the Texas High Plains reproductive-diapause boll weevil control effort, a comparison of expected insecticide use with and without an IPM program indicated an 82% decline in the treatment level over a 10-year period. For that region, it meant a reduction of 8,240,000 lbs of chemicals such as malathion, Toxaphene, methyl parathion, azinphosmethyl, and Bidrin. This involved a $12 million decrease in production costs, while 76,000 bales of cotton were added to the total yield. Also, no adverse effects on wildlife (especially beneficial insects), domestic animals, or human beings have been detected (Lacewell and Casey, 1974).

In another program conducted in a previously high insecticidal use area, strong positive results were demonstrated by an IPM program at Pecos Station, Texas. During 1968-1970, insecticidal application was initiated based on accurate assessment of insect populations in the field. System support was provided by good crop management, including a diversified cropping system which supported beneficial insect populations naturally. The experiment demonstrated that Pecos area cotton producers could reduce their treatment costs by over 90%; saving over $60/acre (Pate et al, 1972).

Initiation of IPM programs for cotton production requires intensive grower education programs. These education programs center around workshops for pest scouting. In Arkansas a small industry of consultants specializes in private scouting.

In recent years, the US Department of Agriculture has assumed a much stronger role through federally funded IPM programs. In 1974, 14 states were involved in cotton scouting programs. Initially implemented as 3-year projects, funding from USDA was formula distributed in each state through the Cooperative Extension Service. In addition to required proof of economic feasibility to the growers, these projects had to provide insect control comparable or better than customary practices.

Grower participation has increased significantly since the 1972 initiation of the 3-year programs. In 1972, only 549,000 acres were involved in the programs compared to 868,000 acres projected for 1974 (6% of the plantings).

Less than 20,000 acres were in each of the federally sponsored programs in New Mexico, Missouri, and Oklahoma; but in many states over 20% of the cotton acreage was committed to IPM programs. These states included Arkansas with 250,000 acres; Alabama with 154,000 acres; South Carolina with 115,000 acres; and Arizona with over 50,000 acres (Good, 1974). Additional acreages (often sizable) in these states were scouted by private consultants.

In the future, as confidence increases with the use of these controls, more fully integrated pest management programs can be expected. As these programs progress by upgrading field checking capabilities, expanding data bases of actual field histories, and experimenting with artificially introduced predators and parasites, more sophisticated biological and cultural controls can be expected. However, it has been stated that IPM systems are not being actively promoted by Federal regulatory agencies despite their potential for the future (RvR Consultants, 1974).

Presently, a bacterial spore formulation of *Bacillus thuringiensis* is registered for use on cotton, but the level of control is not as consistent as existing chemical insecticides. This particular pathogen has potential, since strains 15 to 20 times more effective than earlier varieties have been developed. However, additional research is needed to improve upon the pathogen's insecticidal properties (USDA, ASCS, 1973).

A class of microorganisms that is often mentioned for cotton pest control is the nuclear polyhedral viruses (NPV). Viral diseases have been stated to be highly effective against the cabbage looper, since pest destruction occurs before yield-reducing damage results (USDA, ERS, 1970). Also, there is an experimental permit to use Heliothis virus to control bollworms (USDA, ASCS, 1973).

However, one study indicated that the following characteristics of pathogenic controls merit increased attention before widespread acceptance can occur (NAS, 1974)[1/]:

1. Longer shelf life
2. Greater persistence
3. Ease of application
4. More reliable and consistent control of the target pest
5. Lower cost
6. Capability of meeting EPA registration standards

[1/] A study of the commercial potential of new generation pesticides, including cotton insecticides, has been funded under EPA's Substitute Chemicals Program which will give added data on the potential for biological and other novel controls. The study is to be completed by Fall 1975.

Insects that are either exotic or indigenous to cotton producing areas can be used for pest control purposes (NAS, 1974). Some scientists have advocated searching Central America and Mexico to find exotic predators. It has also been suggested to mass rear natural cotton predators for release in areas of heavy infestation. However, large-scale rearing of predators has not yet been tried, and exotic predator importation has not been successful.

Some of the indigenous insects found in different producing regions considered helpful to control cotton pests include lady beetles, nabids, parasitic wasps, minute pirate bugs, and the larvae of green lacewing (Ledbetter, 1972).

In 1972 one specific biological control program released sterilized pink bollworm moths in the San Joaquin Valley of California (USDA, ASCS, 1973). About 282 million moths were reared in Phoenix, Arizona, and over 99 million were sterilized for release, to prevent the establishment of the pink bollworm in California. Surveillance with a large number of attractant-baited traps indicated that the project was successful.

Another biological control is the use of cotton plant varieties that have characteristics incompatible to pests (NAS, 1974). For instance, crops that mature for harvest in late August or early September, rather than October or November, reduce the opportunity for tobacco budworms to inflict heavy damage. There is also a frego-bract variety of cotton that is resistant to the boll weevil and a nectarless variety that is moderately resistant to Lygus bugs and fleahoppers and slightly resistant to the bollworm complex (Shuster and Maxwell, 1974 and Jenkins and Parrot, 1971).

Trap crops are one cultural technique that can reduce damage related to infestations. A small portion of the cotton field can be planted early to attract overwintering boll weevils. The trap crop can then be treated with an insecticide, shredded, and plowed under the soil (NAS, 1974).

Alfalfa can be used as a trap crop specific to Lygus bugs, since this insect prefers alfalfa to cotton as a food source. Alfalfa can be planted in areas of heavy infestations and treated with relatively small amounts of insecticides for control (Presley, 1972).

There are other cultural pest control practices that merit brief attention. Cotton producers have used desiccants and defoliants to facilitate rapid harvest and to force a shedding of fruiting forms that are food sources for certain pests. Plant stalks can also be destroyed and plowed under, since the stalks may harbor overwintering pests. Diversified cropping may be used to increase populations of beneficial insects. Also, the use of mechanical strippers, rather than spindle pickers, will leave fewer harmful larvae in the fields after harvest (NAS, 1974).

Conclusion

DDT substitute chemicals are available for cotton pest control. The chemical substitutes are generally effective, but pest resistance problems are encountered in some areas.

In addition, IPM programs are substitutes for DDT use in cotton production. These programs can combine chemical, biological, and cultural controls and may achieve results comparable on better than conventional cotton pest control practices. However, most IPM programs are still in the initial stages of development and implementation.

INSECTICIDE USE PATTERNS

Data as of 1972

At the time of the DDT Hearings and the decision in 1972, limited current data were available on insecticide use patterns. There were estimates that up to 38% of the cotton acreage was treated with DDT (Tr:6171-6172), which accounted for as much as 85% of domestic DDT use (soybeans, 5%; peanuts, 9%; and other uses, 1%) (Order of Administrator, p.2). The 1964 and 1966 USDA surveys were the most recent data. Since that time, USDA has conducted a survey for the year 1971 (published in 1974) and private market research data are now available and will be discussed herein.

USDA data: 1964, 1966, and 1971 surveys

Historically more insecticides are used in cotton production than any other domestic agricultural crop. From three insecticide use surveys conducted by the ERS of the USDA for 1964, 1966, and 1971, cotton was estimated to account for 55.6%, 47.2%, and 47.6% respectively, of all agricultural crop insecticides (USDA, ERS, 1968; USDA, ERS, 1970; USDA, ERS, 1974). For these 3 years, DDT accounted for 31.2%, 29.6%, and 17.9% of the total cotton insecticides and represented 74.1%, 73.0%, and 94.0% of the total DDT used on crops.

A profile of quantities of the various insecticides used in cotton production prior to the cancellation of DDT is provided in Table IIID.13 and provides a basis to study past trends. While Toxaphene, exhibited stability of consumption, use of DDT declined from over 23 million pounds in 1964 to near 13 million in 1971. Conversely, organophosphate use about doubled.

The USDA pesticide use surveys indicate a similar pattern on the basis of cotton acreage treated with various insecticides (Table IIID.14). Quite clearly DDT use was on the decline (and the use of organophosphates on the increase) prior to the 1972 cancellation order.

Table IIID.13

Quantities of Selected Types of Insecticides Used on Cotton, United States, 1964, 1966, and 1971

Type of Insecticide Product	1964	1966 (1,000 lbs)	1971
Inorganic Insecticides	2,518	--	69
Botanicals and Biologicals	NA	2	--
Synthetic Organic Insecticides			
Organochlorines			
Lindane	540	163	--
Strobane	NA	2,016	216
TDE (DDD)	191	167	--
DDT	23,588	19,213	13,158
Methoxyclor	NA	6	--
Endrin	1,865	510	1,068
Heptachlor	--	--	--
Dieldrin	--	11	65
Aldrin	17	123	--
Chlordane	NA	3	--
Endosulfan	NA	61	--
Toxaphene	26,915	27,345	28,112
Others	2,660	85	--
Total	55,778	49,703	42,619
Organophosphorous			
Disulfoton	565	300	225
Bidrin	NA	1,857	778
Methyl Parathion	8,760	7,279	22,983
Parathion	1,636	2,181	2,560
Malathion	1,811	559	670
Demeton	47	NA	NA
Diazinon	--	--	--
Trichlorfon	NA	963	144
Azinophosmethyl	250	200	288
Phorate	10	--	100
Ethion	NA	73	6
Other	2,177	212	1,617
Total	15,196	13,624	29,376
Carbamates			
Bux	NA	NA	--
Carbaryl	4,510	1,571	1,214
Carbofuran	NA	NA	--
Methomyl	NA	NA	40
Others	NA	--	37
Total	4,510	1,571	1,291
Other Synthetic Organics	14	--	2
Total Synthetic Organics	72,978	64,898	73,288
Total Insecticides (Not Including Petroleum)	78,016	64,900	73,357
Petroleum	6	468	8
Total Insecticides	78,022	65,368	73,365

Sources

USDA, ERS. Quantities of Pesticides Used by Farmers in 1964, 1968.
USDA, ERS Quantities of Pesticides Used by Farmers in 1966, 1970.
USDA, ERS. Farmers' Use of Pesticides in 1971 - Quantities, 1974.

Table IIID.14

Acres of Cotton Treated with Selected Types of Insecticides United States, 1964, 1966, and 1971

Type of Insecticide Product	1964	1966	1971
		(1,000 acres)	
Inorganic Insecticides	57	--	23
Botanicals and Biologicals	NA	8	--
Synthetic Organic Insecticides			
Organochlorines			
Lindane	636	208	--
Strobane	NA	225	18
TDE (DDD)	61	33	--
DDT	6,901	4,767	2,383
Methoxychlor	NA	6	--
Endrin	1,194	403	262
Heptachlor	negligible	--	--
Dieldrin	--	36	174
Aldrin	16	161	--
Chlordane	NA	6	--
Endosulfan	NA	56	--
Toxaphene	5,016	3,881	3,275
Others	428	285	
Organophosphorus			
Disulfoton	619	473	553
Bidrin	NA	1,416	1,797
Methyl Parathion	5,420	3,577	6,384
Parathion	751	860	682
Malathion	213	245	273
Demeton	322	NA	--
Diazinon	--	--	--
Trichlorfon	NA	512	191
Azinophosmethyl	641	222	119
Phorate	35	NA	182
Ethion	NA	26	30
Others	2,236	534	1,216
Carbamates			
Bux	NA	NA	--
Carbaryl	1,002	415	244
Carbofuran	NA	NA	--
Methomyl	NA	NA	84
Others	NA	--	66
Other Synthetic Organics	102	--	24
Petroleum	NA	71	11

Sources

USDA, ERS. Quantities of Pesticides Used by Farmers in 1964, 1968.
USDA, ERS. Quantities of Pesticides Used by Farmers in 1966, 1970.
USDA, ERS. Farmers' Use of Pesticides in 1971 -- Quantities, 1974.

Therefore, it would appear that DDT and other chlorinated hydrocarbons were diminishing in importance as factors of production in cotton at the national level. Conceivably, if EPA had not issued the cancellation order, factors such as development of DDT-resistant cotton pests and effective chemical and nonchemical substitutes would have contributed to further decline in the chemical's importance.

The USDA surveys did not provide use pattern data by region for individual chemical/crop combinations such as DDT on cotton.

Data since 1972

The above USDA data on cotton insecticide use at the national level are complemented with market research data which show more recent national trends and use patterns of DDT and other insecticides by regions of the United States. These data are utilized to obtain a picture of shifts after the cancellation in the number of farms and acres with treatment of DDT, treatment with other insecticides and with no treatment. In this analysis, data are presented for the 2 years prior to cancellation (1971-1972 average) and for 2 years since (1973-1974 average). Table IIID.15 contains a summary of use pattern data for these 2 periods.

Review of these data indicates:

1. DDT treatments were used on about 17% of US cotton farms in 1971-1972 (18,744 out of a total of 110,724 cotton farms in the US). An additional 32,066 farms (29% of the total) treated with other insecticides, while slightly more than half of US cotton farms used no insecticide treatment on cotton (59,914 farms or 54% of US total).

2. DDT treatments averaged 11.7 million acre applications out of a total of 47.0 million acre applications with cotton insecticides (25% of the US total). 1/ This resulted in 51.8% of US cotton acreage being treated one or more times per year during the 1971-1972 period with the overall average number of applications being 7.3.

1/ An acre application is the use of a chemical or chemical combination on one acre one time. The number of acre applications exceeds the number of acres treated if there are multiple treatments during the year. For example, a farmer treating five times on 100 acres of cotton would have 500 acre applications even though his total treated acreage is only 100 acres.

Table III0.15

DDT Cotton Insecticide Use Patterns in US, by Region, 1971-1972 and 1973-1974 Averages

	South Atlantic		East South Central		West South Central		All Other Regions		Total US	
<u>1971-1972</u>	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Number of farms										
DDT treatments	9,516	(56)	8,576	(20)	--	--	--	--	18,744	(17)
Other treatments	3,764	(22)	14,904	(35)	10,578	(24)	2,472	(43)	32,066	(29)
No treatments	3,706	(22)	18,815	(45)	32,846	(76)	4,547	(57)	59,914	(54)
Total farms	16,986	(100)	42,296	(100)	43,424	(100)	8,019	(100)	110,724	(100)
Number of acre applications (in thousands)										
DDT treatments	5,217	(55)	6,319	(23)	--	--	--	--	11,738	(25)
Other treatments but no DDT	4,216	(45)	20,814	(77)	5,394	(100)	5,046	(100)	35,268	(75)
Total acre applications	9,438	(100)	27,133	(100)	5,394	(100)	5,046	(100)	47,006	(100)
Total acres treated - any chemical[a] (in thousands)	917	(93.1)	3,144	(74.8)	1,486.5	(25.4)	954	(58.7)	6,501	(51.8)
Acres treated/farm	69.1	--	133.9	--	140.5	--	274.8	--	127.9	--
Number of applications/acre	10.27	--	8.62	--	3.6	--	5.29	--	7.3	--
<u>1973-1974</u>										
Number of farms										
DDT treatments	--	--	--	--	--	--	--	--	--	--
Other treatments	11,544	(83)	29,302	(64)	16,662	(33)	6,776	(59)	64,284	(52)
No treatments	2,304	(17)	16,789	(36)	34,454	(67)	4,622	(41)	58,170	(48)
Total farms	13,848	(100)	46,090	(100)	51,116	(100)	11,400	(100)	122,454	(100)
Number of acre applications (in thousands)										
DDT treatments	--	--	--	--	--	--	--	--	--	--
Other treatments	11,032	(100)	30,355	(100)	7,482	(100)	2,261	(100)	51,140	(100)
Total acre applications	11,032	(100)	30,355	(100)	7,482	(100)	2,261	(100)	51,140	(100)
Total acres treated - any chemical[a] (in thousands)	820.5	(92.9)	3,550	(82.7)	1,810	(29)	1,281	(67.4)	7,463	(55.9)
Acres treated/farm	71.1	--	121.2	--	96.2	--	189	--	116.1	--
Number of applications/acre	13.41	--	8.55	--	4.13	--	1.76	--	6.79	--

a/ Percent of total cotton acreage in region treated one or more times (any insecticide).

Source: EPA computations based on <u>Special Pesticide Market Research Survey Information for EPA, Office of Pesticide Programs</u>, 1975

3. DDT was used only in the South Atlantic and East South Central Regions (regional definitions provided on Figure IIID.4).

4. The South Atlantic Region was more dependent on DDT, as more than half of its cotton farms used it compared with less than one-fourth of the farms in the East South Central Region. More than 90% of cotton was treated with an insecticide in the South Atlantic Region compared with only 75% in the East South Central. The number of applications per year was also greater in the South Atlantic (10.3 compared with 8.6).

5. Acreage treated per farm is considerably smaller in the South Atlantic than in the East South Central Region (69.1 acres compared with 133.9 acres in 1971-1972).

6. In 1973-1974, total cotton acreage and the number of farms declined in the South Atlantic Region while increases occurred in the East South Central Region

7. The percentage of acreage treated one or more times remained near 93% in the South Atlantic Region in the pre- and postcancellation periods while it increased quite significantly in the East South Central Region (from 74.8% to 82.7%).

8. The number of applications per year increased between the pre- and postcancellation periods in the South Atlantic Region (from 10.3 to 13.4 treatments per year) while remaining essentially constant in the East South Central Region at near 8.6 treatments per year.

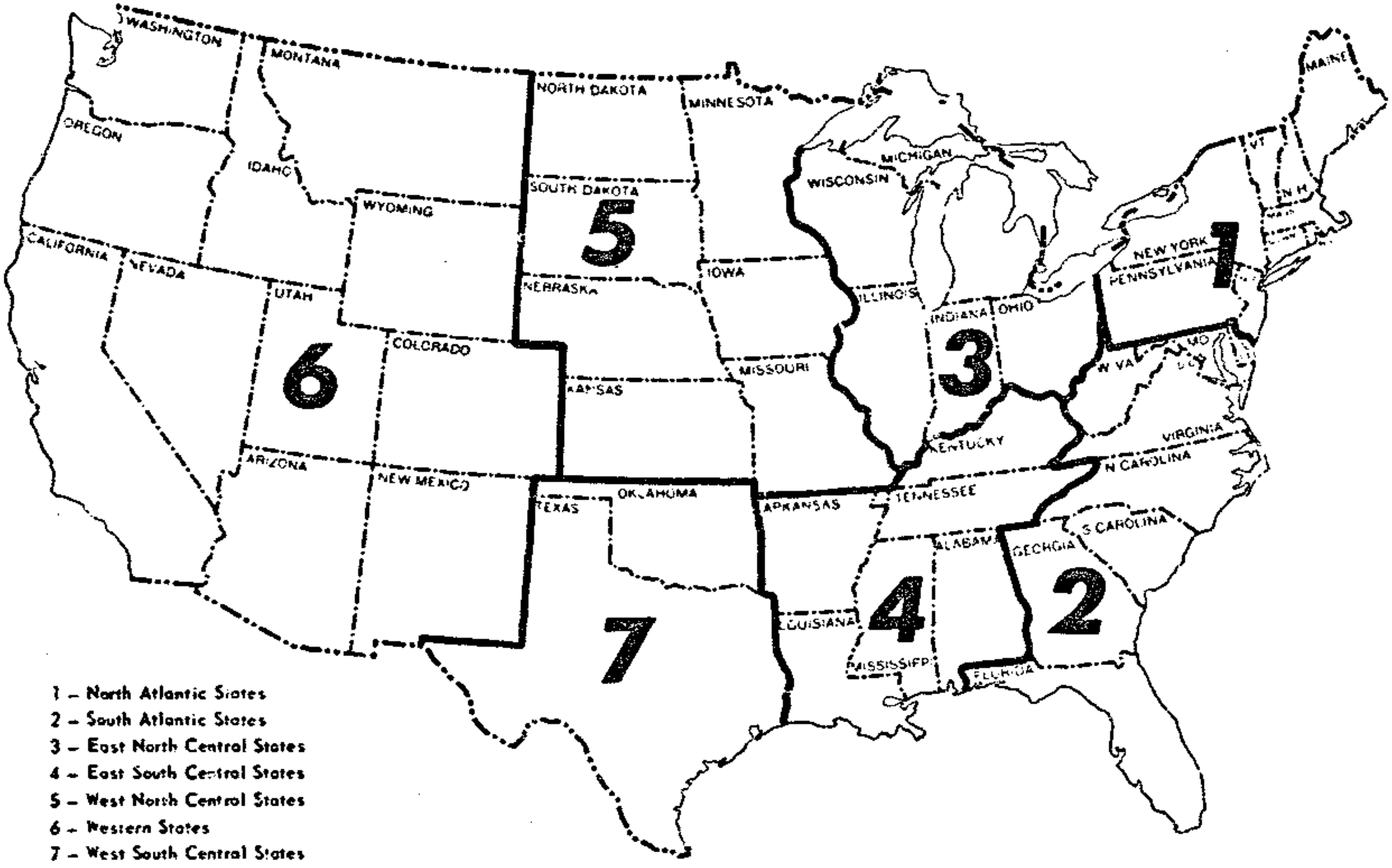
9. The percentage of farms treating with one or more insecticide treatments increased between the pre- and postcancellation periods in both regions (from 78% to 83% in the South Atlantic and from 55% to 64% in the East South Central Region).

Conclusion

DDT was widely used as a cotton insecticide through 1972, although its importance was on the decline. By 1971-1972 it was used on about one-sixth of US cotton farms, and it equalled about one-fourth of total cotton insecticide acre applications.

Figure IIID.4

SPECIAL PESTICIDE MARKET SURVEY: COTTON REGIONS



INSECT CONTROL COSTS

> *Administrator's Finding: By using methyl parathion or other means of pest control, cotton producers can generally produce satisfactory yields at acceptable cost.*

Data as of 1972

The DDT Hearing Record includes testimony by Dr. Ridgeway from Texas (Tr:2495) who referred to an unspecified study which estimated that the replacement of DDT with organophosphates would increase cotton production costs by $15 million (presumably per year). Ridgeway was not concerned as much by the $15 million production cost impact as by possible economic side effects on industry and regional economies that could be associated with cancellation.

Ridgeway contended that increased use of organophosphates after DDT's cancellation would accelerate the development of resistance mechanisms of cotton pests, which would increase the chance of not having adequate controls for cotton pests at some future time. Inadequate controls for cotton pests could force cotton production out of certain geographic regions, which would have economic impact on other segments of the local economy interrelated with cotton production.

Cooke of the USDA testified that use of Toxaphene and methyl parathion as substitutes for DDT would increase the number of insecticide applications, thus increasing cotton production costs. Also, Cooke submitted a USDA study (USDA, ERS, October 1970) which estimated that annual cotton insecticide and application costs would double (i.e., increase by about $54.5 million over those associated with present average insecticide practices) if DDT were cancelled (Tr:2472-2578).

The above estimate was limited to the Southeast, Appalachia, Delta States, and Southern Plains Regions. It was based on 1969 data and the two DDT substitutes Toxaphene and methyl parathion. Cooke indicated that the cost per treated acre in the regions would have increased $9.95 (or $5.24 for all cotton acres). Expressed in terms of 1970 data, the increased cost per pound of lint was 1.2 cents, which was estimated to be about a 5% increase in the cost of production.

Cooke also indicated that the relative increase in insecticide costs would be higher for low insecticide users relative to the high users (Tr: 2578). The insecticide cost per pound of lint produced by the high use farmers was estimated to increase from 4.38 cents to 5.09 cents. For the low use farmers the same cost item was estimated to change from 2.52 cents to 4.67 cents.

The above estimates of impact on the costs of cotton production ($15 million to $54 million per year) are much greater than those indicated by Dr. Headley, an economist from the University of Missouri who testified at the DDT Hearings. Dr. Headley testified that the cancellation of DDT would not have a significant (or adverse) effect upon the cotton economy (Tr:6180-6184), as he believed that pest control costs and the cotton market price would not be influenced by the unavailability of the chemical. This contention was based on the premise that only half of the cotton farms used any insecticide and further that only 38% used DDT. Also, Headley indicated that DDT use was concentrated in the Southeast, Delta States, and eastern half of the Southern Plains with larger farms probably using more DDT than small farms.

Data since 1972

Total expenditures, national level

Expenditures for insecticides to protect cotton have increased sharply since the cancellation. Nationally, annual average insecticide expenditures for cotton increased from $64.6 million in 1971-1972 to $102.9 million in 1973-1974, while the average number of acre applications per year increased only slightly (from 47.0 to 51.1 million) (Table IIID.16). Costs per acre application on the average increased from $1.38 in 1971-1972 to $2.01 in 1973-1974. Total insecticide costs per treated acre increased from $10.07 (7.3 applications x $1.38) to $13.65 (6.79 applications x $2.01).

The largest single shift from the use of DDT combinations obviously was to the use of Toxaphene/methyl parathion combinations, as total acre applications of this combination increased from 2.4 million to 10.4 million. Substantial increases are noted in several other individually named chemicals such as temik, galecron, guthion, and fundal plus endrin/parathion combinations and other miscellaneous combinations. These data at the national level are provided as general background for the review of changes in expenditures for cotton insecticides in the two regions in which DDT was used prior to the cancellation.

Total expenditures, regional level

Cotton insecticide expenditures are presented for the pre- and postcancellation periods for the South Atlantic and East South Central Regions of the US in Tables IIID.17 and 18 including data for all insecticides combined and individually for specific major pesticides including DDT combinations. Average annual expenditures increased very sharply in both regions in the postcancellation period compared to the precancellation period.

In the South Atlantic Region, average annual expenditures increased from $14.2 million per year in 1971/72 to $26.6 million in 1973/74 and from $1.51 to $2.41 per acre application. Costs per acre application more than doubled for ethyl and/or methyl parathion (from $1.89 to $4.35) and increased rather sharply for other miscellaneous combinations $1.37 to $2.53).

Table IIID.16

Average Annual Expenditures and Use of Cotton Insecticides in the US, 1971-1972 and 1973-1974

Type of Insecticide	Average Annual Expenditures (1,000 dollars)		Average Annual Acre Applications (1,000 acre appl.)		Average Cost per Acre Application (dollars)		Average Annual Number Farms Using Insecticides	
	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974
Bidrin	1,118	1,481	1,076	1,380	1.04	1.07	5,392	8,752
Azodrin	5,243	--	2,384	--	2.20	--	3,630	3,319
Di-Syston	391	1,640	220	746	1.78	2.20	1,644	4,950
Toxaphene	376	1,380	512	1,134	0.73	1.22	2,254	3,394
Toxaphene/methyl parathion	3,835	19,916	2,407	10,369	1.59	1.92	5,088	14,618
DDT/methyl parathion/ Toxaphene	15,008	--	11,402	--	1.32	--	17,905	--
Ethyl and/or methyl parathion	15,265	22,640	14,691	14,135	1.04	1.61	17,020	18,359
Temik	--	1,636	--	287	--	5.70	--	2,602
Galecron	--	3,399	--	2,790	--	1.22	--	5,026
Guthion	--	1,034	--	616	--	1.68	--	4,882
Fundal	--	1,320	--	954	--	1.38	--	1,312
Endrin/parathion	--	3,086	--	1,186	--	2.60	--	2,720
Other miscellaneous chemicals	10,296	16,179	6,214	6,930	1.66	2.33	20,046	26,072
Other miscellaneous combinations[a]	12,754	27,503	7,992	10,110	1.60	2.72	10,196	14,302
Unidentified	119	121	18	56	6.61	2.16	292	688
No answer	221	103	75	54	2.95	1.91	--	1,362
Total	64,631	102,930	46,978	51,140	1.38	2.01	50,810	64,283

[a] Includes DDT/Toxaphene treatment in the South Atlantic Region as reported in Table IIID.17

Source: EPA computations based on Special Pesticide Market Research Survey Information for EPA, Office of Pesticide Programs, 1975.

Table IIID.17

Average Expenditures and Use of Cotton Insecticides in South Atlantic Region, 1971-1972 and 1973-1974

Type of Insecticide	Average Annual Expenditures (1,000 dollars)		Average Annual Acre Applications (1,000 acre appl.)		Average Cost per Acre Application (dollars)		Average Annual Number Farms Using Insecticides	
	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974
DDT/methyl parathion/ Toxaphene	6,374	--	4,880	--	1.31	--	8,677	--
DDT/methyl parathion	434	--	336	--	1.29	--	840	--
Toxaphene/methyl parathion	--	3,445	--	2,125	--	1.62	--	3,224
Ethyl and/or methyl parathion	3,528	4,706	1,862	1,082	1.89	4.35	3,116	2,804
Other miscellaneous chemicals	2,323	5,629	1,210	2,724	1.92	2.07	8,508	13,711
Other miscellaneous combinations	1,548	12,718	1,126	5,026	1.37	2.53	4,150	7,654
Unidentified	--	121	--	56	--	2.16	--	688
No answer	16	3	8	8	2.00	0.38	453	320
Total users	14,226	26,624	9,432	11,032	1.51	2.41	13,280	11,544
Total nonusers	--	--	--	--	--	--	3,706	2,304

Source: EPA computations based on Special Pesticide Market Research Survey Information for EPA, Office of Pesticide Programs, 1975.

Table IIID.18

Average Expenditures and Use of Insecticides in the East South Central Region, 1971-1972 and 1973-1974

Type of Insecticide	Average Annual Expenditures (1,000 dollars)		Average Annual Acre Applications (1,000 acre appl.)		Average Cost per Acre Application (dollars)		Average Annual Number Farms Using Insecticides	
	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974	1971-1972	1973-1974
Bidrin	224	--	260	--	0.86	--	1,020	--
Toxaphene/methyl parathion	712	13,747	517	6,843	1.38	2.01	1,330	8,618
DDT/Toxaphene/ methyl parathion	8,343	--	6,319	--	1.32	--	8,576	--
Ethyl and/or parathion	8,601	11,864	10,442	9,915	0.82	1.20	9,102	10,363
Endrin/parathion	--	2,890	--	1,092	--	2.65	--	2,640
Other miscellaneous chemicals	6,351	8,012	4,726	5,110	1.34	1.57	8,753	17,806
Other miscellaneous combinations	5,999	15,616	4,825	7,346	1.24	2.13	5,648	7,714
Unidentified	--	--	--	--	--	--	--	--
No answer	116	72	34	34	3.41	2.12	223	720
Total users	30,348	52,202	27,133	30,354	1.12	1.72	23,481	29,302
Total nonusers	--	--	--	--	--	--	18,815	16,789

Source: EPA computations based on Special Pesticide Market Research Survey Information for EPA, Office of Pesticide Programs, 1975.

Total insecticide costs per treated acre more than doubled between 1971-1972 and 1973-1974, i.e., from \$15.51 (10.27 applications x \$1.51) to \$32.37 (13.43 applications x \$2.41). It is very difficult to determine which chemical combinations were used as alternatives to DDT combinations in the South Atlantic Region. Most of the increases in farms reporting insecticide use occurred in unspecified chemicals or combinations of chemicals (Table IIID.17).

During 1971-1972 cotton insecticide costs in the South Atlantic Region averaged \$1,071 per farm for all farms using insecticides (\$715 per farm for DDT combinations). Costs per farm more than doubled in 1973-1974 (\$2,306 per farm for all users) (average computed from Table IIID.17).

For the East South Central Region, average annual expenditures for cotton insecticides increased from \$30.3 million during the precancellation period to \$52.2 million after cancellation (Table IIID.18). Average costs per acre application increased from \$1.12 to \$1.72 and insecticide costs per treated acre increased from \$9.65 to \$14.71. In this particular region, ethyl and/or methyl parathion applications increased about 50% in contrast with a more than 100% increase in the South Atlantic Region.[1]

During 1971-1972 cotton insecticide costs in the E. South Central Region averaged \$1,292 per farm per year for all farms using insecticides (\$973 per farm for use of DDT combinations). These costs per farm increased by about 38% in 1973-1974 (from \$1,292 to \$1,781), considerably less than in the South Atlantic Region.

Impact of cancellation on insecticide costs

This part of the report is concerned with estimating the impact on the costs to cotton farmers for insecticide materials and application costs in the two regions where DDT was used prior to the cancellation, i.e., South Atlantic and East South Central (Tables IIID.17 and 18).

The procedure to be used in estimating impact of the DDT cancellation on cost is as follows:

1. The number of acre applications with DDT in 1973-1974 is the actual number of acre applications in the region, with all chemicals, times the percentage of acre applications which contained DDT in 1971-1972;

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[1] Average costs per acre application were generally lower in the East South Central Region than in the South Atlantic Region. In the precancellation period the average expenditures per acre application were \$0.39 (\$1.51 versus \$1.12) less in the East South Central Region and in the postcancellation period costs were \$0.69 less (\$2.41 versus \$1.72) (Tables IIID.17 and 18). The reduced number of acre applications of ethyl and/or methyl parathion together with substantial increases in costs of these insecticides suggest a shortage of such materials, particularly in the South Atlantic Region.

2. The cost of DDT combinations in 1973-1974 is estimated as the 1971-1972 cost per acre application for DDT combination plus 20% to allow for price increases at a rate of about 10% per year;

3. The cost of DDT alternatives in 1973-1974 is the actual average cost per acre application for all insecticides (some of which are not used as alternatives to DDT)[1];

4. Compute impact of DDT decision on insecticide costs as number of projected acre applications in 1973/74 with DDT times difference between DDT cost/acre application and other chemicals cost/acre application;

5. Add $1.00 per acre application for application costs assumed to be attributable to DDT cancellation, computed as the total change in acre applications between 1971-1972 and 1973-1974, times the percent of acre applications with DDT in 1971-1972.

Alternative methods could be used; however, this method is thought to give reasonable approximations of cost impact. Impact on yield and changes in crops grown which can affect costs and income (as well as acres grown and production) is not considered in this particular cost analysis.

South Atlantic Region

In the South Atlantic Region[2], DDT was used in two chemical combinations: 1) DDT with methyl parathion and Toxaphene, and 2) DDT with methyl parathion. These two DDT combinations accounted for an average annual expenditure of $6.8 million in 1971-1972 ($1.31 per acre application). This cost annually accounted for about 48% of the total cotton insecticide expenditures for 1971-1972 in the region which were $14.2 million ($1.51 per acre application). Also, the insecticide treatments containing DDT accounted for about 55% of the annual regional acre applications and 72% of the cotton farms utilizing insecticides during this period, which indicates smaller cotton farmers used DDT more than larger acreage growers (Table IIID.17).

The average annual number of acre applications in 1971/72 was about 9.4 million and 13,280 cotton farms were projected to utilize insecticides (Table IIID.17).

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[1] It would be preferable to use the weighted average cost of insecticide actually used as alternate to DDT. However, this could not be done because of data limitations, so the overall average was used.

[2] South Atlantic Region includes Maryland, Delaware, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida.

Following the cancellation of DDT the average annual expenditure for cotton insecticide in the South Atlantic escalated to $26.6 million (Table IIID.17), $12.4 million more than the precancellation average.

Since DDT mixed with other insecticides gave broad spectrum control of many different cotton pests, it is probably reasonable to assume that many alternative insecticides were used as substitutes after DDT's cancellation. If the proportion of acre applications with DDT combinations is assumed to be the same in 1973-1974 as in 1971-1972 (55%), then approximately 6,068,000 acre applications would have been DDT combinations in the South Atlantic during 1973-1974 (55% of 11,032,000).

In the South Atlantic Region the average acre application cost of insecticide materials was $2.41 in 1973-1974. By increasing the acre application cost of DDT treatments by 20% to account for inflation, the average annual acre application cost for DDT treatments in 1973-1974 would be about $0.84 more than non-DDT treatments ($2.41-($1.31 + 20%, or $1.57) = $0.84). Therefore, a rough estimate of the additional insecticide cost associated with DDT substitutes in the postcancellation period would be $0.84 times 6.1 million acre applications, which amounts to about $5.1 million.

If an aerial acre application costs $1.00 and if 55% of the increase in acre applications were due to the DDT cancellation (which is only an assumption), an additional $880,000 can be added as an impact of the cancellation (55% of the 1,600,000 added acre applications, i.e., 11,032,000 compared with 9,432,000).

Therefore, the total annual insecticide and application costs associated with the DDT cancellation in the South Atlantic Region would be approximately $6.0 million.

The increase in insecticide costs attributed to DDT cancellation of $6.0 million would equal $630 per farm based on the average number of farms using DDT in 1971-1972 (9,517 farms).[1] This is a significant cost effect, as these farms had an average cost of $715 per year for DDT combinations in 1971-1972. The $5.1 million increase in insecticide costs equals 41% of the total increase in insecticide costs between 1971-1972 and 1973-1974 (i.e., from $14.2 million to $26.6 million, or $12.4 million). The average insecticide cost per treated acre (all insecticides) in the South Atlantic Region increased from $15.51 in 1971-1972 to $32.37 in 1973-1974. The DDT cancellation accounted for $5.56 to $6.25 of this increase ($16.86) depending on whether the $5.1 million increase is computed on basis of 1971-1972 treated acreage (917,000) or 1973-1974 (820,500).

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[1] This may overstate the impact per farm since more farms than 9,517 may have used DDT in 1973-1974, as the number of acre applications increased significantly between 1971-1972 and 1973-1974.

East South Central Region

In the East South Central Region[1], DDT combined with methyl parathion and Toxaphene accounted for over 27% of the annual cotton insecticide expenditures, which averaged $8.3 million for 1971-1972. DDT mixture accounted for 23% of the acre applications and was used by 36% of the cotton producers utilizing insecticides in the region (Table IIID.18).

Before DDT use was cancelled, the average annual insecticide expenditure in the East South Central totaled about $30.3 million. The average annual number of acre applications was 27.1 million, on about 23,500 cotton farms (Table IIID.18).

For 1973-1974 the East South Central's average annual insecticide expenditures climbed to $52.2 million (Table IIID.17), which was about $21.9 million more than the 1971-1972 average. Also the average acre applications increased to about 30.3 million, which was 3.2 million higher, and the average number of farms utilizing insecticides increased by about 5,800.

By using the same estimation technique applied to the South Atlantic Region, an approximate 7 million acre application of DDT combinations would have been used annually in 1973 and 1974 if DDT had not been cancelled (23% of 30.3 million).

In the East South Central Region, the average acre application cost of insecticide materials was $1.72 in 1973 and 1974. By increasing the acre application cost of DDT treatments by 20% to account for inflation, the average annual application cost would be about $0.14 more than a DDT treatment. Therefore, a rough estimate of the additional insecticide cost associated with DDT substitutes in the postcancellation period would be $0.14 times 7.0 million acre applications, which amounts to about $1.0 million. The $1.0 million increase in insecticide cost amounts to about $0.30 per treated acre of cotton in the region, out of an increase from $9.65 per acre in 1971-1972 to $14.71 per acre in 1973-1974.

The change in the number of acre applications attributable to the DDT cancellation was about 750,000 (23% of 30.3-27.1 million). If an aerial acre application costs $1.00, the increased cost of applying the DDT substitutes would be $750,000 per year.

Therefore, the total annual insecticide and application costs associated with the DDT cancellation in the East South Central Region would be approximately $1.75 million.

1/ East South Central Region includes Kentucky, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana.

The insecticide cost increases due to DDT cancellation (about $1.0 million) would be about $116 per farm, based on the 8,576 farms using DDT in 1971-1972. This compares with a cost per farm for DDT combinations in 1971-1972 of $973.00. This impact plus the application cost impact brings the total cost impact to about $200 per farm.

Conclusion

The analysis of cost impact for the two regions where DDT was used in 1971-1972 results in a total cost of $7.75 million, of which $6.1 million was insecticide costs and $1.63 million was application costs. Whether this increase in application costs (1.63 million) can be fairly attributed to DDT cancellation is unknown, but it is consistent with the hypothesis that DDT is more persistent than alternatives and therefore they require more treatments.

This analysis does not address the possibility of impact in 1973-1974 in areas where DDT was not used in 1971-1972 and does not take into account the declining trend in DDT use which may have continued through 1973-1974 without the cancellation.

The cost impact of $7.75 million per year on cotton production costs due to the DDT decision is well within the range of estimates in the record at 1972 Hearings (from Headley with no increase in costs to Cooke with $54 million per year). The $7.75 million cost impact is significant in local regions where DDT was used. It amounted to an average of more than $600 per farm in the most significantly affected region, a near doubling of per-farm insecticide costs. The $7.75 million is a nominal impact on the average consumer of cotton products, i.e., about 2.2 cents per capita per year.[1]

INTRAREGIONAL AND INTERREGIONAL IMPACT ASSOCIATED WITH CANCELLATION OF DDT

The previous analysis has considered the gross cost impact associated with shifting from use of DDT in cotton pest control to alternative insecticides. It has been demonstrated that increased costs of alternative controls are not distributed evenly across all cotton producing areas. On an interregional basis, cotton producers in the Southeast were more reliant on DDT than those in other areas. In addition, a greater percentage of cotton acreage is treated with insecticides in the Southeast than in other regions (Appendix IIID.2).

The differential rates of economic impact stemming from cancellation have been evaluated within an equilibrium framework through the use of a national-interregional linear programming model of US agriculture which was developed to assess the impact of pesticide policies. A national model was chosen for this analysis because of the high degree of substitution between various land uses within a region and between regions for production of a given crop when comparative advantage is altered by differential changes in production techniques or input availability (Appendix IIID.2).

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[1] Based on 1973-1974 lint consumption of 17.3 lbs/capita and US lint production of 5,922 million lbs.

The DDT cancellation on cotton was evaluated by solving the linear programming model for equilibrium land use allocation when DDT is available and, alternatively, when DDT is not available. Both solutions are based on the year 1975, which simulates a typical year in the period 1973-1977. The results of these two solutions are reported in Appendix IIID.2 and can be summarized in acreage shifts, costs of production, and economic returns to land (a proxy for profit).

The cancellation of DDT caused a slight reduction in total cotton acreage in the US as evaluated within the framework of the linear programming model (from 10.972 million acres to 10.952 million acres). The reduction in acres was distributed as follows: Atlanta, -3,924 acres (-0.42%); Memphis, -8,915 acres (-0.37%); New Orleans, -24,056 acres (-7.21%); Louisville, -625 acres (-34.05%); San Francisco, +17,590 acres (2.24%) (see map in Appendix IIID.2 for regions). The relatively minor shifts in acreage demonstrate that the change in production costs associated with cancellation is not large enough to generate significant changes in comparative advantage among regions, and therefore does not affect cropping patterns for cotton or alternative crops.

Aggregate costs of cotton production were affected both by a change in production costs per acre in some regions and by the slight changes in acres planted between regions. In the Atlanta region, aggregate production costs increased by $2.1 million (1.4%); in Memphis, the increase was $1.8 million (0.5%); in New Orleans, where cotton acreage decreased the largest, total production costs declined by $3.0 million (-6.45%); in San Francisco, the increased plantings led to increased production costs of $4.3 million (2.2%). Total US production costs increased by $5.2 million (0.4%) as a result of the cancellation.

Returns to land, which serve as a proxy measure for impact on the profitability of cotton production, were affected slightly. In the Atlanta region, these returns decreased by 0.37% (from $45.35 million to $45.19 million); in Memphis, the decline accounted for a 1.93% reduction in the precancellation returns of $63.53 million; and in New Orleans the $100,000 reduction in returns accounted for 0.93%. San Francisco encountered an increase in returns to land of 0.26% (from $33.41 million to $33.50 million).

Conclusion

The analysis which was carried out through comparative analysis of linear programming solutions indicates that production cost increases due to the DDT cancellation on cotton are of insufficient magnitude to cause sizable shifts in economic parameters at the regional or national levels, e.g., acreage, production, total costs and returns to land. A more detailed discussion of the results of the linear programming analysis is presented in Appendix IIID.2.

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ECONOMICS OF THE MINOR USES OF DDT

The minor uses of DDT present special problems for economic analysis, not only of data but also of simple identification of the uses. At the Public Hearings on DDT in 1971, no party was able to identify all uses for which DDT was registered. The cancellation orders simply cancelled all registrations of products containing DDT and TDE (EPA, OPP, January 1971; EPA, OPP, March 1971). The Department of Agriculture submitted a list of uses it deemed essential (EPA Hearing, Admission 1), but this list was never taken to be a comprehensive statement of all registered uses. It was finally agreed by all parties that the only uses of DDT at issue in the hearing and on which evidence would be taken were those contested by the registrants. These uses, designated in the Hearing Record as Admission 11 (Table IIID.19), are the only uses on which the Administrator needed to make a determination of risks and benefits. All other uses of DDT were finally cancelled prior to the hearing because all parties failed to appeal the original cancellation notice. This analysis is confined to those contested uses of DDT.

Generally, the hearings produced very little economic data concerning minor uses. Most of the economic information presented concerned cotton, by far the largest use of DDT. Since the presentation of the economic benefits of DDT was taken to be the responsibility of the registrants and others opposing cancellation, neither EPA nor EDF prepared analyses of economic benefits and costs. Most of the information in this analysis has been prepared since the final cancellation decision and deals with observed economic effects in the 2 years since cancellation.

CONTESTED NONESSENTIAL CROP USES

> *Administrator's Finding: DDT is useful for controlling insects that attack the following: beans (dry, lima, snap), sweet potatoes, peanuts, cabbage, cauliflower, brussels sprouts, tomatoes, fresh market corn, sweet peppers and pimentos, onions, garlic, and commercial greenhouse plants. The use of DDT is not necessary for the production of these crops.*

Crops which do not require use of DDT because adequate substitute chemicals are available at reasonable costs are listed in Table IIID.20. The Administrator found that the registered alternative insecticides were sufficiently effective to allow the maintenance of crop yields without burdening farmers with increased insecticide costs.

Table IIID.19

Cancelled Uses of DDT subjected to Objection
by Group Petitioners and Other Uses Deemed Essential by USDA

Use Pattern	Notes and Limitations
1. Fresh Market Corn	
Armyworm	
Corn Earworm	
European corn borer	
Cutworm	
2. Peanuts	
Whitefringed beetle	Soil application
Cutworm	
3. Cabbage, Cauliflower, Brussels Sprouts	
Cutworm	
4. Tomatoes	
Cutworm	
5. Lettuce	
Corn earworm	
Cutworm	Fall lettuce only (Northeast)
6. Potatoes	
Flea beetles	
White grubs	
Wireworms	
7. Sweet potatoes	
Cucumber beetle	
Flea beetle	
Sweet potato weevil	
8. Commercial Greenhouses and Nurseries	Necessary for State-Federal quarantine and generally safer to humans than alternatives
9. Beans (dry, lima, snap)	
Armyworms	
Corn earworms	
Loopers	
10. Public Health Pests	
Bats	
Rodents	
11. Agriculture, Health and Quarantine Treatments in Emergencies as Recommended by and under Direction of State-Federal Officials	
12. Peppers and Pimentos	
European corn borer	
13. Fabric Treatment	Military only
14. Onions/Garlic	
Cutworm	

Source: Public Hearings on DDT, Admission 11, 1972.

Table IIID.20

Crop/Pest Combinations for Which DDT Use Was Found Not to be Necessary

Crops	Pests
Sweet corn	Armyworm, Corn earworm, European corn borer, Cutworm
Peanuts	White-fringed beetle, Cutworm
Cabbage	Cutworm
Cauliflower	Cutworm
Brussels sprouts	Cutworm
Tomatoes	Cutworm
Garlic	Cutworm
Lettuce	Corn earworm, Cutworm
Potatoes	Flea beetle, White grub, Wireworm
Dry beans	Armyworms, Corn earworm, Loopers
Lima beans	Armyworms, Corn earworm, Loopers
Snap beans	Armyworms, Corn earworm, Loopers

Source: Ruckelshaus, W.D. Opinion of the administrator. Public Hearings on DDT, Admission 11, 1972.

Data as of 1972

During the Consolidated DDT Hearings limited evidence was presented on the benefits or lack of benefits of DDT use for crops listed as essential. On the benefits side was the contention that these uses of DDT were essential, and the testimony of USDA entomologists that DDT was needed for control of the specified pests on the indicated crops.

On the other hand, Respondents pointed out that Group Petitioners never quantitatively defined "essential" and, in fact, the hearing examiner refused to allow any testimony or cross-examination challenging the "essential use" contention. (The hearing examiner was under the mistaken impression that by allowing the USDA list of essential uses to be designated as an Admission, the Respondents in fact agreed that these uses were essential. However, Respondents merely agreed the USDA considered them essential.)

No accurate data were presented on either current DDT use or trends in DDT use on the affected crops. The 27 Group Petitioner registrants did submit their total domestic sales for 1970 by region and crop and the aggregated data were included in the hearing record (Table IIID.21; EPA Hearing Admission 6, 1972). The data, however, only break down the crop usage into cotton, soybeans, peanuts, and others. The state sales breakdowns are for the total DDT sales only, and not on a crop-by-crop basis. The data gave no indication of DDT use for any of the individual contested uses, except peanuts.

The hearings produced no data on the efficacy or yield effects of DDT compared to the registered alternatives, beyond the personal observations and beliefs of entomologists. There was no analysis made by either side of yield, quality, or pest control cost impacts of switching from DDT to the alternatives. The limited information in hearing testimony has been incorporated into the analysis of economic impacts since cancellation.

The Administrator's finding that DDT was not necessary for production of these minor use crops was based primarily on the fact that alternative insecticides were registered for those contested uses (Ruckelshaus, 1972). He also took into account the lack of any information presented about the possible benefits of DDT use.

Data since 1972

Since the 1972 cancellation of DDT there have been virtually no economic data developed outside EPA on the contested minor uses of DDT. It is possible, however, to obtain some idea of the economic impact since the cancellation took effect. This analysis will focus on estimates of the extent of use of DDT prior to cancellation, on observed changes in crop yields since cancellation, and on estimates of changes in insect control costs brought about by loss of DDT. To the extent possible, these effects will be identified for each use under consideration.

Table IIID.21

Summary of 1970 DDT Domestic Sales

Item	DDT (100% BASIS)
Total pounds of DDT sold[a]	11,966,196
<u>Types of DDT formulations sold</u>	
Emulsifiable sprays	10,318,915
Dust	1,506,186
Wettable powder	127,350
Granular	13,736
<u>Use</u>	
Cotton	10,277,258
Soybeans	603,053
Peanuts	937,901
Other	158,853
<u>States</u>	
Alabama	1,139,256
Arkansas	1,193,175
California	2,500
Delaware[b]	21,400
Florida	74,888
Georgia	1,600,556
Louisiana	2,712,347
Maryland	133
Mississippi	3,731,876
Missouri	11,895
North Carolina	426,810
New Jersey	2,352
New Mexico	6,948
New York	2,612
Oklahoma	865
Oregon	200
Pennsylvania	33
South Carolina	1,016,286
Tennessee	207,104
Texas	97,422
Virginia	13,282
Washington	1,000

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[a] Number of DDT Formulators: 27.

[b] Information supplied by H.P. Cannon and Sons.

Extent of DDT use

As previously stated the DDT Hearings produced no complete data on the extent to which DDT was used by farmers for the minor uses at issue. Associate USDA Entomologist Clarence H. Hoffman did state that the minor uses were limited to specific, usually small, regions of the country (Tr:1958). Beyond this, however, there was no attempt to define the areas encompassed by each of the minor uses in question.

The US Department of Agriculture surveys of pesticide use provide some indication of the extent to which DDT was utilized by farmers (USDA, AER-252, 1974; USDA, AER-179, 1970; USDA, AER-131, 1968). These data are presented in Table IIID.22.

As the table indicates, DDT use on peanuts fell dramatically between 1966 and 1971. As a proportion of the total acreage harvested, DDT (and TDE) treated acres dropped from 35.2% to 1.5% of the peanut acreage. DDT use on potatoes rose from 21.9% to 32.1% of the total acreage between 1964 and 1966, but by 1971 had fallen to 2.7% of the potato acreage. Use of DDT on vegetables other than potatoes has declined steadily over the period from 19.6% of the acreage to about 2.8% of the acreage in 1971.

These published USDA data do not go into any more detail on the individual crops within the category Other Vegetables, but all of the contested minor crop uses should be included in this group. As aggregated as the data are, they do show that in the last few years prior to cancellation, DDT was becoming a much less important insecticide for the uses in question. This trend is probably due to the development of resistance in target pests and to the advent of more effective insecticides.

Beyond these published use data, the Department of Agriculture has a few more detailed accounts of DDT use on the crops within the Other Vegetables group (USDA, unpublished, 1974). The level of precision of the USDA survey makes the accuracy of DDT use estimates for these individual crops highly speculative. These figures should not be construed as official USDA estimates but merely serve as a guide to the relative magnitude of DDT use on these crops. They are, however, the only such figures available.

Table IIID.23 presents these more detailed use data in terms of acres treated. Also presented are total acres harvested in 1971, and the estimated percentage of the national acreage treated with DDT. As the table indicates, USDA picked up no use of DDT on five of the crops listed. This does not mean that DDT was not used on these crops, but it does indicate that these uses were probably very small. Another factor is that the indicated use on these crops may include treatment for insects other than those for which use was contested. Thus, of the estimated 8.8% of the cabbage acres treated with DDT, some may have been treated for insects besides cutworms, the only contested use on this crop.

Table IIID.22

DDT and TDE Use in the US, 1964, 1966, 1971

Crop	1964	1966	1971
Peanuts			
lbs	NA[a]	2,265,000	62,000
acres	NA[a]	500,000	22,000
% of US acres	NA[a]	35.2	1.5
Potatoes			
lbs	373	633,000	77,000
acres	279	470,000	38,000
% of US acres	21.9	32.1	2.7
Other Vegetables			
lbs	1892	1,428,000	407,000
acres	641	406,000	88,000
% of US acres	19.6	11.9	2.8

a/ In 1964 peanuts were included in a category called Other Field Crops.

Sources

USDA, ERS. Quantities of Pesticides Used by Farmers in 1964, 1968.
USDA, ERS. Quantities of Pesticides Used by Farmers in 1966, 1970.
USDA, ERS. Farmers' Use of Pesticides in 1971 - Quantities, 1974.
USDA. Agricultural Statistics 1973, 1973.

Table IIID.23

DDT Use by Crop in the US, 1971

Crop	Acres Treated with DDT[a]	Total Acres Harvested	Percent Treated with DDT
Sweet corn	12,800	606,100	2.1
Peanuts	22,000	1,454,500	1.5
Cabbage	9,600	108,480	8.8
Cauliflower	--	25,710	--
Tomatoes	61,900	391,040	15.8
Lettuce	--	217,000	--
Brussels sprouts	--	6,140	--
Potatoes	38,000	1,391,300	2.7
Snap beans	700	323,710	0.2
Dry beans	--	1,316,000	--
Lima beans	--	71,130	--
Garlic	--	3,700	--
Total	145,000	5,914,810	2.4

a/ Includes acres treated with TDE.

Sources

USDA, ERS. Unpublished data from 1971 survey of farmers' use of pesticides, 1974.
USDA, ERS. Farmers' Use of Pesticides in 1971 - Quantities, 1974.
USDA. Agricultural Statistics 1973, 1973.

Some information on DDT use is available for individual states. The state of California publishes annual reports of pesticide use by crop in the state (Cal. Dept. Food Agric. 1971, 1972, 1973, 1974). These reports are most accurate for those pesticides whose use is restricted by California and must be reported to county and state officials. Since DDT is on this restricted list, the use figures should be quite accurate. The California use data for the crops of interest here are presented in Table IIID.24. The figures show that in that state DDT use fell drastically between 1970 and 1971, and went to 0 by 1972. This sudden decline in use is due to the removal of DDT from state insect control recommendations and to the banning of DDT use within California. It appears, therefore, that the Administrator's 1972 decision to cancel DDT actually had no economic effect on California, as DDT use on these crops had been eliminated before the decision was made.

The state of Arizona also publishes data on the total quantities of pesticides used within that state (University of Arizona, 1974). Table IIID.25 presents the agricultural use figures for DDT from 1967 through 1973, with the exception of 700 lbs used in 1970, DDT use was entirely eliminated in Arizona by 1969. Further, a conversation with an extension entomologist in North Carolina revealed that that state had stopped recommending DDT several years prior to the DDT Hearings and that there was virtually no DDT use at the time of cancellation. This information implies that neither Arizona nor North Carolina should have been affected economically by the cancellation of the contested drop uses of DDT. These three states, California, Arizona, and North Carolina, together account for some 16% of the national acreage of the contested crops.

For this review, an attempt has been made to estimate the number of acres of the contested crops that would have received DDT treatments in 1973 had DDT not been cancelled. These estimates are based on the proportions generated from the USDA data and various other information as described below. The estimates are presented in Table IIID.26.

The figure for lettuce in Table IIID.26 represents the 1973 acreage for fall lettuce in the Northeast since Admission 11, Public Hearings on DDT specifically limited the contested use to this area and season. For the other crops the estimated acreage was calculated by subtracting from the 1973 national harvested acreage of these crops, the acreage contained in the three states (California, Arizona, and North Carolina) in which it was known that DDT would not have been used. The remaining acres were multiplied by the estimated percentage of the 1971 acreage treated (Table IIID.23 with the assumption that this proportion would also be treated in 1973. For those crops for which the USDA survey showed no DDT use, the average percentage treated for all the crops, 2.4%, was used.

For the harvested crop acreages found in <u>Vegetable-Fresh Market-1974 Annual Summary</u>, only the acreages for the fresh market were presented. It was, therefore, necessary to estimate the additional acreage harvested for the processing market. After determining a ratio of fresh market acreage to processing market acreage from 1972 data (USDA, 1972), the ratio was applied

Table IIID.24

DDT Use in California, 1970-1973

Crop	Acres			
	1970	1971	1972	1973
Sweet corn	74	0	0	0
Peanuts	0	201	0	0
Cabbage	4,570	210	0	0
Cauliflower	9,680	549	0	0
Tomatoes	106,882	8,891	0	0
Lettuce	416	0	0	0
Brussels sprouts	182	20	0	0
Potatoes	0	40	0	0
Snap beans	0	0	0	0
Dry beans	16,088	1,078	0	0
Lima beans	1,699	0	0	0
Garlic	0	0	0	0
Other uses	504,308	52,663	42,095	544
Total	643,899	63,652	42,095	544

Source: California Department of Food and Agriculture. Pesticide Use Reports, 1970, 1971, 1972, 1973.

Table IIID.25

Agricultural Use of DDT in Arizona, 1967-1973

Year	Quantity Used (lbs Tech. Material)
1967	2,519,900
1968	528,000
1969	0
1970	700
1971	0
1972	0
1973	0

Source: University of Arizona. Agricultural Use of Pesticides in Arizona, 1974.

Table IIID.26

Estimated Acres Affected by DDT Cancellation

Crop	Estimated Affected Acreage[a/]
Sweet corn	17,800
Peanuts	20,000
Cabbage	8,000
Cauliflower	200
Brussels sprouts	0
Tomatoes	14,500
Lettuce	900
Potatoes	32,700
Snap beans	600
Dry beans	28,300
Lima beans	1,200
Garlic	0
Total	124,200

[a/] For derivation see text.

Sources

USDA. Agricultural Statistics - 1973, 1973.
USDA, SRS. Crop Production - 1973, 1974.
USDA, SRS. Vegetables - Fresh Market - 1974 Annual Summary, 1974.

to 1973 data (USDA, SRS, 1974) to estimate harvested acreage for the processing market. These acreage estimates were added to the appropriate fresh market acreages to represent the 1973 total harvested acres.

The estimated total acreage of these crops that would have been treated is about 124,000 acres or about 2.4% of the national acreage of these crops. There is no acreage indicated for brussels sprouts or garlic because both of these crops are produced entirely in California.

The acreage figures in Table IIID.26 should not be taken as being in any way as price estimates. They are merely the best estimates based on the extremely limited data available. Furthermore, even these rough estimates do not take into account the fact that some of the treatment in 1971 may have been for insects not at issue in the hearings. These estimates also do not reflect the decline in DDT that would likely have continued even if it had not been cancelled.

Yield changes since DDT cancellation

Considerable research has failed to uncover any studies which document per acre yield changes due to the inability to use DDT on the contested crop uses. DDT has not been the standard insecticide treatment for purposes of efficacy comparisons in these crops since the mid-1960's. Data from this time cannot be used today because of the rapid changes in insect resistance conditions that have occurred. About the best that can be done is to compare reported average yields and production for these crops before cancellation with those since the DDT cancellation. While changes in yield and production cannot be shown to be casually related to the loss of DDT, these changes may help evaluate Hoffman's claim that "if growers are unable to have the use of DDT, they will be unable to produce these crops (on USDA's essential list)" (Tr:1891).

Table IIID.27 presents the comparisons of pre- and postcancellation yields and production. The precancellation figures are the averages of the 1968 through 1972 average national yields and production, whereas the postcancellation figures are the averages of 1973 and 1974 yields and production. The comparisons for sweet corn are for fresh market only, and the figures for lettuce are only for fall lettuce in the Northeast (i.e., New Jersey). Brussels sprouts and garlic do not appear in the comparisons because all of their production was in California and changes in yields and production could not be related to the DDT cancellation. The postcancellation figures for peanuts, potatoes, and dry beans are for 1973 only, and those for lima beans were not available.

As Table IIID.27 shows, total production has increased in five of the crops, and per acre yield has increased in 6 since the DDT cancellation took effect. Average yields of cauliflower declined 9.8 cwt (about 10%) while

Table IIID.27

Production and Yield of Contested Crops
US 1968-1974

Crop	Production			Yield		
	1968-1972	1973-1974 (million cwt)	Difference	1968-1972	1973-1974 (cwt/acre)	Difference
Sweet corn[a]	12.8	13.3	+0.5	69.6	77.5	+7.9
Peanuts[b]	28.7	34.5	+5.8	19.6	23.0	+3.4
Cabbage	23.3	24.4	+1.1	215.6	226.0	+10.4
Cauliflower	2.6	2.9	+0.3	98.8	89.0	-9.8
Tomatoes[a]	18.8	19.7	+0.9	133.0	149.0	+16.0
Lettuce[c]	0.21	0.16	-0.05	172.0	185.0	+13.0
Potatoes[b]	309.5	297.4	-12.1	225.6	228.0	+2.4
Snap beans[a]	3.2	3.0	-0.2	36.8	35.0	-1.8
Dry beans[b]	17.5	16.8	-0.7	12.5	12.1	-0.4

[a] Fresh market crop only.
[b] 1973 yield and production only.
[c] Includes only Fall lettuce from the Northeast.

Sources

USDA. Agricultural Statistics 1973, 1973.
USDA, SRS. Crop Production - 1973 Annual Summary, 1974.
USDA, SRS. Vegetables - Fresh Market - 1974 Annual Summary, 1974.

yields of snap beans and dry beans declined very slightly. Production declines in potatoes, snap beans and dry beans were nominal. However, the decline in fall lettuce equalled 28% of the 1968-1972 average.

Again, there is no way to determine the degree to which any of the yield or production effects may have been caused by loss of DDT. So many factors such as temperature, rainfall, levels of insect and disease infestation, and others influence crop yields and production that the impact, if any, of DDT alone is impossible to separate. Furthermore, there is no way to determine whether DDT was even used in the areas in which these declines took place. About the most that can be said is that farmers have continued to produce the contested crops despite loss of DDT. Yield and production of most of the crops has actually increased since cancellation, and there is no evidence that the declines which have occurred are due to EPA's cancellation of DDT.

Changes in insecticide costs

Another measure of the economic impact of the DDT cancellation is through the changes in insecticide costs to farmers. Farmers previously using DDT had to switch to some alternative insecticide or other means of pest control. These alternative controls may cost more per pound, may be applied at different rates per acre, and may require more applications per year than DDT.

Several difficulties arise in actually attempting to compute these cost effects. There are considerable differences across the country in amounts and frequency with which DDT was applied. Identifying the alternatives used in place of DDT is also difficult. State insect control recommendations provide a clue to the alternatives, but they are not always indicative of what is actually used. Even if per acre cost changes can be estimated, there still exists the uncertainty as to the total number of acres on which this cost change would occur.

A rough estimation of these costs has been attempted and is shown in Table IIID.28. The rate and frequency of DDT applications have been assumed based on the testimony at the DDT hearings of entomologists Joseph Capizzi, Dr. Stuart Race, and Dr. William Eden (Tr, 1972). The alternative insecticides and their rates of application have been based on surveys of recent state insecticide recommendations for the crops and pests under consideration. It has been assumed that the alternatives would be applied with the same frequency as DDT (Brogdon, personal communication, 1975). The costs of alternatives are the average of the prices from two pesticide dealers, one on the East Coast (Agrotec, Inc., 1973) and one in the Midwest (E-Z Flow Chemical Company, 1973). The price of $1.27 per pound active ingredient for DDT is the price paid by farmers in Washington and Idaho for DDT in 1973 to control the pea leaf weevil under a temporary emergency use permit. This price is assumed to approximate the price that would have been paid by most farmers in 1973.

Table IIID.28

Estimated Changes in Insect Control Costs, US 1973 Basis[a]

Crop	Pounds of DDT Per Acre Application	DDT Applications Per Season	DDT Cost Per Acre	Pounds of Substitutes Per Acre Application	Substitute Applications Per Season	Substitute Cost Per Acre	Change in Cost Per Acre	Estimated Total Change in Cost
Sweet corn	1	5	$ 6.35	Carbaryl 2 Methomyl 0.45	5	$11.95	$+5.60	$+99,800
Peanuts	10	1	12.70	none listed	NA	NA	NA	NA
Cabbage	1	3	3.81	Dylox 1 Toxaphene 3	3	6.90	+3.09	+24,700
Cauliflower	1	3	3.81	Dylox 1 Toxaphene 3	3	6.90	+3.09	+ 618
Tomatoes	1	3	3.81	Carbaryl 2 Toxaphene 2	3	5.94	+2.13	+30,885
Lettuce	1	3	3.81	Carbaryl 2 Phosdrin 0.75	3	11.22	+7.41	+ 6,700
Potatoes	6	1	7.62	Dyfonate 4 Diazinon 4	1	12.92	+5.30	+173,300
Snap beans	1	3	3.81	Carbaryl 2	3	8.04	+4.23	+ 2,500
Dry beans	1	3	3.81	Carbaryl 2	3	8.04	+4.23	+119,700
Lima beans	1	3	3.81	Carbaryl 2	3	8.04	+4.23	+ 5,100
								+460,700

[a] See text for sources and derivation.

The table indicates that based on the above assumptions, per acre costs for insect control on the contested crops increased between \$2.13 and \$7.42 when DDT could no longer be used. Multiplying these per acre cost increases by the acreage estimates in Table IIID.26 will give a very rough estimate of the total increase in farmer pesticide expenditures brought about by the loss of DDT. The total increase in insecticide costs are estimated to be about \$460,700, at 1973 prices. For the individual crops the total estimated cost increases range from about \$600 for cauliflower to \$173,300 for potatoes. There is insufficient data to attempt any discussion of the regional distribution of these costs.

It should again be emphasized that these dollar values cannot be taken as precise estimates of impact. They merely serve to demonstrate the order of magnitude of the economic effects of the DDT cancellation and not the actual values of these effects. Accurate specification of the economic impacts requires much more data than presently exist.

Conclusion

1. The consolidated DDT Hearings brought out limited information relating specifically to economic consequences of a DDT cancellation on minor use crops, i.e., limited estimation of production yield and price effects on these crops.

2. Based on estimates of DDT use, only about 2.4% of the national acreage of these crops would have been treated with DDT had it not been cancelled.

3. National average yields per acre have increased in six of the nine crops and total production has increased in five of the crops since the cancellation took effect.

4. It is estimated that insect control costs to farmers have risen somewhat due to DDT cancellation. The estimated total cost increase for these contested uses is \$400,000-\$500,000. It is possible that the cost impact in this range is more than offset by production increases in other crops, their neutralizing overall impact on the consumer.

5. Available information indicates that farmers have been able to continue producing the contested crops since DDT was cancelled. There have been some slight-to-moderate declines in production, none directly attributable to loss of DDT.

SWEET POTATOES, SWEET PEPPERS, AND ONIONS

> *Administrator's Finding: Adequate substitute chemicals, namely, methyl parathion and other organophosphates--for the most part--exist for...crops except: sweet potatoes, heavy infestations of corn borer attacking sweet peppers grown on the Delmarva Peninsula, and onions attacked by cutworms.*

The Administrator found that DDT may be the only useful treatment of sweet potatoes in storage, and for control of European corn borers attacking sweet peppers on the Delmarva Peninsula and cutworms attacking onions. Final cancellation of this use was not ordered by the Administrator in June 1972 because of questions about the supply of these crops, registration of alternatives and so forth could be resolved during a transitional period.

Data as of 1972

The Administrator based his finding that DDT may be necessary for these three uses primarily on the fact that no party had demonstrated that any alternative insecticides were registered. While Toxaphene and diazinon were registered for general cutworm control, it was not clear whether this included registration for control of cutworms on onions (Ruckelshaus, 1972).

Sweet potatoes

Testimony indicated that DDT was the only registered insecticide that would satisfactorily protect stored sweet potatoes from attack by sweet potato weevils. Dr. Dale Newsom, an entomologist from LSU, testified that Imidan is a satisfactory alternative (Tr:2397), but it was not registered at the time of the hearing. No clear information on the quantities of DDT use on sweet potatoes was reported.

Sweet peppers

The hearings brought out that the European corn borer is an important pest of sweet peppers on the Delmarva Peninsula that are grown almost entirely under contract to H.P. Cannon and Sons, a vegetable processor. Infestations of corn borers higher than 10% rendered the peppers unsuitable for canning and, therefore unsalable for the farmers. Carbaryl was registered for corn borer control, but a Delaware entomologist testified (Tr: 1623-1671) that will not work during heavy infestations. He also testified that Furadan (carbofuran) was a completely acceptable alternative, but at the time of the Hearing it was not registered for this use.

Onions

Little evidence was presented concerning cutworm control in onions. An entomologist from Oregon testified (Tr:2775-2831) that DDT was the best cutworm control for onions, but this use of DDT was not included in the state insect control recommendations. He testified that the results of a USDA survey indicated that the only state with cutworm problems on onions was California.

Data since 1972

Sweet potatoes

The 1971 USDA pesticide survey data indicated some use of DDT on stored sweet potatoes. The survey reported that DDT was used on 127 million pounds of sweet potatoes in 1971. Since total production in that year was 1.17 billion pounds (USDA, 1973), about 10.8% of the sweet potato crop was treated.

At the time of the hearings, there were no acceptable registered substitutes for DDT, but since the cancellation EPA has registered Imidan for sweet potato weevil control. Since Imidan has the same effectiveness as DDT for this use (Tr:2397) the cancellation should have had no effect on sweet potato production. Sweet potato production in 1973 was down 5% from the average level of the 5 previous years but this is less than the average annual variation in production within this period (USDA, 1973).

No information is currently available on the differences, if any, in the cost of sweet potato treatment between Imidan and DDT. Any cost differentials should, however, be small, since DDT was only applied at a rate of 5 lbs active per 1,000 bushels.

Onions

Since hearing testimony brought out that cutworms were only a problem on onions in California there should have been little, if any, impact from the 1972 cancellation decision. The California pesticide use report (1973), indicates that only 50 acres of onions were treated with DDT in 1972. This represents only 0.2% of the onion acreage in that state. The economic impact of loss of DDT from this acreage would be clearly negligible.

Sweet peppers

According to Dr. Paul Burbatis (personal communication, 1975), a witness at the DDT Hearings and probably the leading expert on this use, there are about 4,000 acres of green peppers (also known as sweet peppers or bell peppers) in the Southern New Jersey and Delmarva area. DDT was used throughout this area for control of the European corn borer. The University of Delaware includes green peppers as one of the crops in its Pilot Pest Management Program. The reports for 1972 and 1973 (Graustein et al, 1973 and 1974) are available and provide a contrast between pest control costs before and after DDT was cancelled.

In the 1972 pest control program, European corn borers were controlled with DDT. 12,127 pounds active ingredient of DDT were applied to 1,100 acres at a cost of $7,158. The average DDT cost to farmers was, therefore, $6.51 per acre.

In the 1973 program Furadan (carbofuran) was used for European corn borer control. Furadan is a systemic insecticide, usually formulated as a 10% granular, and needs only be applied twice during a season, compared with 3-5 times for DDT. In this year, 4,165 lbs (active ingredient) of Furadan were applied to 850 acres at a cost of approximately $21,658 (based on the 1973 price for Furadan 10G of $0.52/lb). The average cost of European corn borer control in 1973 was approximately $25.48 per acre.

Cancellation of DDT and subsequent substitution of Furadan increased costs of corn borer control by about $18.97 per acre for a season. For the approximately 4,000 acres involved in the contested green pepper use the total increase in pest control costs were about $75,800. Even this figure probably overstates the cost impact had DDT not been cancelled. It is likely that the price of DDT would have risen along with other pesticide costs, decreasing the difference between its price and that of Furadan.

Dr. Burbatis indicated that Furadan can be used with no declines in green pepper yield from the levels when DDT was used. He did indicate, however, that in the first year after cancellation, 1973, there was an unexpectedly large infestation of armyworms which had apparently previously been controlled with the DDT. This infestation caused some loss in yields in 1973, but farmers were ready for the armyworm population in 1974 and experienced no adverse effects on yields.

Conclusion

1. The Administrator's finding with respect to DDT use on stored sweet potatoes is probably no longer valid. Imidan, not registered at the time of the Hearings, has since been registered and is an acceptable alternative to DDT.

2. The need for DDT to control cutworms on onions is restricted to California. Since DDT was used on only a very small number of acres there the impact of cancellation has been negligible.

3. Loss of DDT for use on green peppers has had little adverse impact on growers in the Delmarva area because Furadan has been registered for the European corn borer. The primary impact has been on insecticide costs which have increased about $76,000 over the whole region.

MILITARY USE OF DDT

> *Administrator's Findings: DDT is used for exterminating bats and mice by the military. a) Fumigation and nonchemical methods can guard against bat infestations. b) Warfarin is effective for exterminating house mice.*

The Administrator found that acceptable alternatives are available for the military uses of DDT. These include all military uses that are not for the purpose of health quarantine.

Data as of 1972

Very little information was generated at the DDT Hearings regarding the use of DDT by the military. The only quantitative data involved a statement by Col. Fowler of the Armed Forces Pest Control Board to the effect that the military used only about 800-900 lbs for bat and mouse control (Ruckelshaus, 1972). There were no data presented concerning the efficacy or costs of alternative means of pest control.

Data since 1972

In cooperation with OPP/EPA the Armed Forces Pest Control Board is in the process of preparing a short statement on the military uses of DDT and, to the extent possible, on the impact of the cancellation. This statement has not yet been completed.

PUBLIC HEALTH

> *Administrator's Finding: DDT is considered useful to have in reserve for public health purposes in disease vector control.*

The Administrator found that DDT is useful to have in reserve for public health purposes in disease vector control. The cancellation order exempted public health and quarantine uses by official government agencies.

Data as of 1972

The Hearings revealed that DDT was no longer the primary insecticide for disease vector control in this country. However, no quantitative data on use were produced. The main emphasis on DDT use in vector control was the worldwide dependence on DDT as an inexpensive method of malaria and typhus control. The international use was not really relevant to the hearings since domestic cancellation had no effect on DDT production for the export market.

Data since 1972

The cancellation of DDT had virtually no effect on the public health uses since they were exempted from the order. The cancellation may have made DDT somewhat more difficult to obtain for public health agencies.

According to Dr. Darsie of the Public Health Service, Center for Disease Control (personal communication, 1975), DDT is very seldom used in this country for vector control. It is used for lice control, but even then in only a few states. Most body lice are controlled with either a lindane or a malathion preparation (Pratt and Littig, 1973). No figures could be obtained on the extent of current DDT use for public health purposes.

Conclusion

DDT is of minor importance for public health vector control in this country. Furthermore, if an emergency arises, DDT may still be used by public health officials.

PEA LEAF WEEVIL

The use of DDT against the pea leaf weevil was not considered at the DDT hearings but subsequently was the subject of a special request for use, which was granted for the 1973 and 1974 growing seasons.

As a result of the work done under the limited use registration, alternatives have been tested and registered, making it no longer necessary to use DDT, as discussed in more detail below.

Since 1970, an area of Northern Idaho and Eastern Washington which produces 95 percent of America's dried peas has been subject to economically critical infestations of the pea leaf weevil. The only effective control for this weevil had been DDT. The growers commission involved (Washington and Idaho Dry Pea and Lentil Commission) felt that the cancellation of this use of DDT placed dried pea production in serious economic jeopardy. As permitted under FIFRA, through regulations promulgated in the Federal Register on January 9, 1973, parties may petition for special use exemptions to a cancellation or a denial of registration of a pesticide.

With the support of the dry pea industry in the states of Idaho and Washington the Crop King Chemical Company petitioned the Administrator of EPA on December 13, 1972, requesting permission for a registration to employ DDT on dried pea acreage in the infested areas of their states. Following an EPA review of the matter, the Administrator determined that the use of DDT was indeed critical for pea leaf weevil control because of the economic importance of the industry and the absence of viable substitutes. On April 27, 1973, EPA granted the request by the Crop King Chemical Company for a temporary registration of DDT for use against the pea leaf weevil. The use exemption was implemented and then officially expired August 1, 1973.

With the support of the industry, Crop King Chemical Company again petitioned the EPA for a DDT use exemption on January 25, 1974. On February 15, 1974, EPA convened a public hearing in Spokane, Washington to review much of the petition. On February 22, 1974, the application was approved for 90 days' DDT use during the 1974 growing season. The approval was based on a determination that in absence of alternative controls, DDT control of the pea leaf weevil was indeed economically critical. The decision was based on evidence presented by the growers indicating losses of 600 to 800 pounds per acre would be incurred in absence of pest control. This is quite large given average yields range from 1200 to 1600 pounds per acre.

Whereas barley can be grown in place of dry peas, based on February, 1974 prices, the comparative value of barley was $101 per acre and for dry peas was $380. This represents a marginal difference of $279. Moreover, from an agricultural standpoint, it was revealed that dry peas have proved to be far more effective than spring barley as a cover crop to prevent soil erosion, which is a chronic problem in the rolling terrain of the region. In addition, dry peas provide nitrogen to the soil, thus reducing the fertilizer requirements of the winter wheat crop; in contrast, spring barley is nitrogen depleting. Finally, it was revealed that this region not only supplied the majority of the U.S.

demand for dry peas during the previous two years, but it supplied 13 to 15 percent of world market. Thus, with as much as 70 percent of the crop going to export markets, there were obvious balance of payment considerations.

The exemption was granted, provided that pea growers and the pesticide industry (with assistance of EPA and university scientists) would launch a scouting program designed to monitor and reduce the amount of DDT released into the environment.

Operationally, the weevil scouting involved sifting soil and young pea shoots from sample rows and counting weevils. Aerial spraying of DDT was limited to fields or parts of fields, where the weevil count per plant exceeded a predetermined economically critical threshold. By this procedure, scouting records were available to determine which fields should be sprayed. Only about 12 percent of some 89,000 acres surveyed were certified for spraying.

The scouting program provided protection at minimum spray costs to the farmer and, at the same time, afforded an opportunity for further testing of three chemicals -- methoxychlor, Imidan, and malathion ULV -- which had shown some promise as alternatives to DDT. Other possible alternatives to DDT were tested in 1974 as well. This was accomplished on a matching fund basis with the Washington and Idaho Dry Pea and Lentil Commission, USDA, and EPA each supplying partial funding.

The program subsequently established that Imidan and methoxychlor are viable substitutes for DDT. They are now registered and are being employed during the 1975 growing season. Further match-funding research for DDT alternatives is being conducted during the current fiscal year in order to explore other chemical and biological control possibilities.

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FOREST USES OF DDT

HISTORY OF USE ON FOREST PESTS

Among the many insect pests which prey upon North American forests, two groups account for the overwhelming majority of tree losses: defoliators, and bark beetles.

In the discussion which follows, major attention will be given to defoliating insects, since bark beetles, because of the location of their attacks, are not amenable to control by mass spraying methods. While the discussion is intended to generalize about defoliators, it is recognized that exceptions are common and most of these are noted for the three major pests discussed.

Bark beetles

Several species of bark beetles attack numerous forest tree species, especially conifers. Adult beetles typically penetrate the outer bark, laying eggs in or near the soft inner bark which hatch into feeding larvae. The larvae consume the inner bark while protected by the outer bark, often girdling and killing the tree. Several species of bark beetle attack already weakened or dying trees and are considered secondary pests. A few, e.g., the southern pine and mountain pine beetles, may become primary killers when epidemic populations develop. DDT has never been an important control agent for bark beetles.

Defoliators

The overwhelming majority of forest tree defoliation results from the attacks of insects in two orders: *Lepidoptera*, mostly moths and a few butterflies; and *Hymenoptera*, principally sawflies.

The larvae of defoliating moths and sawflies feed on the needles and leaves of many important trees. During the period 1945-1972, efforts to control defoliating forest pests were mounted on nearly 30 million acres of US forests. On almost 95% of this area, control efforts were directed at four defoliating moths: the western budworm; gypsy moth; spruce budworm; and Douglas fir tussock moth (Sartwell and Alligood, 1974).

The population dynamics and feeding patterns of these moths make them ideally suited to control by aerially applied insecticides. The typical pattern of population development is for the insect to maintain endemic low levels of population for periods of several years, then for reasons yet unknown, to develop epidemic numbers, usually in localized areas which may persist for 3 years or longer. During the epidemic population phase, the larval stage feeds on the foliage of host trees in large numbers frequently causing complete defoliation in a matter of weeks. The emergence of the larvae of most species is timed to coincide with the production of new foliage during the late spring and early summer. New foliage is usually consumed first. In most cases, the larvae complete their growth at about the time defoliation is complete. They then change to the pupal stage for a period of one or more weeks emerging in summer as adults, completing the life cycle by reproducing and laying eggs.

During the outbreak phase, epidemic attacks are usually quite localized. However, migration for some distances is possible during both the early larval and adult stages when insects may be carried long distances by prevaling air currents (adult female gypsy moths are flightless). The gypsy moth may also be distributed into new areas by the transport of egg masses on recreation vehicles. Adult moths seek out any convenient protected surface and frequently attach their egg masses to camping vehicles during late June. Thus, new localized outbreaks may occur many miles apart expanding in size over succeeding years of population buildup. Because large numbers of insects are concentrated on relatively small areas aerial detection is quite often possible. Since the timing of egg hatching and larval feeding can be predicted, foresters are able to anticipate the timing of control sufficiently in advance to plan aerial spray control efforts. Egg hatching may vary over several weeks in a given attack area. Since the purpose of control is to reduce the amount of defoliation and prevent epidemic buildup, the application of the insecticide must be carefully timed to achieve the highest possible mortality of feeding larvae. The most severe defoliation (as opposed to damage) occurs during the last 2-4 weeks of the 3-8 week larval stage. It is, thus, easy to understand why persistent pesticides, such as DDT, have been favorite control tools. Larvae from late hatching eggs can be controlled even after the time of application.

Use of DDT prior to 1972

DDT was relied on almost completely for control of defoliating insects from 1945 to 1958 . During those 14 years more than 20 million acres were aerially sprayed for the control of some 22 different defoliating pests. Four of these pests accounted for nearly 96% of the nearly 30 million acres to which insecticides have been applied for the period 1945-1972 (Sartwell and Alligood, 1974). Table IIID.29 presents the acreage breakdown by chemical agent, showing DDT was applied to more than 88% of the total.

Table IIID.30 presents the 34 forest insects requiring control efforts during the period 1945-1972. Three of these, the western and spruce budworms and the Douglas fir tussock moth, attack various species of spruce, the true firs, and Douglas fir. The gypsy moth attacks a wide variety of trees, feeding most heavily on oaks. This moth was introduced at Medford, Mass. about 1869, by a French naturalist who had intended to cross it with the silkworm. During the next 40 to 50 years, the moth spread gradually throughout most of New England and by 1973 was causing extensive damage in these states as well as New York, Pennsylvania, and New Jersey (US Forest Service and APHIS, USDA, 1974).

Table IIID.29

Materials Aerially Applied to Suppress Forest Insect Populations

US Total 1945-1972

Material	Area (1,000 acres)	Percent of Total
DDT	25,713	88.1
carbaryl	2,187	7.5
mexacarbate	550	1.9
malathion	380	1.3
fenitrothion	222	0.8
trichlorfon	51	0.2
Douglas fir tussock moth virus	16	--
Gardona[a/]	14	--
lead arsenate	9	--
methoxychlor	7	--
phosphamidon	7	--
Bacillus thuringiensis	5	--
dimethoate	2	--
propoxur	1	--
Giant Basin tent caterpillar virus	1	--
Total	29,165	100.0

[a/] Trademark, Shell International Chemical Co.

Source: Sartwell and Alligood, 1974

Table IIID.30

Forest Acreage Sprayed for Particular Pests
US Total 1945-1972

Insect	Acreage (1,000 acres)[a]	Percent of Total
Western budworm	12,816	43.9
Gypsy moth	12,324	42.3
Spruce budworm	2,113	7.2
Douglas fir tussock moth	724	2.5
Pine butterfly	255	0.8
Pitch-pine looper	239	0.8
Fall cankerworm	132	0.5
Jack-pine budworm	123	0.4
Western hemlock looper	104	0.3
Saratoga spittlebug	102	0.3
Great Basin tent caterpillar	54	0.2
Pine tussock moth	41	0.1
Elm spanworm	24	b/
Blackheaded pine sawfly	18	b/
Western blackheaded budworm	16	b/
Redheaded pine sawfly	14	b/
Saddled prominent	14	b/
Lodgepole needle miner	13	b/
New Mexico fir looper	10	b/
Pine reproduction weevil	6	b/
White fir needle miner	5	b/
Grasshoppers	4	b/
White fir sawfly	3	b/
Arkansas sawfly	2	b/
Eastern hemlock looper	1	b/
Fall webworm	1	b/
Forest tent caterpillar	1	b/
Larch sawfly	1	b/
Loblolly pine sawfly	1	b/
Lodgepole pine sawfly	1	b/
Southwestern pine tip moth	1	b/
Utah cankerworms	1	b/
Virginia pine sawfly	1	b/
European pine sawfly	--	--
Total	29,165	100.0

a/ These figures may not represent actual acreage, as the same land may have been treated more than once in different years.

b/ Less than 500 acres or 0.05%.

Source: Sartwell and Alligood, 1974.

The most serious effect of defoliation, usually resulting from several successive years of attack, is the outright killing of the host trees. Less obvious but extensive damage also occurs from partial defoliation which often results in top killing. Damaged trees suffer reduced growth and vigor making them subject to later mortality from other environmental agents, especially bark beetles (Wickman et al, 1973). In general, the softwoods are less able to withstand repeated defoliation than hardwoods. Two to 3 years of nearly complete defoliation usually results in the death of conifers while hardwoods may withstand as many as 6 or 7 consecutive years of heavy defoliation (US Forest and APHIS, USDA, 1974).

The development of extensive control efforts since World War II was made possible by 1) the availability of DDT, a persistent broad spectrum insecticide, effective as both a contact and a stomach agent; and 2) the use of aircraft for rapid detection of attacked areas and for rapid, broad scale application of this inexpensive chemical. (Gypsy moth detection remains heavily dependent upon ground sampling techniques which include egg-mass surveys and sex pheromone baited traps.) Due to reliance upon aerial detection lower levels of attack not resulting in visible defoliation may go undetected during the first year. This has meant that insects have been able to build up to epidemic proportions before discovery and effect considerable damage before control can be accomplished. It has been observed of many forest insect pests that periodic epidemic outbreaks often run their course in a period of 3-5 years (sometimes longer) in the absence of controls. The causes for the collapse of epidemic populations are not fully understood. For example, studies of the Douglas fir tussock moths have identified a virus disease of these insects which may be responsible, in combination with starvation, for the almost complete collapse of large populations in a single year (US Forest Service, 1975). Since past control efforts have usually been mounted only when epidemic numbers are detected, it appears that massive spraying programs may have been delivered on the target pests during the decline or collapse phase of the epidemics (Wickman et al, 1973). Consequently, it has been very difficult to assign easily measured benefits to these control programs.

During the last 10 years, research has been intensified to improve forest managers' techniques of pest control. Several aspects of the control problem have been attacked with limited success. Earlier detection of incipient epidemic outbreaks is now possible through the use of synthesized sex attractants, recently developed for the gypsy moth. They are used to monitor insect population levels, helping to identify areas of potential build-up in insect numbers. In addition, experimental use permits have been issued the US Department of Agriculture for the aerial application of a synthetic sex pheromone attractive to the male gypsy moth. Large acreage applications, following earlier small plot trials, are being made to substantiate the finding that the presence of the pheromone results in confusion of the male. This confusion impairs the male's ability to locate a virgin female and results in reduced mating success. Other problem areas being researched include the development and wide scale production of disease causing agents specific to target pests; identification and rearing of parasitic or predacious insects which, if successful, can be introduced into target populations; and development of chemical insecticides having short residual life and a minimum of unwanted ecological effects.

Alternative controls

During the period 1945-1958 aerial spraying efforts to control defoliating insects relied almost exclusively on DDT (Table IIID.31), but included two minor applications of lead arsenate (9,000 acres, 1945) and malathion (4,000 acres, 1957). Of the nearly 26 million acres of DDT applications which ended in 1967, 78% occurred prior to 1959 (Sartwell and Alligood, 1974). In 1959, there began a major shift to carbaryl and other agents. Use of carbaryl has risen gradually over the years as the use of DDT was phased out by 1967. The last major application of DDT was in 1974 for the control of the Douglas fir tussock moth, under an emergency exemption granted by EPA, March 5, 1974. In the face of a large and apparently expanding epidemic of these insects and lacking any registered substitute control, the US Forest Service, together with the States of Oregon and Washington and private landowners applied DDT at the rate of 0.75 lbs/acre to approximately 430,000 acres. Experimental tests of lower application rates for DDT and tests of other control agents were also conducted, as directed by EPA (EPA, 1974b).

Four other chemicals have been used with varying success: malathion (extensively, 1963-1956); mexacarbate (Zectran1/), used in token amounts until 1972 when 500,000 acres were sprayed; fenitrothion (1968 and 1970) (Sartwell and Alligood, 1974); and trichlorfon (US Forest Service, 1974 and 1975).

The decline in DDT usage was coincident with increased reliance on several more environmentally favorable control agents. Table IIID.32 shows comparisons between DDT and the major alternatives. Malathion was also used on extensive acreage.

In a final environmental statement for a proposed spruce budworm suppression project, the US Forest Service summarized the findings of five studies on the efficacy of malathion against the spruce budworm. It was concluded that "malathion can be used safely in the environment and that it will have no significant effects on man or other animals when suitable aerial spraying precautions are taken. However, malathion has not demonstrated consistently satisfactory control at the registered dosage." Use of malathion on forest pests has been minimal in recent years (US Forest Service, 1974). Of the six alternatives (some of which are not currently registered for control of forest defoliators), four are chemical insecticides: carbaryl, mexacarbate, fenitrothion, and trichlorfon: and two are biological control agents (*Bacillus thuringiensis* and Polyhedrosis viruses). Bioethanomethrin and resmethrin synthetic pyrethroids also have shown promise as controls for

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1/ Tradename, Dow Chemical Co.

Table IIID.31

Forest Area (1,000 acres) Aerially Sprayed with Insecticides in the United States

Year	DDT	Carbaryl	Mexacar-bate	Mala-thion	Fenitro-thion	Trichlor-fon	DFTM virus[a/]	*Bacillus thuringiensis*	Other[b/]	Total
1945	7	---	---	---	---	---	---	---	9	16
1946	64	---	---	---	---	---	---	---	---	64
1947	533	---	---	---	---	---	---	---	---	533
1948	218	---	---	---	---	---	---	---	---	218
1949	661	---	---	---	---	---	---	---	---	661
1950	1,548	---	---	---	---	---	---	---	---	1,548
1951	1,105	---	---	---	---	---	---	---	---	1,105
1952	880	---	---	---	---	---	---	---	---	880
1953	700	---	---	---	---	---	---	---	---	700
1954	1,733	---	---	---	---	---	---	---	---	1,733
1955	3,653	---	---	---	---	---	---	---	---	3,653
1956	2,306	---	---	---	---	---	---	---	---	2,306
1957	4,898	---	---	4	---	---	---	---	---	4,902
1958	1,773	---	---	---	---	---	---	---	1	1,774
1959	216	86	---	3	---	---	---	---	---	305
1960	430	11	---	1	---	---	4	---	4	450
1961	218	29	---	5	---	---	---	---	7	259
1962	1,592	31	---	---	---	---	---	---	---	1,623
1963	2,074	130	---	---	---	---	12	---	20	2,236
1964	632	97	---	---	---	---	---	2	2	733
1965	363	234	---	---	---	---	---	1	1	599
1966	---	275	5	---	---	---	---	---	---	280
1967	100	203	3	---	---	---	---	---	1	307
1968	---	201	7	10	10	39	---	---	1	268
1969	---	95	16	---	---	6	---	---	10	127
1970	---	233	---	212	212	3	---	---	3	663
1971	---	390	19	---	---	---	---	---	1	410
1972	---	172	500	---	---	3	---	2	2	679
1973[c/]	---	47	504	22	---	125	---	---	2	700
1974[c/]	240	91	469	11	---	77	---	15	4	907
Total	25,944	2,325	1,523	268	222	253	16	20	68	30,639

a/ Douglas fir tussock moth virus.

b/ Trichlorfon, Lead Arsenate, Methoxychlor, Phosphamidon, Dimethoate Propoxur, GBTC Virus, Gardona (Trade name, Shell International Chemical Co.).

c/ These figures are for fiscal years 1973 and 1974. The DDT application for the Douglas fir tussock moth extended into FY 75, covering a total of about 430,000 acres.

Sources

Sartwell and Ailligood, 1974 (calendar years 1945-1972).
US Forest Service, 1974 and 1975 (fiscal years 1973 and 1974).

Table IIID.32

Comparison of DDT and Alternative Controls on Major Forest Defoliating Insects

	DDT	Carbaryl	Mexacarbate	*Bacillus thuringiensis*	Polyhedrosis Virus	Fenitrothion	Trichlorfon
Registration							
Spruce budworm	No	Yes	Yes	EP[a]	No	Yes	No
Gypsy moth	No	Yes	No	Yes	No	No	Yes
Tussock moth	No	No	No	No	EP[a]	No	No
Availability	NA[b]	Limited	Unavailable[c]	Good	Limited	Limited	Good
Persistence	Several years	2 weeks	2 days	Several days to 2 weeks	[d]	2 weeks	1 week
Chemical cost ($/A)	$1.00	$1.50	$1.68	$9.00	Unknown[e]	$1.10	$3.38
Total cost[f] ($/A)	$3.00	$3.50	$3.68	$11.00		$3.10	$5.38

a/ EP - An experimental permit has been granted by EPA.
b/ Montrose Chemical Co. produces DDT for export purposes.
c/ Dow Chemical Co. was the sole producer of mexacarbate (Zectran - registered trademark). The product is no longer produced due to the limited market.
d/ Virus persistence and spread is dependent on biological and environmental factors.
e/ The virus is in the developmental stage.
f/ Total cost includes the application cost assumed to be $2/A. This assumes maximum economies of scale in large area applications. Smaller areas require higher per acre application costs.

Sources

Registration: Registration Division, Office of Pesticide Programs, EPA.
Availability: Hofacker, 1975.
Persistence: US Forest, 1972a, and Northeastern Regional Pesticide Coordinators, 1972.
Chemical Costs: The Charles H. Lilly Co., 1974.

tussock moth but much further testing of formulations and application techniques must be done (EPA, 1974a).

The shift from DDT to alternatives can be characterized by a changeover to non-persistent control agents. DDT is very broad spectrum, affecting many non-target insects and other organisms. Carbaryl and fenitrothion are also broad spectrum to a degree but their low persistence allows nontarget species to recover to near normal levels in a short time (US Forest Service, 1974).

Problems

At present, no one alternative is registered for all three major forest pests. There are currently no registered products available for use against the tussock moth, although an experimental use permit has been issued for polyhedrosis virus. Of the alternative controls, only mexacarbate is now unavailable. Dow Chemical Company was the only manufacturer and ceased production in 1972 due to the limited and highly uncertain market for the compound. Carbaryl and fenitrothion are available in limited amounts due to allocation programs following the shortages of many pesticide compounds in the previous two years. Other biological controls are essentially in the developmental stage and it is doubtful that commercial quantities would be available for widespread use if needed on short notice.

BENEFITS OF CONTROL

The benefits of control are entirely due to preventing or reducing the loss of living trees. Primary losses result from reduction in commercial wood supply, loss of valuable esthetic trees, and major changes in some ecosystems. Secondary losses result from disruption of normal harvesting of timber and management of forests, as well as the consequent economic and social losses occurring to the dependent communities. These and other losses are discussed further.

Timber losses

The most obvious impact of epidemic defoliation is the killing of commercially valuable trees. Areas attacked may suffer losses varying from 5-100%. Individual areas may vary from a few to several hundred acres. Salvage of this killed timber is often feasible where sufficient quantities per acre are harvested, providing the harvest occurs promptly after death. Prompt salvage of all killed timber is almost never possible and recovery may be limited to 50% or less. There are several reasons for this. Many areas requiring salvage are inaccessible until roads are built to serve them. The economics of harvesting is closely related to the amount of wood harvested per acre. Harvesting of small volumes per acre where mortality is light is uneconomical particularly where new roads must be built. Where large volumes are involved, but are scattered or patchy within a single timbershed (area serving a processing center), the time required for major salvage may exceed the durable life of the dead timber. In northern timber areas of the United States, where the most serious epidemics have occurred, trees usable for sawtimber may remain salvageable for up to 3 years. In the south most dead trees have lost salvage value after 1 year. Trees, in the north, salvageable for pulping may last for 6 or 7 years for some species. In all cases, there is a gradual deterioration in value over time. In many cases, the delayed mortality of trees initially weakened by partial defoliation, further increases the amount of unrecovered loss.

A less obvious, though possibly as serious a loss, may occur from the reduction in growth rate in many young trees not killed. Repeated defoliation, even partial, reduces new wood formation during the attack year and for several subsequent years. Where repeated partial defoliation affects wide areas of poorly stocked stands, the loss represents a sizable reduction in forest productivity and becomes serious where young, immature stands are affected.

Disruption of harvesting and management

As indicated, the costs of harvesting dead or injured trees is usually considerably higher than normal harvesting costs. Combined with this is the continued deterioration in the value of the salvaged wood. At some point these combined losses exceed the value of the wood delivered for processing. The pace of harvest is necessarily limited by the processing capacity within hauling distance of the affected forest and/or the pace of road building. Where processing plants run continuously on raw material from salvage operations, the quality of their product is necessarily lowered. Marketing this lower quality material may seriously affect the profit position of the mills.

The saw and pulp mills may be required to run at an accelerated pace, requiring additional labor for the period of salvage. This may result in overtime payments to regular workers, and possibly the importation of workers for extra shifts. A short-term stimulating effect on local employment and business may follow; however, a long-term reduction of timber supply can result in future curtailment of economic activity in these communities.

Disruption in the management of a forest property results in both short- and long-term effects. An epidemic insect attack may require that all management personnel and equipment be involved in control efforts. Other normally scheduled activities such as timber sale preparation, tree planting, and fire suppression are temporarily suspended. The consequent organization of salvage activities further interferes with the conduct of normal management functions. Extensive areas of dead and dying timber also increase the hazard of explosive, highly destructive wild fires. The threat of catastrophic loss from wild fire may continue for several years requiring additional equipment, personnel, and preparation. Layout and construction of access roads to effect salvage of killed timber will require extra efforts and personnel during the period of salvage.

Long-term effects on systematic management of forests are more subtle. Forests, fully organized to provide a sustained level of annual harvests, require a fairly even distribution of areas in progressive stages of growth from seedlings to mature trees. Very few forests in the United States, particularly in the West, have yet achieved this degree of organization. Under an ideal forest organization, areas to be harvested in a given year would consist of one or a few sizable blocks of timber which could be harvested with a minimum of new road building or maintenance. Where insect attacks result in widely scattered, small areas of liquidated forests replaced by new established stands, future management efforts, including eventual harvests, are further complicated and correspondingly costly. Aside from these complications, the overall management of the forests may be disrupted seriously only when these attacks result in an overbalance of young stands in relation to juvenile and mature timber. Many, if not most, of the western forests, particularly public forests, have a serious overbalance of mature timber. Accelerated harvest and replacement of older stands on these forests results in accelerated forest growth by replacing old, slowly growing forests with young ones. To the extent that this condition exists, the future productivity of these forests may, in fact, be increased rather than decreased. Thus, it is entirely possible that, provided localized timber losses are of principally mature timber and are not too severe, the dependent mills and local communities may suffer little if any long-term loss in stability.

Effects on other values

The effects on wildlife from epidemic losses of timber are directly related to the patterning of timber kills. Extensive areas of killed timber which is later salvaged, will provide a new habitat of low vegetation attractive to grazing animals and the smaller herbiverous forms. To the extent that this habitat has been scarce, it may provide a very attractive food source for several big game species. These areas would likewise provide increased range forage for livestock where this is an important forest use.

Watershed values are particularly important in western mountainous forests. Much water useful to man is derived from forested watersheds. This yield of water is heavily dependent upon the accumulation of snowfall during the winter months. It is well established that clearing or partial clearing of timber increases the accumulation of snowpack and consequent water yield from watersheds. However, these increased water yields may be delivered through snowmelt resulting in increased flooding and damage. The effects of clearing and increased snowpack on the dry season (summer and fall) water yield is less clear. Where watersheds have been cleared extensively, there appears to be a reduction in dry weather yield of water. Where clearing is patchy and partial, it is possible that the total yield of usable water may be increased without serious loss of dry season flows.

The losses in esthetic values from defoliation, temporary or permanent, is felt most heavily in developed recreation areas and homesites. Loss of shade and visual beauty during the summer months may reduce use and enjoyment. These effects have been particularly serious in eastern states attacked by the gypsy moth and occasionally by the spruce budworm. Fortunately, recreation areas are generally accessible, frequently visited, and as a consequence, usually receive early control efforts to reduce losses. In this connection, there are additional effects from the attack of both tussock moth and the gypsy moth. Since these pests attack heavily during the recreation season, their presence is distasteful to visitors and the larvae may cause allergic reactions in some people. Workers on the earliest salvage of tussock moth-killed timber are also hindered by this nuisance.

Measurement of benefits

Estimates of the expected benefits from control have been made for a number of recent control projects and are incorporated in the environmental impact statements. However, these estimates are very difficult to document since little serious effort has been directed at evaluating the impacts of past epidemic insect attacks. As indicated, the nature of damage is highly varied and the extent of damage may be serious in a given situation.

Estimates of the timber damage prevented are uncertain for a number of reasons. The effects of man's efforts to control epidemic insect populations is complicated by his inability to predict the development or collapse of the pest population. As described, the stage of insect population development or possible spread has in many cases defied our best efforts at prediction. The widespread incidence of the virus disease of the Douglas fir tussock moth has been associated with the onset of the decline phase of an outbreak. However, other factors not yet understood also seem to contribute to both the spread and the collapse of epidemic populations.

Tree mortality as a result of defoliation is somewhat predictable within wide confidence limits. The possible recovery of trees from multiple years of defoliation appears to be highly dependent upon the weather patterns of succeeding years. When attack-free years following the first or second year of defoliation are characterized by mild temperatures and ample moisture, tree recovery may be the rule. However, initial recovery may leave trees in a condition of reduced vigor, making them susceptible to attacks by secondary pests especially bark beetles (Wickman et al, 1973). Thus, mortality over several succeeding years may be higher than would be true in nonattacked stands.

Reductions in growth of immature stands through partial defoliation may be only temporary. Where this is combined with scattered mortality in dense stands, the surviving trees may experience stimulated growth in succeeding years equal to or exceeding the growth of nonattacked stands (Wickman and Scharpf, 1972). Thus, the prediction of growth loss becomes highly complex and dependent in part on future weather patterns.

Evaluation of higher harvest cost losses due to salvage activity together with the reduced value of products can be more easily estimated once the extent of salvage has been determined. Once again, the orderly progress of salvage activities, in part weather-dependent, must be assumed in order to estimate the maximum amount of salvage from the total recovery program. The impact on local communities providing the labor for processing plants can be estimated given certain assumptions concerning the market, salvaged material, and the extent and duration of the salvage program. Since markets for wood products, especially lumber, fluctuate widely with the prosperity of the housing and construction market, the salability and price of these products determine the level and stability of employment in these processing plants. To date only limited efforts have been made to estimate these employment effects directly traceable to epidemic insect attacks and consequent salvage operations (USFS and APHIS, 1974: EPA, 1974b).

The effects, both short- and long-term on forest management have been described. No known effort has been made to quantify these effects (McCay and White, 1973).

Measurement of other values

Very little effort is directed to evaluation of insect epidemic attacks on wildlife, watershed, or esthetic values. The Forest Service, Regions II and IV[1] have attempted to evaluate the impact of past epidemics of defoliating insects in the inter-mountain region on losses to recreation, wildlife, and timber values. The value of residential property losses has been estimated based on number of trees, expected mortality, lot size and value (McCay and White, 1973).

In order to provide additional information on the benefits of control of the tussock and gypsy moths, a study has been funded to evaluate benefits of DDT and other controls of these two pests. This study is conducted under an EPA/USDA interagency agreement at a level of effort of $320,000, is now underway and will be completed in 1977. It is expected to significantly add to the other research USDA/FS is doing in the area of costs and benefits of control of forest insect pests.

FEDERAL POLICY ON USE OF PERSISTENT PESTICIDES

US Department of Agriculture

In 1964, the Secretary of Agriculture issued a memorandum urging discontinuation of use of persistent pesticides (USDA, 1964). The expressed concern for environmental effects was particularly directed at the widespread use of DDT.

Over the next 4 years, the Forest Service was actively testing a number of substitute chemicals, while attempting to phase out the use of DDT. In

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[1] Region II includes South Dakota, Nebraska, Kansas, Colorado, and part of Wyoming. Region IV includes Nevada, Utah, and parts of Wyoming and Idaho.

1969, the Secretary of Agriculture issued Memorandum number 1666, (USDA, 1969) directing that persistent pesticides will not be used except when no alternatives are available. It also directed that pest control actions emphasize the use of integrated pest management strategies and, where chemical pesticides were required, they should be nonpersistent formulations. The Cooperative State Research Service was directed to encourage research on nonpersistent pesticides and biological controls.

In 1973, the Secretary of Agriculture issued a replacement memorandum for the 1969 policy statement. This memorandum repeated several policies enunciated earlier and further emphasized the Department's dedication to research into effective biological, cultural, and integrated pest control materials and methods. It also pledged the Department to cooperate with other public and private organizations in the development and evaluation of pest control materials and methods, assessment of benefits and potential hazards in control operations, monitoring for pesticide residues, and dissemination of pesticide safety information. Department users of pesticides were strongly urged to heed label directions and exercise constant care in pesticide application, storage, and disposal for the protection of people, animals, and our total environment (USDA, 1973).

The US Forest Service has been involved in most forest pest control activities conducted by states or private owners. The Forest Pest Control Act of 1947 (16 USCA Sections 594 et seq.), administered by the Forest Service, instituted a program of surveying pest hazards and provided fifty percent cost sharing for control of insect pests on state and private ownerships. This program enabled private owners and the states to participate in control activities at the reduced costs made possible by large scale control operations.

US Department of the Interior

Several of the Services and Bureaus of the Department of the Interior are concerned with management of wild lands, management of water resources, or both. In 1964, Secretary Udall issued a policy memorandum discontinuing use by Department agencies of chlorinated hydrocarbon pesticides. In 1970, Secretary Hickel issued a more comprehensive policy statement. Attached to this statement is a list of prohibited chemicals and another list of restricted control agents. No agency of the Department was permitted to use any pesticide on the prohibited list, including DDT (USDI, 1970).

Thus, by 1970, the two Federal departments which had major responsibilities for land management and concern for water quality had discontinued or severely restricted the use of persistent pesticides, including DDT. This was two or more years prior to the EPA order cancelling most uses of DDT. Thus, these issues were not addressed by the cancellation order.

Conclusion

DDT was widely used against defoliating forest insects through the mid-1960's. However, both USDA and USDI discontinued use of DDT and other chlorinated hydrocarbon insecticides, as a matter of policy, by the late 1960's because of concern for environmental effects. There are registered alternatives to DDT for the spruce budworm and the gypsy moth, but none for the tussock moth.

An experimental use permit has been issued by EPA for use of Polyhedrosis virus against the tussock moth. EPA also authorized emergency use of DDT against this pest in 1974.

Benefits of control of forest insect pests by alternative means have been evaluated to some extent but further evaluation is in process via a study under a USDA/EPA interagency agreement. This study is scheduled to be completed by 1977 and will enhance our ability to quantify these benefits.

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APPENDICES

ENVIRONMENTAL PROTECTION AGENCY

[I. F. & R. Dockets Nos. 63, etc.]

CONSOLIDATED DDT HEARINGS

Opinion and Order of the Administrator

Published herewith is my opinion and order issued June 14, 1972, concerning the registrations of products containing the insecticide DDT.

Done this 30th day of June 1972.

WILLIAM D. RUCKELSHAUS,
Administrator.

STEVENS INDUSTRIES, INC., ET AL.

OPINION OF THE ADMINISTRATOR

Before the Environmental Protection Agency: In re: Stevens Industries, Inc., et al. (Consolidated DDT Hearings), I.F. & R. Docket No. 63 et al.

This hearing represents the culmination of approximately 3 years of intensive administrative inquiry into the uses of DDT. Part I sets forth the background of these proceedings and Part II contains a discussion of the evidence and law and my factual conclusions. I am persuaded for reasons set forth in Part III of this opinion that the long-range risks of continued use of DDT for use on cotton and most other crops is unacceptable and outweighs any benefits. Cancellation for all uses of DDT for crop production and nonhealth purposes is hereby reaffirmed and will become effective December 31, 1972, in accordance with Part V of this opinion and the accompanying order, except that certain uses, for green peppers, onions, and sweet potatoes in storage may continue on terms and conditions set forth in Part V of this opinion and the accompanying order.

I—A. *Background.* DDT is the familiar abbreviation for the chemical (1,1,1,trichloro-2,2-bis(p-chlorophenyl) ethane), which was for many years the most widely used chemical pesticide in this country. DDT's insecticidal properties were originally discovered, apparently by accident, in 1939, and during World War II it was used extensively for typhus control. Since 1945, DDT has been used for general control of mosquitoes, boll weevil infestation in cotton-growing areas, and a variety of other uses. Peak use of DDT occurred at the end of the 1950's and present domestic use of DDT in various formulations has been estimated at 6,000 tons per year.[1] According to Admission 7 of the record, approximately 86 percent or 10,277,236 pounds of domestically used DDT is applied to cotton crops. The same admission indicates that 603,063 pounds and 937,921 pounds, or approximately 5 percent and 9 percent of the total formulated by 27 of the petitioners to these hearings are used respectively on soybean and peanut crops. All other uses of the 11,966,196 pounds amount to 158,833 of the total, or little over 1 percent.[2]

Counsel for the Agency has called to our attention publication of the Department of Agriculture, The Pesticide Review of 1971, which estimates "a domestic disappearance" rate of 26,457,000 pounds for DDT in 1970. *See* p. 28. The motion to incorporate this publication is granted, as is the motion by registrants to supplement the record, see infra. I do not believe, however, that the Pesticide Review figure can be accepted, on its face, without further explanation. Since the result I reach today would, if anything, only be reinforced by the higher figure, I see no need to remand.

For the above uses it appears that DDT is sold in four different formulations: Emulsifiable sprays; dust; wettable powder; and granular form.

Public concern over the widespread use of pesticides was stirred by Rachel Carson's book, "Silent Spring," and a natural outgrowth was the investigation of this popular and widely sprayed chemical. DDT, which for many years had been used with apparent safety, was, the critics alleged, a highly dangerous substance which killed beneficial insects, upset the natural ecological balance, and collected in the food chain, thus posing a hazard to man, and other forms of advanced aquatic and avian life. In 1969, the U.S. Department of Agriculture commenced a review of the health and environmental hazards attendant to the use of DDT.

Certain uses of DDT were canceled by the Department of Agriculture in 1969 and informal review of remaining uses continued through 1970.[3] In early 1971, this Agency commenced formal administrative review of DDT registrations by the cancellation of all registrations for DDT products and uses pursuant to section 4(c) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 7 U.S.C. section 135 (1972).[4]

B. *Statement of the case.* This hearing is the final stage of formal administrative review.[5] Thirty-one registrants have challenged 18 of the canceled uses of DDT and its metabolite, TDE.[6] These uses of DDT include applications to cotton fields to control the boll weevil and bollworm applications to various vegetable crops, and a variety of lesser uses in public programs. The case for cancellation has been presented by counsel for the Pesticides Office of the Environmental Protection Agency and attorneys for the Environmental Defense Fund which is an intervenor. Other parties include Eli Lilly & Co., which held a DDT registration for "topocide," a prescription drug.[7] H. P. Cannon & Son, a user of DDT,[8] and representatives of the chemical manufacturing industry and various wildlife groups.[9]

The testimony and exhibits cover in exhaustive fashion all aspects of DDT's chemical and toxicological properties. The evidence of record, however, is not so extensive concerning the benefits from using DDT, and most of it has been directed to the major use, which is on cotton crops.[10]

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[1] Admission 6 shows that domestic shipments of DDT by its sole manufacturer, Montrose Chemical Co., totaled 8,827,000 pounds between January 1 and August 1, 1971. Total domestic sales in 1970 were 11,966,196, as stipulated in Admission No. 7. The Examiner found, apparently based on Admission 7, that domestic use in 1970 "was just under 12 million pounds." Exam Report at 42.

[2] Some discrepancy in the figures exists since the figures given in breakdown of use categories total 11,977,085 pounds, slightly more than the total sold by the 27 formulators who supplied figures.

[3] PR Notice 69-17. Among the canceled uses were applications to trees for control of Dutch Elm disease, tobacco, home uses, and aquatic uses. 34 F.R. 18827 (1969).

[4] In Environmental Defense Fund v. Ruckelshaus, 439 F. 2d 584 (D.C. Cir. 1971), the court of appeals held that cancellation proceedings should be commenced whenever a registration of a pesticide raises a "substantial question of safety" which warrants further study. On Jan 15, 1971, all uses of DDT not canceled in 1969 were canceled. PR Notice 71-1. And on Mar. 18, 1971, notices of cancellation were issued for all registered uses of TDE, a DDT metabolite. PR Notice 71-5.

[5] Under FIFRA a registrant is entitled to either a public hearing or a scientific advisory committee or both to review his registration. Pending completion of that review, a registrant is allowed to continue shipment of his product.

[6] Unless specified, discussion of DDT in this opinion applies to TDE. DDT has three major breakdown products, DDA, DDE, and DDD; separate registrations exist for TDE (DDE).

[7] There has been some controversy over Eli Lilly's status because it failed to appeal cancellation of its registration within 30 days as required by section 4(c) of FIFRA. For the purposes of this case I believe they should be accorded status as parties.

[8] There has been some question as to whether or not a "user" has standing to appeal a cancellation and thus seek reinstatement of a canceled use even though no registrant has stepped forward to appeal. The same reasoning employed by the court in Environmental Defense Fund v. Ruckelshaus, supra, and Environmental Defense Fund v. Hardin, 428 F. 2d 1093 (D.C. Cir. 1970), which accords standing to "public interest" groups gives "users" a right to appeal a cancellation.

[9] The groups are: National Agricultural Chemicals Association; National Audubon Society; The Sierra Club; and West Michigan Environmental Action Council. As already noted, the Secretary of Agriculture, in addition to being a party-registrant by virtue of registrations held by its Plant Regulation Division, has appeared as an intervenor.

[10] The following uses are involved: For cotton; for military use on clothing; for peppers and pimentos; for fresh market corn; for peanuts; for cabbage, cauliflower, and brussel sprouts; for tomatoes; for lettuce; for potatoes; for sweet potatoes in storage (Southern States only); for use in commercial greenhouses and nurseries; for beans (dry, lima, snap); for bat and rodent control; for emergency use for agriculture, health or quarantine purposes, and for onions and garlic; and for lice control. There has been considerable controversy as to what uses were at issue during the hearing. Admission No. 2 sets forth those uses which the Department of Agriculture considers essential. Many of those uses have been canceled and no appeal was taken. The uses at issue in this hearing are only those noted in Admission 11.

The Pesticides Office and Environmental Defense Fund (EDF), in presenting their cases against continued registration for DDT, lean most heavily on evidence which, they contend, establishes (1) That DDT and its metabolites are toxicants which persist in soil and the aquasphere; (2) that once released, DDT is an uncontrollable chemical which can be transported by leaching, erosion, runoff, and volatilization; (3) that DDT is not water soluble and collects in fat tissue; (4) that organisms tend to collect and concentrate DDT; (5) that these qualities result in accumulations of DDT in wildlife and humans; (6) that once stored or consumed, DDT can be toxic to both animals and humans, and in the case of fish and wildlife inhibit reproduction of species; and (7) that the benefits accruing from DDT usage are marginal, given the availability of alternative insecticides and pest management programs, and also the fact that crops produced with DDT are in ample supply. The testimony and exhibits include numerous reports of expert scientists who have described observed effects of DDT in the environment and the laboratory.

Group Petitioners and the U.S. Department of Agriculture (USDA) seek to discredit the Agency's case by citing the record of safety DDT has compiled throughout the years, and point to the negative findings of epidemiological and human feeding studies carried out over the years on industrial workers and volunteers exposed to concentrated levels of DDT far in excess of that to which the average individual is exposed. Proponents of continued registration have also introduced expert testimony to the effect that DDT's chronic toxicity to man or animals has not been established by adequate proof. The registrants have attacked the assumption that laboratory data, as to effects of exaggerated doses of DDT, can provide a meaningful basis for extrapolating effects on man or the environment. In the alternative, Group Petitioners contend that whatever harm to the environment might be attributed to DDT, it results from misuse and overdosing that occurred in years past. Lastly, Group Petitioners and USDA have attempted to prove that DDT is effective and that its use is more desirable than the organophosphates which are more acutely toxic and costly than DDT.

On April 25, the Hearing Examiner issued an opinion with *proposed findings*, conclusions and orders recommending that all "essential" uses of DDT be retained and that cancellation be lifted.[11] The Examiner's report which has findings, conclusions, and an opinion, is attached below. The Examiner apparently accepted in his report the Agency's proof that DDT is a hazard to aquatic and terrestrial wildlife and substitutes exist. He found, as a "matter of fact," DDT can have adverse effects on beneficial animals; that it is transferred through the food chain; that DDT is fat soluble. He concluded, however, as a "matter of law," that DDT is neither a carcinogen nor teratogen, that the particular uses at issue do not adversely affect wildlife, that DDT use has rapidly declined. (Examiner's Rept. p. 93.)

The Pesticides Office of this Agency and Intervenor Environmental Defense Fund (EDF) filed exceptions to the Examiner's report,[12] challenging his application of the burden of proof to this case, his findings of fact, conclusions of law, and numerous evidentiary rulings. *Exception* was also taken to the Examiner's application of the so-called "risk and benefit" standard of FIFRA.

On May 2, 1972, the Judicial Officer propounded by order, at my direction, a series of questions for briefing and discussion at oral argument, and oral argument was held on May 26. That argument was transcribed and is part of this record. Group Petitioners, USDA, Eli Lilly, and H. F. Cannon & Sons have also responded to the briefs on exceptions.

II—A. *Applicable law.* The basic FIFRA scheme has been outlined in court opinions and Agency decisions (see EDF v. EPA, D.C. Cir. Slip Op. 71-1365, ______ F. 2d ______, May 5, 1972 (opinion of Judge Leventhal); Stearns Elec. Paste Co. v. EPA, 7th Cir. Slip Op. No. 71-1112, ______ F. 2d ______, May 11, 1972, Continental Chemiste Co. v. EPA, 7th Cir. Slip Op. No. 71-1828, ______ F. 2d ______, May 11, 1972; EDF v. Ruckelshaus (opinion of Judge Bazelon), supra; Statement of Reasons Concerning the Registration of Products Containing DDT, 2,4,5-T, and Aldrin/Dieldrin, March 18, 1972; In re Hari-Kari Lindane Pellets, et al., I F&R. No. 6 (1971)). While there is no need to trace in detail once again the statutory scheme, a brief summary provides a useful prism for filtering the evidence.

1. *FIFRA.* The Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. section 135 (1972), establishes a strict standard for the registration of pesticides. Any "economic poison" which cannot be used without injury to "man or other vertebrate animals, vegetation, and useful invertebrate animals" is "misbranded,"[13] and is therefore subject to cancellation.[14]

While the language of the statute, taken literally, requires only a finding of injury to nontarget species, the inquiry cannot, however, end with a simplistic application of this plain statutory language. Both judicial and administrative precedent recognize that Congress intended the application of a balancing test, that would measure the risks of using a particular chemical against its benefits.[15] If a product is "misbranded" within the meaning of the Act, i.e., if it bears a label for use that does not meet the criteria of section 2, it may no longer be shipped in interstate commerce and stocks in hand in the original package may be seized. 7 U.S.C. section 135(g) (1972).

2. *Risks and benefits.* It follows from the statutory scheme and this Agency's decisions that evidence of each alleged risk must be reviewed and a conclusion reached as to whether or not, and in what degree, such risk is incident to the directed use of a particular product. The task, however, is complicated in the case of a "persistent" pesticide by its possible chronic effects. The degree of persistence, extent of overall usage and mobility all bear on the amplitude or indeed the existence of the risk curve.[16] I believe, however, it is useful to isolate the alleged risks and evaluate each on the assumption that they are unaffected by overall levels of use, and defer to Part IV the discussion of the significance of the relationship between risk and overall use.

III—A. *Analysis of evidence—1. Risks—a. Health effects and environmental properties.* There is no dispute on this record that DDT is a nonspecific chemical that kills both target and nontarget species in the immediate area of application. Few chemicals, however, are so selective that they can be used without causing some injury to "nontarget" species. We must therefore proceed to the evidence bearing on other "risks" and the "benefits" from using DDT.

I am convinced by a preponderance of the evidence that, once dispersed, DDT is an uncontrollable, durable chemical that persists in the aquatic and terrestrial environments. Given its insolubility in water and its propensity to be stored in tissues, it collects in the food chain and is passed up to higher forms of aquatic and terrestrial life. There is ample evidence to show that under certain conditions DDT or its metabolites can persist in soil for many years,[17] that it will volatilize or move along with eroding soil.[18] While the degree of transportability is unknown, evidence of record shows that it is

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[11] There is some confusion as to what the term "essential" means. By Admission No. 2 the parties stipulated that certain uses were "essential" in the view of USDA. No stipulation exists that these uses are, in fact, essential in that no alternatives exist or that a shortage of a crop would result without DDT.

[12] Exceptions have also been received in Docket 106, In Re Wallerstein. Stark Bros. Nurseries held a registration for use of DDT on nursery plants. The Examiner recommended cancellation on the grounds that this was not an "essential" use according to USDA.

[13] Secs. 2(z)(2) (c), (d), and (g), respectively provide:

"The term 'misbranded' shall apply—

(a) To any economic poison—

* * * * *

(c) If the labeling accompanying it does not contain directions for use which are necessary and if complied with adequate for the protection of the public;

(d) If the label does not contain a warning or caution statement which may be necessary and if complied with adequate to prevent injury to living man and other vertebrate animals, vegetation, and useful invertebrate animals;

* * * * *

(g) If in the case of an insecticide, nematocide, fungicide, or herbicide when used as directed or in accordance with commonly recognized practice it shall be injurious to living man or other vertebrate animals, or vegetation, except weeds, to which it is applied, or to the person applying such economic poison;

* * * * *

[14] Sec. 4 permits the Administrator to cancel a registration "if it appears that 'the article and its labeling * * * do not comply with [the Act].'" Since the Act prohibits distribution of a "misbranded" pesticide, sec. 3(a)(5), the registration for a "misbranded" product may be canceled.

[15] See EDF v. EPA (opinion of Judge Leventhal), supra; EDF v. Ruckelshaus (opinion of Judge Bazelon), supra, DDT Statement of *Reasons*, supra; *see also* Statement of Reasons Underlying Suspension and Cancellation of Products Containing Mercury, 37 F.R. 6419 (Mar. 29, 1972).

[16] Other factors bearing on risk may include the geographical location of application, see, e.g., Statement of Reasons Underlying Registrations for Strychnine, 1080, and Sodium Cyanide, 37 F.R. 5718 (1972), although this may not be as significant where the chemical is highly volatile as is the case with DDT. See also Statement of Reasons Underlying the Cancellation of Mirex, Determination and Order of the Administrator at 7 (37 F.R. 10987, June 1, 1972).

[17] Method of application and type of soil and climate can affect persistence in soil and likewise runoff into aquatic areas.

[18] Registrants have made much of the fact that aquatic contamination and the spread of DDT have resulted from drift during aerial application. While the Examiner's report dwells at some length on improved methods of application, it recognizes runoff as a significant source of aquatic contamination, even with improved aerial spraying techniques.

occasionally found in remote areas or in ocean species, such as whales, far from any known area of application.

Persistence and biomagnification in the food chain are, of themselves, a cause for concern, given the unknown and possibly forever undeterminable long-range effects of DDT in man, and the environment.[illegible] Laboratory tests have, however, produced tumorigenic effects on mice when DDT was fed to them at high levels[illegible] Most of the cancer research experts who testified at this hearing indicated that it was their opinion that the tumorigenic results of tests thus far conducted are an indicator of carcinogenity and that DDT should be considered a potential carcinogen[illegible]

Group Petitioners argue that the testimony is in conflict and fasten on to the testimony of the Surgeon General that of Drs. Loomis and Butler. The Surgeon General's statement was, however, cautious and, by no means, carries the burden that the Group Petitioners seek to place on it. In very general terms the Surgeon General stated: "We have no information on which to indict DDT either as a tumorigen or as a carcinogen for man and on the basis now available, I cannot conclude DDT represents an imminent health hazard." (Tr. 1250) This testimony, however, does not bear on the long-term effects of DDT, nor did the Surgeon General express a view on what uses, apart from health uses, would justify continued use of DDT. Indeed, the entire thrust of the Surgeon General's testimony was only that use for immediate health needs outweighs the possible long-range effects of DDT on human health. Group Petitioners' other witnesses, Drs. Loomis and Butler, while men of stature in their fields—toxicology and pathology—and knowledgeable about cancer treatment and diagnosis are not specialists in cancer research as is Dr Saffiotti. Indeed, Dr. Butler disclaimed such expertise

Group Petitioners also take refuge under a broad canopy of data—human feeding studies and epidemiological studies—and support it with the increasingly familiar argument that exposure to any substance in sufficient quantities may cause cancer.

None of the feeding studies carried out with DDT have been designed adequately to detect carcinogenicity, and given the latency period of cancer, these studies would have to be carried out for a much longer period. Statistical population samples for epidemiological studies are also virtually impossible given the latency period for cancer and the long-term exposure of the general population. Since there is no sharp distinction between population groups exposed to low doses and higher doses of DDT, adequate control groups cannot be established. The "everything is cancerous argument" fails because it ignores the fact that not all chemicals fed to animals in equally concentrated doses have produced the same tumorigenic results.

b. *Environmental effects*. The case against DDT involves more, however, than a long-range hazard to man's health. The evidence presented by the Agency's Pesticides Office and the intervenors, EDF, compellingly demonstrates the adverse impact of DDT on fish and birdlife. Several witnesses testified to first-hand observed effects of DDT on fish and birdlife, reporting lethal or sub-acute effects on aquatic and avian life exposed in DDT-treated areas. Laboratory evidence is also impressively abundant to show the acute and chronic effects of DDT on avian animal species and suggest that DDT impairs their reproductive capabilities[illegible]

The petitioner-registrants' assertion that there is no evidence of declining aquatic or avian populations, even if actually true, is an attempt at confession and avoidance. It does not refute the basic proposition that DDT causes damage to wildlife species Group petitioners' argument that DDT is only one toxic substance in a polluted environment, and thus, whatever its laboratory effects, it cannot be shown to be the causative agent of damage in nature, does not redeem DDT, but only underscores the magnitude of effort that will be necessary for cleaning up the environment. Were we forced to isolate in nature, rather than in the laboratory, the effects of various toxic substances, it would be difficult if not impossible to make a judgment as to the chronic effects of any chemical. As our DDT statement of March 1971 has noted: "Development of adequate testing protocols and facilities is a priority undertaking But in the short term, extrapolation from small-scale laboratory analyses must err on the side of safety." See DDT Statement of Reasons, at 11.

Finally, I am persuaded that a preponderance of the evidence shows that DDE causes thinning of eggshells in certain bird species. The evidence presented included both laboratory data and observational data. Thus, results of feeding experiments were introduced to show that birds in the laboratory, when fed DDT, produced abnormally thin eggshells. In addition, researchers have also correlated thinning of shells by comparing the thickness of eggs found in nature with that of eggs taken from museums. The museum eggs show little thinning, whereas eggs taken from the wild after DDT use had become extensive reveal reduced thickness.

Group Petitioners and USDA argue that the laboratory feeding studies, conducted with exaggerated doses of DDE and under stress conditions, provide no basis for extrapolating to nature. They suggest that the study results are contradictory and place particular emphasis on documents which were not part of the original record and the inconsistencies in Dr. Heath's testimony as brought out during cross-examination. Group Petitioners also contend that the observed phenomenon of eggshell thinning and DDE residue data are tied by a statistical thread too slender to connect the two in any meaningful way.

Viewing the evidence as a total picture, a preponderance supports the conclusion that DDE does cause eggshell thinning. Whether or not the laboratory data above would sustain this conclusion is beside the point. For here there is laboratory data and observational data, and in addition, a scientific hypothesis, which might explain the phenomenon[illegible]

B. *Benefits*—1. *Cotton*. I am convinced by the evidence that continued use of DDT is not necessary to insure an adequate supply of cotton at a reasonable cost. Only 30 percent of cotton-producing acreage is treated with DDT, although the approximately 10,277,258 pounds used in cotton production is a substantial volume of DDT and accounts for most of its use. The record contains testimony by witnesses called by registrants and USDA attesting to the efficacy of organophosphate chemicals as substitutes for DDT and, long-range, the viability of pest management methods, such as the diapause program. At present most areas that use DDT combine it with an organophosphate and toxaphene in a 4-2-1 mixture (4 lbs. toxaphene, 2 DDT, 1 methyl parathion). Some areas, however, according to the testimony, which normally use DDT occasionally apply concentrated methyl parathion in a 4-pound mixture.

There is evidence that organophosphates would not raise costs to the farmer and might, indeed, be cheaper. Any suggestion that the organophosphates are not economically viable cannot be maintained in face of the undisputed evidence that cotton continues to be tenable crop in Arkansas and Texas where DDT use has declined.[24] There is

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[illegible] It is particularly difficult to anticipate the long-range effects of exposure to a low dose of a chemical. It may take many years before adverse effects would take place. Diseases like cancer have an extended latency period. Mutagenic effects will be apparent only in future generations. Lastly, it may be impossible to relate observed pathology in man to a particular chemical because of the inability to isolate control groups which are not exposed in the same degree as the rest of the population.

[illegible] Tumorigenic effects have been noted in a number of laboratory experiments. The most positive results were developed by the Bionetics Study and the Lyons and Milan tests. The Bionetics Study of the National Cancer Institute fed 120 compounds to two strains of mice. DDT was one of 11 compounds to produce an elevated incidence of tumors. The Lyons and Milan Studies of the International Agency for Research of the World Health Organization is a multigenerational study (still in progress) of 6,000 mice of in- and out-bred strains. Increased hepatomas were noted in male and female mice fed DDT at 250 p.p.m. Metastasis to the lungs or kidneys has been recorded in five instances.

[illegible] Witnesses testifying to the positive correlation between tumorigens and carcinogens were Dr. Umberto Saffiotti, Associate Scientific Director for Carcinogenesis, Etiology Area, National Cancer Institute; Dr Marvin Schneiderman, Associate Chief, Biometry Branch and Associated Director for Demography, National Cancer Institute; Dr Samuel Epstein, Senior Research Associate in Pathology, Children's Cancer Research Foundation, Inc., Boston.

[illegible] See the testimony of Drs. Tarzwell, Nicholson, Philip Butler, Duke, Burdick, Dimond, Risebrough, Hickey and Cade.

While the Examiner erroneously excluded testimony as to economic losses caused by DDT's contamination of the aquatic environment—losses to commercial fishermen caused by inability to market contaminated fish—this risk is significant, even if it could not be economically quantified. Not all risks can be translated into dollars and cents, nor can all benefits be assessed in cash terms.

[illegible] The chief witness introduced to rebut Drs. Risebrough, Hickey, and Cade was a graduate student with limited training in statistical analysis In view of the credentials of EDF's witnesses—Dr Hickey, Professor of Wildlife Ecology at College of Agriculture, University of Wisconsin; Dr. Risebrough, Associate Ecologist, University of California at Berkeley; and Dr Cade, Professor of Zoology at Cornell and Research Director of Cornell Ornithology Laboratory—I cannot credit this attempt at rebuttal.

The Hearing Examiner apparently resolved the conflict in the evidence by concluding that "there was no evidence that DDT was the only factor in a decline of bird populations * * *" and that no evidence "focused its direct thrust on damage to birds by the uses of DDT that are permitted under the registrations in question." Examiner's Report, 70 71 In view of DDT's persistence and mobility, evidence as to the causal effect of these uses was not required.

At argument and by motion Group Petitioners have offered additional evidence, some of which bears on the issue of eggshell thinning I have granted that motion and considered all that data.

[24] The parties have referred neither in briefs nor argument to testimony or exhibits describing in detail the economics of cotton production or substitutes. There is general testimony that cotton producers receive a per bushel subsidy and that this

(Footnote 24 continued on next page)

also testimony in the record to the effect that methyl parathion costs less per application than the DDT-toxaphene formula. Nor are the testimony and exhibits that show cotton insects develop resistance to organophosphate chemicals to the point. The very same exhibits make clear that DDT is also subject to resistance.[illegible]

Group Petitioners and USDA, while not disputing the lesser persistence of organophosphates, have stressed their demonstrated acute toxicity. While they are toxic to beneficial soil insects and non-target species particularly birds alighting on treated fields, these organophosphates break down more readily than DDT. They apparently are not transported in their toxic state to remote areas, unlike DDT which has been found far from treated areas and consequently do not pose the same magnitude of risk to the aquasphere. Both testimony and exhibits also demonstrate that organophosphates are less acutely toxic to aquatic life, although different compounds have different toxicities. The effect of organophosphates on non-target terrestrial life can, unlike the effects of DDT, also be minimized by prudent use. Application in known nesting areas for rare or extinct birds can be avoided.

2. *Other crop and produce uses.* The testimony of record, while sparse, shows that registered alternatives, primarily organophosphates, exist for all other crop and ornamental uses of DDT, except for storage use on sweet potatoes to control weevils, on heavy corn borer infestations of green peppers, and perhaps onions.[illegible]

3. *Noncrop uses.* In addition to the registrations for use on crops and in nurseries, several registrations for noncrop uses are also in issue. Admission 11 lists "public health pests—bats and rodents," "Agricultural, Health and Quarantine Treatments in Emergencies as Recommended by and Under Direction of State-Federal Officials" and "fabric treatment" by the military.

The record is not, unfortunately, well developed as to the scope or method of application for these uses nor as to the overall volume applied for these purposes. While use for bat and mice control is characterized in Admission 11 as a "public health use," application for those purposes is not supervised by public health officials. The briefs suggest that use for control of bats and mice is a proprietary use by the military, even though a private pest control operator testified that use for bats was considered essential by private operators.[illegible] With respect to "Agricultural and Quarantine" uses it is difficult to determine to what extent applications are for health purposes or for nuisance prevention.

With respect to all of these uses, both for public health programs and proprietary use, alternatives do exist. The Public Health Service testified that DDT is no longer the chemical of choice for controlling disease vectors. As for mice, warfarin is used effectively, and fumigation and nonchemical means are available for use on bats. Colonel Fowler testified that the military has not used DDT in this country for 2 years for mothproofing purposes and stated that he was aware of alternatives.

C. *Weight to be accorded the examiner's opinion.* In reaching the factual conclusions set forth in the preceding sections, I have been mindful of Group Petitioners' argument, stressed in their briefs and at oral argument, that the Hearing Examiner's findings deserve particular deference in view of his opportunity to resolve contradictions in testimony based on demeanor evidence.

Nowhere does the Examiner state that his conclusions were based on credibility choices.[illegible] Whatever extra weight, then, that might be due findings based expressly on a credibility judgment is not appropriate in the case before me. See, e.g., NLRB v. Dinion Coil Co., 201 F. 2d 484 (2d Cir. 1952) where the Examiner's report set forth his assessment of the witnesses' credibility.[illegible]

IV. The application of the risk-benefit test to the facts of record is by no means, simple. We have noted in our statement of March 18, 1971, that the variables are numerous. It should also be borne in mind that the variables are not static in point of time. As build-up of a chemical occurs or is detected in the environment, risk increases. Indeed, it may be that the same tendency of a chemical to persist or build up in the food chain is present but not known about substitute chemicals. It may also be that circumspect application of a chemical in limited quantities for those uses most necessary changes the benefit-risk coefficients so as to tilt the scales differently than when we weigh aggregate use for all purposes against aggregate benefits. See generally EDF v. EPA (opinion of Judge Leventhal), supra.

A. *Burden of proof.* The crux of a cancellation proceeding is the safety of the product when used as directed or in accordance with "commonly recognized practice." Stearns Phosphorus Paste Co. v. EPA, supra. This, simply stated, means that this Agency has the burden of going forward to establish those risks which it believes to require cancellation.[illegible] In addition, an affirmative aspect of the Agency's case should be the availability of preferable substitute means of controlling the pests that are controlled by the canceled chemical where the Agency is relying on this fact to establish that risks outweigh benefits.[illegible] Evidence showing the availability of a registered chemical or other means of control which this Agency's Pesticides Office is prepared to recommend as a substitute at that point in time, coupled with the Agency's proof on risk, makes out an affirmative case.[illegible]

The burden of rebuttal then falls on registrants or users. They may either seek to negate the proof on risks either by rebutting the basic scientific data or by showing that a particular use is so limited as not to en-

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[illegible]—Continued
subsidy is the difference between profit and break-even. It is not clear whether or not break-even includes a return to the farm owner in terms of salary or return on his investment. While some evidence suggests that organophosphates are more costly, because of higher price and the need for repeated applications in concentrated quantities, there is little to suggest that the possible increased variable cost from use of organophosphates would be a disincentive to producers. Indeed, with subsidies it is not clear what rate of return a cotton producer receives for invested capital. There was a reference made to an unidentified study showing that the cost of using substitutes would involve $16 million. This figure alone has no meaning. While later testimony suggests that elimination of DDT would increase variable costs per acre by 6 percent, this, too, is of limited significance since the record does not relate it to the support program and the study looked at only a limited area.

[illegible] I cannot accept the suggestion that we should continue to use DDT until it is good to the very last drop. Whatever the long-term efficacy of the organophosphates the fact remains that they generally work. While the fact of insect resistance is important and underscores the need for retaining a variety of chemicals or methods to manage the same pest problem, this fact does not justify an avoidable use of a harmful chemical.

[illegible] Toxaphene and diazinon are registered for control of cutworms but it is not clear from the record as to whether or not these chemicals are registered or effective to control cutworm infestations on onions. While none of the parties have pointed to helpful evidence in connection with use for controlling cutworms on onions and weevils on stored sweet potatoes, I have taken judicial notice of the nonexistence of registered alternatives.

[illegible] The only evidence as to the amount of DDT used for these purposes was given by Col. Fowler, who said the total used by the military for bat and mouse control is approximately 800–900 pounds.

[illegible] During oral argument counsel admitted that the Examiner's report did not purport to make findings based on credibility of witnesses, nor could he point to findings which might be explained in light of a credibility contest. (Transcript of Argument, p. 96 98.) The basic questions of fact in this case, the hazard to man and the environment, were cast and resolved by the Examiner as "conclusions of law."

[illegible] The precedents, moreover, make clear that the Agency is free to make its own findings and that the Examiner's findings and report only comprise part of the record which a court will then evaluate. FCC v. Allentown Broadcasting Corp., 349 U.S. 358 (1955); Universal Camera Corp. v. NLRB, 340 U.S. 474 (1951). Even where an Examiner's findings are based on credibility, the Agency may reach a contrary conclusion. See FCC v. Allentown Broadcasting Corp., supra.

[illegible] The legislative history of FIFRA, judicial decisions and Agency pronouncements all state that the "burden of proof" remains on the registrant to demonstrate that his product satisfies the requirements for registration under the Act. See S. Rept. 573 at 5 (88th Cong., first sess., 1963); H. Rept. 1125 at 4 (88th Cong., first sess., 1963); EDF v. EPA, supra; EDF v. Ruckelshaus, supra; Statement of Reasons, Mar. 18, 1971. There has, unfortunately, been a great deal of misunderstanding concerning these statements. Simply stated, the burden of proof referred to by the legislative history is the burden of persuasion which requires a party to establish the existence of primary facts. It should not be confused with the burden of going forward which is generally a rule to establish the order for the presentation of evidence. The burden of going forward may, however, have substantive consequences. Where a party which has the burden of going forward fails to satisfy that burden, the facts will be decided against him, even though the other party may have been responsible for the burden of persuasion.

While in most legal proceedings the party which has the burden of going forward bears the burden of persuasion, this is not necessarily the case. On some issues, like contributory negligence in some jurisdictions, it may be that once one party has introduced evidence to put the issue in the case, the other party bears the burden of persuasion on that point. In a FIFRA cancellation hearing the proponent of cancellation bears the burden of going forward, but does not bear the burden of persuasion.

[illegible] While a mere showing of a high degree of risk would make out a prima facie case for cancellation, where the Agency is relying on the existence of an alternative rather than simply a showing of risk, it should, as here, present its own witnesses.

[illegible] This hearing was conducted under rules which have since been amended. (See 37 F.R. 9476 (May 11, 1972)). Under the Agency's former rules registrants proceeded first at the hearing. This order of presentation, which is now changed, was not prejudicial in this case. The Agency twice then discharged its burden to put on a prima facie case. Registrants had an ample opportunity for rebuttal. At worst this inverted presentation unnecessarily protracted the hearing.

gender the risks from widespread use of the chemical. They can also seek to establish aggregate benefits. Where, as here, the existence of alternatives bears on the benefit of the chemical under review they may choose to show nonviability of alternatives, either for general substitution or in a particular geographical region. They may also seek to show the nondesirability (or risks) of the alternative if they disagree with the staff judgment of this Agency.

B. Application of risk-benefit to crop uses of DDT. The Agency and EDF have established that DDT is toxic to nontarget insects and animals, persistent, mobile, and transferable and that it builds up in the food chain. No label directions for use can completely prevent these hazards. In short, they have established at the very least the risk of the unknown. That *risk is* compounded where, as is the case with DDT, man and animals tend to accumulate and store the chemical. These *facts* alone constitute risks that are unjustified where apparently safer alternatives exist to achieve the same benefit. Where, however, there is a demonstrated laboratory relationship between the chemical and toxic effects in man or animals, this risk is, generally *speaking*, rendered even more unacceptable, if alternatives exist. In the case *before* us the *risk* to human health from using DDT cannot be discounted. While these risks might be acceptable were we forced to use DDT, they are not so trivial that we can be indifferent to assuming them unnecessarily.

The evidence of record showing storage in man and magnification in the food chain is a warning to the prudent that man may be exposing himself to a substance that may ultimately have a serious effect on his health.

As Judge Leventhal recently pointed out, cancer is a "sensitive and fright-laden" matter and noted earlier in his opinion that carcinogenic effects are "generally cumulative and irreversible when discovered." EDF v. EPA, Slip Op. at 12 and 16. The possibility that DDT is a carcinogen is at present remote and unquantifiable; but if it is not a siren to panic, it is a semaphore which suggests that an identifiable public benefit is required to justify continued use of DDT. Where one chemical tests tumorigenic in a laboratory and one does not, and both accomplish the same task, the latter is to be preferred, absent some extenuating circumstances.

The risks to the environment from continued use of DDT are more clearly established. There is no doubt that DDT runoff can cause contamination of waters and given its propensity to volatilize and disperse during application, there is *no* assurance that curtailed usage on the order of 12 million pounds per year will not continue to affect widespread areas beyond the location of application. The Agency staff established, as well, the existence of acceptable substitutes for all crop uses of DDT except on onions and sweet potatoes in storage and green peppers.

Registrants attempted but failed to surmount the evidence of established risks and the existence of substitutes by arguing that the buildup of DDT in the environment and its migration to remote areas has resulted from past uses and misuses. There is, however, no persuasive evidence of record to show that the aggregate volume of use of DDT for all uses in question, given the method of application, will not result in continuing dispersal and buildup in the environment and thus add to or maintain the stress on the environment resulting from past use. The Department of Agriculture has, for its part, emphasized DDT's low acute toxicity in comparison to that of alternative chemicals and thus tried to make the risk and benefit equation balance out favorably for the continued use of DDT. While the acute toxicity of methyl parathion must, in the short run, be taken into account, see infra, it does not justify continued use of DDT on a long-term basis. Where a chemical can be safely used if label directions are followed, a producer cannot avoid the risk of his own negligence by exposing third parties and the environment to a long-term hazard.

Accordingly, all crop uses of DDT are hereby canceled except for application to onions for control of cutworm, weevils on stored sweet potatoes, and sweet peppers. Shipments of DDT labeled for those uses may continue on terms set forth in Part V-A. We defer to Part V-B, infra, consideration of the proper timing of cancellation of other uses in light of the short-run dangers of switching to the use of organophosphates without providing training.

C. Application of risk-benefit to noncrop uses. There remains the question of the disposition on the registered health and Government uses and other noncrop uses of DDT. It should be emphasized that these hearings have never involved the use of DDT by other nations in their health control programs. As we said in our DDT statement of March 1971, "this Agency will not presume to regulate the felt necessities of other countries." Statement, at 8. Indeed, the FIFRA does not apply to exports. Section 7, 7 U.S.C. section 135 (1972).

Given the alternatives for mothproofing and control of bats and mice—proprietary governmental uses of DDT—I am persuaded that the benefits are even more de minimis than the risks. On the other hand, public health and quarantine programs fall into a wholly separate category. See EDF v. Ruckelshaus, 439 F. 2d at 594; DDT Statement of Reasons at 11.

While alternatives also exist for use in public health quarantine programs and, in most instances, DDT is no longer the yeoman chemical, I believe that it would be unwise to restrict knowledgeable public officials to the choice of one or two chemicals. Like a physician, the public official must have an ample arsenal for the combat of disease and infestation.

I cannot, however, be indifferent to the fact that the record suggests that "health and quarantine" uses have, in the past, apparently included proprietary uses by government. Nor can I be complacent about nonsupervised use for these purposes by private citizens. I am, accordingly, requiring a label which will restrain indiscriminate use of DDT for a wide variety of purposes under the rubric of official use. That label language is set forth in the order accompanying this opinion, and is designed to restrict shipment of DDT only to U.S. Government officials and State health departments who will be knowledgeable as to the most effective means for control and mindful of the risks of using DDT. Thus, on an application-by-application basis for necessary health and quarantine purposes, the benefits will be maximized and outweigh the risks. Cf. 42 U.S.C. section 4332 (1971) which requires an environmental impact statement on ongoing official programs.

V. I turn now to the disposition of these dockets in light of the foregoing principles. At the outset it should be noted that recent judicial decisions have urged this Agency to use its "flexibility, in both final decisions and suspension orders, to differentiate between uses of the product." (See EDF v. EPA (opinion of Judge Leventhal), supra, at 20), and reminded us that creative adaptability is the keystone of a workable regulatory process. Cf. SEC v. National Securities, Inc., 393 U.S. 453, 465 (1969). EDF v. EPA, while discussing suspension, serves as a beacon in this record, suggesting that registration be continued selectively, taking into account "restrictions on kinds and extent of use." Id. at 21. Bearing these principles in mind, I turn first to the form and shape our orders should take.

A. Disposition as to onions, stored sweet potatoes, and sweet peppers. There is evidence that DDT is the only useful chemical for controlling heavy corn borer infestations which attack green peppers in the Del Marva Peninsula. The record shows that about 13,800 pounds of DDT are used regularly as a ground application for prophylactic purposes. Sevin, guthion, and phosphamidon can, however, be used at less than 30 percent infestation. Del Marva produces less than 6 percent of the nation's sweet peppers and other crops can be profitably produced. The Agency staff has conceded in its April 16 brief in support of proposed findings, conclusions, and order that this use of DDT "comes closest—of all the uses in issue—to being necessary in the sense that no real alternative insect control method exists under certain conditions." (Brief, at 91.)

The evidence concerning use of DDT to control cutworms is less clear cut. Apparently cutworm infestations in the Northwest are sporadic and localized. While it would appear that other chemicals could be used to control cutworm infestations on

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[illegible] Where there is a generally viable substitute, which will insure an adequate crop supply, the nonviability of the alternative in a particular area will bear on the advisability of a transition period. See part IV, infra.

[illegible] In enacting the present law one of the greatest concerns expressed to Congress was the risk of the unknown. See statement of Congressman Dingell, Hearings before the Subcommittee on Departmental Oversight and Consumer Relations of the House Committee on Agriculture, at 88 (89th Cong., first sess., 1965).

[illegible] Registrants adduced considerable testimony on the effects of organophosphates on nontarget species. Sevin, it appears, is highly toxic to bees and most witnesses agreed that the organophosphates were toxic to nontarget animals, usually birds and insect life, present when a field is sprayed. The present evidence demonstrates, however, that these organophosphate compounds are less "persistent," and thus do not leach or erode into waters or collect in the human food chain. While it may be that in time the familiar phrase "familiarity breeds contempt" will apply, as we learn more about these compounds, they appear not to present a long-range hazard to man or aquatic areas. Where registrants have scored is by demonstrating the acute toxicity of methyl parathion which is the primary alternative chemical for many of the crop uses in question. That fact does not, however, alter the long-term balance between the risks and benefits, in view of the nonpersistence of the organophosphates.

[illegible] The use of DDT in Topocide, a prescription drug, is regulated by both the Food and Drug Administration and this Agency. The alternative, Kwell, is a lindane product. I am, however, taking judicial notice of the fact that lindane registrations are presently under review by this Agency's Pesticides Office and several uses of lindane have in the past, been the subject of cancellation proceedings. See In Re Kar; Kurt Lindane, supra. I am not prepared to judge on this record whether or not the risk to the environment and the public at large from DDT shampoo is greater than from lindane shampoo. As for the direct effects on the user of the drug, this matter is for FDA and the prescribing physician.

onions as with peanuts, none are apparently registered. No party has cited evidence of record showing what percent of the onion-producing acreage would be affected by a cancellation of DDT.

The evidence with respect to use of DDT as a "dip" to protect stored sweet potatoes against weevil infestation is even spottier. Neither counsel for the parties nor our research has pointed us to evidence of record showing the precise volume of DDT use for this purpose, its likely effect on the environment, or the degree of loss that might be sustained by producers.

While it would be far easier simply to cancel or not cancel the registrations for these uses, I believe that environmental problems should be pursued with a scalpel, not a hacksaw. While EDF and my own staff urge cancellation on the ground that producers can easily shift to producing different crops, there is no evidence as to how long such transition might require. Moreover, it may be that continued use of a limited volume of DDT in these few areas, taken in conjunction with aggregate volume of use for other purposes, like health, present no risk to the environment. Obviously much of the stress on the "global" environment is reduced by curtailing overall volume of usage and we must then estimate the impact of use, both on the environment as a whole, and the local surroundings. Lastly, it may well be relevant to examine the impact on overall supply of a commodity. Even though peppers, onions, and sweet potatoes may not be food "staples," it may be that the other acreage is not suited for producing these crops. In that event, it will be necessary to determine whether or not supplies will satisfy demand, and whether or not a transition period should be fixed to permit a market adjustment.[illegible]

It follows that additional evidence is required to determine the answers to these questions. In the interim the cancellation orders will remain in effect, subject to registrants or users petitioning to present additional evidence. In that event, a stay order will issue pending the determination on remand. If these users or registrants can demonstrate that a produce shortage will result and their particular use of DDT, taken with other uses, does not create undue stress on the general or local environment, particularly the aquasphere, cancellation should be lifted. If no produce shortage will result because other acreage is suitable for these crops, it shall still be open to demonstrate that a transitional period is required for switching to new crops. If the interim use of DDT does not constitute an environmental risk, final orders of cancellation for these uses will be deferred until the transition can be accomplished, provided assurances are received at the hearing that formulators and users will not permit bootlegging.

B. *The switch to methyl parathion.* The need for a transition period arises also in connection with those uses that are being canceled based on the existence of methyl parathion.

The record before me leaves no doubt that the chief substitute for most uses of DDT, methyl parathion, is a highly toxic chemical and, if misused, is dangerous to applicators.[illegible] This was the virtually unanimous opinion of all the witnesses. The introduction into use of organophosphates has, in the past, caused deaths among users who are untrained in their application and the testimony and exhibits of record point to the unhappy experience of several years ago where four deaths occurred at the time methyl parathion began to be used on tobacco crops. Other testimony noted the increase in nonfatal accidents and attributed almost one-half reported pesticide poisonings to the organophosphate group. A survey conducted after the organophosphates began to replace chlorinated hydrocarbons in Texas suggests a significantly increased incidence of poisonings.

That the skilled and trained user may apply organophosphates with complete safety is of comfort only if there is an orderly transition from DDT to methyl parathion so as to train workers now untutored in the ways of proper use.

I am accordingly making this order effective as of December 31, 1972, insofar as the cancellations of any particular use is predicated on the availability of methyl parathion as a substitute. In the months that follow the Department of Agriculture and State extension services and representatives of EPA will have time to begin educating those workers who will have to use methyl parathion in future growing seasons. Such a program can also introduce farmers to the less acutely toxic organophosphates, like carbaryl, which may be satisfactory for many uses.

VI. Far from being inconsistent with the general congressional mandate of FIFRA, a period of adjustment to train users of methyl parathion or permit a needed transition where no substitutes exist is a logical outgrowth of a sensible application of risk-benefit analysis. While the legislative history does not address the specific problem before me—the timing of cancellation orders—the hearings that preceded the enactment of FIFRA indicate that congressional concern for safety of the farmer-user of pesticides was no less than Congress' solicitude for the environment. While Congress ultimately struck a balance that generally places the risk of negligence on the applicator, see Stearns v. EPA, supra, it did so in light of assurances that farmers are for their own safety as well as that of the environment being trained in proper methods of application. See Hearings before the Subcommittee on Departmental oversight and Consumer Relations of the House Committee on Agriculture, supra, at 64, 68.[illegible]

The risk-benefit equation is a dynamic one. Timing is a variable in that equation. What may, in the long run, be necessary to protect the environment could be a short-term threat to human health. This is exactly the case before me now. The benefits of using organophosphates are a long-range benefit and the risks of DDT result from continued long-term use. In the very short run, however, the equation balances out very differently.[illegible] Likewise, the prospect of dislocation which might ensue were the use of DDT immediately halted where no alternatives exist is a fact we must reckon with. The major environmental regulatory statutes, enacted and pending, provide "leadtime" for an adjustment to new requirements.[illegible]

While impatience is understandable in view of the past history of delay, we must not be lulled into the belief that long-standing problems can be corrected by overnight solutions. Today's decision provides a definitive answer to the status of DDT registrations and all concerned: to this Agency, farmers, manufacturers, the Department of Agriculture, and extension services, all must proceed with alacrity toward the implementation of this order.

FACTUAL FINDINGS

I. SCOPE OF CASE

A. PR Notices 71-1, 71-3, 71-5 canceled all registered uses of DDT and TDE.

B. Appeals have been received by 31 formulators who held registrations for formulating DDT or TDE. These formulators appeared at this proceeding by a single counsel.

C. Wyco, Inc. and the Wallerstein Co. and Stark Bro's. Nurseries have also appeared by separate counsel.

D. The Plant Regulation Division of the Department of Agriculture was a party to this hearing as a registrant and the Department was an intervenor as to all uses.

E. Eli Lilly & Co. and H. P. Cannon & Sons were parties to this hearing.

F. National Agricultural Chemicals Association; Environmental Defense Fund; the Sierra Club; West Michigan Environmental Action Counsel; and National Audubon Society are intervenor parties.

G. The following canceled uses were appealed and at issue in this hearing:

Crop Uses

1. Cotton.
2. Beans (dry, lima, snap).
3. Sweet potatoes.
4. Peanuts.
5. Cabbage, cauliflower, and brussels sprouts.
6. Tomatoes.
7. Fresh market corn.
8. Sweet peppers and pimientos.
9. Onions.
10. Garlic.
11. Commercial greenhouses.

[illegible] It is a recognized policy of common law nuisance and also of Federal environmental legislation to afford affected producers a transitional period for implementing new requirements.

[illegible] Not all of the possible substitutes for DDT are equally potent. For example, trichlorofon, monocrotophos, malathion, and carbaryl, among others, are available to control many cotton pests; carbaryl is an all-purpose chemical for most cotton pests. It is, however, abundantly clear that methyl parathion will be widely used.

[illegible] At least two courts have given express recognition to the similarity between the regulatory schemes in FIFRA and the Food, Drug, and Cosmetic Act. See Welford v. Ruckelshaus, 439 F. 2d 598 (D.C. Cir. 1971); Nor-Am v. Hardin, 435 F. 2d 1133 (7th Cir. 1970) (en banc). I believe that the trail Congress intended me to follow is marked by its directive in section 348 of the Food, Drug, and Cosmetic Act, 21 U.S.C. section 348(f)(3) (1971), which permits the Secretary to set an effective date for his orders. While similar language has not been expressly included in FIFRA, its omission can hardly be considered advertent in view of the legislative history. See S. Rept. No. 573 (88th Cong., first session 1963); H. Rept. No. 1125 (88th Cong., second session 1964). The purpose of the 1964 amendments was to eliminate registration under protest.

[illegible] I do not believe that the Seventh Circuit's decision in Stearns Phosphorous Paste Co. v. EPA, supra, precludes me from taking into account the short-term dangers that could result from increased use of methyl parathion by untrained users. Stearns holds that a product is not "misbranded" simply because it can be highly dangerous if the user is careless. This reasoning does not, however, compel me to ignore the tendency of human beings to be negligent where we are dealing with the implementation of an order that will increase use of a highly dangerous substance. Even negligence can be minimized by training.

[illegible] While the Examiner excluded from evidence a study of the DDT problem for this Agency undertaken by a Committee of the National Academy of Sciences, it is appropriate to note that Committee recommended a phase-out period for the same reasons outlined in this opinion. While I reach my conclusions without relying on that report's factual findings and recommendations, and base them on the record as compiled below, I believe the report was erroneously excluded from the record, particularly in view of the offer by counsel for the Agency to produce a committee member for cross-examination.

Noncrop Uses

1. Control of house mice and bats (military only).
2. Fabric treatment (military only).
3. Disease vectors.
4. Quarantine.
5. Control of body lice in prescription drugs.

II. CHEMICAL PROPERTIES OF DDT

A. Basic findings:

1. DDT can persist in soils for years and even decades.

2. DDT can persist in aquatic ecosystems.

3. Because of persistence, DDT is subject to transport from sites of application.

a. DDT can be transported by drift during aerial application.

b. DDT can vaporize from crops and soils.

c. DDT can be attached to eroding soil particles.

4. DDT is a contaminant of freshwaters, estuaries and the open ocean and it is difficult or impossible to prevent DDT from reaching aquatic areas and topography nonadjacent and remote from the site of application.

B. Ultimate finding:

The above factors constitute a risk to the environment.

III. ACTIVITY IN FOOD CHAIN AND IMPACT ON ORGANISMS

A. Basic findings:

1. DDT is concentrated in organisms and transferred through food webs.

a. DDT can be concentrated in and transferred through terrestrial invertebrates, mammals, amphibians, reptiles, and birds.

b. DDT can be concentrated and transferred in freshwater and marine plankton, insects, mollusks, other invertebrates, and fish.

2. The accumulation in the food chain and crop residues results in human exposure.

3. Human beings store DDT.

B. Ultimate finding:

The above factors constitute an unknown, unquantifiable risk to man and lower organisms.

IV. TOXICOLOGICAL EFFECTS

A. Basic findings:

1. DDT affects phytoplankton species' composition and the natural balance in aquatic ecosystems.

2. DDT is lethal to many beneficial agricultural insects.

3. DDT can have lethal and sublethal effects on useful aquatic freshwater invertebrates, including arthropods and molluscs.

4. DDT is toxic to fish.

5. DDT can affect the reproductive success of fish.

6. DDT can have a variety of sublethal physiological and behavioral effects on fish.

7. Birds can mobilize lethal amounts of DDT residues.

8. DDT can cause thinning of bird eggshells and thus impair reproductive success.

9. DDT is a potential human carcinogen.

a. Experiments demonstrate that DDT causes tumors in laboratory animals.

b. There is some indication of metastasis of tumors attributed to exposure of animals to DDT in the laboratory.

c. Responsible scientists believe tumor induction in mice is a valid warning of possible carcinogenic properties.

d. There are no adequate negative experimental studies in other mammalian species.

e. There is no adequate human epidemiological data on the carcinogenicity of DDT, nor is it likely that it can be obtained.

f. Not all chemicals show the same tumorigenic properties in laboratory tests on animals.

B. Ultimate finding:

DDT presents a carcinogenic risk.

V. BENEFITS

A. Basic findings:

1. DDT is useful for the control of certain cotton insect pests.

2. Cotton pests are becoming resistant to DDT.

3. Methyl parathion and other organophosphate chemicals are effective for the control of cotton pests.

a. Methyl parathion and organophosphates are less toxic to aquatic life than DDT.

b. Methyl parathion and organophosphates appear to be less "persistent" and do not build up in the food chain.

c. Methyl parathion is acutely toxic by dermal, respiratory exposure and oral ingestion.

4. By using methyl parathion or other means of pest control cotton producers can generally produce satisfactory yields at acceptable cost.

5. DDT is considered useful to have in reserve for public health purposes in disease vector control.

6. DDT is considered useful as a mothproofing agent.

a. DDT is not presently used by the military for treatment of fabric.

b. Alternatives exist.

7. DDT is useful for public quarantine programs.

8. Quarantine programs are administered by public officials and are a nonproprietary use of DDT.

a. This is of little use in controlling the overall gypsy moth problem.

9. DDT is useful for controlling certain insects that attack the crops listed in finding number (I)G.

10. Adequate substitute chemicals, namely, methyl parathion and other organophosphates—for the most part—exist for controlling the diseases that attack the crops listed in finding number (I)G except:

a. Sweet potatoes;

b. Heavy infestations of corn borer attacking sweet peppers grown on the Delmarva Peninsula.

c. Onions attacked by cutworms.

11. DDT is effective for controlling body lice:

a. Kwell, a Lindane product, is a substitute.

b. Lindane registrations are being reviewed.

12. DDT is used for exterminating bats and mice by the military.

a. Fumigation and nonchemical methods can guard against bat infestation.

b. Warfarin is effective for exterminating house mice.

B. Ultimate findings:

1. The use of DDT is not necessary for the production of crops listed in finding (I)G except that it may be necessary to produce those crops listed in finding V10 (a), (b), and (c).

2. Noncrop uses of DDT for mothproofing and to control bats and mice are proprietary uses for which DDT is not necessary.

VI. MATTERS RELATING TO METHYL PARATHION

A. Basic findings:

1. Many poisonings have been attributed to the use of methyl parathion.

2. Untrained users of methyl parathion are frequently not sufficiently careful in its use despite label directions.

3. Methyl parathion can be used safely.

4. Training programs are useful in averting the negligent use of methyl parathion.

5. Methyl parathion is a substitute for most crop uses of DDT.

B. Ultimate findings:

1. Methyl p[illegible] is dangerous to users and presents a [illegible] them.

2. An opportunity to train users will minimize the risks and keep down the number of accidents.

VII. GENERAL FINDINGS

A. No directions for use of DDT, even if followed, can over the long run completely eliminate DDT's injury to man or other vertebrate animals.

B. No warning or caution for use of DDT, even if followed, can over the long run prevent injury to living man and other vertebrate animals and useful invertebrate animals.

C. The present total volume of use of DDT in this country for all purposes is an unacceptable risk to man and his environment.

D. The use of DDT in controlled situations in limited amounts may present less risk than usage in greater amounts, but still contaminates the environment.

E. The public health program and quarantine uses of DDT by officials, when deemed necessary, can be judged on an application-by-application basis by professionals.

F. A particular official use, in an isolated instance, may be important.

CONCLUSIONS OF LAW

1. DDT formulations when labeled with directions for use in the production of those crops named in finding (I) G and for use on bats, mice, and fabric are "misbranded," within the meaning of section 2(z)(2) (c), (d), and (e) of FIFRA, 7 U.S.C. section 135.

2. DDT when labeled with directions "for use by and distribution to only U.S. Public Health Service officials or for distribution by or on approval by the U.S. Public Health Service to other health service officials for control of vector diseases, for use by and distribution to the Public Health Service, USDA, and military for quarantine use, for use in prescription drugs to be dispensed only on authorization by a certified medical doctor" along with the caution printed in bold type "use for any purpose not specified or not in accordance with directions and use by unauthorized persons is disapproved by the Federal Government. This substance is harmful to the environment," is not "misbranded."

ADMINISTRATOR'S ORDER REGARDING DDT

Order. Before the Environmental Protection Agency. In regard: Stevens Industries, Inc., et al. (Consolidated DDT Hearings), I.F. & R. Docket No. 63 et al.

In accordance with the foregoing opinion, findings and conclusions of law, use of DDT on cotton, beans (snap, lima, and dry), peanuts, cabbage, cauliflower, brussel sprouts, tomatoes, fresh market corn, garlic, pimentos, in commercial greenhouses, for mothproofing and control of bats and rodents are hereby canceled as of December 31, 1972.

Use of DDT for control of weevils on stored sweet potatoes, green peppers in the Del Marva Peninsula and cutworms on onions are canceled unless within 30 days users or registrants move to supplement the record in accordance with Part V of my opinion of today. In such event the order shall be stayed, pending the completion of the record, on terms and conditions set by the Hearing Examiner: *Provided*, That this stay may be dissolved if interested users or registrants do not present the required evidence in an expeditious fashion. At the conclusion of such proceedings, the issue of cancellation shall be resolved in accordance with my opinion today.

Cancellation for uses of DDT by public health officials in disease control programs and by USDA and the military for health quarantine and use in prescription drugs is lifted.

In order to implement this decision no DDT shall be shipped in interstate commerce or within the District of Columbia or any American territory after December 31, 1972 unless its label bears in a prominent position in bold type and capital letters, in a manner satisfactory to the Pesticides Regulation Division, the following language:

> (1) For use by and distribution to only U.S. Public Health Service Officials or for distribution by or on approval by the U.S. Public Health Service to other Health Service Officials for control of vector diseases; (2) For use by and distribution to the USDA or Military for Health Quarantine Use; (3) For use in the formulation for prescription drugs for controlling body lice; (4) or in drug; for use in controlling body lice—to be dispensed only by physicians.
>
> Use by or distribution to unauthorized users or use for a purpose not specified hereon or not in accordance with directions is disapproved by the Federal Government: This substance is harmful to the environment

The Pesticides Regulation Division may require such other language as it considers appropriate.

This label may be adjusted to reflect the terms and conditions for shipment for use on green peppers in Del Marva, cutworms on onions, and weevils on stored sweet potatoes if a stay is in effect.

Dated: June 2, 1972.

WILLIAM D. RUCKELSHAUS

[FR Doc.72-10340 Filed 7-6-72;8:50 am]

I B.

APPENDIX

DDT REGULATORY HISTORY: A BRIEF SURVEY

Background

DDT (Dichloro-diphenyl-trichloroethane), for many years one of the most widely used pesticidal chemicals in the United States, was first synthesized in 1874. Its effectiveness as an insecticide, however, was only discovered in 1939. Shortly thereafter, particularly during World War II, the U.S. began producing large quantities of DDT for control of vector-borne diseases such as typhus and malaria abroad.

After 1945, agricultural and commercial usage of DDT became widespread in the U.S. The early popularity of DDT, a member of the chlorinated hydrocarbon group, was due to its reasonable cost, effectiveness, persistence, and versatility. During the 30 years prior to its cancellation, a total of approximately 1,350,000,000 pounds of DDT was used domestically.

After 1959, DDT usage in the U.S. declined greatly, dropping from a peak of approximately 80 million pounds in that year to just under 12 million pounds in the early 1970's. Of the quantity of the pesticide used in 1970-72, over 80 percent was applied to cotton crops, with the remainder being used predominantly on peanut and soybean crops. The decline in DDT usage was the result of (1) increased insect resistance: (2) the development of more effective alternative pesticides; (3) growing public concern over adverse environmental side effects: and (4) increasing government restrictions on DDT use.

In addition to domestic consumption, large quantities of DDT have been purchased by the Agency for International Development and the United Nations and exported for malaria control. DDT exports increased from 12 percent of the total production in 1950 to 67 percent in 1969. However, exports have shown a marked decrease in recent years dropping from approximately 70 million pounds in 1970 to 35 million in 1972.

Public Concern

Certain characteristics of DDT which contributed to the early popularity of the chemical, particularly its persistence, later became the basis for public concern over possible hazards involved in the pesticide's use. Although warnings against such hazards were voiced by scientists as early as the mid-1940's, it was the publication of Rachel Carson's book <u>Silent Spring</u> in 1962 that stimulated widespread public concern over use of the chemical. After Carson's alert to the public concerning the dangers of improper pesticide use and the need for better pesticide controls, it was only natural that DDT, as one of the most widely used pesticides of the time, should come under intensive investigation.

Throughout the last decade, proponents and opponents of DDT have faced one another in a growing series of confrontations. Proponents argue that DDT has a good human health record and that alternatives to DDT are more hazardous to the user and more costly. Opponents to DDT, admitting that there may be little evidence of direct harm to man, emphasize other hazards connected with its use. They argue that DDT is a persistent, toxic chemical which easily collects in the food chain posing a proven hazard to non-target organisms such as fish and wildlife and otherwise upsetting the natural ecological balance.

Both the pro's and con's of DDT use were considered by four Government committees who issued the following reports: (1) May 1963, "Use of Pesticides," A Report of the President's Science Advisory Committee (PSAC); (2) November 1965, "Restoring the Quality of Our Environment," A Report of the Environmental Pollution Panel, PSAC; (3) May 1969, Report of the Committee on Persistent Pesticides, Division of Biology and Agriculture, National Research Council, to Agriculture Department; (4) December 1969, Mrak Commission Report. All four reports recommended an orderly phasing out of the pesticide over a limited period of time.

Public concern further manifested itself through the activities of various environmental organizations. Beginning in 1967, the Environmental Defense Fund, the National Audubon Society, the National Wildlife Federation, the Izaak Walton League and other environmental groups became increasingly active in initiating court proceedings leading to the restriction of DDT use at both local and Federal levels.

State Regulatory Actions

Varying restrictions were placed on DDT use in different States.

DDT use was outlawed except under emergency conditions in Illinois, Iowa, Massachusetts, New Mexico, New York, Rhode Island, Vermont, and Wisconsin.

Alaska, Arizona, California, Colorado, Connecticut, Florida, Idaho, Kentucky, Maine, Maryland, Michigan, Minnesota, New Hampshire, North Carolina, Ohio, Utah, Virginia, and Washington have all placed some limitation on the use of DDT.

Although the remaining States have provisions for the "restricted use" classification of pesticides, no specific mention is made of DDT.

Initial Federal Regulatory Actions

The Federal Government has not been oblivious to the hazards of DDT use as is indicated by various Government studies and actions undertaken since the late 50's.

1. In 1957, as a matter of policy, the Forest Service, U.S. Department of Agriculture (USDA), prohibited the spraying of DDT in specified protective strips around aquatic areas on lands under its jurisdiction.

2. In 1958, after having applied approximately 9-1/2 million pounds of the chemical in its Federal-State control programs since 1945, USDA began to phase out its use of DDT. They reduced spraying of DDT from 4.9 million acres in 1957 to just over 100,000 acres in 1967 and used persistent pesticides thereafter only in the absence of effective alternatives. The major uses of DDT by the Forest Service have been against the gypsy moth and the spruce budworm. The development of alternative pesticides such as Zectran, which was in operation in 1966, contributed to further reduction in DDT use by the Department.

3. In 1964, the Secretary of the Interior issued a directive stating that the use of chlorinated hydrocarbons on Interior lands should be avoided unless no other substitutes were available. This regulatory measure, as well as others which followed, was reaffirmed and extended in June 1970, when the Secretary issued an order banning use of 16 types of pesticides, including DDT, on any lands or in any programs managed by the Department's bureaus and agencies.

4. Between November 1967 and April 1969, USDA cancelled DDT registrations for use against house flies and roaches, on foliage of more than 17 crops, in milk rooms, and on cabbage and lettuce.

5. In August 1969, DDT usage was sharply reduced in certain areas of USDA's cooperative Federal-State pest control programs following a review of these programs in relation to environmental contamination.

6. In November 1969, USDA initiated action to cancel all DDT registrations for use against pests of shade trees, aquatic areas, the house and garden and tobacco. USDA further announced its intention to discontinue all uses nonessential to human health and for which there were safe and effective substitutes.

7. In August 1970, in another major action, USDA cancelled Federal registrations of DDT products used as follows: (1) on 50 food crops, beef cattle, goats, sheep, swine, seasoned lumber, finished wood products and buildings; (2) around commercial, institutional, and industrial establishments including all nonfood areas in food processing plants and restaurants, and (3) on flowers and ornamental turf areas.

EPA Regulatory Actions

On December 2, 1970, major responsibility for Federal regulation of pesticides was transferred to the U.S. Environmental Protection Agency (EPA).

1. In January 1971, under a court order following a suit by the Environmental Defense Fund (EDF), EPA issued notices of intent to cancel all remaining Federal registrations of products containing DDT. The principal crops affected by this action were cotton, citrus, and certain vegetables.

2. In March 1971, EPA issued cancellation notices for all registrations of products containing TDE, a DDT metabolite. The EPA Administrator further announced that no suspension of the registration of DDT products was warranted because evidence of imminent hazard to the public welfare was lacking. (Suspension, in contrast to cancellation is the more severe action taken against pesticide products under the law.) Because of the decision not to suspend, companies were able to continue marketing their products in interstate commerce pending the final resolution of the administrative cancellation process. After reconsideration of the March order, in light of a scientific advisory committee report, the Administrator later reaffirmed his refusal to suspend the DDT

registrations. The report was requested by Montrose Chemical Corporation, sole remaining manufacturer of the basic DDT chemical.

3. In August 1971, upon the request of 31 DDT formulators, a hearing began on the cancellation of all remaining Federally registered uses of products containing DDT. When the hearing ended in March 1972, the transcript of 9,312 pages contained testimony from 125 expert witnesses and over 300 documents. The principal parties to the hearings were various formulators of DDT products, USDA, the EDF, and EPA.

4. On June 14, 1972, the EPA Administrator announced the final cancellation of all remaining crop uses of DDT in the U.S. effective December 31, 1972. The order did not affect public health and quarantine uses, or exports of DDT. The Administrator based his decision on findings of persistence, transport, biomagnification, toxicological effects and on the absence of benefits of DDT in relation to the availability of effective and less environmentally harmful substitutes. The effective date of the prohibition was delayed for six months in order to permit an orderly transition to substitute pesticides. In conjunction with this transition, EPA and USDA jointly developed "Project Safeguard," a program of education in the use of highly toxic organophosphate substitutes for DDT.

5. Immediately following the DDT prohibition by EPA, the pesticides industry and EDF filed appeals contesting the June order with several U.S. courts. Industry filed suit to nullify the EPA ruling while EDF sought to extend the prohibition to those few uses not covered by the order. The appeals were consolidated in the U.S. Court of Appeals for the District of Columbia.

On December 13, 1973, the Court ruled that there was "substantial evidence" in the record to support the EPA Administrator's ban on DDT.

Actions Taken Under the New Pesticides Law

On October 21, 1972, the Federal Environmental Pesticides Control Act, a far-reaching amendment to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) was enacted. These amendments provide EPA with more effective pesticide regulation mechanisms than were previously available under the FIFRA.

1. In April 1973, EPA, in accordance with authority granted by the amended law, required that all products containing DDT be registered with the Agency by June 10, 1973.

2. On April 27, 1973, EPA granted a request by the States of Washington and Idaho for a temporary registration of DDT for use against the pea leaf weevil. A similar application was approved on February 22, 1974, for use of DDT during the 1974 growing season. The chemical was registered for 90 days following a determination by EPA that control of the pea leaf weevil was an economic necessity and that DDT was the only practical and effective control agent available. The EPA order designated spray restrictions, monitoring guidelines, and research requirements for the control program. The order provided for further testing of three chemicals--methoxychlor, Imidan, and malathion ULV--which have shown some promise as alternatives to DDT. Other possible long-range alternatives to DDT were tested in 1974, as well.

3. On February 26, 1974, EPA granted a request by the Forest Service for use of DDT to combat the Douglas-fir tussock moth epidemic in the Northwest. Previous requests by the Forest Service had been denied on the grounds that the risks of DDT use was outweighed the benefits. A week long investigation in September 1973, a technical seminar on November 16, 1973, and a series of hearings in January 1974, aided EPA in reassessing the need for DDT. On the basis of information acquired during these sessions, the Administrator concluded that the potential for an economic emergency existed in 1974 and that no effective alternative to DDT was available. The control program was carried out under strict spraying restrictions and with a requirement that research programs to evaluate alternatives to DDT, and monitoring activities, be conducted by the Forest Service.

Use of a cancelled pesticide is made possible by the recent amendments to FIFRA which permit EPA to exempt any Federal or State agency from any of the provisions of the Act if emergency conditions exist. All such requests are considered on a case-by-case basis.

4. On March 14, 1975 the Administrator denied the State of Louisiana a request for emergency use of 2.25 million pounds of DDT on 450,000 acres of cotton to control the tobacco budworm in 1975. This decision was affirmed by the Administrator on April 1, 1975, after reconsideration on the grounds of "no substantial new evidence which may materially affect the 1972 order with respect to the human cancer risk posed by DDT, the environmental hazards of DDT and the need to use DDT on cotton." (Federal Register, April 8, 1974, p. 15,962)

III B.1

APPENDIX

Acute Human Hazard Information on Alternatives to DDT

Excerpts from
Substitute Chemical Program
Initial Scientific Review,
completed as of May, 1975

Symptoms of Poisoning - The symptoms of mild exposure to parathion or methyl parathion as a result of orchard spraying or other activities associated in the fruit-growing industry have been described by Sumerford et al. (1953) and Arterberry et al. (1961). The modes of exposure and the symptomatology have been discussed by Hamblin and Golz (1955). The signs and symptoms of 246 patients admitted to a hospital in Greece with acute parathion poisoning have been reviewed by Tsachalinas et al. (1971). Namba (1971) has presented an excellent description of the signs and symptoms of organophosphate poisoning in patients. Reference should be made to Hamblin and Golz's paper (1955) for the onset and progressions of symptoms in subjects exposed to toxic amounts of parathion in spraying operations. Namba (1971) has classified the signs and symptoms observed in 77 patients who developed poisoning by the application of ethyl and methyl parathion. The more prominent symptoms were weakness, nausea or vomiting, excessive sweating, headache and excessive salivation. Namba points out that if the exposure to organic phosphorus insecticides is sufficient to produce symptoms, they usually appear in less than 12 hours. Symptomatology that appears 24 hours after exposure is unlikely to be due to these pesticides. A critical clinical observation is the occurrence of miosis, which is found in about 50% of the patients, and the latter symptom appears in subjects even in the mild cases. Death is usually attributed to failure of the respiratory muscles and paralysis of the respiratory center. Cardiac involvement may occur, but is usually seen only at the terminal stage. Man appears to be more sensitive to the organophosphate insecticides in that he exhibits symptoms earlier than experimental animals, particularly central nervous system manifestations. If an untreated organophosphate-poisoned victim is alive after 24 hours, he is likely to recover. The account by Kanagaratnam et al. (1960) describes a parathion poisoning incident resulting from the use of contaminated barley in India. There were 53 persons involved, and the clinical features described included collapse, fits, sweating, dyspnoea, the effect on the pupils, the eye, blood pressure, coma, and muscular fasciculation.

Gershon and Shaw (1961) felt that chronic exposure to organophosphate compounds produced psychiatric disorders in orchard workers. In a small field survey, they observed in 14 men and two women schizophrenic and depressive reactions with severe impairment of memory and difficulty in concentration. The range of exposure for these subjects was 1-1/2 to 10 years.

No other surveys of this nature were found in the literature.

Brown (1971) reported on the electroencephalographic changes and disturbance of brain function following organophosphate exposure. Acute organophosphate poisoning disturbs central nervous system functions by causing disorientation in space and time, a sense of depersonalization, and hallucinations; with heavy exposure, convulsions occur. Acute inhibition of brain cholinesterase would be expected to cause effects related to the temporal lobe. EEG changes in acute organophosphate poisoning have been reported to resemble those seen in the interictal EEG of temporal lobe epileptics.

Accidents - Parathion and methyl parathion are the pesticides most frequently cited in incidents involving accidental exposure to pesticides. Preliminary data from the EPA Pesticide Accident Surveillance System (PASS) shows that parathion is the third and methyl parathion is the fifth most frequently cited pesticide in 1973. Based on an analysis of PASS data, Osmun (1974) stated that for 1972 and 1973, parathion and/or methylparathion were connected with 78% of the reported episodes relating to agricultural jobs, particularly those involving fields sprayed with pesticides for which safe reentry times for workers had been set.

Some 125 episodes involving methyl parathion are included in the PASS computerized system. Approximately 45, 30, and 15% of these episodes were reported from EPA Regions IV, VI, and IX, respectively. This distribution is not consistent with that of the domestic consumption pattern.

There are a number of limitations, however, in attempting to use PASS data. First of all, the cause-effect relationship between the pesticides cited and the effects observed have generally not been established. Second, generally only data for 1972 through about January 1974 have been computerized and are readily available for retrieval. Third, a large portion of the data provided to PASS comes from California. This skewed distribution probably represents bias caused by the efficient level with which the State of California documents pesticide information. During a review of PASS files, data in addition to the preliminary information found on the pesticide episode reporting form (Form ACEC1, December 1972) were found on only nine of the approximately 125 episodes involving methyl parathion and 12 of the 257 episodes involving parathion. Further duplicate entries in PASS have been noted for a few incidents.

Data Relating to Other Substitutes

Methomyl

Human Toxicity and Epidemiology

Symptoms of Poisoning and Antidotes - Warning symptoms as listed on the label of Lannate® 90% (methomyl) water soluble powder (EPA Reg. No. 352-342) are typical of those associated with exposure to an anticholinesterase agent. These include weakness, blurred vision, headache, nausea, abdominal cramps, sweating and constriction of pupils.

Occupational and Accidental Exposure - Beginning in 1971, EPA and the States of California and Arizona became aware of serious problems in workers handling Lannate® 90% (methomyl) soluble powder. The California Department of Health estimated 150 incidents involving Lannate poisoning in California. There have been no fatalities.

After an extensive investigation by State and Federal Officials and with the assistance of Dupont Chemical Company and various users it was concluded that most cases of 54 documented Lannate poisoning cases would not have occurred if the label directions were followed and proper protective clothing worn. (Memo from Mr. Brian Sturgess, Region IX to Acting Director Operations Division regarding Lannate Investigations in Arizona and California, April 19, 1973). Due to possible inhalation of the powder, it is very important that goggles and a mask or suitable respirator be worn. It should be noted that often the extreme heat in certain areas of California and Arizona make the wearing of any protective equipment very difficult.

Better hygiene and improved closed systems for loading and mixing pesticides would lessen the chance for accidents not only with Lannate but other highly toxic pesticides.

Two cases of methomyl poisoning in men who mix pesticides, probably resulting from inhalation of powder during mixing, were reported in Australia in early 1974. Blood cholinesterase levels were between 0%-35% for one individual and 35%-65% in the other reported poisoning incident; normal values range between 80% and 120%.

"One serious point was that when methomyl caused a fall in plasma cholinesterase activity, further exposure to organic phosphate could deplete red blood cell cholinesterase values as well. Poisoning could probably occur more quickly and could be potentiated by the carbamate material."

Other incidents involving methomyl poisoning were also reported, but these cases were complicated by the fact that the men involved had handled various other organophosphate insecticides during the same time period they had come in contact with methomyl (Simpson and Penney, 1974).

No epidemiology studies involving methomyl have been reported.

Aldicarb

Symptoms of Poisoning - Symptoms of aldicarb poisoning are typical of those seen with anticholinesterase agents (see methomyl).

Accidents - Aldicarb has been cited in a small number of accidental exposure reports. The EPA Pesticide Accident Surveillance System (PASS) computerized data base lists a total of 11 episodes involving aldicarb. This data base includes most data reported for 1972 through January 1974. Eight of the 11 reported episodes took place in Region IX. The available data, however, is not sufficient to establish any relationship between accident frequency and specific uses of aldicarb.

Disulfoton

Accidental Exposures - Watson et al. (1971) reported the accidental poisoning of cattle when eight discarded disulfoton bags were blown from a potato field into a pasture. As a result of chewing on the empty bags containing disulfoton residues, one animal was found dead and several others were severely sick. Within three days, six additional animals had died. In addition to the bags containing residues, it was suspected that some of the irrigation water from the sprayed field also entered the farm pond used as a source of drinking water for the affected cattle.

Accidental exposures to disulfoton are also recorded by the EPA Pesticide Episode Review System (PERS). The computerized PERS data base, which generally included data through January 1974, shows disulfoton to be the 21st most frequently cited pesticide in the episodes* reported. A total of 63 disulfoton episodes are included in the computerized data (through January 1974). Twenty-eight additional episodes have subsequently been reported. Approximately two-thirds of these 91 episodes involved human exposure.

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* Episodes reported include those involving humans, animals, plants, and contaminated areas. In most cases, however, disulfoton was not conclusively established as the cause of the episodes, i.e., cause-effect relationships generally have not been established.

The distribution of the reported episodes by EPA regions is as follows:

Region	I	0
	II	2
	III	1
	IV	16
	V	4
	VI	10
	VII	8
	VIII	16
	IX	22
	X	12

Unfortunately, the information available was too limited to establish any relationship between the episodes and any specific application or use of disulfoton.

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APPENDIX
EPA Report of National Pesticide Episodes* for DDT Substitues 1971-1974

Primary DDT Substitutes	Human Accident Episodes	Animal Poisoning/ Contamination	Contamination of food/water	Total Episodes	% of total that are humans injuries
Parathion	230	64	70	366	63
Malathion	115	24	24	162	71
Methyl Parathion	84	12	42	153	55
Carbaryl	60	31	15	109	55
Methomyl/ Lannate	101	2	7	105	96
Phosdrin	119	4	14	131	91
Diazinon	105	7	12	132	80
Chlordane	112	9	28	140	80
27 Other DDT Substitutes**	391	212	269	830	47
TOTALS	1317	365	481	2128	62

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[*] Confirmed episodes reported in this table have not been differentiated from those which are not confirmed cases of pesticide injury.

[**] Other DDT Substitutes reported include:
Methoxchlor, Endrin, Azinphos Methyl, Guthion,
Azodrin, Galecron, Toxaphene, EPN, Di-syston,
Dasanit, Naled, Dimethodate/Cygon Bidrin,
Dyfonate, Heptachlor, Dieldrin, Aldrin,
Thimet, Systox, Dylox, Dipterex, Carbophenothion
Meta-Systox-R Galecron, Endosulfan (Thiodan, SD-
8447/ Gardona, Furadan, Aldicarb/Temik, Surracide

Source: Special Ingredient Report, Pesticide Episode Review System, Pesticide Use Analysis Branch, Operations Division, OPP, EPA, Feb. 19, 1975.

III D. 1

APPENDIX

Efficacy and Cost Effectiveness of Alternatives to DDT for Cotton Insect Pests

Excerpts from
Substitute Chemical Program
Minieconomic Review,
1975

Methyl Parathion

The use of methyl parathion on cotton in 1972 is estimated at 33,500,000 lb of active ingredient, i.e., 84.3% of the total domestic consumption. It is primarily used to control the cotton boll weevil, bollworm and tobacco budworm, but is also recommended for control of thrips, cotton leafworms, grasshoppers, fall armyworms, spider mites, fleahoppers, lygus bugs, aphids, garden webworms, false chinch bugs, cabbage loopers and cutworms.

Methyl parathion can be applied by itself or in combinations with other insecticides. Prior to the restriction of DDT a typical application consisted of 0.5 gal/acre of a mixture of 4 lb toxaphene, 2 lb DDT and 0.5 lb of methyl parathion to control bollworms. The number of applications would vary depending upon the degree of infestation. A high-use farmer might make 14 to 15 total applications, with one or two of these applications consisting solely of methyl parathion to suppress the late hatch of bollworms. Many states are now recommending a formulation consisting of 6 lb of toxaphene and 3 lb of methyl parathion per gallon at a rate of 1 to 2 qt/acre.

<u>Efficacy Against Pest Infestation</u> - The use of methyl parathion expanded significantly as resistance of the tobacco budworm to DDT increased. Adkisson et al. (1965)1/ found a high level of DDT resistance in the budworm and bollworm. Tests showed that methyl parathion killed 85% of the bollworm larvae when applied at 0.25 lb/acre whereas 1.0 lb/acre of DDT killed only 51%.

Wolfenbarger et al. (1971)2/ found that methyl parathion killed 85% of the bollworms and tobacco budworms. Yields in a test at Brownsville, Texas, in 1967 increased 689 lb of seed cotton over the check. Good control of the bollworm, tobacco budworm, and pink bollworm was achieved.

1/ Adkisson, Perry L., and Stanley Nemec, "Efficiency of Certain Insecticides for Killing Bollworms and Tobacco Budworms," Progress Report PR-2357, Texas Agr. Exp. Sta. (1965).

2/ Wolfenbarger, D. A., and Rex McGarr, "Low Volume and Ultra-Low Volume Sprays of Malathion and Methyl Parathion for Control of Three Lepidopterous Cotton Pests," Production Research Report No. 126, U.S. Department of Agriculture and Texas Agr. Exp. Sta. (1971).

Nemec et al. (1968)[1] evaluated ULV and CLV methyl parathion sprays at College Station, Texas in 1966 and achieved 100% kill of the bollworm and budworm 48 hr after application of 1.0 lb/acre. They concluded that ULV sprays should provide more effective and economical control.

Hopkins et al. (1970)[2] evaluated methyl parathion and other insecticides in 1968 and 1969 at Florence, South Carolina, and found that methyl parathion gave good control of the bollworm and boll weevil. Yields increased 1,629 lb/acre in 1968 and 867 lb/acre in 1969 compared to the untreated checks. The yields from the untreated checks were 255 and 10 lb/acre, respectively.

Adkisson et al. (1967)[3] compared various insecticides and found that methyl parathion at 1.0 lb/acre killed 100% of the bollworm larvae after 48 hr and 89% kill was achieved when methyl parathion was applied at 0.5 lb/acre. They also found that 0.75 lb/acre methyl parathion provided 97% kill of tobacco budworm larvae after 48 hr and 100% kill of the adult boll weevil under the same conditions when 0.25 lb/acre were applied. These tests were conducted at College Station, Texas, in 1966.

McGarr et al. (1969)[4] evaluated insecticides at Brownsville, Texas, in 1968 and reported that although methyl parathion was effective against the budworm and bollworm it did not give adequate control. Yield increases from three tests varied from 6 to 219 lb/acre. When methyl parathion was applied at 2.0 lb/acre, better control was achieved and yields increased 845 lb/acre.

In 1968, Nemec et al. (1968)[5] noted that the tobacco budworm population in the Lower Rio Grande Valley, and perhaps near College Station

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[1] Nemec, S. J., P. L. Adkisson, and H. W. Dorough, "Laboratory Tests of Ultra-Low Volume and Conventional Low Volume Sprays for Controlling the Bollworm and Tobacco Budworm," J. Econ. Entomol., 61:209-213 (1968).

[2] Hopkins, A. R., H. M. Taft, W. James, and C. E. Jernigan, "Evaluation of Substitutes for DDT in Field Experiments fof Control of the Bollworm and the Boll Weevil in Cotton, 1967-1969," J. Econ. Entomol., 63:848-850 (1970).

[3] Adkisson, Perry L., and S. J. Nemec, "Insecticides for Controlling the Bollworm, Tobacco Budworm, and Boll Weevil," MP-837, Texas Agr. Exp. Sta. (1967).

[4] McGarr, R. L., and D. A. Wolfenbarger, "Field Evaluations of Insecticides for Control of Cotton Insects, Brownsville, 1968," Progress Report PR-2670, Texas Agr. Exp. Sta. (1969).

[5] Nemec, S. J., P. L. Adkisson, and H. W. Dorough, "Laboratory Tests of Ultra-Low Volume and Conventional Low Volume Sprays for Controlling the Bollworm and Tobacco Budworm," J. Econ. Entomol., 61:209-213 (1968).

had developed a low-level resistance to methyl parathion: large doses of the insecticide were needed to kill the budworms in laboratory tests. The LD_{50} values had also indicated a 2.0- to 2.5-fold increase over the previous year. These tests showed a 97% kill in 48 hr when applied at 2.0 lb/acre on College Station larvae. This dropped to a 41% kill rate when 0.5 lb/acre was applied. There were no indications of resistance in the bollworm or voll weevil.

Nemec conducted similar tests in 1969 (Nemec, 1970[1/]) and found that the LD_{50} value for methyl parathion increased 1.5-fold over the 1968 value in budworms from the Brazos River Valley and twofold over the 1968 value in the Welasco area. Methyl parathion at 2.0 lb/acre resulted in a 90% kill in 48 hr at College Station in 1969. At 0.5 lb/acre it gave a 44% kill. In Welasco the results at the above rates were 79% and 23%, respectively.

Nemec et al. (1973)[2/] summarized the yearly tests comparing the effect of methyl parathion on the budworm and bollworm. He reported that prior to 1968 when resistance was detected in the budworm the cost of control was $28/acre. By 1972 the cost for control of the bollworm complex averaged $60/acre due to higher rates and more frequent applications of insecticides, greater populations of the budworm and higher costs of certain insecticides.

The results of tests showed that the LD_{50} values for methyl parathion on the budworm increased 50-fold between 1964 and 1972 at College Station, Texas. A fivefold increase from 1968 to 1972 was reported in the Rio Grande Valley, Texas.

Some resistance of the bollworm to methyl parathion was also indicated. The LD_{50} values at College Station were at the same level from 1967 to 1971, but doubled in 1972. Bollworms in the Pecos area were shown to be more tolerant to methyl parathion than those from College Station.

[1/] Nemec, S. J., "Topical Application and Caged Plant Evaluations of Insecticide Toxicities to Bollworms, Tobacco Budworms and Boll Weevils," Progress Report PR-2845, Texas Agr. Exp. Sta. (1970).

[2/] Nemec, S. J., and P. L. Adkisson, "Organophosphate Insecticide Resistance Levels in Tobacco Budworm and Bollworm Populations in Texas, Investigations of Chemicals for Control of Cotton Insects in Texas," Technical Report No. 73-20, pp. 18-25, Texas Agr. Exp. Sta. (1973).

Wolfenbarger et al. (1973)[1] evaluated budworm resistance to methyl parathion in Texas, Mexico, Central America, Florida, and Mississippi, and found the highest levels of resistance in the Mante Tampico area of Mexico. They concluded that these insects in this area and Brownsville, Texas were resistant to methyl parathion while those in Mississippi, Southern and Western Mexico were susceptible. The bollworms from Central America and Southern Mexico were resistant to methyl parathion whereas the United States resident bollworms were susceptible.

Apparently, the resistance of the budworm to methyl parathion is limited to the Texas area. Canerday (1974)[2] showed that there were no substantial and consistent differences in the response of bollworms and budworms to methyl parathion in tests conducted in Georgia between 1970 and 1972.

Cost Effectiveness of Pest Control - Numerous studies have been conducted comparing increased yields of methyl parathion treated cotton. Most of these studies were made available from the Texas Agricultural Experiment Station and were supplemented by tests conducted in Mississippi, Louisiana, and South Carolina. The tests covered the period from 1956 to 1972. The 1972 farm value, including an allowance for support payments, was 15.1¢ for the lint and 2.5¢ for the seed in a pound of seed cotton. Therefore, the total farm value of a pound of seed cotton was 17.6¢ in 1972 (Agricultural Statistics, 1974[3]). Methyl parathion costs averaged $1/lb in 1972 (Chambers and Miller, 1974[4]).

The range of yield changes from all of the data reviewed varied from a loss of 52 lb/acre to an increase of 1,629 lb when compared to untreated test plots. The economic benefit after subtracting the cost of the methyl parathion ranged from a loss of $20.15/acre to a gain of $270.45/acre.

The results of the yield tests are tabulated in Table 25.

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[1] Wolfenbarger, D. A., M. J. Lukefahr, and H. M. Graham, "LD_{50} Values of Methyl Parathion and Endrin to Tobacco Budworm and Bollworms Collected in the Americas and Hypothesis on the Spread of Resistance in These Lepidopterans to These Insecticides," J. Econ. Entomol., 66:211-216 (1973).

[2] Canerday, T. D., "Response of Bollworm and Tobacco Budworm in Georgia to Methyl Parathion," J. Econ. Entomol., 67:299 (1974).

[3] Agricultural Statistics, 1973, U.S. Department of Agriculture (1973).

[4] Chambers, William, and Daniel Miller, Farmland Industries, Kansas City, Missouri, personal communication with Mr. David F. Hahlen (1974).

Table 25. RESULTS OF METHYL PARATHION APPLIED TO COTTON PESTS

	Application						
Date	Rate (lb AI/acre)	No.	Yield increase* (lb/acre)	Additional income* ($/acre at 17.6¢/lb)	Application cost (AI $1/lb + 50¢/ application)	Economic benefit* ($)	Source
1967	1.25	8	436	76.74	14.00	62.74	a/
1956	0.3	9	1,530	269.28	7.20	262.08	b/
1956	0.25	9	476	83.78	6.75	77.03	
1959	0.25	13	68	11.97	9.75	2.22	
1960	0.25	14	265	46.64	10.50	36.14	
1961	0.25	13	290	51.04	9.75	41.29	
1967	0.25	11	487	85.71	8.25	77.46	
1967	0.75	11	194	34.14	13.75	20.39	
1968	1.0	6	119	20.94	9.00	11.94	
1969	1.0	10	775	136.40	15.00	121.40	
1971	0.25	7	122	21.47	5.25	16.22	
1971	0.125	7	158	27.81	4.38	23.43	
1971	0.25	7	97	17.07	5.25	11.82	
1971	1.0	7	255	44.88	10.50	34.38	
1972	1.0	10	197	34.67	15.00	19.67	
1973	1.0	3	34	5.98	4.50	1.48	
1972	1.0	12	366	64.42	18.00	46.42	
1971	1.0	7	337	59.31	10.50	48.81	
1971	1.0	8	499	87.82	12.00	75.82	
1963	1.0	12	350	61.60	18.00	43.60	c/
1966	1.0	9	165	29.04	13.50	15.54	
1969	1.0	8	547	96.27	12.00	84.27	
1971	1.0	7	376	66.18	10.50	55.68	
1971	1.0	7	460	80.96	10.50	70.46	
1966	1.0	9	177	31.15	13.50	17.65	
1966	1.0	9	75	13.20	13.50	(.30)	
1969	1.0	7	773	136.05	10.50	125.55	
1973	1.0	5	220	38.72	7.50	31.22	
1967	0.75	12	201	35.38	15.00	20.38	d/
1968	0.75	4	157	27.63	5.00	22.63	
1969	0.75	9	801	140.98	11.25	129.73	
1968	0.75	13	1,629	286.70	16.25	270.45	e/
1969	1.0	16	867	152.59	24.00	128.59	
1967	1.0	17	689	121.26	25.50	95.76	f/
	1.0	17	576	101.38	25.50	75.88	
1968	1.0	6	219	38.54	9.00	29.54	g/
	1.0	11	175	30.80	16.50	14.30	
	0.75	12	6	1.06	15.00	(13.94)	
	2.0	17	845	148.72	42.50	106.22	
1968	2.0	12	800	140.80	30.00	110.80	h/
	1.25	12	636	111.94	21.00	90.94	
1968	1.25	8	419	73.74	14.00	59.74	a/
	1.0	6	629	110.70	9.00	101.70	
	0.75	6	411	72.34	7.00	64.84	

(Note: Income and benefit figures have been adjusted for error in source document.)

Table 25. (Continued)

Date	Application		Yield increase* (lb/acre)	Additional income* ($/acre at 17.6¢/lb)	Application cost (AI $1/lb + 50¢/application)	Economic benefit* ($)	Source
	Rate (lb AI/acre)	No.					
1969	1.5	6	65	11.44	12.00	(.56)	g/
	1.5	6	105	18.48	12.00	6.48	
	1.6	8	65	11.44	16.80	(5.36)	
	2.0	13	601	105.78	31.50	74.28	
1969	1.5	12	236	41.54	24.00	17.54	i/
1969	1.17	6	115	20.24	10.02	10.22	j/
1970	1.5	4	290	51.04	8.00	43.04	k/
1971	1.5	6	98	17.25	12.00	5.25	l/
	1.5	6	(52)	(9.15)	12.00	(21.15)	
1971	1.5	8	439	77.26	16.00	61.26	m/
	1.5	8	596	104.90	16.00	88.90	
	0.8	8	449	79.02	10.40	68.62	
	1.5	8	711	125.14	16.00	109.14	
	1.5	8	614	108.06	16.00	92.06	
	0.8	8	384	67.58	10.40	57.18	
1972	1.5	10	414	72.86	20.00	52.86	n/
1972	1.5	8	364	64.06	16.00	48.06	o/

(Note: Income and benefit figures have been adjusted for error in source document.)

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* Data in parentheses indicate decreases yield, income, and economic benefit.

a/ Cowan, C. B., Jr., and J. W. Davis, "Field Tests With Conventional Low Volume or Ultra-Low Volume Sprays for Control of the Boll Weevil, Bollworm, and Tobacco Budworm on Cotton in 1967," J. Econ. Entomol., 61:1115-1116 (1968).

b/ Bost, W. M., Director, Cooperative Extension Service, Mississippi State University, State College, Mississippi, Summary of Test Results at Stoneville and Verona, Mississippi, and Costs of Pesticides, personal letter to Mr. David F. Hahlen.

c/ Cox, John A., Director, Louisiana Cooperative Extension Service, Baton Rouge, Louisiana, Summary of Test Results in Louisiana, personal letter to Mr. David F. Hahlen (1974).

d/ Legett, J. E., T. C. Cleveland, and W. P. Scott, "Comparison of Several Insecticide Combinations for Control of Heliothis spp.," J. Econ. Entomol., 65:1182 (1972).

e/ Hopkins, A. R., H. M. Taft, W. James, and C. E. Jernigan, "Evaluation of Substitutes for DDT in Field Experiments for Control of the Bollworm and the Boll Weevil in Cotton, 1967-1969," J. Econ. Entomol., 63:848-850 (1970).

f/ Wolfenbarger and McGarr, op. cit. (1971).

g/ McGarr and Wolfenbarger, op. cit. (1969).

Table 25. (Continued)

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h/ Hanna, R. L., "Field Performance of Chemicals for Control of Tobacco Budworms, Bollworms, and Carmine Spider Mites on Cotton, College Station, 1968," Progress Report PR-2671, Texas Agr. Exp. Sta. (1969).

i/ Hanna, R. L., "Field Tests of Chemicals for Control of Tobacco Budworms, Bollworms, and Carmine Spider Mites on Cotton, College Station," Progress Report PR-2842, Texas Agr. Exp. Sta. (1970).

j/ Cowan, C. B., Jr., and J. W. Davis, "Field Evaluation of Insecticides for Control of the Boll Weevil, Bollworm and Tobacco Budworm on Cotton, Waco Area, Central Texas, 1968," Progress Report PR-2672, Texas Agr. Exp. Sta. (1969).

k/ Hanna, R. L., "Field Tests of Chemicals for Control of Tobacco Budworms and Bollworms on Cotton, College Station," Technical Report 19, pp. 19-22, Texas Agr. Exp. Sta. (1971).

l/ McGarr, R. L., "Field Tests With the Delta-Endotoxin of Bacillus thuringiensis HD-1 and Chemical Insecticides for Control of the Tobacco Budworm and Bollworm and the Cotton Leafperforator, 1970 and 1971, Investigations of Chemicals for Control of Cotton Insects in Texas 1970-1971," Progress Report PR-3082, pp. 1-4, Texas Agr. Exp. Sta. (1972).

m/ Hanna, R. L., "Field Tests of Chemicals for Control of Tobacco Budworms and Bollwor on Cotton, College Station, Investigations of Chemicals for Control of Cotton Insects in Texas, 1970-1971," Progress Report PR-3084, pp. 22-36, Texas Agr. Exp. Sta. (1972).

n/ Cowan, C. B., Jr., and J. W. Davis, "Chemicals Evaluated in Field Tests Against Cotton Insects, Investigations of Chemicals for Control of Cotton Insects in Texas," Technical Report No. 73-20, pp. 9-12, Texas Agr. Exp. Sta. (1973).

o/ McGarr, R. L., "Field Tests With Bacillus thuringiensis HD-1 and Chemical Insecticides for Control of the Tobacco Budworm and the Bollworm at Brownsville, Texas, 1972, Investigations of Chemicals for Control of Cotton Insects in Texas," Technical Report No. 73-20, pp. 13-17, Texas Agr. Exp. Sta. (1973).

Aldicarb

Approximately 440,000 lb AI of Temik® were used to treat cotton insects and nematodes in 1972. It has been shown to be effective in controlling thrips, aphids, boll weevils, leaf miners, desert spider mites and fleahoppers.

Efficacy Against Past Infestation

Temik® has been evaluated for insect control on cotton by a number of researchers. These tests were conducted prior to registration and in noncommercial trials since registration. For this reason the results may not be representative of actual field conditions, but they have been included so that the review may be more complete. (See Table 14.)

Beckham (1970)[1] evaluated Temik® and other insecticides for the control of thrips on cotton in Georgia. Results of tests conducted in 1967 and 1968 showed that Temik® was highly effective in thrips control. Davis and Cowan (1972)[2] showed that Temik® applied in the seed furrow at planting gave effective control of thrips, the cotton aphid, and the cotton fleahoppers. Davis and Cowan (1974)[3] conducted tests with Temik® and concluded that effective control of thrips, cotton aphids and cotton fleahoppers was achieved. The director of the Cooperative Extension Service in Mississippi, W. M. Bost (1974)[4], reporting on tests of Temik® at Verona, Mississippi, in 1971, found the pesticide gave excellent thrips control and reduced the number of boll weevils. Its effect on fleahoppers was inconclusive.

Fifty additional tests, conducted from 1965 to 1973, compared yields of Temik®-treated plots at Stoneville, Mississippi (Bost, 1974). Substantial yield information was also obtained from Union Carbide pesticide petitions registered with EPA.

1/ Beckham, C. M., "Influence of Systemic Insecticides on Thrips Control and Yield of Cotton," J. Econ. Entomol., 63:936-938 (1970).

2/ Davis, J. W., and C. B. Cowan, Jr., "Field Evaluation of Three Formulations of Aldicarb for Control of Cotton Insects," J. Econ. Entomol., 65:231-232 (1972).

3/ Davis, J. W., and C. B. Cowan, Jr., "Early Season Insects on Cotton: Control with Two Systemic Insecticides," J. Econ. Entomol., 67:130-131 (1974).

4/ Bost, W. M., Director, Cooperative Extension Service, Mississippi State University, State College, Miss., Personal letter to D. F. Hahlen (Midwest Research Institute, St. Louis, Mo.) (1974).

In addition to the above test data, Union Carbide has submitted the results of 1974 efficacy and comparative yield tests for cotton. This data has been compiled and evaluated in the same manner as the published data and is presented in Table 15. These tests are results of commercial use and are likely to be more representative of actual field conditions than the experimental trials in Table 14. The tests were conducted in several states and, therefore, probably cover a wide spectrum of environmental conditions. Most of the yield increases are averages of several tests and in the cases where the number of tests was given, this number has also been presented. The average change in yield has been calculated as a weighted average based on the number of tests from which each yield change was derived. This supplementary data on cotton gave no indication of the efficacy of insect control but the tests did report increases in yield of from 0 to 390 lb/acre in South Carolina and Alabama respectively. The weighted average of all the tests indicated that the use of Temik® caused an average increase in cotton yield of 75.6 lb/acre.

Cost Effectiveness of Pest Control

The 1972 price received by farmers for cotton was 24.0¢/lb for lint. Additional income from cottonseed of 4.2¢/lb and government price supports of 12.5¢/lb brought the total income to 40.7¢/lb of cotton (*Agricultural Statistics*, 1973)[1] Aldicarb costs amounted to $9.50/lb of active ingredient (Bost, 1974).

For the data reviewed from non-commercial use situations the range of changes in cotton varied from a decline of 281 lb/acre to an increase of 1413 lb/acre. The economic benefit after subtracting the cost of Temik® ranged from a loss of $133.37/acre to an increase of $558.75/acre. The 1974 commercial use data indicates a range of economic benefits from a loss of $5.70/acre to an increase of $153.03/acre. The average economic benefit shown by this data is an increase of $25.07/acre. However, in typical farm situations this increase to farmer income would be reduced nominally by costs of insecticide application and costs of harvesting the additional output. The actual application cost was treated here as a joint cost with the planting operation; therefore, a rather nominally low figure resulted. Furthermore, there is no indication that this supplementary data is a statistically representative sample of all comparative yield tests conducted on cotton.

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[1] U.S. Department of Agriculture, *Agricultural Statistics*, 1973.

Table 14. SUMMARY OF EFFICACY TESTS ON COTTON

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1964	0.6	8	3.26	5.70	(2.44)	a/
	1.0	37	15.06	9.50	5.56	
	2.0	73	29.71	19.00	10.71	
1964	2.0	(98)	(39.89)	19.00	(58.89)	
	4.0	65	26.46	38.00	(11.54)	
Unknown	1.06	(192)	(78.14)	10.07	(88.21)	
Unknown	0.5	328	133.50	4.75	128.75	b/
	1.0	277	112.74	9.50	103.24	
	0.6/100 lb seed	152	61.86	5.70	56.16	
	1.0/100 lb seed	87	35.41	9.50	25.91	
1965	2.0	(119)	(48.43)	19.00	(67.43)	
	1.0	(38)	(15.46)	9.50	(24.96)	
1965	3.0	851	346.36	28.50	317.86	
1965	1.0	83	33.78	9.50	24.28	
	2.0	523	212.86	19.00	193.86	
1965	0.6	396	161.17	5.70	155.47	
	1.0	917	373.22	9.50	363.72	
1965	3.0	395	160.77	28.50	132.27	
	3.0	130	52.91	28.50	24.41	
	3.1	300	122.10	29.45	92.65	
	3.1	(60)	(24.42)	29.45	(53.87)	
	3.7	820	333.74	35.15	298.59	
	3.7	600	(244.20)	35.15	(279.35)	

Table 14. (Continued)

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1966	0.98	892	363.04	9.31	353.73	b/
	1.94	839	341.47	18.43	323.04	
	3.68	586	238.50	34.96	203.54	
1966	1.1	230	93.61	10.45	83.16	
	2.5	365	148.56	23.75	124.81	
1965	1.0	(38)	(15.46)	9.50	(24.96)	
1965	3.0	851	346.36	28.50	317.86	
1966	3.0	1,253	509.97	28.50	481.47	
1966	3.0	1,281	521.37	28.50	492.87	
1966	1.0	(210)	(85.47)	9.50	(94.97)	
	2.0	360	146.52	19.00	127.52	
	3.0	(100)	(40.70)	28.50	(69.20)	
1966	1.0	320	130.24	9.50	120.74	
	2.0	250	101.75	19.00	82.75	
	3.0	350	142.45	28.50	113.95	
	0.55	553	227.11	5.23	221.88	
	1.25	661	269.03	11.88	257.15	
	1.72	1,413	575.09	16.34	558.75	
	2.56	1,224	498.17	24.32	473.85	
	0.60	300	122.10	5.70	116.40	
	1.38	230	93.61	13.11	80.50	
	1.90	60	24.42	18.05	6.37	
	2.68	(70)	(28.49)	25.46	(54.95)	
	1.0	(281)	(114.37)	9.50	(123.87)	
	1.0 + 1.0	(281)	(114.37)	19.00	(133.37)	
	1.0 + 2.0	150	61.05	28.50	32.55	
	1.0 + 3.0	207	84.25	38.00	46.25	

Table 14 (Continued).

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1966	0.1	614	249.90	0.95	248.95	b/
	0.25	937	381.36	2.38	378.98	
	0.5	970	394.79	4.75	390.04	
1967	1.0	54	21.98	9.50	12.48	c/
1968	1.0	152	61.86	9.50	52.36	
1970	0.6	296	120.47	5.70	114.77	d/
	2.1	384	156.29	19.95	136.34	
	0.9	351	142.86	8.55	134.31	
	1.8	394	160.36	17.10	143.26	
	1.0	381	155.07	9.50	145.57	
1972	0.8	309	125.76	7.60	118.16	e/
	1.2	443	180.30	11.40	168.90	
1970	1.0	307	124.95	9.50	115.45	f/
	2.0	164	66.75	19.00	47.75	
1972	1.0	11	4.48	9.50	(5.02)	g/
	1.125	231	94.02	10.69	83.33	
1972	1.0	433	176.23	9.50	166.73	h/
	0.5	221	89.95	4.75	85.20	
1972	0.33	907	369.15	3.14	366.01	i/
	0.67	898	365.49	6.37	359.12	
	1.0	701	285.31	9.50	275.81	
1972	0.5	595	242.17	4.75	237.42	f/
1972	2.0	632	257.22	19.00	238.22	j/
	2.0	846	344.32	19.00	325.32	k/

Table 14. (Continued)

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1972	0.25	300	122.10	2.38	119.72	k/
	0.5	197	80.18	4.75	75.43	
	1.0	50	20.35	9.50	10.85	
1965	1.0	83	33.78	9.50	24.28	
1965	2.0	523	212.86	19.00	193.86	
1965	0.5	(114)	(46.40)	4.75	(51.15)	
1965	1.0	157	63.90	9.50	54.40	
1965	2.0	538	213.37	19.00	199.97	
1966	0.5	1,258	512.01	4.75	507.26	
1966	0.1	614	249.90	0.95	248.95	
1966	0.25	937	381.36	2.38	378.98	
1966	0.5	970	394.79	4.75	390.04	
1966	1.0 + 2.0	150	61.05	28.50	32.55	
1966	1.0 + 4.0	206	83.84	47.50	36.34	
1967	0.5	310	126.17	4.75	121.42	
1967	0.75	542	220.59	7.13	213.46	
1967	0.25	585	238.10	2.38	235.72	
1967	0.1	10	4.07	0.95	3.12	
1967	0.25	321	130.65	2.38	128.27	
1967	0.5	134	54.54	4.75	49.79	
1968	0.25	277	112.74	2.38	110.36	
1968	1.0	207	84.30	9.50	74.80	
1968	0.25	280	113.96	2.38	111.58	
1968	0.5	81	32.97	4.75	28.22	
1969	0.25	363	147.74	2.38	145.36	
1969	0.1	675	274.73	0.95	273.78	
1969	0.25	293	119.25	2.38	116.17	
1969	0.5	266	108.26	4.75	103.51	

Table 14. (Continued)

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1970	0.25	545	221.82	2.38	219.44	k/
1970	0.5	536	218.15	4.75	213.40	
1970	0.1	207	84.25	0.95	83.30	
1971	0.1	232	94.42	0.95	93.47	
1971	0.25	260	105.82	2.38	103.44	
1971	0.5	223	90.76	4.75	86.01	
1971	1.0	330	134.31	9.50	124.81	
1971	0.25	117	47.62	2.38	45.24	
1971	0.5	308	125.35	4.75	120.60	
1971	1.0	366	148.96	9.50	139.46	
1971	0.25	155	63.09	2.38	60.71	
1972	0.25	657	267.40	2.38	265.02	
1972	0.25	137	55.76	2.38	53.38	
1972	0.25	195	79.37	2.38	76.99	
1972	0.5	198	80.58	4.75	75.83	
1972	0.25	49	19.94	2.38	17.56	
1972	0.25	53	21.57	2.38	19.19	
1972	0.5	171	69.60	4.75	64.85	

Table 14. (Continued)

Date	Application (lb AI/acre)	Yield increase* (lb/acre)	Additional income* ($/acre at 40.7¢/lb)	Aldicarb cost at $9.50/lb ($/acre)	Economic benefit* ($/acre)	Source
1973	0.3	89	36.22	2.85	33.37	
1973	0.6	120	48.84	5.70	43.14	
1973	0.15	130	52.91	1.43	51.48	
1973	0.3	281	114.37	2.85	111.52	
1973	0.6	189	76.92	5.70	71.22	
1973	0.5	228	92.80	4.75	[illegible]3.05	
1973	1.0	215	87.50	9.50	78.00	

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* Data in parentheses indicate decreases in yield, income, and economic benefit.

a/ Union Carbide Corp., EPA Pesticide Petition Files, Section 1[illegible].

b/ Union Carbide Corp., EPA Pesticide Petition 8F0637.

c/ Beckham, _op cit_. (1970).

d/ Davis and Cowan, _op cit_. (1972).

e/ Davis and Cowan, _op cit_. (1974).

f/ Birchfield, W., "Cotton," _Fungicide and Nematocide Test Results of 1970_, Report No. 277, American Phytopathological Society, St. Paul, Minn. (1970).

g/ Blackman, _op cit_. (1972).

h/ Birchfield, _op cit_. (1972).

i/ Bird et al., _op cit_. (1972).

j/ Smith, F. H., "Cotton," _Fungicide and Nematocide Test Results of 1972_, Report No. 312, American Phytopathological Society, St. Paul, Minn. (1972).

k/ Bost, _op cit_. (1974).

Note: AI = active ingredient.

Table 15. 1974 RESULTS OF TEMIK® APPLICATION ON COTTON

Location	Application (lb AI/acre)	Yield Change (lb)	Value of Yield Change($) [1]	Temik® Cost [2]	Economic Benefit [3]	No. Tests
Calif.-Ariz.	.6	79	32.15	5.70	26.45	14
Calif.-Ariz.	2.0	144	58.61	19.00	39.61	N/S
Texas	.6	93	37.85	5.70	32.15	25
N.C.-S.C.	.6	11	4.78	5.70	-1.22	20
Ark.-Mo.	.6	73	29.71	5.70	24.01	5
Georgia	.6	274	111.52	5.70	105.82	10
Alabama	.6	390	158.73	5.70	153.03	2
Mississippi	.6	40	16.28	5.70	10.58	45
S.C	.6	0	0	5.70	-5.70	1
S.C.	.6	25	10.18	5.70	4.78	1
S.C.	.5	50	20.35	4.75	15.60	1
S.C.	.5	25	10.18	4.75	5.43	1
S.C.	.5	25	10.18	4.75	5.43	1
Average, All Tests -	.6	75.6	30.77	5.70	25.07	

[1] Change in cotton yield x $.407/lb (1972 average price).
[2] Lb AI/acre x $9.50/lb AI; since most Temik® is applied at planting, application cost (usually calculated with planting costs) is not evaluated.
[3] Value of Yield Change minus Temik® Cost equals Economic Benefit.
Note: N/S - pests not specified; AI = active ingredient.
Source: Comparative yield data submitted to EPA by Dr. Richard Back, Union Carbide Corporation, Washington, D.C.

The use of malathion on cotton is primarily for control of the boll weevil as it enters diapause. It is also recommended in some areas for the control of thrips, two spotted spider mites and grasshoppers.

Efficacy Against Pest Infestation - The three major insects that attack cotton are the tobacco budworm, the bollworm and the boll weevil. Malathion is relatively ineffective against the budworm and bollworm and is not recommended in some states for this use against those insects. In a test of several organophosphate insecticides, Plapp (1971)1/ found that malathion was not highly toxic to either the budworm or bollworm. Similar results were obtained by Cowan and Davis (1968)2/ who concluded that malathion did not control bollworms or tobacco budworms.

Malathion has been found to be effective on the boll weevil as it enters diapause. Lloyd et al. (1972)3/ concluded that ULV formulations of malathion gave effective control of boll weevils during tests conducted in 1966 and 1967 in Carroll County and State College, Mississippi. Applications of 0.25 to 0.50 lb of malathion every 4 to 5 days provided effective control. Cowan and Davis (1968) also concluded that ULV applications of malathion at 0.4 to 0.8 lb/acre gave good control of the boll weevil. These tests were conducted at Waco, Texas, in 1967.

1/ Plapp, F. W., Jr., "Insect Resistence in Heliothis: Tolerance in Larvae of H. virescens as Compared with H. zea to Organophosphate Insecticides," J. Econ. Entomol., 64:999-1002 (1971).

2/ Cowan, C. B., Jr., and J. W. Davis, "Field Tests with Conventional Low Volume and Ultra-Low-Volume Sprays for Control of the Boll Weevil, Bollworm and Tobacco Budworm on Cotton in 1967," J. Econ. Entomol., 61:1115-1116 (1968).

3/ Lloyd, E. P., J. P. McCoy, W. P. Scott, E. C. Burt, D. B. Smith, and F. C. Tingle, "In-Season Control of the Boll Weevil with Ultra-Low-Volume Sprays of Azinphosmethyl or Malathion," J. Econ. Entomol., 65:1153-1156 (1972).

There appears to be little change in the efficacy of malathion to the boll weevil. Namec and Adkisson (1968 to 1972)[1] have conducted toxicity tests of insecticides to the boll weevil. Data since 1968 are shown below.

Table 34. MALATHION EFFICACY TESTING RESULT ON BOLL WEEVILS

Insecticide	Lb/acre	% kill (48 hr)	Year
Malathion	1.0	78	1968
Malathion	1.0	92	1969
Malathion	1.0	82	1970
Malathion	0.5	100	1971
Malathion	1.0	100	1971

Cantu and Wolfenbarger (1969 to 1972)[2] have conducted tests on the toxicity of two spotted spider mites to malathion. The results as shown below do not indicate any reduction in efficacy over a 4-year period.

Table 35. MALATHION EFFICACY TESTING RESULTS ON SPIDER MITES

Insecticide	% concentration (ppm)	% kill after 72 hr (foliar spray)	Year
Malathion	0.25	90	1969
Malathion	0.01	27	1969
Malathion	0.25	88	1970
Malathion	0.01	24	1970
Malathion	0.25	86	1971
Malathion	0.01	20	1971
Malathion	0.25	88	1972
Malathion	0.01	20	1972

On the basis of these results it appears that there is no reduction in the efficacy when malathion is used to control the boll weevil and two spotted spider mites.

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[1] Nemec, S. J., and P. L. Adkisson, "Laboratory Tests of Insecticides for Bollworm, Tobacco Budworm and Boll Weevil Control," Investigations of Chemicals for Control of Cotton Insects in Texas (1968-1972).

[2] Cantu, E., and D. A. Wolfenbarger, "Effectiveness of Experimental Insecticides for Control of the Tobacco Budworm, Boll Weevil, Fall Armyworm, and Two Spotted Spider Mites," Investigations of Chemicals for Control of Cotton Insects in Texas (1969-1972).

Cost Effectiveness of Pest Control - There have been a limited number of studies on the change in cotton yield due only to the use of malathion. It is most often used in mixtures with methyl parathion to control the budworm and the boll weevil.

Yield increases from tests comparing malathion-treated cotton to untreated test plots varied widely depending upon the number of applications and the degree of pest infestation. Data were only available from seven tests conducted in Mississippi and Texas.

The wide range in yield increase is often due to the variance in the rate of pest infestations. Pfrimmer et al. (1971)[1/] reported that during tests in 1969 a field that normally produced 1,500 to 2,000 lb of seed cotton per acre produced only one-tenth of the normal yield without any insecticidal treatment.

The 1972 price received by farmers for cotton was 24.0¢/lb for lint. Additional income from cottonseed at 4.2¢/lb and government price supports of 12.5¢/lb brought the total income to 40.7¢/lb of cotton (Agricultural Statistics, 1973[2/]). Malathion costs averaged $1.20/lb (Bost 1974[3/]); application costs are $1.25 per treatment. Economic benefits would range from $5.95 to $683.96.

The range of yield changes from all of the data reviewed varied from a small gain of 20 lb/acre to a substantial increase of 1,730 lb/acre when compared to untreated test plots. The economic benefit after subtracting the cost of the malathion ranged from $6.70/acre to $700.21/acre.

[1/] Pfrimmer, T. R., R. E. Furr, and E. A. Stadelbocher, "Materials for Control of Boll Weevils, Bollworms, and Tobacco Budworms on Cotton at Stoneville, Mississippi," J. Econ. Entomol., 64:475-478 (1971).

[2/] Agricultural Statistics 1973, U.S. Department of Agriculture (1973).

[3/] Bost, W. M., Director, Cooperative Extension Service, Mississippi State, Mississippi, personal letter to D. F. Hahlen (1974).

The results of the yield tests are tabulated below.

Table 36. YIELD AND BENEFIT ANALYSIS RESULTS OF MALATHION ON SELECTED COTTON PESTS

Date	Application		Yield increase (lb/acre)	Additional income ($/acre at 40.7c/lb)	Application Cost at $1.20/lb plus treatment cost at $1.25/effort	Economic benefit ($)	Source
	Rate (lb AI/acre)	No.					
1956	1.0	5	205	83.45	12.25	71.20	a/
1956	1.0	9	458	186.41	22.05	164.36	a/
1958	0.5	7	714	290.60	12.95	277.65	a/
1967	0.25	13	1,730	704.11	20.15	683.96	a/
1967	0.5	13	1,170	476.19	24.05	452.14	a/
1967	0.4	3	20	8.14	2.19	5.95	b/
1967	0.8	3	40	16.28	3.63	12.65	b/

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a/ Bost, *op. cit.* (1974).

b/ Cowan et al., *op. cit.* (1968).

Parathion

Parathion is registered for a wide variety of cotton insects. The tobacco budworm, bollworm, boll weevil, aphids, fleahoppers, leaf hoppers, cabbage loopers, spider mites, and thrips are major cotton pests treated with parathion. Application rates vary from 0.25 to 1.0 lb/acre, depending upon the type of insect. The number of applications depends upon the degree of infestation. Repeated applications are recommended for the bollworm, budworm, and boll weevil until adequate control is achieved.

Efficacy Against Pest Infestation - Data is available on the efficacy of parathion for control of the budworm, bollworm, and boll weevil-- the three major cotton pests--'from tests conducted in Texas.

Adkisson et al. (1966)[1] compared a wide variety of insecticides for control of bollworm larvae near College Station, Texas in 1965. The use of parathion resulted in a 70% kill after 48 hr when applied at 0.5 lb/acre.

Adkisson et al. (1967)[2] conducted similar tests in 1966 and reported an 85% kill of bollworm larvae 48 hr after parathion was applied at 0.5 lb/acre. Parathion was also less effective against the budworm with an 83% kill at 0.75 lb/acre after 48 hr compared to a 97% kill for 0.75 lb/acre of methyl parathion. Against adult boll weevils, 0.25 lb/acre of parathion resulted in a 97% kill after 48 hr compared to 100% for methyl parathion at the same rate.

Wolfenbarger (1973)[3] found that tobacco budworms from a susceptible strain were 2.45 times more resistant to parathion than to methyl parathion during tests conducted in Brownsville, Texas in 1970.

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[1] Adkisson, Perry L., and S. J. Nemec, "Comparative Effectiveness of Certain Insecticides for Killing Bollworms and Tobacco Budworms," Publication B-1048, Texas Agr. Exp. Sta. (1966).

[2] Adkisson, Perry L., and S. J. Nemec, "Insecticides for Controlling the Bollworm, Tobacco Budworm, and Boll Weevil," MP-837, Texas Agr. Exp. Sta. (1967).

[3] Wolfenbarger, D. A., "Tobacco Budworm: Cross Resistance to Insecticides in Resistant Strains and in a Susceptible Strain," J. Econ. Entomol., 66:292-294 (1973).

Cost Effectiveness of Pest Control - Information was found on only one test relating yield changes to parathion usage. Bost (1974)[1] summarized tests conducted between 1956 and 1973 at Stoneville, Mississippi. The results of one test in 1956 showed a 253 lb/acre gain over an untreated check when nine applications of parathion at 0.5 lb/acre were made.

The 1972 price received by farmers for cotton was 14.0¢/lb for lint. Additional income from cottonseed of 4.2¢/lb and government price supports of 12.5¢/lb brought the total income to 40.7¢/lb (*Agricultural Statistics, 1973*).[2] Parathion costs averaged $1/lb in 1972, while application costs averaged $.50 per treatment (Chambers et al., 1974).[3]

Using the above cost and price data, the additional income would amount to $102.98/acre. Subtracting the cost of parathion at $9.00/acre would result in an economic benefit of $93.98/acre when parathion was used to control boll weevils, bollworms, and tobacco budworms.

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[1] Bost, W. M., Director, "Cooperative Extension Service Mississippi State University, Mississippi State Mississippi, Summary of Test Results at Stoneville and Verona, Mississippi, and Costs of Pesticides," personal letter to Mr. David F. Hahlen (1974).

[2] U.S. Department of Agriculture, Agricultural Statistics 1973.

[3] Chambers, William, and Daniel Miller, Farmland Industries, Kansas City, Missouri, conversation (1974).

III D.2

APPENDIX

THE VALUE OF DDT IN COTTON PRODUCTION

PRELIMINARY SUMMARY REPORT

TO

ENVIRONMENTAL PROTECTION AGENCY

CONTRACT # 68-01-2483

JULY 1, 1975

MANAGEMENT SCIENCE SYSTEMS
6121 Lincolnia Road • Alexandria, Va 22312 • (703) 750-2660

Some farmers and their representatives contend that they should be allowed, once again, to use DDT in the production of cotton. The question of social costs and benefits must be answered. The social costs of using DDT are still very controversial and this study does not attempt to address them. The purpose here is, rather, to assess the potential benefits of allowing DDT utilization in cotton production.

In order to allow for both within and among region changes in crop production within a framework which takes account of historic responsiveness, a constrained optimization model was employed. The linear programming (LP) model previously developed by MSS was modified for this purpose. Two solutions were obtained: a base model (BASE2) which allowed DDT for cotton in 1975; and an alternative which did not (COTQD1).

The Linear Programming Model

Activities were defined by producing (129) regions to provide for

- production of crops (by method, land class and region); and
- costs of change from historic production patterns.

Activities were defined by consuming region (27) to provide for

- exports of commodities;
- utilization of commodities for feed; and
- transportation of commodities between pairs of consuming regions.

Constraints were defined by producing are to

- limit land use to the quantity actually available (by land class);
- to provide crop acreage targets; and
- limit the proportion of cotton acreage using DDT.

Constraints were defined by consuming region to

- balance commodity production and demands.

The objective was to minimize production cost, transportation cost and flexibility penalties.

<u>The Base Model</u>

The LP model constrained the maximum production of cotton using DDT and using no pesticides to be no greater than the proportions shown in Table 1. The "Doane" regions referred to are:

2 - Georgia, Carolinas, Virginia;

3 - Texas, Oklahoma;

4 - Kentucky, Tennessee, Alabama, Arkansas, Mississippi and Louisiana;

5 - Missouri; and

6 - California, Arizona, New Mexico.

As Table 1 shows, only regions 2 and 4 utilized DDT in any significant proportion.

Two benefits may accrue to the use of DDT--decreased costs and increased efficacy. This analysis focuses on the interregional impacts of changes in cost which resulted from the DDT cancellation. The questions of efficacy and yield effects were evaluated only in as much as fewer applications per year were assumed to be required with DDT. This phenomena was reflected in regional insecticide cost estimates. A second cost impact occurs because DDT costs less than alternative insecticides. Table 1 shows the assumed costs of insecticide (including application) when DDT is allowed and when it is not.

In the LP model three distinct cotton production activities were defined on each land class in each producing area:

- Cotton with DDT (constrained to be less than the proportion of total cotton shown in Table 1);
- Cotton with other insecticides;
- Cotton with no insecticides (constrained to be less than the proportion receiving none as shown in Table 1).

Results of the Base Model

Tables 2 and 3 illustrate the conformance of the model results with both observed and projected acreages and total production. All results are somewhat lower than the observed and projected levels. This occurs because of substantially lower export requirements shown in Table 4. With lower total demands, of course the acreage and production will decline.

Table 5 shows the regional distribution of cotton production for both models and for observed 1973. The distribution in the models show a greater concentration in Texas than has been observed historically. Otherwise the distribution is quite similar.

Table 6 shows the regional distribution of cotton acreages among the insecticide options. These data correspond with the upper limits imposed on "DDT" and "No Pesticides" as shown in Table 1.

Results of the No DDT Model (COTQD1)

With DDT disallowed, certain production shifts must occur. The farmers who had used DDT must replace it with some other insecticide or stop producing cotton. As shown in Table 5, very few reduced production. The Atlanta region declined by 3,900 acres (.4%), Memphis declined 8,900 acres (.4%), New Orleans declined by 24,000 acres (7.2%), Louisville declined by 600 acres (34.0%) and San Francisco increased by 17,500 acres (2.2%). Since the yield is higher in the San Francisco region, total production remained constant even though total acreage declined by 19,900 acres (.18%).

It follows that most farmers utilized other, higher cost, insecticides. Table 7 shows that this is the case. Comparing it with Table 6 shows that nearly all the cotton previously using DDT was shifted to other insecticides--a total of 980 thousand acres.

The land idled by those farmers who elected not to grow cotton in the southeast and delta states was generally left idle, although 2,250 acreas in the Atlanta region were planted to soybeans. In Memphis, cotton is shifted to higher yielding land classes, causing a degradation in soybean and oat yields there. The land in San Francisco on which cotton production was increased was previously slack; thus no shift in other crops was observed.

There was a negligible impact on equilibrium prices which are, by definition, the marginal cost of production. Since each region was forced in each solution to produce some cotton using other insecticides for each acre using DDT, and since there was no direct yield impact, the marginal cost of production was not increased by the removal of the low cost option. Thus comsumers are not noticeably impacted by the removal of DDT.

Average costs were, of course, increased. This reduces the return to land, which is a proxy for net farm income. Table 8 illustrates the changes in land values. The Memphis region suffered most with a decline of 1.93% in return to land. Other regions in the southeast and delta also suffered some loss with Atlanta declining .37% and New Orleans declining .93%. The San Francisco region, conversely, realized a gain of .26%. These changes are quite small even on a regional basis--although some individual farmers may suffer substantial losses. At the national level, the returns to land declined by .08%.

Summary and Conclusions

Given the data on comparative insecticide costs and DDT upper limits, the impact of restricting DDT use on cotton is quite small. The national impact is negligible for both producers and consumers. Regionally, there are small losses in some regions and gains in one for producers. On the basis of this study, we must conclude that the value of DDT in cotton production is not overwhelming.

Table 1. Historic cotton insecticide use.

Doane Region	Insecticide Cost		Proportion Treated	
	DDT	Other	DDT	Any
	$ acre	$/acre	%	%
2	48.53	59.60	30.00	93.1
3	-	15.03	-	27.2
4	24.47	27.05	26.9	79.0
5	-	6.19	-	28.0
6	-	12.38	-	72.4

Table 2. Comparison of observed and projected planted acreage (million acres).

	Observed 1973	Timetrend 1975	Model 1975
Barley	11.33	11.33	8.38
Corn	71.61	66.85	54.18
Cotton	12.50	12.62	10.97
Soybeans	57.30	55.72	49.35
Oats	19.21	15.01	10.32
Sorghum	16.26	15.66	15.05
Wheat	59.01	58.49	45.00
---Total	247.22	235.68	193.25

Table 3. Comparison of observed and projected crop commodity production (millions).

	Observed 1973	Time Trend 1975	Model 1975
Barley (bu)	424.2	460.2	337.8
Corn (bu)	5,636.6	5,760.1	5,389.7
Cotton (ba)	13.2	13.3	11.2
Soybeans (bu)	1,568.4	1,508.8	1,622.6
Oats (bu)	663.2	564.2	457.0
Sorghum (bu)	936.6	946.1	865.8
Wheat (bu)	1,711.2	1,826.5	1,402.9
Cottonseed (cwt)	98.96	110.0	92.7

Table 4. Comparisons of observed and projected crop commodity consumption and export (millions).

	Domestic Consumption (excluding Feed)		Export	
	Observed 1973	Model 1975	Observed 1973	Model 1975
Barley (bu)	145	186.1	66.0	50.5
Corn (bu)	423.0	769.5	1,258.0	932.5
Cotton (ba)	7.47	7.4	5.0	3.8
Soybeans[1]	141.0	180.9	681.	565.9
Oats (bu)	[illegible]3.0	124.4	24.0	5.0
Sorghum (bu)	6.0	33.9	212.0	74.6
Wheat (bu)	526.4	608.7	1,184.2	701.9
Cottonseed[1] (cwt)	9.7	12.4	37.0	26.3

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[1] Estimated

Table 5. Regional Distribution of cotton acreage as percent of US total: base model, with DDT disallowed, observed 1973.

	Observed 1973	Base Model 1975	DDT Disallowed 1975
Atlanta	11.28	8.48	8.46
Jacksonville	.09	.11	.11
Memphis	23.19	21.70	21.66
Houston	18.04	20.60	20.64
New Orleans	4.34	3.04	2.83
Louisville	.003	.02	.01
St. Louis	1.50	.83	.83
Amarillo	31.09	36.26	36.32
San Francisco	7.17	7.14	7.31
Los Angeles	3.28	1.81	1.82
--Total	100.00	100.00	100.00

Table 6. Regional distribution of cotton acreage by insecticide treatment: base model (million acres).

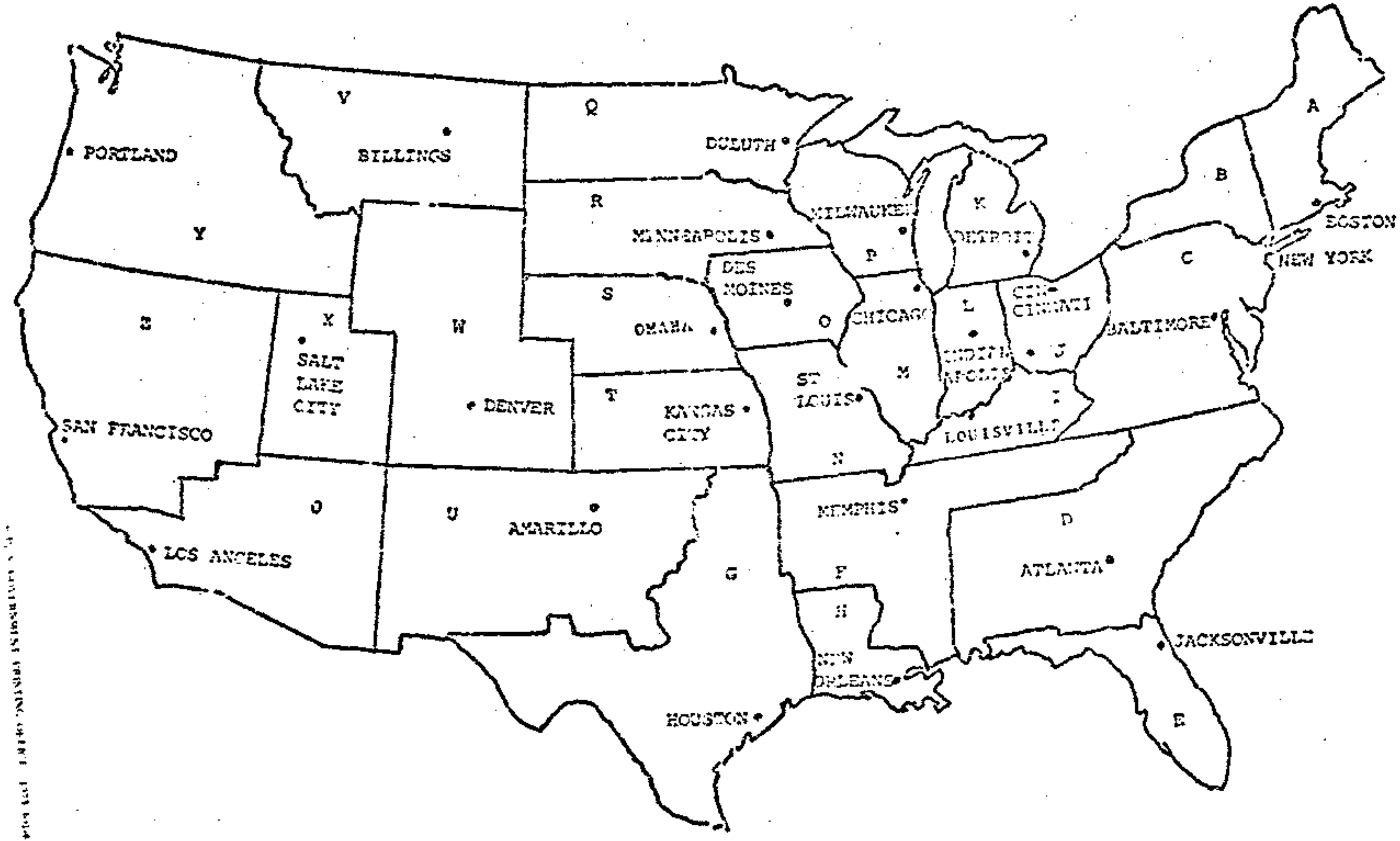
Region	No Pesticide	DDT	Other Pesticides	Total Acreage
Atlanta	.125	.266	.539	.930
Memphis	.500	.641	1.241	2.381
Houston	1.645	-	.615	2.260
New Orleans	.070	.090	.174	.334
Louisville	-	-	.002	.002
St. Louis	.066	-	.026	.091
Amarillo	2.842	-	1.133	3.978
San Francisco	.216	-	.567	.783
Los Angeles	.055	-	.144	.199
--Total	5.520	.996	4.439	10.972

Table 7. Regional distribution of cotton acreage by insecticide treatments: model with DDT disallowed (million acres).

Region	No Pesticides	DDT	Other Pesticides	Total
Atlanta	.124	-	.802	.926
Jacksonville	-	-	-	.012
Memphis	.498	-	1.874	2.372
Houston	1.645	-	.615	2.260
New Orleans	.065	-	.245	.310
Louisville	-	-	.001	.001
St. Louis	.066	-	.026	.091
Amarillo	2.842	-	1.133	3.978
San Francisco	.221	-	.580	.801
Los Angeles	.055	-	.144	.199
--Total	5.517	-	5.419	10.952

Table 8. Returns to land by region.

Region	Base Model ($ million)	DDT Disallowed ($ million)	Change (%)
Atlanta	45.35	45.19	- .37
Jacksonville	3.74	3.74	0.00
Memphis	63.53	62.30	-1.93
Houston	48.38	48.38	0.00
New Orleans	10.47	10.37	- .93
Louisville	11.95	11.95	0.00
St. Louis	44.39	44.39	0.00
Amarillo	121.48	121.48	0.00
San Francisco	33.41	33.50	+ .26
Los Angeles	7.73	7.73	0.00



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