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Analysis of the Risks and Benefits of Seven Chemicals Used for Subterranean Termite Control

ANALYSIS OF THE RISKS AND BENEFITS

OF SEVEN CHEMICALS

USED FOR SUBTERRANEAN

TERMITE CONTROL

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OFFICE OF PESTICIDES AND TOXIC SUBSTANCES

OFFICE OF PESTICIDE PROGRAMS

ENVIRONMENTAL PROTECTION AGENCY
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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

This paper responds to the concerns expressed in the General Accounting Office (GAO) report "Need for a Formal Risk/Benefit Review of the Pesticide Chlordane."

In August, 1980 the GAO summarized its investigation of the adequacy of the Environmental Protection Agency's (EPA) regulation of pesticides used in and around the home. During this review, the GAO concluded that underground application of pesticides to control termites, may pose unreasonable risks to man and the environment. The GAO report specifically cited problems the United States Air Force has had with contamination in military housing where chlordane had been applied for termite prevention or control.

The GAO report concluded that the EPA should conduct a Rebuttable Presumption Against Registration (RPAR) review of chlordane to determine whether the potential risk of the termite use outweighs the benefits of this use. In support of this conclusion, the report cites the National Cancer Institute's finding that chlordane causes cancer in laboratory mice, and the Air Force incidents showing airborne concentrations of chlordane in the living quarters of homes built on slab with heating/cooling ducts in or under the slab previously treated with chlordane.

The Agency responded to the GAO report in September, 1980. In the response, entitled "Response to GAO Report Need for a Formal Risk/Benefit Review of the Pesticide Chlordane", EPA agreed with GAO's finding that there is cause for concern about the use of chlordane for termite control in some treated structures. Exposure from the termite-control use of chlordane was not anticipated at the time of the 1974 decision to cancel all other uses of chlordane.

However, the Agency stated that an RPAR review of chlordane would not be the best approach to the problem. Although chlordane is the most widely used termiticide, several other compounds are also registered for this use, and some are similar in structure and effects to chlordane. Therefore, the same problem now associated with chlordane could occur with some or all of the other compounds.

The Agency proposed a comparative risk/benefit analysis of the termiticides as a cluster. This approach results in a more efficient use of Agency resources than chemical-by-chemical RPAR proceedings and it identifies those termiticide chemicals requiring further regulatory action. Moreover, this approach would ensure that the Agency would not take regulatory action against a pesticide only to have the market replace it with a more hazardous pesticide.

The major objective of the termiticide project is to identify and assess the health risks to man associated with the use of the termiticides as well as the benefits derived from their use. The chemicals included in the cluster are those currently registered for subterranean termite control: chlordane, heptachlor, aldrin, dieldrin, lindane, pentachlorophenol, and chlorpyrifos. Once the potential risks and benefits are discussed, and compared, further actions, regulatory and non-regulatory, are identified to ensure that the concerns raised by the GAO investigation are adequately addressed.

This report is composed of five chapters in addition to this introduction, Chapter I. In Chapter II the termiticide chemicals are identified and a synopsis of the EPA's regulatory actions on each chemical is presented. Chapter III is a discussion of the subterranean termite and the costs and benefits associated with its control. This information on current control practices, benefits of control, and economic scenarios of possible regulatory options was compiled by the Agency's Benefits and Field Studies Division, Office of Pesticide Programs.

Chapter IV summarizes the data on the health effects and human exposure associated with the termiticides. Data on the possible health effects of the cyclodienes - chlordane, heptachlor, aldrin, dieldrin - are presented together because of the similarity of these chemicals. The data for the remaining termiticides are presented for each chemical individually. The summaries of the health effects data are based upon a report entitled "An Assessment of the Health Risks of Seven Pesticides Used for Termite Control" developed by the National Academy of Sciences, August, 1982 as well as other published reviews. Exposure data were taken from the open literature and unpublished data were obtained from the Departments of the Air Force, Navy and Army.

Chapter V presents a summary of the health risks and benefits associated with the use of the termiticides and the final chapter, Chapter VI, presents the Agency's conclusions and recommendations.

CHAPTER II

IDENTIFICATION AND REGULATORY HISTORY OF CHEMICALS IN THE TERMITICIDE CLUSTER

Identification

The chemicals included in the termiticide cluster are those currently registered with the Agency for subterranean termite control. A list of the common names along with the chemical names of these pesticides is presented below:

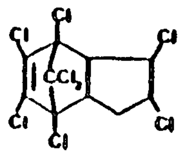
Common Name	Chemical Name
Chlordane	1,2,4,5,6,7,8,8-Octachloro-4,7-methano-3a,4,7,7a-tetra-hydroindane
Heptachlor	1,4,5,6,7,8,8a-Heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
Aldrin	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene
Dieldrin	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethano-naphthalene
Lindane	Hexachlorocyclohexane
Pentachlorophenol	same as common name
Chlorpyrifos	o,o-Diethyl o- (3,5,6-trichloro-2-pyridyl) phosphorothioate

The chemical structure of each termiticide is displayed in Table II-1. Chlordane, heptachlor, aldrin, and dieldrin are all chlorinated cyclodiene pesticides. Because of the structural similarity of the cyclodiene pesticides, the behavior of these chemicals in the environment and associated health effects are similar. Lindane and pentachlorophenol are also chlorinated hydrocarbons. Chlorpyrifos is an organophosphate pesticide and thereby, is structurally different from the other termiticides.

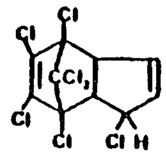
A complete listing of the physical and chemical properties of the termiticides is presented in the Appendix to this document.

TABLE II-1

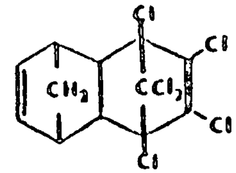
CHEMICAL STRUCTURE OF TERMITICIDES



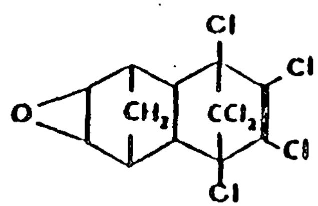
CHLORDANE



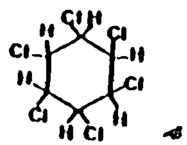
HEPTACHLOR



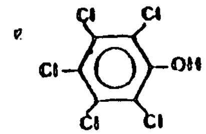
ALDRIN



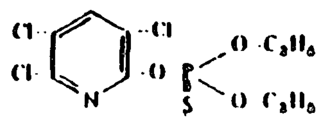
DIELDRIN



LINDANE



PENTACHLOROPHENOL



CHLORPYRIFOS

Regulatory History

Chlordane/Heptachlor

1947 - Chlordane first produced commercially in the United States.

1953 - Commercial production of heptachlor reported in the United States.

March 18, 1971 - EPA Administrator announced that an active internal review was being initiated on a number of pesticide products including those containing chlordane and heptachlor.

November 26, 1974 - A Notice of Intent to cancel all registered uses of heptachlor and chlordane, except for subsurface ground insertion for termite control and dipping of roots and tops of nonfood plants, appeared in the Federal Register.

July 25, 1975 - EPA Administrator issued a Notice of Intent to suspend the registrations of certain pesticide products containing heptachlor and chlordane.

November, 1977 - Cancellation proceedings continued until 11/77 at which time EPA and Velsicol Chemical Corporation (registrant) entered into settlement negotiations.

March 6, 1978 - Final cancellation order putting into effect terms of settlement was issued.

Aldrin/Dieldrin

1948 - Aldrin and dieldrin synthesized in laboratory.

1951 - Commercial production registered in United States.

March 18, 1971 - EPA Administrator announced issuance of appropriate notices of cancellation of aldrin and dieldrin.

August 2, 1974 - A Notice of Intent to suspend the registration of certain pesticide products containing aldrin and dieldrin was issued. The use to control termites was continued.

October 18, 1974 - EPA Administrator announced all pesticide products containing aldrin or dieldrin were suspended and the production for use of all such pesticide products is prohibited. Subsurface ground insertion for termite control, dipping of non-food roots and tops, moth-proofing by manufacturing processes in a closed system uses were allowed to continue.

Lindane

Early 1950's - Pesticide products containing lindane are federally registered.

February 17, 1977 - Position Document 1; Notice of Rebuttable Presumption Against Registration (RPAR) was issued. Termiticide use was not considered in this review.

June, 1980 - Position Document 2/3 in RPAR process was issued. Termiticide use was not considered in this review.

Pentachlorophenol

1930's - Use as wood preservative began.

1950 - Commercial production in United States reported.

October 18, 1978 - Position Document 1; Notice of Rebuttable Presumption Against Registration (RPAR) was issued. Termiticide use was not considered in this review.

January, 1981 - Position Document 2/3 in RPAR process was issued. Only wood preservative use of pentachlorophenol were considered in the wood preservatives RPAR PD 2/3; no discussion of penta as a soil termiticide was included in the PD 2/3.

Chlorpyrifos

1979 - Dow Chemical Co. obtained state/local need registration (24-C) from EPA for use of chlorpyrifos in subsurface termite control.

August, 1980 - Conditional registration granted for general use as a termiticide.

CHAPTER III

THE COSTS AND BENEFITS OF SUBTERRANEAN TERMITE CONTROL

Subterranean Termites: The Nature of the Beast

Subterranean termites belong to a number of species in three genera in the United States. Generally, the genera *Reticulitermes* and *Coptotermes* are considered the subterranean termites of economic importance, but the dampwood termites of the genus *Zootermopsis* may also be included. The most common pests are species from the genera *Reticulitermes*. The genus *Coptotermes* are subterranean termites but are able to sustain colonies without soil contact, if there is moisture in the wood.

Termites are social insects like ants, and some bees and wasps. A colony is made up of several castes, each with specific functions within the colony. A complete colony consists of a pair of primary reproductives or supplementary (secondary) reproductives and two non-reproductive castes, known as workers, and soldiers. The primary reproductives are darkly pigmented, ant-like winged termites and are most commonly observed. In North America, they are usually seen in the spring when swarming to establish new colonies.

After the swarming flight, males and females pair off and seek suitable nesting sites. After mating, the queen begins egg-laying. Only a few eggs are laid the first year, and about six weeks pass before the eggs hatch. The primary pair cares for the eggs and the early growth stages of the nymphs, and also maintains the colony. Gradually, as the nymphs increase in size and number, castes are formed.

The workers maintain and feed the colony. Workers are the damage-producing caste, destroying wood while tunneling for food. The soldiers have larger head capsules and powerful mandibles that enable them to protect the colony. If supplementary reproductives develop, the growth of the colony accelerates. A colony started by a single pair of primary reproductives, develops three to four years before the first winged reproductives are seen.

Caste regulation is accomplished by an intricate system of hormones or pheromones. Termites engage in a large amount of fraternal feeding, or trophallaxis, and almost incessant grooming. In doing so, they transfer the hormonal chemicals that maintain the colony's social cohesiveness. Pheromones are believed to inhibit or allow development of members of one sex or the other, and to regulate the numbers of each caste.

Generally, subterranean termites must maintain contact with the soil. They are susceptible to dessication and need the protection of the soil for moisture. As noted earlier, exceptions occur rarely in Reticulitermes but more often in Coptotermes and Zootermopsis species, which can maintain colonies in constantly dampened wood. Subterranean termites can become a problem any time they encounter moist, warm soil containing sufficient food, either wood or other material containing cellulose. Termites range between the 40°F annual mean isotherm north and south of the equator. In most centrally-heated buildings, termites can feed all year. In unheated buildings located in the cooler extremes of the termites' range, feeding is reduced or may cease entirely during the winter. In such instances the termites may remain in the nest deep in the soil. However, termites may be spread inside previously infested lumber and building materials above this isotherm. Colonies can then maintain themselves in soils under modern, centrally heated structures.

The Consequences of Termites

The Damage

Termites feed on the cellulose in plants and plant materials. In natural habitats this is beneficial, in that the termites degrade dead plant materials to their original elemental state. On the other hand, when termites feed on man-made structures, they can be extremely destructive and must be controlled. Like most wood-destroying insects, subterranean termites primarily attack processed wood in use.[35] The U.S. Department of Agriculture has estimated that throughout the U.S., 46 million dwelling units are subject to termite attacks annually.[35] The damage caused by wood-destroying insects is responsible for major economic losses throughout the United States. Damage caused by subterranean termites accounts for an estimated 95% of all the termite damage in the U.S.[35]

The Costs

No national data base has been compiled and published on the costs of subterranean termites. Several estimates of the annual national cost, ostensibly including both the loss due to termite damage and the cost of control, appear in the literature. These estimates range from $100 million to $3.5 billion. Ebeling's estimate of $500 million is the most frequently quoted figure.[35]

One measure of the cost of subterranean termite damage is the cost of termite control and damage prevention. The amount people are willing to spend to prevent possible termite damage is a lower-bound estimate of their expectation of termite losses. In a 1979 USDA report, Richard Smythe and Lonnie Williams used the state records of a few states to estimate numbers of wood-destroying insect treatments during 1970 and their cost in 1976 dollars. These estimates were for single family dwellings in 11 southern states with high rates of termite infestation.[35]

The estimates derived by Symthe and Williams indicate that nearly 440,000 treatments for subterranean termites were performed in 1970. Of the total, 323,000 were remedial treatments and 115,000 were preventive or pretreatment. In 1970, an estimated $130.2 million (1976 dollars) was spent by owners of single dwelling homes to prevent and control subterranean termite infestation. The costs incorporated into this estimate include: $79.4 million for remedial treatments, $13.8 million for pretreatments and $37.0 million for contract renewal or damage insurance. The cost estimate could be further increased by an estimated $38.6 million for expenses of damage repair done by persons other than those in the pest control industry.[35]

Symthe and Williams have estimated a lower bound for the value of termite losses in 11 southern high termite infestation states. In order to construct national estimates one would have to have similar data on treatment incidence and costs for the remaining states. Unfortunately, very few states maintain extensive records of this type. Given this problem, the cost of potential nationwide termite damage had to be estimated by extrapolating the Smythe and Williams estimates using national survey data on pesticide usage. These data came from the EPA National Household Pesticide Usage Study 1976-77 which indicated frequency of termite treatments by EPA region throughout the U.S.[4] The extrapolation resulted in an estimated 1.2 million treatments of single family dwellings for subterranean termites being performed in 1970, at a cost of $260.3 million (1976 dollars). Including an estimated $102.9 million for contract renewal or damage insurance raises the total national potential loss estimate in 1970 to $363.2 million. This estimate can be further increased by adding the estimated $107.6 million for damage repair by someone other than the pest control industry, bringing the total potential loss to $470.8 million.

This loss estimate is in 1976 dollars; it can be inflated to 1980 dollars using the Bureau of the Census New One-Family Houses Construction Cost Index.[35] Inflating by this index produces a national potential loss estimate in 1980 dollars of $753.4 million annually. The potential loss estimate presented here would be increased significantly by adding losses in multifamily dwellings, commercial establishments, public buildings and the major growth in housing stock between 1970 and 1980. Although these national loss estimates for single family dwellings probably have an upward bias since they were developed by extrapolating information for 11 southern high infestation states, this bias is no doubt more than totally offset by the downward bias resulting from the exclusion of potential losses in multi-family dwellings, commercial establishments and public buildings. Velsicol Chemical Corporation estimates that these excluded losses appear to be on the order of $250 million annually. However, it should be noted, that this is an extrapolation of an extrapolation, based on uneven data from 11 high infestation level states. Given the available data, 0.75-1.00 billion dollars per annum appears to be the best available estimate of the magnitude of the subterranean termite problem in the U.S. This figure is an estimate based on treatment costs, cost of renewal and/or damage insurance and the cost of damage repair. The potential loss estimate represents a lower-bound estimate of expected termite losses.[35]

Control Methods

Introduction

There are three basic methods for preventing or controlling termite infestation. The first method is mechanical alteration. The second method is chemical control. The third method is integrated pest management which encompasses mechanical alteration and chemical control along with several other methods and non-chemical methods. In addition to these three control methods, there is also the use of nonwood construction materials or wood resistant to termite attack.

Mechanical Alteration

Mechanical alteration prevents termite infestation in two basic ways: reduction or denial of potential food sources, and dessication of the microhabitat.

Mechanical alteration entails such things as sanitation of wood scraps during construction, manipulation of microhabitats by increasing crawl space ventilation to reduce moisture levels or grading so that water drains properly, and use of construction techniques that do not allow wood-soil contact.

Termite shields were used more in the past than in recent years. These shields were thought to aid in protecting against termites but instead just allow for better inspection for termites.

Chemical Control

Chemical control occurs on two occasions. The first is preconstruction treatment or pre-treatment. The second is post-construction or remedial treatment, and is usually in response to an identified infestation problem. In either case, the methods of chemical application are similar. Notable differences between the two types of application are: cost (pre-treatment is more economical); ease of treating a site rather than drilling and rodding chemicals into the soil under a structure; and pre-treatment is more thorough and, thereby, effective.

Professional Application Practices

This section paraphrases the 1980 Approved Reference Procedures for Subterranean Termite Control published by the National Pest Control Association (NPCA) headquartered in Dunn Loring, Virginia.[18] The current labeling of termiticide compounds contains application instructions which are similar, but not always as extensive as those provided by the NPCA.

Subterranean termites can be controlled or deterred by impregnating the soil adjacent to a structure with a termite toxicant. Chemicals to control or prevent termite infestation are used in three basic ways: soil treatment, foundation treatment, and wood treatment. Only soil and foundation treatments will be considered here. Basically, in soil and foundation treatment, chemicals are applied along the inside and outside of foundations; around the bases of supporting piers, chimney bases, plumbing and conduits; under filled porches, entrances and terraces; under floor structures resting on soil or gravel fill; and exposed soil areas under structures.

One commonly used method of treating inside or outside a foundation is called trenching. Usually the trench need not be more than 8 to 12 inches wide, should penetrate the soil to the top of the footing, and be dug to slope towards the foundation wall and the top of the footing. Where the tops of footings are too deep to be easily reached via trenching, a combination of trenching and grouting or rodding is used to apply the chemical to the tops of footings. The chemical is poured along the bottom of the trench. A layer of fill is replaced, then more chemical is applied, another layer of fill is replaced, then there is another application, until the trench is filled. The last layer of treated soil is covered by a layer of untreated soil or another suitable barrier such as polyethylene sheeting. In special cases, such as near a well or cistern, the backfill may be treated elsewhere and returned to the trench. In lighter soils or along rock ledges, the trench may first be lined with a heavy polyethylene film to prevent the leaching of the pesticide away from the trench and foundation.

Treatment along the inside of foundation walls is basically similar to the trenching done for treatment outside the walls, although the trenches need not be as deep or wide. In cases where the soil is covered with concrete, rodding or grouting may be necessary. Trenching is being used less now than in the past and rodding has increased in use. Currently, trenching is typically used in combination with rodding to prevent runoff. Trenching is also done in low crawl spaces.

Grouting rods are pushed or driven into the ground along a foundation. Rods are placed about a foot from the wall and driven in at an angle to the top of the footing at one foot intervals. Pesticide is then pumped through the rods to the footing. Often the pumping is concurrent with driving the rod, to aid in penetration. Less commonly, solid rods are driven down to about the footing, removed, and the pesticide is poured down the holes. The interior of foundation walls are sometimes treated by rodding, especially if concrete floors cover the soil. Holes are drilled through the concrete floor at 18 inch intervals 8 to 12 inches from the wall. The grouting rod is then driven into the soil below the concrete floor.

Treatment of fill under filled porches, terraces and slab entry platforms can be done by tunneling or by drilling, then injecting or spraying the pesticide. To inspect or treat such areas, an opening is made in the side of a porch or terrace, then soil is excavated from against the outside wall of the foundation. This practice breaks any soil-wood contact, allows inspection for termite activity and also provides space for a trench treatment, if one is necessary. Alternatively, the slab may be drilled vertically or the sides may be drilled horizontally and the pesticide pumped into the fill under the slab or inside the porch.

Masonry walls of block, brick, stone, tile or other materials have voids which provide termites with ready, hidden access to wooden building members. The principle reason for treating foundation voids is to place the chemical so it can seep through cracks or voids to the top of the footing. This prevents the termites from entering via the faults or voids. This treatment is administered by drilling holes into each void of blocks or about every 18 inches of bricks or into the top of a crack in masonry wall, and then pumping pesticide into the drill hole so that it can seep downward. Generally, the holes are drilled just above grade. After application, the drill holes and cracks are sealed with mortar.

Another application which appears to be confined to California involves surface (spray) treatment of the soil beneath existing structures. In the past, chlordane, heptachlor, and lindane were applied as a broadcast spray often under high pressure. More recently, the California Department of Food and Agriculture (CDFA) has made regulations concerning spray application of chlorinated hydrocarbons for subterranean termites more restrictive. Surface application must be made under low pressure as a perimeter band not exceeding 18 inches and only when conditions (access) will not permit trenching or rodding. However, the soil surface treatment issue has not been resolved in California since there is still considerable discussion on how restrictions on surface treatment should be enforced. The term "California Wash" is now used to refer to any process where surfaces under a structure are sprayed in treating for termites. It connotes an over-treatment or drenching of the soil surface with little concern for contact with the foundation walls or sub-flooring.

Comparative Efficiency

The efficacy of termiticides is measured by the time over which the toxic barrier remains effective in resisting penetration by the termites. The efficacy of a specific termiticide may vary depending on soil type, temperature, alkalinity, and weather conditions.

There is very little primary literature on the efficacy of termiticides. However, nearly all of the truly historic and current studies have been or are being conducted at the USDA Southern Forest Experiment Station at Gulfport, Mississippi. The station has unpublished data indicating 100% effectiveness for 34 years with chlordane and slightly less with the other cyclodienes. Many compounds have been screened for activity in controlling termites. Williams indicated data exist demonstrating about 15 years of 100% effective control with chlorpyrifos.[35] These tests are still in progress. Dr. Raymond Beal also of the Southern Forest Experiment Station, informed the Agency that lindane applied at 0.4% was effective for 11 years.[35] By doubling the rate to 0.8%, effectiveness was only increased by two additional years. Dr. Beal also indicated that endosulfan, which is not registered for termite control, was tested at 0.5% and provided about 10 years control. Increasing the rate of endosulfan to 2.0% made it "hold up for a few years longer".

Numerous insecticides have been under study for many years in soils in southern Mississippi for protection against subterranean termite attack.[35] Of these, aldrin, chlordane, dieldrin, and heptachlor applied at various concentrations and rates are still effective after 17 to 21 years.

These tests are still underway and indicate that chlordane remains an effective barrier for at least 34 years, whereas heptachlor, aldrin, and dieldrin continue to be effective after 29 years.[35] Soil residue studies were also conducted which indicated that the insecticides moved only a few inches during 17 to 21 years of exposure to the elements. In practice, as they are placed in and under buildings, the cyclodiene termiticides movement, without climatic weathering, appears to be negligible.

In 1972, Beal and Smith published the results of a long term study which evaluated new compounds in terms of termite control.[35] They studied Baygon®, Dimetilan®, Sevin®, Dursban®, Strobane®, Diazinon®, Zyton®, and the numbered compounds GS-12968 and GS-13005. As a result, they said: "Dursban® is the only insecticide that is still 100% effective after 4 years at both 1 and 2% concentrations in both tests...". They also concluded: "We know that some of these chemicals will give at least 4 years of protection against termites... This is a much shorter time than the 33 years that chlordane has continued to control termites".

Dr. Raymond Beal reported on test data obtained after about 11 years of testing.[35] Beal said: "We chose insecticides for field testing after screening chemicals in laboratory tests. Only those chemicals with a low mammalian toxicity, low toxicity to other soil insects, relatively low water solubility, and a manufacturer willing to market the material [were chosen] ..." Nine compounds were selected that met those criteria. These were: GS-12968, methidathion, diazinon, and dimetilan (Ciba-Geigy Corp.); chlorpyrifos and Zytron® (Dow Chemical Corp.); and carbaryl (Union Carbide Corp.). As a result of this study, Beal concluded "dimetilan, diazinon, GS-12968, methidathion and Zytron® were ineffective as soil insecticides. Under a concrete slab, camphechlor, propoxur, and chlorpyrifos remained 100% effective, for 11 years at the 2.0% rate of application. Of these, chlorpyrifos remains the most promising new compound to date".

In conclusion, chlordane, heptachlor, aldrin, and dieldrin are the most effective termiticidal compounds and are comparable in efficacy.

Integrated Pest Management and Non-chemical Control

An integrated pest management (IPM) approach for termite protection begins with the design of structures, and continues through site preparation and construction to maintenance, moisture control, environmental modification, inspection, and judicious chemical treatment. In essence, these measures are a combination of the mechanical and chemical control methods already described.

The most promising IPM innovation in termite control appears to be the bait-block method of insecticide delivery, which can be used with conventional toxicants, insect growth regulators, antibiotics, and other control agents. Among the more innovative approaches to chemical control using bait-blocks is the use of the juvenile hormone analog methoprene. Methoprene is an analog of a naturally occurring insect growth regulator and, when applied as an insecticide, it disrupts the development of the insect which eventually results in mortality. Methoprene is currently registered for use against mosquitoes, certain flies, and fleas.[35]

A non-chemical alternative to termite control has been recently announced by The Nematode Farms, Inc. in Pest Control Magazine, October, 1983. The product is called SPEAR™. The active ingredient of SPEAR™ is a Steinernematid nematode which is a microscopic organism with an appetite for termites. The nematodes can search for termites by sensing their body heat, carbon dioxide, and waste trails. After discovery of the termite, SPEAR™ enters the pest through a natural body opening and within 24-48 hours the termite is destroyed. The product is packaged in a water soluble gel and can be applied with conventional pest control equipment. EPA has considered whether products such as SPEAR™ must be registered in accordance with FIFRA. The Agency decided that there is not yet any reason to believe that the use of nematodes as biological control agents presents any problems that cannot be adequately controlled by other Federal agencies and, therefore, such products are exempt from registration by EPA.

The Economics of Termite Control

The Termite Control Industry

Services Offered

Pest control firms provide two types of inspection services. The first type determines if treatment is required. If treatment is required, the cost of inspection is included in the treatment fee. If the inspection is for certification of pest-free status for a real estate sale or transfer, a separate fee is charged to the seller. Such inspection generally relates to the presence of all wood-destroying organisms, or to all structural pests, not just to termites.

Contracts for remedial treatment generally include a retreatment guarantee for a period of one year. That is, if a building hich has been treated is found to be infested within one year of treatment, retreatment is performed at no cost to the owner. Such guarantees are renewable yearly for an annual fee. These renewal agreements usually provide for an annual inspection and retreatment, if necessary.

In some cases, additional guarantees are offered. Depending on the type of structure and the type of treatment performed, the pest control firm may offer a guarantee against structural damage for a one-year period. These damage guarantees are available only if a retreatment guarantee is in effect. These guarantees apply only to termite damage and commit the pest control firm to repair all termite-producing structural damage. This sort of guarantee is also renewable on an annual basis.

The Cost and Pricing Structure of the Termite Control Industry.

Table III-1 presents a breakdown of variable costs for the termite control industry. This breakdown of costs is based on data provided by three leading pest control companies.

The fee charged for treatment is based primarily on the amount of time (labor) required to do the treatment. The amount of time required to perform a termite treatment is a function of both the mode of application and the area (linear feet) to be treated. The mode of application, in turn, is determined by the type of structure (e.g., slab, crawl space, etc.). To simplify computation of the treatment charge, most termite control companies use a pricing schedule.

Wages, equipment, vehicles, chemicals, other direct costs, in addition to overhead and profit margins are factored into the dollar charge per linear foot presented in the schedule. Some companies convert linear feet into a time factor before referring to the pricing schedule, while the others have already accounted for this conversion in their schedule.

Comparative Cost-Effectiveness of the Registered Termiticides

Background and Market Preference

For more than 25 years, foundations and soil beneath houses have been treated with cyclodiene insecticides (chlordane, aldrin, dieldrin, and heptachlor) to control termite colonies and to prevent future infestations. Currently, chlordane is the most widely used insecticide for subterranean termite control, followed by heptachlor. Before 1974, chlordane competed closely with aldrin for the major share of the market.[35] Generally, 55% of the market went to chlordane, while aldrin accounted for about 40%. The remaining portion was primarily taken up by heptachlor. Following EPA's

TABLE III-1

Variable or "Direct" Costs of Termite Control Industry Expressed as a Percentage of Total Termite Control Revenue

Item	% of Total Revenue a/b/
Labor (wages)	15-20
Chemical	6-7
Equipment (pumping units, hoses)	2-5
Vehicles (includes maintenance)	7-13
Damage Claims	1-3
Other (miscellaneous expenses, uniforms, insurance, taxes)	10-20

a/ Based on chemical prices prior to the 60 percent increase in the price of chlordane in the fall of 1982.

b/ Information source: Orkin Pest Control, Terminix International, Inc., Western Termite and Pest Control cancellation of most of aldrin and dieldrin uses, Shell Chemical Company discontinued the manufacture and sale of both compounds in the United States. One of Shell's major customers, Terminix, a major structural pest control applicator, purchased the remaining supply of technical aldrin and continued to formulate aldrin products for about a year. From 1975 to 1976, Amvac Chemical Corporation synthesized aldrin for Terminix from available intermediates, but these materials eventually ran out. Currently, Terminix relies on Shell International (U.K.) for its supply of technical aldrin.

Terminix imported aldrin in 1977 and 1978, but aldrin lost its price competitiveness and was not imported in 1979 and 1980. Between 1980 and 1981 chlordane costs increased significantly, which improved aldrin's competitiveness.

There is little evidence of usage of the other chemicals registered to control subterranean termites, with the exception of heptachlor. Heptachlor is typically used in combination with chlordane and has limited use as a single active ingredient termiticide. Dieldrin was never used to any significant extent in the past, primarily because of its high cost. The major uses of lindane are as a seed treatment and for control of various species of wood inhabiting beetles, but a limited quantity is applied for termite control by a few pest control operators (PCO's)(primarily in California). Although registered to be used in the soil for controlling subterranean termites, pentachlorophenol (penta) is rarely applied in this manner. Penta is used as a termiticide only for special applications, such as wood impregation when termites are associated with decay. A concentrated formulation of chlorpyrifos for subterranean termite control has been developed by Dow Chemical Company. Although registered with EPA in late 1980, the product has only recently been introduced for the 1981 market season. There was some use of chlorpyrifos (Dursban®) for subterranean termites in California under 24-C registration (late 1979) from about June 1980 to December 1980. Currently, the chlorpyrifos termiticide is more expensive than the chlorinated hydrocarbons, and provides an option to PCO's and their customers. Table III-2 presents production and usage information on the termiticides.

Costs of Termiticides

Table III-3 presents the comparative costs of the termiticides in current use. These are bulk user prices. From the table, it can be seen that chlordane, heptachlor, and aldrin are virtually identical in cost and significantly cheaper than either chlorpyrifos or lindane. Dieldrin is not included in the cost table because it is currently not available or

Table III-2
Production and Usage of Termiticide Chemicals

Chemical	Producer	Amount of Chemical Used in Termite Control (1980) (lbs./ai)	Most Common Formulated Products Used in Termite Control	Comments
Chlordane	Velsicol Chemical Corporation	Approx. all of 10 million pounds used for termite control	C-100 (8lbs/gal)[1] C-50 (4 lbs/gal)[1] 8EC (8 lbs/gal)[1] Termide® (4.2 lbs. chlordane/gal; 2.1 lbs. heptachlor/gal.)[2]	Most widely used insecticide for subterranean termite control in 1980. Largest quantity of chlordane initially distributed to Region IV.
Hepatchlor	Velsicol Chemical Corporation	Approx. 90% (1-2 million lbs)	H-60 (2 1/2lbs/gal)[3] Termide® (2.1 lbs/ heptachlor/gal; 4.2 lbs. chlordane/ gal.)	Used in smaller quantities and on fewer sites than chlordane.
Aldrin	Imported from Shell International Chemical Company		Aldrin 4-E (4 lb/gal)[4]	Aldrin was not imported in 1979 or 1980. Aldrin was imported again in 1981. Use as a termiticide seems to be increasing in response to chlordane price increases.

1/Chlordane concentrations are typically diluted with water to obtain a 1.0%/gal. emulsion before use.
2/Chlordane-heptachlor mix is diluted with water to obtain a 0.5% chlordane/0.25% heptachlor emulsion.
3/Heptachlor concentrate is typically diluted and applied as a 0.5% emulsion.
4/Emulsifiable concentrate is mixed 1 gal. (EC) to 95 gallons of water to form a 0.5% use strength emulsion.

Table III-2
Production and Usage of Termiticide Chemicals

Chemical	Producer	Amount of Chemical Used in Termite Control (1980) (lbs.a.i.)	Most Common Formulated Products Used in Termite Control	Comments
Dieldrin	Shell International Chemical Company	No production in U.S. since 1974.	-	Not available in the U.S. and no known consumption in U.S.
Lindane	Zoecon Corporation	11,000-12,000	-	No domestic production of lindane since 1976; Usage level has remained constant for the last 5 years; Few PCO's identify lindane as preferred termite control agent; Use apparently limited to few pest control firms in So. California; Most lindane used in termite control is applied to soil as surface spray.
Pentachlorophenol	-	Very low percentage of the 40-50 million lbs. produced is used in termite control	-	No application to soil reported by PCO's; Use limited to specific termite control problems (e.g., where termites have been associated with decay or direct application to infested wood structures).

Table [illegible]
Production and Usage of Termiticide Chemicals

Chemical	Producer	Amount of Chemical Used in Termite Control (1980) (lbs. a.i.)	Most Common Formulated Products Used in Termite Control	Comments
Chlorpyrifos	Dow Chemical Company	Few thousand lbs. sold by end of 1980. (California only)	Dow Termiticide[5] concentrate 44.4% EC Dursban® TC 42.09% EC[5]	In 1979 Dow obtained a state local need registration (24-C) for chlorpyrifos to be used for subsurface termite control in California. Conditional registration as termiticide granted in 1981.

5/Two gallons of concentrate are mixed with 100 gallons of water to yield a 1.0% use strength emulsion.

TABLE III-3

Comparative Costs of Termiticide Chemicals[a]

Chemical	Formulation	Cost ($/gal.)	% Dilute Solution	Cost/gal. Dilute Ready-to-Use Solution	Approx. Chemical Cost for Protection Equivalent of 1 gal. cyclodienes[b] ($)	Approx. Total of Production Equivalent to 1/gal. cyclodienes[c][d] ($)
Chlordane	8 EC	30.00	1.0	0.30	0.30	5.00
Aldrin	4 EC	25.00	0.5	0.25	0.25	5.00
Chlordane/ Heptachlor	4.2 Chlor. 2.1 Hepta.	28.00	0.5 0.25	0.27	0.27	5.00
Chlorpyrifos	4 EC	65.00	1.0	1.30	2.60	12.00
Lindane	1 EC	12.00	0.8	0.77	1.54	10.94

a/ Figures based on bulk user prices paid by Orkin, Western, and Terminix in 1981.

b/ Assumes chlorpyrifos and lindane persist 1/2 as long as cyclodienes.

c/ Assumes cyclodiene chemical cost to 6% of total application costs.

d/ Costs presented are 1981 estimates and reflect the 1980-1981 increase in chlordane costs.

consumed in the United States and, therefore, current price estimates are not available. In the past, the cost of dieldrin was typically higher than the cost of the other cyclodienes, which contributed to lower dieldrin usage relative to the other cyclodienes. When the reduced persistance of lindane and chlorpyrifos is taken in account, cost differences between these chemicals and the cyclodienes widen still further. If one assumes that chlorpyrifos and lindane persist half as long as the cyclodiene termiticides, the chemical cost of the protection equivalent to that provided by one gallon of cyclodiene termiticides increases from $1.30 to $2.60 with chlorpyrifos and from $0.77 to $1.54 with lindane.

The application costs of the retreatments required with the chlorpyrifos and lindane will further expand the cost differential, from $5.00 with the cyclodienes to approximately $12.00 with chlorpyrifos and to $10.94 with lindane.

Another factor that would increase the differential on costs for the application of chlorpyrifos compared to the cyclodienes is the cost for monitoring the blood cholinesterase level of applicators before the use of the chemical and on a regular basis.

As can be seen from this and the previous section, chlordane, heptachlor, and aldrin are the most cost-effective chemicals for termite control. Lindane or chlorpyrifos are alternatives which can be used where use of the other termiticides is restricted either by the structure's owner or government regulation.

There appears to be some disagreement within the PCO industry as to which of the cyclodienes is best in terms of ease of handling and applicator health effects. On balance, the choice between the cyclodienes seems to be one of personal preference rather than documented advantages or disadvantages.

The efficacy of a number of chemicals, not currently used as termiticides, was previously discussed. While some were effective, their persistence compares unfavorably with those chemicals currently in use. Mobay Chemical Company has a compound, Oftanol®, that was registered as a restricted use pesticide for control of subterranean termites July 19, 1982. However, insufficient testing has been done to date to allow evaluation of its viability as an alternative to the cyclodienes.

It is reasonable to expect that as long as the cyclodienes remain on the market and/or are relatively inexpensive, the outlook for new chemical controls will be bleak because of the difficulties in finding cost competitive alternatives to the existing chemicals. There is currently little incentive to develop new control methods as long as inexpensive, effective products are available.

Summary

Subterranean termites are colonial insects which damage wooden structures by eating the cellulose in the wood. The estimated annual cost of this damage to the nation is at least three quarters of a billion dollars. This estimate is based on treatment costs, cost renewal and/or damage insurance and the cost of damage repair. Subterranean termites can be prevented partially by proper construction methods and design, and by prophylaxis with termiticides. When termites do become established in a structure, they can generally be controlled with pesticides. The preferred pesticides, considering price, efficacy, and extended period of protection, are the cyclodiene pesticides, particularly chlordane or aldrin. While the extended period of protection is a major advantage of the cyclodiene pesticides, current practices in the field indicate that treatment with the cyclodienes occurs more frequently than the 30 plus years of termite control shown by these chemicals. If, in practice, the consumer is not able to take advantage of the extended period of protection, then the benefits of the cyclodienes would diminish. Pest control operators as well as the financial and real estate institutions must be aware that frequent retreatments with cyclodienes are not necessary unless a reinfestation is found in a structure.

CHAPTER IV

RISK ANALYSIS

An analysis of the risks associated with the use of the chemicals in the termiticide cluster considers information on health effects in combination with an assessment of the exposure likely to occur from this registered use. The first part of this chapter consists of a discussion of the available information on the health effects for each of the chemicals. Chlordane, heptachlor, aldrin, and dieldrin, referred to as the cyclodienes, will be considered together because of similarity in chemical structure and associated health effects. Lindane, pentachlorophenol, and chlorpyrifos will be discussed individually. The summaries on toxic effects are taken from extensive published reviews and assessments of the data on the termiticides, particularly the recently completed National Academy of Sciences report, "An Assessment of the Health Risks of Seven Pesticides Used for Termite Control" (referred to as NAS report). In cases where a specific study is discussed, the author of the study is given so that the study may be identified. However, in most cases the original study was not reviewed by the Agency, but rather the information was taken from a secondary source. The secondary source is then referenced and listed in the bibliography.

The second part of this chapter discusses the information available on the extent of human exposure to the termiticides.

HEALTH EFFECTS DATA

Cyclodienes - Chlordane, Heptachlor, Aldrin, Dieldrin

Acute toxicity information for the cyclodienes is presented in Table IV-1. Toxicity for the cyclodienes is characterized by effects on the central nervous system.[15,39,40]

Table IV-1

Acute Oral Toxicity Data By Chemical

Chemical	Oral LD_{50} Value (rats, mg/kg)
Chlordane	335-430
Heptachlor	100-160
Aldrin	46-63
Dieldrin	38-52

Data show that exposure to the cyclodiene termiticides can affect the central nervous system in humans and animals. Symptoms of acute poisoning in man include: dizziness, nervousness, convulsions, and loss of coordination.[40]

Oncogenicity

Carcinogenicity data on the cyclodiene termiticides have been reviewed extensively. Studies have been conducted in several species of laboratory animals to evaluate the carcinogenic potential of each of the chemicals. The analyses and interpretations of the results of these studies regarding carcinogenic potential vary for each compound and species/strain/sex of the test animal. Tests conducted in rats were all negative for chlordane, heptachlor, aldrin and dieldrin. Chlordane, heptachlor, aldrin, and dieldrin are carcinogenic in mice, producing liver neoplasms after oral administration of the chemicals. Data concerning the carcinogenicity of these chemicals in rats are inconclusive.[41] The one consistent result observed is that all four of the cyclodienes produce a significant increase in the incidence of hepatocellular carcinomas in the B6C3F1 strain of mice.[15,39,40]

The limited human studies with long-term exposure to any of the cyclodienes have not revealed any consistent or significant detrimental health effects.

Teratogenicity and Reproductive Effects

The available teratogenicity and reproductive effects data for the cyclodienes are not as extensive as the carcinogenicity data and are inconclusive.

In a study (Ingle, 1952) in which rats were fed chlordane in the diet at 5,10,30, 150, or 300 ppm, one female rat from each test group was mated at the 24th and 48th week. No effects on litter size or number were reported by the authors. Heptachlor, fed to rats in the diet at 6 mg/kg body weight, caused a decrease in litter size in a multigeneration study (Mestitzova, 1967).[15]

Several studies investigating the teratogenic potential of aldrin and dieldrin were cited in the NAS report.[15] Pregnant hamsters were given single oral doses of aldrin at 50 mg/kg and dieldrin at 30 mg/kg on day 7,8, or 9 of gestation (Ottolenghi et al., 1974). The authors of the study reported an increase in fetal deaths, compared with controls, and an increase in anomalies such as open eye, cleft palate, and webbed feet. Mice, given aldrin at 25 mg/kg or dieldrin at 15 mg/kg on day 9 of gestation, showed no effect on fetal survival or weight but some anomalies were noted.

In other studies on mice and rats administered dieldrin at 1.5, 3, and 6 mg/kg/day on days 7-16 of gestation, no teratogenic effects were observed (Chernoff et al., 1975). However, at 6 mg/kg a 41% increase in mortality was noticed in rats and increased liver-to-body weight ratios and decreased weight gain in mice was observed.[15]

In a six-generation mouse reproduction study, aldrin and dieldrin were administered at 25 mg/kg per day in the diet. The authors noted marked effects in fertility, gestation, viability, and lactation at 25 mg/kg (Deichmann, 1972).[15]

Mutagenicity

Data from the tests including the Salmonella microsome assay and the dominant-lethal test (mouse) indicate that pure chlordane is negative in all of these test systems but technical chlordane was mutagenic in Salmonella without mammalian activating enzymes (Simmon et al., 1977).[15,39] When chlordane was administered in a single dose of 50 or 100 mg/kg/body weight to Charles River CD-1 male mice that were then mated to untreated females, no dominant lethal effects were noted in the offspring (Arnold et al., 1977).[15]

In a recent study, chlordane and heptachlor were investigated for genotoxicity in cells derived from the organ in which they produce tumors (liver cells). The authors concluded that both chlordane and heptachlor were negative in the ARL-HGPRT mutagenesis, which is a sensitive system for detecting mutagenic potential of various compounds (Telang et al., 1982).[24]

Additionally, heptachlor was found not to be mutagenic when tested in several strains of Salmonella typhimurium with and without a rat-liver microsomal activation system (Marshall et al., 1976). In a dominant-lethal test rats were fed a diet of heptachlor at 1 or 5 mg/kg. Significant number of resorbed fetuses and increases in the number of abnormal mitoses were absorbed in the second and third generations (Arnold et al., 1977).[15,39]

The results of several studies indicate that dieldrin was not mutagenic in several strains of Salmonella typhimurium with or without liver activation systems. One study reported that dieldrin was mutagenic in two or three strains of Salmonella typhimurium without activation (Majumber et al., 1977).[15]

Lindane

The acute oral LD_{50} value for rats is between 125-230 mg/kg/body weight. Earliest signs of lindane toxicity include: headache, dizziness, and vomiting. Other symptoms are: diarrhea, hypothermia, hyperirritability, incoordination, and convulsions.[15,36]

Oncogenicity

Several carcinogenicity studies have been conducted on lindane. In a study similar to those conducted on the cyclodienes, groups of 50 B6C3F1 mice of each sex were fed 80 or 160 ppm lindane in the diet for 80 weeks (NCI, 1977). The results indicated a significant increase in the incidence of hepatocellular carcinoma in the males of the low-dose group compared to the controls. However, no significant difference in the incidence of hepatocellular carcinoma was found in the high-dose group when compared to the controls. The authors of the study concluded that lindane was not carcinogenic in mice.[15]

In another study, 400 ppm lindane in the diet was fed to CF1 mice (Thorpe and Walker, 1973). Increases in liver tumors were observed in both male and female mice.[15]

Groups of 50 Osborne-Mendel rats of each sex were fed lindane in the diet for 80 weeks; 236 or 472 ppm for males and 135 or 270 ppm for females (NCI,1977). No significant increase in the incidence of tumors was observed in any of the test groups.[15]

Teratogenicity and Reproductive Effects

Several studies have been conducted on the teratogenic and reproductive effects potential of lindane. Lindane does not appear to cause teratogenic or reproductive effects. Fetal effects at or above the dosage that causes general maternal toxicity have been observed.

In a three-generation rat study, lindane was fed in the diet at 25, 50, or 100 ppm (Palmer *et al.*, 1978). No reproductive effects were observed and no increase in malformations were observed.[15] When lindane was given orally at 5, 10, or 15 mg/kg/body weight to rabbits on days 6-18 of gestation and to rats on days 6-16 of gestation, no teratogenic effects were observed.[40]

In another study, lindane was given orally to female rats at 0.5 mg/kg (Naishtein and Leibovich, 1971). Disturbances in the estrus cycle and diminished reproductive capacity were observed.[40]

Mutagenicity

Mutagenicity was not a concern at the time Position Document 2/3 was developed by the Agency. The mutagenicity data base for lindane is not complete, but available studies suggest little mutagenic activity, if any.[36]

Pentachlorophenol

The oral LD_{50} of pentachlorophenol for rats is 146-175 mg/kg. Symptoms of intoxication include accelerated respiration, vomiting, increased body temperature, tachycardia, neuromuscular weakness, and cardiac failure. Similar symptoms of loss of appetite, respiratory difficulties, hyperpyrexia, sweating, dyspea, and coma have been reported in humans.[40]

In the Notice of Rebuttable Presumption Against Registration (October 18, 1978), the Agency cited three studies concerning the possible oncogenicity of pentachlorophenol. Innes *et al.* (1969) administered by gavage 46.4 mg/kg pentachlorophenol to mice on days 7 through 28 of age, followed by 130 ppm (17 mg/kg/day) in the diet for 2 years did not increase tumor incidence over control animals. Boutwell and Bosch (1959) applied 0.3% dimethylbenzanthracene in benzene as an initiator to the shaved backs of mice. As a promoter, a solution of 20% penta in benzene was applied similarly twice weekly for 15 weeks.[34]

These papers were reviewed by the Agency's Carcinogen Assessment Group and were found to be negative with respect to oncogenic effects of penta. However, since that time several other studies pertinent to the oncogenic potential of commercial pentachlorophenol and its contaminants became available. The National Cancer Institute reports two bioassay studies dealing with the possible carcinogenicity of two isomers of hexachlorodibenzo-p-dioxin (HxCDD), a contaminant of pentachlorophenol. The results of one study, on the dermal application of HxCDD to mice were negative. In the second study, rats and mice were given oral doses of HxCDD ranging from 1.25 mg/kg/week to 10 mg/kg/week. Under the conditions of this study, HxCDD increased the incidence of benign and neoplastic liver tumors in mice of both sexes and in female rats.[34]

Teratogenicity and Reproductive Effects

Embryotoxic and fetotoxic effects were observed in Sprague-Dawley rats given pure or commercial grade pentachlorophenol at dosage levels of 15 mg/kg/body weight or greater (Schwetz *et al.*, 1974). In another study by the same author, no effects on neonatal survival and development were observed in rats fed 3 mg/kg of pure pentachlorophenol prior to mating, during mating, during gestation and lactation. At 30 mg/kg, a reduction in body weight was observed among adult rats as well as a decrease in neonatal survival and growth.[15]

Mutagenicity

Pentachlorophenol did not induce sex-linked recessive lethals in *Drosophila melanogaster*.[40]

Chlorpyrifos

The oral LD_{50} of chlorpyrifos for rats is between 82-245 mg/kg. Acute data in rats suggest that chlorpyrifos is absorbed through the skin in acutely toxic amounts. A study in humans indicates that absorption through the skin is limited to only a small fraction of the applied dose.[19] Symptoms of chlorpyrifos poisoning include: nervousness, giddiness, headache, blurred vision, weakness, nausea, cramps, diarrhea, and discomfort in the chest.[10,15]

Oncogenicity

Two long-term feeding studies have been conducted to investigate the effects of chlorpyrifos. In a 2-year study, groups of rats and dogs received dose levels of up to 3 mg/kg body weight/day chlorpyrifos. Dosages of 0.1 mg/kg/day or less had no effect on plasma and red-cell cholinesterase activity in rats and no effect was observed in dogs at 0.03 mg/kg body weight/day. Higher dietary concentrations of chlorpyrifos caused significant decreases in cholinesterase activity (McCollister *et al.*, 1974).[15]

In another study, CD-1 mice were given chlorpyrifos in the diet at 0.85, 6.72, and 15.8 ppm for 105 weeks (approximately 0.05, 0.5, and 1.5 mg/kg body weight/day) (Warner *et al.*, 1980). No significant effects were observed in the treated group. Tumors and other lesions were observed in treated and control groups but no tumors appeared to be related to the treatment of chlorpyrifos.[15]

Teratogenicity and Reproductive Effects

No teratogenic effects were observed in pregnant CF-1 mice administered chlorpyrifos by gavage at 1, 10, or 25 mg/kg on days 6-15 of gestation (Deacon et al., 1980). At 25 mg/kg severe maternal toxicity and fetotoxicity was observed and a decrease in plasma and red-cell cholinesterase was reported at all dosages. In a repeated experiment, a decrease in cholinesterase activity was noted at 1 and 10 mg/kg.[15]

Mutagenicity

Mutagenicity tests in several strains of *Salmonella typhimurium* and *Escherichia coli* were negative.[15]

EXPOSURE DATA

Available evidence of potential human exposures to the termiticides is presented in the discussion that follows. Distinct groups of people that could be exposed to termiticides have been identified: workers engaged in the manufacture of termiticides; persons who apply termiticides, including professional applicators and the general public who use household products which contain these chemicals; and persons residing in structures which have been treated with termiticides. Although some exposure data are available for each of the groups identified above, the information is primarily on exposure to chlordane.

Human exposure to termiticides has been previously considered and various exposure levels have been established. The American Conference of Governmental Industrial Hygienists 1982 (ACGIH) has adopted a Threshold Limit Value-Time Weighted Average (TLV-TWA) of 500 ug/M^3 for chlordane in workroom air. This value can be interpreted as the maximum level to which workers may be continuously exposed to chlordane in the workplace (8 hours/day, 5 days/week) without adverse effect. The Occupational Safety and Health Administration's (OSHA) permissable workplace exposure limit is 500 ug/M^3.

Similarly, exposure levels have been established for the other termiticides and are listed below:

Chemical	ACGIH Level (ug/M3)	OSHA Level (ug/M3)
Heptachlor	500	500
Aldrin/Dieldrin	250	250
Lindane	500	500
Pentachlorphenol	500	500
Chlorpyrifos	200	-

The exposure analysis that follows considers inhalation and dermal exposure to these chemicals from their termite control use. Exposure to these chemicals as a result of other uses is not considered for the purposes of this discussion. Although the most widely used termiticides, the cyclodienes, have not been registered for uses other than termite control (and certain phase-out uses of chlordane and heptachlor) since the mid-1970's, these chemicals are very persistent in the environment. Therefore, other sources of exposure, as a result of former registered uses is very probable. The other termiticides, lindane, pentachlorophenol, and chlorpyrifos are not widely used for termite control but have numerous other registered uses. Also, since all of these chemicals are available for homeowner use, the additional potential sources of exposure are difficult to estimate. Therefore, the exposure estimates do not represent total possible exposure to any of the chemicals but rather attempt to estimate the amount of exposure from just the termite control use.

Workers Involved in Manufacture of Termiticides

The few studies that have been conducted to investigate the occupational exposure to the termiticides have focused on exposure to chlordane. The most recent investigation studied a cohort of 1,403 workers employed for longer than three months in the manufacture of chlordane and heptachlor at two plant locations between 1946 and 1976 (Wang and McMahon, 1979). Data obtained from Social Security records, death records, and employment records, indicated no overall excess of deaths from cancer. There was a statistically significant excess of deaths from cerebrovascular disease but the authors concluded that these deaths occurred after termination of employment and were not related to duration of exposure.[15]

Shindell and Associates (1980) continued to study former and current employees at the two plants of the Velsicol Chemical Corporation. This cohort consisted of 1,115 people who worked at the Memphis plant between January, 1952 and December, 1979 and 783 people who worked at the Marshall, Illinois plant from January, 1946 through December, 1979. The authors concluded that the mortality among workers at the Marshall, Illinois plant was significantly lower than expected while at the Memphis plant the mortality was lower than expected, but not significantly so.

There was a statistically significant positive trend in the standard mortality ratio for cancer deaths in workers with increasing duration of employment. However, the increase in standard mortality ratios from one to 20 years of exposure was not large. The findings among workers who had a minimum of 20 years of employment were seven deaths from cancer with 6.6 deaths expected; for workers with 10 or more years of employment there were 14 deaths with 13.6 deaths expected; and for workers with a minimum of five years employment there were 16 deaths with 16.5 deaths expected. None of the individual values has statistical significance. The authors of the study concluded that there was no evidence to indicate that current or past workers at Velsicol plants are at an increased risk for health-related problems. The NAS report indicates that the results of this epidemiology study suggest a trend in cancer deaths with duration of employment but advise that more complete data are needed before firm conclusions can be reached with regard to the carcinogenicity of chlordane in humans.[15,23]

Additionally, a retrospective cohort mortality study to examine mortality among workers employed in the manufacture of the chlorinated hydrocarbon pesticides was initiated by the National Institute of Occupational Safety and Health (NIOSH).[6] The intent of the study was to examine the mortality of workers employed in plants where the following pesticides are manufactured: chlordane, heptachlor, DDT, aldrin/dieldrin, and endrin. Four U.S. manufacturing plants were selected for the study and each cohort included all workers employed for at least six months prior to December 1, 1964. The study group consisted of 2100 individuals.

The vital status for each of the individuals in the cohorts was followed up to December 31, 1976. The Standard Mortality Ratio (SMR) for all causes of death in each cohort was below the expected level. In one of the plant cohorts (aldrin/dieldrin/endrin) deaths due to nonmalignant respiratory system disease were significantly above that expected.

The authors stated that the deaths observed due to "all malignant neoplasms" in each plant were less that the number expected. Although there were no statistically significant excesses or deficits in mortality for any specific cancer site, for the following several sites the observed number of deaths slightly exceeded the expected number for individual plants: stomach, esophagus, rectum, liver, lymphatic and hematopoietic system. There was a deficit for respiratory cancer in one plant.

The overall conclusions of the study investigators were that due to the small number of workers included in the study, the statistical power does not support a conclusion that no association exists between cause-specific mortality and employment at the study plants. The authors stated that the primary reason for the small cohort numbers is due to the rapid turnover at the plants and, therefore, most workers who were hired left before completing six months of employment.

Professional Applicator Exposure

The National Pest Control Association (NPCA) has provided estimates of the number of personnel engaged in structural pest control work. These estimates are presented in Table IV-2.

Table IV-2

Number of Personnel Engaged in Structural Pest Control Work

Year	Total Number of Personnel Engaged in General Pest Control	Personnel Specializing in Control of Wood Destroying Organisms
1974	31,000	8,600
1979	42,000	11,524
1980	36,500	13,500

Information on potential exposure levels for applicators of termiticide chemicals is limited to a study conducted jointly by Velsicol Chemical Corporation and the California Department of Food and Agriculture. This study determined potential chlordane exposure to applicators and inhabitants in six houses of two types: crawl space and slab construction. The treatments were conducted by commercial pest control operators. Exposure was measured by monitoring the concentration of chlordane in the applicator's breathing zone and by attaching cloth patches to the applicator's coveralls. Air samples were taken as follows: air inside and outside applicator's respirator, air during and after application, air samples taken 24 and 48 hours after application, and 7 and 30 days after application. The levels of chlordane detected from the cloth patches and gauze material worn on the applicator's overalls were similar for the slab and crawl space treatments. The levels of chlordane from the slab treatment ranged from 0.005-1.70 ug/M^2 and for the crawl space 0.019-2.90 ug/M^2.[3,12]

Nonprofessional (Homeowner) Applicator Exposure

There are no known data on the number of people who use commonly available products containing the termiticides. However, EPA estimates that approximately 1.5 million pounds of these chemicals are sold annually to the general public for the period 1979-1981. In 1982, 1.4 million pounds of chlordane were sold. Velsicol forecasts that 600,000 pounds of chlordane will be sold for home owner use in 1983.

The National Household Pesticide Usage Study, 1976-1977 provides some information on homeowner usage of chlordane-containing products. In this study, 8254 households were interviewed and asked to provide information regarding all pesticides that they had used or stored during the past year. The data from this survey pertaining to chlordane are presented below and provides an indication of homeowner usage. However, the time period considered in this study preceded the restriction of chlordane usage to subterranean termite control.

Chlordane ranked fourth among 12 known pesticides observed most frequently in the study. From the survey, 639 households reported having used or stored 694 chlordane products within the previous year. Based on these data, it was estimated that 7.7% of the households in the U.S. used or stored chlordane-containing packages or containers and that over 6.2 million chlordane products were used by 5.7 million U.S. households. Sixty-five percent of the household use was application to the lawn, yard or flower gardens; 17.2% application inside houses; and 14.1% application to vegetable gardens.

Residents of Buildings Treated with Termiticides

Several reports and studies are available on possible exposure to residents of termiticide-treated dwellings.

U.S. Department of Defense Monitoring Program

Department of the Air Force

Airborne chlordane contamination of military housing units following treatment for termites was reported by the Department of the Air Force in the early 1970's. The first incident occurred at Webb Air Force Base, Texas in the spring of 1970. Twenty-eight air samples from two houses with cardboard duct work in a concrete slab were analyzed for chlordane. The concentrations of chlordane ranged from 800 to 1600 ug/M^3 initially and from 34 to 180 ug/M^3 eighteen days after attempts to clean the chlordane from the duct work.

A second incident occurred at Wright-Patterson Air Force Base, Ohio during 1974-1975. Air samples were obtained from 537 newly constructed houses that had been pretreated with chlordane. Measurable levels of chlordane were detected in 412 of 537 houses sampled. Concentrations ranged from a trace ($\geq$0.4 ug/M^3) to 34 ug/M^3.

In October of 1978, two houses at Scott Air Force Base, Illinois, were monitored as a result of occupant complaints of odors following subslab injection of chlordane. The chlordane concentration in these units were 263 and 26 ug/M^3. These results prompted a survey of 11 other units treated in a similar manner in 1978. Chlordane concentrations ranged from 0.4 ug/M^3 to 22 ug/M^3 in these units. In 1980, the study was expanded to include all 498 housing units, 63 of which had no record of termiticide treatment. Measurable levels of chlordane ranging from a trace (>0.2 ug/M^3) to 38 ug/M^3 were found in 335 out of 435 treated units (77%). The study investigations concluded that there was a statistical difference in chlordane levels in units treated in 1978 as compared to units treated in other years.

These several occurrences of chlordane contamination of houses prompted the Air Force to conduct extensive tests in houses throughout the Air Force with a history of chlordane treatment and with ducts in or beneath the concrete slab. Two studies were conducted, the first in 1975 following discovery of the contamination at Wright-Patterson Air Force Base and the second following discovery of contaminated houses at Scott Air Force Base. The 1975 study included only houses with preconstruction treatment and involved sampling 165 houses at five Air Force bases. Sample results ranged from none detected (<0.2 ug/M^3) to 4.1 ug/M^3. A more extensive program was begun in 1980 which included all houses with a history of chlordane treatment regardless of the method of application. Approximately 6400 Air Force houses were included in the study. A three-year program was established with those houses treated by subslab injection receiving the highest priority for evaluation. Second priority for evaluation were those houses that received preconstruction treatment. Finally, those houses evaluated in the 1975 study were to be reevaluated.

The data from the air samples collected since 1973 in the Air Force owned houses are summarized in Table IV-3 by house construction type and type of chlordane treatment. The levels of chlordane presented in the table represent only the initial samples collected in houses with potential chlordane contamination. Specifically, these houses were those chlordane-treated houses constructed over an enclosed crawl space with ventilation ducts traversing the crawl space. Based on these monitoring results, the air in 55% of the units of slab or crawl space construction were found to have no detectable amounts of chlordane, 40% had detectable levels of ≤ 5 ug/M^3 chlordane, and 5% had levels of >5 ug/M^3 chlordane.[1]

In a report "Chlordane in Air Force Family Housing: A Study of Slab-On-Grade Houses, April 1983", the Air Force noted the difference between measurable air levels in slab houses treated prior to construction versus houses treated after construction. An explanation offered for this difference was that preconstruction ground treatment provided a considerably more uniform ground application than that of post-construction. Furthermore, it was stated that high pressure injection techniques used in post-construction treatment may have resulted in an uneven distribution or concentration of chlordane under the slab. Additionally, the possibility exists that the pesticide could be forced into cracks in the duct or slab during high pressure injection.

Based on the monitoring data collected, the Air Force noted that chlordane intrusion into slab houses peaked during cold weather months when heating systems were utilized. The warm air passing through the ducts heated adjacent to chlordane treated surfaces increased the vaporization of chlordane. In houses with poorly sealed ductwork, chlordane vapors entered the ducts with subsequent distribution throughout the ventilation system.

Air Force investigators have noted that modifications to the ventilation system in slab houses decreased airborne chlordane concentrations 93-97%. (Livingston, J.M. et al., 1981) [30]. The modifications consisted of sealing all subslab ducting and relocating ventilation ductwork inside the house.

TABLE IV-3

Summary of Chlordane Air Monitoring Program of Housing Units Located at U.S. Air Force Installations

Type Construction	Type Chlordane Treatment	Total Units Sampled	Number of Chlordane Air Samples				
			Non-detectable	>N.D.-<2ug/M³	>2ug/M³-<5ug/M³	>5ug/M³-<10ug/M³	>10ug/M³
Slab	Subslab Injection - Post Construction	987	255	493	190	37	12
	Subslab Ground Application - Preconstruction	2818	2145	481	152	31	9
	Trenching-Post Construction	12	10	1	1	0	0
Crawl-Space	No treatment records, some treatment suspected	210	177	24	8	1	0
	Crawl-space soil application-post construction (surface or trenching)	749	37	360	206	98	48
Total		4776	2624	1359	557	167	69
			(54.9%)	(28.5%)	(11.7%)	(3.5%)	(1.4%)

For example, at Scott Air Force Base slab ducts were sealed and relocated overhead in 39 houses where chlordane levels were found to be $\geq$ 4 ug/M^3. The interiors of the houses were repainted. A resampling of air levels showed a decrease in airborne chlordane levels of 93-95% in the reducted units.

As a result of the monitoring data collected and published in the previously cited April, 1983 report, the Air Force concluded the following: airborne chlordane concentrations are not likely to exceed 5 ug/M^3 in sub- or intraslab ducted houses that have only been treated prior to construction; airborne levels of chlordane in the living area of sub- or intraslab ducted houses is likely to occur following pesticide treatment of these dwellings using high pressure injection techniques; sub- or intraslab ventilation ductwork is the source of chlordane intrusion into the living area of slab houses; and sealing sub- or intraslab ducts and relocating the ventilation ducting overhead will reduce chlordane levels in family housing living areas by 93-97%.

The Air Force recommended for their installations that "family housing units with sub- or intraslab ventilation ducting should not be treated for termites using injection techniques unless absolutely necessary to save the structure"; and "if sub- or intraslab ducted houses have been treated for subterranean termite control, airborne chlordane concentrations in the house should be measured to determine if relocating the ventilation system ductwork inside the structure is necessary".

U.S. Department of the Navy

The Naval Facilities Engineering Command, Department of Navy conducted a monitoring program for airborne levels of termiticides in Navy and Marine Corps family housing units. This program was conducted during the 1981-1982 heating season in nearly 4,000 family housing units which were identified as units whose construction included sub- and intra-slab heating or cooling ducts, including single and multi-family units. As of October 18, 1982, 3957 buildings located at thirty-two installations across the United States had been sampled and the samples had been analyzed for levels of chlordane, heptachlor, aldrin, and dieldrin.

The results from the initial sampling are presented on the next page. In most units where detectable levels of a termiticide were found, the termiticide was chlordane since it was the probably the termiticide used the most. Some samples from units also contained heptachlor, aldrin and dieldrin. However, the data are only available in aggregate form and are not broken down for each chemical. The guideline levels used were the National Academy of Sciences guidelines of 5 ug/M^3 chlordane, 2 ug/M^3 heptachlor, and 1 ug/M^3 aldrin/dieldrin.

Number of Housing Units	Levels of Termiticides
3160 (79.9%)	Below detection limit
740 (18.7%)	Detectable, below NAS guidelines levels
57 (1.4%)	Greater than NAS guideline levels

As a result of this monitoring effort, the occupants of the fifty-seven housing units having termiticide levels exceeding the action levels were relocated.[11]

Department of the Army

The Department of the Army is conducting a monitoring program for airborne levels in the 19,741 Army housing units that have sub- and intra-slab heating and cooling ducts. Of the 3,061 housing units sampled as of June, 1983, 27 units had levels of chlordane exceeding the 5 ug/M^3 NAS interim guideline. Twenty-three of these twenty-seven units were located at one installation, and the four remaining units were located on 2 different installations (Smith, Department of the Army, personal communication).

Non-Military Termiticide Monitoring Studies

Five additional monitoring studies are available. A brief description of each study and the results are presented in Table IV-4. Four of the five studies monitored for indoor airborne concentrations of chlordane, heptachlor, aldrin, or dieldrin and one study monitored for chlorpyrifos. Houses of the following types were monitored in these various studies: plenum, crawl space, slab and combination of crawl space/slab basement.

TABLE IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions		
Pesticide Residues in Houses Utilizing Forced Air Plenum Distribution Systems, 1975; Colorado Epidemiology Pesticides Studies Center	Air, Soil, Blood	Chlordane Heptachlor Dieldrin	Houses-treated with cyclodienes	Dieldrin (ng/M^3)	Chlordane (ng/M^3)	Heptachlor (ng/M^3)
			6 plenum,1-3 yrs.old	n.d.-120	7-3654	3-269
			6 plenum,9-12 yrs.old	25-467	12-41	.7-27
			Houses-Not Treated			
			3 plenum,1-3 yrs.old	.7-2	7-16	.6-6
			2 crawl space,1-3 yrs.old	1.0	9,53	1,3
			3 plenum,9-12 yrs.old	2-99	12-53	2-5
			1 crawl space,9-12 yrs.old	2	39	5
			6 conventional,crawl space 1-3 yrs.old	2-46	27-1513	7-622
			5 conventional,crawl space 9-12 yrs.old	1-108	15-180	3-25

Conclusions

Mean levels of cyclodienes in air higher in samples from treated plenum houses than air samples collected from treated conventional houses.

TABLE IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions
Airborne Concentrations of Chlorpyrifos Monitored in Buildings During and After Application of Formulation M-4328 for Control of Subterranean Termites. Dow Chemical Company, 1979.	Air	Chlorpyrifos	5 Crawl Space Houses (Georgia) 4 Basement Houses (California)	Crawl Space Houses - Highest concentrations found during and after application in living areas: .003 mg/M^3 and .002 mg/M^3 respectively. Basement Houses - Highest concentrations found during and after application (24 hrs.) in living areas: .037 mg/M^3 and .013 mg/M^3, respectively. <u>Conclusions</u> - Authors of study concluded that airborne concentrations found in structures during and after treatment are believed to be well below levels expected to cause a health concern to occupants of treated structures.

TABLE IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions
Assessment of Exposure Following the Use of Aldrin as a Termiticide in Homes, Shell Research Limited, Sittingbourne Research Centre, December, 1982.	Air	Aldrin,Dieldrin	3 Concrete Slab Houses (California)	24 Hours After Application <.04-.27ug/M^3 (aldrin) <.04-.06ug/M^3 (dieldrin) 7-56 Days After Application <.04-.15ug/M^3 (aldrin) <.04ug/M^3 (dieldrin)
			3 Crawl Space Houses	24 Hours After Application .09-7.0ug/M^3 (aldrin) <.04ug/M^3 (dieldrin) 7-56 Days After Application .05-.55ug/M^3 (aldrin) <.04-.17ug/M^3 (dieldrin)

Table IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions
A Study in So. California in July 1979 of the Potential Dermal and Inhalation Exposure of Applicators and Other Persons Who Might Later Enter or Occupy Areas Treated with Chlordane Used Against Subterranean Termites Under Houses; 1979. Maddy et al, California Department of Food and Agriculture	Air	Chlordane	3 Crawl Space Houses 3 Slab Houses	During Application (Levels in Living Areas) Crawl: N.D.-.001 mg/M^3 Slab: N.D. After Application (Levels in Living Areas) Immediately After Application Crawl: N.D. Slab: N.D. 24-48 Hours After Application Crawl: N.D. Slab: N.D. 7 Days After Application Crawl: .004-.007mg/M^3 Slab: .004-.013mg/M^3 30 Days Crawl: N.D. Slab: N.D.

Table IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions
Applicator and Inhabitant Exposure to Chlordane During and After Termiticide Applications in California Cahill,W.P. and M.K.Stumphy, 1979. (Velsicol Results of Study Cited on p. IV-19.)				Immediately After Application Crawl: N.D.-.104mg/M^3 Slab: N.D.-.0023mg/M^3 24-48 Hours After Application Crawl: N.D.-.084mg/M^3 Slab: N.D.-.0017mg/M^3 22 Days After Application Crawl: .0010-.064mg/M^3 Slab: No samples

TABLE IV-4

Summary of Non-Military Termiticide Monitoring Studies

Title of Study and Author	Types of Samples Collected	Chemical Analyzed For	Description of Dwelling Monitored	Study Results/Conclusions
Termite Control Produces Low Levels Chlordane and Heptachlor in Treated Houses. Wright, C.G. and R.B. Leidy. Pest Control Technology, July, 1982 pp.44-45,55.	Air	Chlordane, Heptachlor	6 Houses Infested with Subterranean Termites Having Crawl Spaces or Crawl Space/ Slab Basement	Ranges of Mean Values of 1% Chlordane Product Used - Immediately After Application through 1 Year After: 2.75-5.01 ug/M^3 Ranges of Mean Values After Termide®(.5% Chlordane and .25% Heptachlor) Product Used-Immediately After Application through 1 Year After: Chlordane: 2.34-5.81 ug/M^3 Heptachlor: 1.00-1.80 ug/M^3

CHAPTER V

RISK/BENEFIT ANALYSIS

The purpose of this chapter is to summarize the risks and benefits associated with the chemicals used in subterranean termite control and to then compare these risks and benefits for this use.

Summary of Risks

Health Effects

Data indicate that all of the cyclodiene termiticides cause central nervous system effects in humans and animals after acute exposure. Symptoms include: dizziness, nervousness, convulsions, and loss of coordination. Lindane has also been shown to be toxic to the central nervous system to animals and humans after both short and long term exposure.

The symptoms identified from exposure to pentachlorophenol include loss of appetite and respiratory difficulties. Other effects include pathologic changes in the liver and kidneys. Embryotoxicity and fetotoxicity was observed in the offspring of rats.

The primary effect noted as a result of an acute exposure of humans to chlorpyrifos is a reduction in plasma and red-cell cholinesterase activity. Symptoms include: nervousness, giddiness, headache, blurred vision, weakness, nausea, cramps, diarrhea, and discomfort in the chest. All of the cyclodienes have induced hepatocellular carcinomas in the B6C3F1 strain of mice. However, this response was not observed in rats. The results of the carcinogenicity tests in rodents administered lindane have not been consistent, with both positive and negative results reported. The data available for pure pentachlorophenol and chlorpyrifos do not indicate a carcinogenic effect. However, technical pentachlorophenol is contaminated with the carcinogenic dioxin, hexachlorodibenzo-p-dioxin (HxCDD).

In the recent investigation of the risks of the termiticides by the National Academy of Sciences (NAS), it was concluded that available data are insufficient to determine whether carcinogenesis is the critical biological end-point (health effect) of concern when humans are exposed to the cyclodienes and lindane. However, the NAS report did state that available animal data allow a comparison to be made of carcinogenic potential for 5 out of 7 pesticides that were tested under similar experimental protocols and had similar results - hepatocellular carcinomas in B6C3F1 strain of male mice.

On the basis of the ED_{10}, the dosage producing an incidence in liver tumors 10% above background level, the ranking from greatest to least carcinogenic risk potential would be aldrin, dieldrin; heptachlor; chlordane; lindane.[15]

In the NAS report, it was noted that a direct comparison of the carcinogenic potential of chlorpyrifos with the cyclodienes is not possible. The reason is that the available studies on the compounds used a different test protocol and a different strain of mice (cyclodienes used B6C3F strain and chlorpyrifos used CD-1 strain). The authors of the NAS report continued to point out that if the highest dose in the chlorpyrifos study, 15.8 ppm, and the same experimental conditions were used, estimates of the proportion of animals that would be expected to have tumors after exposure to other pesticides could be made. On this basis, chlordane and lindane would be expected to yield negative results if tested under the same conditions as chlorpyrifos and the carcinogenicity potential of chlorpyrifos cannot be predicted. While it is true that the carcinogenicity of chlorpyrifos cannot be predicted, the effects of higher doses of chlorpyrifos will be depression of acetylcholinesterase. Therefore, for chlorpyrifos this dosage can be considered maximum since higher doses would result in survival problems due to the acute toxicity and cholinesterase depression effects associated with chlorpyrifos.

Exposure

A discussion of possible health effects provides only half of the risk assessment of a chemical. The issue of whether or not humans are exposed to termiticides as a result of their proper, registered use must be settled in order to assess if the use of these chemicals poses an unreasonable risk to man.

A level of exposure to any of the termiticides below which there would be no biologic effects has not been determined. In its August, 1982 report the NAS Committee on Toxicology suggested interim airborne concentration level guidelines for five termiticides as follows: chlordane (5ug/M^3), heptachlor (2 ug/M^3), aldrin/dieldrin (1 ug/M^3), and chlorpyrifos (10 ug/M^3). A guideline was not suggested for lindane because available data are not adequate to provide a basis for an airborne exposure limit and because lindane is not currently used to control termites in military housing. Similarly, a guideline was not set for pentachlorophenol because of the lack of definitive data and it also is not now used to control termites in military housing.

In the NAS report, these exposure guidelines for each of the termiticides were presented for the purpose of providing guidance in estimating the health risks of these chemicals in military housing. These exposure limits were based on health considerations as well as the judgement of scientists participating in the NAS study. It should be noted that the NAS interim guidelines apply to long-term continuous exposure and the NAS Committee did not consider short-term exposure guidelines. Therefore, the guidelines would be applicable to termiticide concentrations measured over an extended period such as a year but not to concentrations measured over shorter periods.

The Agency views the interim levels as useful for guiding efforts to determine on a case-by-case basis whether particular individuals in fact face a health risk in a particular environment. Such a determination would often involve testing and health monitoring beyond the sampling of air concentrations. The guidelines will be reassessed once the further toxicology and air monitoring data are generated and then reviewed by the Agency.

The information on exposure to applicators is limited to one study in which air monitoring was only done for chlordane. The results indicate levels ranging from non-detectable to .073 ug/M^3 of chlordane inside slab and crawl space houses up to 30 days after application.

The data pertaining to exposure to residents of treated dwellings also is primarily for chlordane and the majority of the data were collected in military housing units in dwellings wth heating/cooling ducts in or below the slab and houses with crawl spaces. In the aggregate, military data on the sub- and intra-slab duct houses and some crawl space houses indicate that out of 11,794 housing units tested, 320 (2.7%) had detectable levels of chlordane, heptachlor, aldrin or dieldrin.

In the most recent study conducted on civilian houses with crawl space or combination crawl space/slab basement-treated with chlordane and chlordane/heptachlor, mean levels of chlordane immediately and up to 1 year after application ranged from 2.34-5.81 ug/M^3. The respective levels for heptachlor were 1.00-1.89 ug/M^3.[42]

Thus, given the information available to the Agency at this time, residents of dwellings of certain construction types may be exposed to the chemicals used to treat the dwellings for termite control.

Summary of Benefits

Chlordane is the most widely used insecticide for subterranean termite control. Heptachlor and aldrin are used in much smaller quantities than chlordane for termite control. Aldrin, imported in 1981, could capture as much as 25% of the termiticide market in response to chlordane price increases. To date, there are no known sales or use of dieldrin in the United States. The use of lindane as a termiticide seems to be limited to pest control firms in California. Pentachlorophenol is used only for specific termite control problems where termites have been associated with decay or direct application to infested wood structures. It is not used for subsurface applications. A few thousand pounds of chlorpyrifos were sold in 1980, primarily in California.

Available data indicate that chlordane is presently the most effective termiticide. Heptachlor, aldrin, and dieldrin are comparable in effectiveness. Dieldrin was rarely used as a termiticide because of its high price. Chlorpyrifos seems to be the most promising new compound. However, to obtain equivalent pest control cost is at least twice that of chlordane/heptachlor/aldrin.

Within the pest control industry, the choice between cyclodienes appears to be one of personal preference rather than documented advantages and disadvantages of the individual chemicals.

No national data have been compiled and published on the costs society has incurred as a result of the subterranean termite. A number of estimates of the annual national cost, including both the loss due to termite damage and the cost of control have been noted in the literature. The most frequently cited figure is $500 million. The Agency has estimated the potential cost of termite infestation by extrapolating from data on control and damage repair costs in eleven states. This nationwide estimate, inflated to 1980 dollars, is $753.4 million. If multi-family, commercial, and public dwellings are considered, the estimate is expanded to $1.022 billion.

In summary, the benefits for the termiticides, particularly the cyclodienes, are very high.

Risk/Benefit

After consideration of the available information on the risks and benefits for the termiticides the Agency concludes that the benefits from their use to control subterranean termites are extremely high.

The risk assessment for these chemicals is incomplete because of the lack of definitive data on the extent of human exposure, the amount of exposure, and, most importantly, data on the critical biological end point (health effect) in humans exposed to these pesticides. At this time in assessing the risks and benefits associated with the total national use of the termiticides based on available data, and considering the lack of data outlined above, the Agency finds that the benefits from the use of the currently registered termiticide products outweigh the potential risks. The Agency recognizes that in individual cases where termiticides were improperly applied or misused in treating a residential dwelling, the risks from exposure to the chemicals may exceed the benefits.

CHAPTER VI

CONCLUSIONS

As a result of the analysis of the information on the risk and benefits associated with the use of the termiticides, the Agency has concluded that the benefits, particularly for the cyclodienes, are very high and the cyclodienes are the most effective chemicals currently registered for termite control. The Agency cannot complete a risk assessment of the termiticides due to a lack of definitive health and exposure data.

The information on possible health effects associated with the use of the termiticides is summarized in Chapter IV of this document. One major inadequacy of the existing termiticide data base is that it consists only of dietary exposure studies. In the case of termiticide use, inhalation is clearly the route of exposure to be considered in assessing the risk. Moreover, in the recent termiticide risk review conducted by the National Academy of Sciences, it was concluded that the data were not sufficient to determine whether carcinogenicity is the critical biological end-point (health effect) in humans exposed to the termiticides. The Agency accepts this conclusion and has determined that additional toxicology data are needed to assess the risks to humans exposed to termiticides.

Additionally, the Agency has concluded that exposure is the principal issue in assessing the health risks posed by the use of the termiticides. The Agency has recently reviewed monitoring data that showed contamination of living quarters following termite treatment. The data consist mostly of contamination incidents in military housing units constructed with sub- and intra-slab ducts. To a limited extent, some contamination incidents were also reported in military housing units with crawl spaces. Information is not available on the termiticide treatment use history for the monitored military housing units or for other types of housing structures. Therefore, it cannot be determined if the termiticide contamination problem is confined to houses with sub- and intra-slab ducts and, possibly, crawl spaces and, if applied properly, if contamination in these structures will always occur. However, from the available monitoring data and individual incidents reported, exposure to the termiticides may occur in a low percentage of houses of specific construction types.

The risk assessment for these chemicals is incomplete because of the lack of definitive data on the extent of human exposure, the amount of exposure, and, most importantly data on the critical biological end point (health effect) in humans exposed to these pesticides. At this time in assessing the risks and benefits associated with the total national use of the termiticides based on available data, and considering the lack of data outlined above, the Agency finds that the benefits from the use of the currently registered termiticide products outweigh the potential risks.

The Agency recognizes that in individual cases where termiticides were improperly applied or misused in treating a residential dwelling, the risks from exposure to the chemicals may exceed the benefits.

The Agency has developed an action plan to obtain the necessary toxicology and exposure data to fully assess the health risks and determine further regulatory action. Given the uncertainties with respect to human health effects and exposure, the immediate short term actions that have been taken focus on reducing possible human exposure to the termiticides and obtaining additional information on health effects and exposure.

Label Improvement Program

The Label Improvement Program (LIP) that is being carried out by the Registration Division, Office of Pesticide Programs has resulted in the addition of several statements to labels of products registered for the control of termites. These statements are designed to prevent potential hazards by reducing the possibility of misuse and, consequently, exposure. A number of statements specifically caution the application of termiticides near heating ducts, near domestic water supplies (cisterns, private wells, etc.), and around structures containing sub-floor crawl spaces.

The majority of registrants have compiled with the LIP. The Agency is currently notifying the remaining registrants regarding compliance with the LIP for termiticides.

Restricted Use Classification

Currently, federally registered products containing chlordane, heptachlor, aldrin, dieldrin, lindane, pentachlorophenol, and chlorpyrifos are not classified as restricted use pesticides. That is, products containing the above listed chemicals are available to homeowners for purchase and use, and are not required to be applied by certified applicators.

Six states have already taken regulatory action to restrict the use of chlordane to application only by certified applicators or individuals under their direct supervision. These states are: Connecticut, Hawaii, Massachusetts, New Mexico (products with concentrations >5%), New Jersey (effective 12/83), and Vermont.

The Agency has identified restricting the use of the termiticides as a measure to alleviate possible misuse of these chemicals and, thereby, reduce human exposure. The Agency is contacting state regulatory agencies to obtain information on incidents of misuse that would support the classification of restricted use.

Prohibit Use of Cyclodienes on Specific Structures

Measures concerning the use of the cyclodiene termiticides on certain types of structures have already been taken by registrants and the National Pest Control Association (NPCA). The manufacturer of chlordane has voluntarily added to the label the statement not to use chlordane on plenum housing. NPCA also instructs its membership not to treat plenum houses with the cyclodienes. Additionally, NPCA cautions its members to locate ductwork prior to treatment of houses with sub- and intra-slab ducts.

The Agency is currently evaluating the measures outlined above in light of available monitoring data and monitoring data that is being requested by the Agency.

Concurrent with pursuing the above short-term measures, the Agency has identified data that are needed to complete a qualitative and quantitative risk assessment on each of the termiticides and determine if additional regulatory action is necessary.

Toxicology Data

As stated previously, the toxicology data available on the termiticides consists of animal studies where the route of exposure is dietary. Inhalation is the route of exposure of concern in dealing with the problems of termiticide use. Additionally, the critical biological end point as a result of exposure to these chemicals cannot be determined from existing data. Therefore, the Agency is requiring registrants of termiticides in the cluster considered in this report to submit the following data under the authority of Section 3(c)(2)(B) of the Federal Insecticide, Fungicide, and Rodenticide Act: mutagenicity tests and a subchronic inhalation study.

The battery of mutagenicity tests would consist of the following (in vivo activation): host mediated assay with bacterial indicator or sex-linked recessive lethal assay in Drosophila; chromosomal aberrations assay in bone marrow cells, or a micronucleus test, or a sister-chromatid exchange test; unscheduled DNA synthesis in hepatocytes from treated rodents; and cell transformation in primary cultures from treated hamsters. These specific studies will allow for an evaluation of mutagenic risk and for assessment of oncogenic risk for the cyclodienes.

A subchronic inhalation study will provide data on the critical biological end point after exposure to these chemicals. The Agency reserves the right to request chronic inhalation studies pending the results and analysis of the subchronic studies.

Monitoring Data

The Agency is requiring, under the authority of Section 3(c)(2)(B) of the Federal Insecticide, Fungicide, and Rodenticide Act, registrants of termiticides to submit indoor air monitoring data of dwellings treated with a termiticide. The dwellings included in the monitoring study should be of different construction types: sub- and intra-slab duct, crawl space, full basement. A treatment history should also be available for each of the houses included in the study. These data will then be used to determine if exposure to the dwelling occupant occurs when termiticides are applied according to current label directions and application rates.

Concurrent with the requirement for registrants to submit monitoring data, the Agency is contacting several private researchers and state regulatory agencies for any monitoring data that they may have collected as a result of complaints and/or enforcement efforts.

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APPENDIX 1

PHYSICAL AND CHEMICAL PROPERTIES OF TERMITICIDES

CHLORDANE

chemical name:	1,2,4,5,6,7,8,8-Octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane
Chem. Abstr. Services Reg. No.:	57-74-9
molecular weight:	409.8
color:	amber
odor:	chlorine odor
melting point:	106-107°C (cis-isomer); 104-105°C (trans-isomer);
boiling point:	decomposes at 1 atm.
solubility:	Insoluble in water; soluble in most organic solvents, including petroleum hydrocarbons
physical state:	liquid
density:	d^{25} 1.59-1.63
vapor pressure:	0.00001 mm at 25°C
viscosity:	75-120 centistokes at 55°C
stability:	loses chlorine in presence of alkaline reagents; should not be formulated with solvents, carriers, diluents, emulsifiers, which have alkaline reactions;

HEPTACHLOR

chemical name:	1,4,5,6,7,8,8a-Heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
Chem. Abstr. Services Reg. No.	76-44-8
molecular weight:	373.5
molecular formula:	$C_{10}H_5Cl_7$
color:	white (pure); light tan (technical)
odor:	camphor-like odor
melting point:	93°C
boiling point:	135-145°C at 1-1.5 mm
solubility:	practically insoluble in water; soluble in ethanol, xylene, carbon tetrachloride, acetone, and benzene
physical state:	crystalline solid
density:	1.57-1.59
vapor pressure:	0.0003 mm at 25°C
viscosity:	not applicable
stability:	stable in daylight, air, moisture, and moderate heat; oxidized biologically to heptachlor epoxide;

ALDRIN

chemical name:	1,2,3,4,10,10-Hexachloro-1,4,4a,5 8,8a-hexahydro-1,4,5,8-dimethanonapthalene
Chem. Abstr. Services Reg. No.:	309-00-2
molecular weight:	364.9
molecular formula:	$C_{12}H_8Cl_6$
color:	white (pure); tan to dark brown (technical)
odor:	chemical-like odor
melting point:	104-104.5°C
boiling point:	decomposes at 1 atm.
solubility:	very soluble in most organic solvents; practically insoluble in water;
physical state:	crystalline solid
density:	1.70 at 20°C
vapor pressure:	2.31×10^{-5} mm Hg at 20°C
viscosity:	not applicable for solid
stability:	stable with alkali and alkaline-oxidizing agents; not stable with concentrated mineral acids, acid catalysts, acid-oxidizing agents, phenols, active metals

DIELDRIN

chemical name:	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene
Chem. Abstr. Services Reg. No.:	60-57-1
molecular weight:	380.9
molecular formula:	$C_{12}H_8Cl_6O$
color:	white (pure); light tan (technical)
odor:	odorless
melting point:	176-177°C
boiling point:	decomposes at 1 atm.
solubility:	practically insoluble in water; slightly soluble in petroleum oils; moderately soluble in acetone; soluble in aromatic solvents;
physical state:	crystalline solid
density:	1.70 at 20°C
vapor pressure:	1.78×10^{-7} mm Hg at 20°C
viscosity:	not applicable for solid
stability:	stable in alkalis and in acids except strong mineral acids;

:cc

CHLORPYRIFOS

chemical name:	O,O-Diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate
Chem. Abstr. Services Reg. No.:	2921-88-2
molecular weight:	351
molecular formula:	$C_9H_{11}Cl_3NO_3PS$
color:	white
odor:	mild mercaptan odor
melting point:	42.5-43°C
boiling point:	
solubility:	soluble in most organic solvents
physical state:	crystalline solid
density:	
vapor pressure:	1.87×10^{-5} mm Hg at 25°C
viscosity:	
stability:	stable under normal storage conditions