

● INSECTICIDE FACTSHEET

CYPERMETHRIN

Cypermethrin is a synthetic pyrethroid insecticide used to kill insects on cotton and lettuce, and to kill cockroaches, fleas, and termites in houses and other buildings.

Cypermethrin is toxic to the nervous system. Symptoms of exposure include dizziness, nausea, headaches, and seizures. It also suppresses the immune system, inhibiting the formation of antibodies to disease-producing microbes.

If exposed to cypermethrin during pregnancy, rats give birth to offspring with developmental delays. In male rats exposed to cypermethrin, the proportion of abnormal sperm increases. It causes genetic damage: chromosome abnormalities increased in bone marrow and spleen cells when mice were exposed to cypermethrin. Cypermethrin is classified as a possible human carcinogen because it causes an increase in the frequency of lung tumors in female mice.

Among structural pest control operators in California, cypermethrin is the fourth most common cause of pesticide-related illness.

After household treatments, it persists in the air and on walls and furniture for about three months.

Cypermethrin is toxic to bees, other beneficial insects, earthworms, fish, and shrimp. Birds in cypermethrin-treated areas are less successful at raising nestlings because their insect food sources are killed.

BY CAROLINE COX

Cypermethrin is an insecticide in the synthetic pyrethroid family. It was first marketed in 1977.¹ The primary manufacturers in the U.S. are Zeneca Inc., FMC Corp., and American Cyanamid Co. Common brand names are Demon, Cymbush, Ammo, and Cynoff.²

All of the insecticides in this family have chemical structures that are loosely based on pyrethrins, insecticidal compounds found in chrysanthemum flowers. (See Figure 1.) Most synthetic pyrethroids are complex molecules; cypermethrin is no exception. Because of its complexity, there are eight different ways that the atoms that make up the cypermethrin molecule can arrange themselves in three dimensions. These are called isomers. Cypermethrin is a mixture of all eight isomers.¹

Over ninety percent of the cypermethrin manufactured worldwide is used to kill

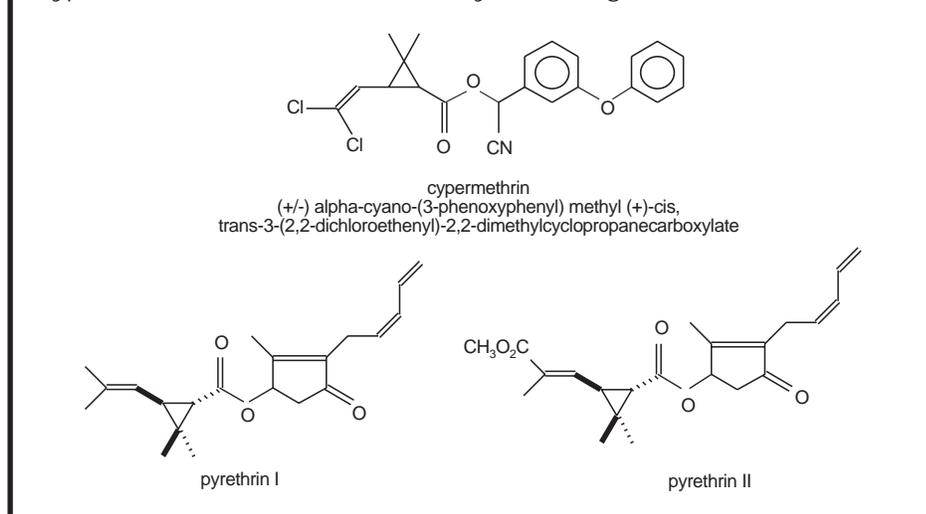
insects on cotton.¹ In the U.S., use on cotton is important in 5 states.³ (See Figure 2.)

It is also used on lettuce and pecans, to kill cockroaches (and other indoor pests) in buildings, and to kill termites. In California,

where pesticide use reporting is more comprehensive than other states, use of cypermethrin in homes and other buildings is the predominant use.⁴ (See Figure 3.)

Mode of Action

Figure 1
Cypermethrin and Related Naturally-Occurring Insecticidal Chemicals



Caroline Cox is JPR's editor.

Figure 2
Agricultural Uses of
Cypermethrin in the U.S.



Cotton (total annual use 46,000 pounds)



Lettuce (total annual use 21,600 pounds)



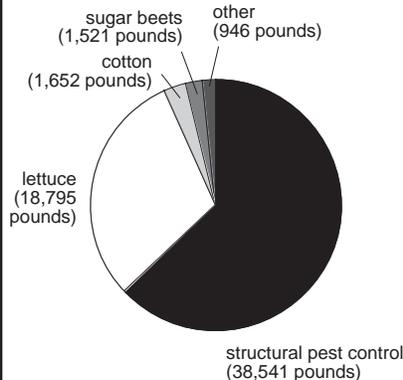
Onions (total annual use 7,500 pounds)

Sources:
U.S. Dept. of Agriculture. National Agricultural
Statistics Service. Economics Research
Service. 1996. Agricultural chemical usage:
1995 field crops summary. Washington, D.C.
(March.)
U.S. Dept. of Agriculture. National Agricultural
Statistics Service. Economics Research
Service. 1995. Agricultural chemical usage.
Vegetables: 1994 summary. Washington, D.C.
(July.)

Cypermethrin's most important agricultural
uses are on cotton, lettuce, and onions.

Cypermethrin, like all synthetic pyrethroids, kills insects by disrupting normal functioning of the nervous system. In insects, as well as all other animals including humans, nerve impulses travel along nerves when the nerves become momentarily permeable to sodium atoms, allowing sodium to flow into the nerve. Pyrethroids delay the closing of the "gate" that allows the sodium flow.⁵ This results in multiple nerve impulses instead of the usual single one. In turn, these impulses cause the nerve to re-

Figure 3
Use of Cypermethrin
in California (1993)



California Environmental Protection Agency.
Dept. of Pesticide Regulation. Information
Services Branch. 1995. Pesticide use report.
Annual 1993. Indexed by chemical. Sacramento,
CA. (June.)

In California, cypermethrin's predominant use is for structural pest control: killing termites, cockroaches, and fleas in homes and other buildings.

lease the neurotransmitter acetylcholine and stimulate other nerves.⁶

Cypermethrin has other effects on the nervous system. It inhibits the γ -aminobutyric acid receptor, causing excitability and convulsions.⁷ In addition, it inhibits calcium uptake by nerves⁸ and inhibits monoamine oxidase,⁹ an enzyme that breaks down neurotransmitters.

Cypermethrin also affects an enzyme not directly involved with the nervous system, adenosine triphosphatase. It is involved in cellular energy production, transport of metal atoms, and muscle contractions.¹⁰

Acute Toxicity

Humans: Symptoms of cypermethrin poisoning in humans include facial burning and tingling (called paraesthesia¹), dizziness, headaches, nausea, anorexia, fatigue,¹¹ and loss of bladder control.¹² With greater exposure, symptoms include muscle twitching, drowsiness, coma, and seizures.¹¹

Laboratory Animals: Symptoms of cypermethrin toxicity in laboratory animals include pawing, burrowing, salivation, tremors, writhing, and seizures.¹³

The median oral lethal dose (the dose

that kills 50 percent of a population of test animals; LD₅₀) is variable. In rats the LD₅₀ can vary from 250 to over 4,000 milligrams per kilogram (mg/kg) of body weight. This variability is partly due to the solvents used in the test, and partly due to variability in the proportions of cypermethrin's isomers. In mice, it can vary from 80 to almost 800 mg/kg.¹² The U.S. Environmental Protection Agency (EPA) uses LD₅₀s of 250-300 mg/kg.¹⁴ This puts cypermethrin in toxicity category II ("Warning").²

Juvenile rats are almost twenty times more susceptible to cypermethrin than adults. This is probably due to incomplete development of detoxification enzymes.¹⁵

Synergy: Pyrethroid insecticides, including cypermethrin, are broken down by enzymes called esterases. The same enzymes are inhibited by organophosphate insecticides. If the two kinds of insecticides are used together, cypermethrin will not be broken down as fast as it normally is. The result is that the two kinds of insecticides are synergistic: the toxicity of cypermethrin in combination with an organophosphate insecticide is greater than the toxicity of either insecticide alone.¹⁶

Skin and Eye Irritation: Cypermethrin and some cypermethrin-containing products are skin sensitizers. This means that when cypermethrin is applied to skin several times, later applications will have a more serious response than the first application.¹⁷

Cypermethrin has caused the cornea of laboratory animals to become opaque.¹⁷

Effects on the Immune System

In both rabbits and rats, cypermethrin has been shown to suppress immune system function. Rabbits fed cypermethrin produced fewer antibodies to a *Salmonella* bacteria than did unexposed animals. They also produced a smaller reaction to a tuberculin skin test. Some effects were significant at doses of 1/40 of the LD₅₀.¹⁸ (See Figure 4.)

Rats fed cypermethrin produced fewer antibodies to foreign blood cells and foreign proteins. Effects were significant at doses of 1/10 of the LD₅₀.¹⁸

Effects on Reproduction

Exposure of pregnant laboratory animals to cypermethrin can affect their offspring. Feeding pregnant rabbits cypermethrin resulted in a small increase in the number of organ and skeletal abnormalities in their offspring.¹ Rats exposed prenatally showed developmental delays: events such as the emergence of a tooth, opening of eyes, and development of particular reflexes occurred up to three days later in exposed rats than in unexposed rats.¹⁹

Male reproduction is also affected by cypermethrin. In mice, the proportion of abnormal sperm increased with increasing dose of cypermethrin.²⁰

Other research has shown that a receptor protein found in high concentration in the testes is inhibited by cypermethrin. This indicates that cypermethrin could disrupt the normal functioning of sex hormones.²¹

Mutagenicity

Tests on mice have shown that cypermethrin damages genetic material. Injection of cypermethrin caused an increase in the number of cells with abnormal chromosomes in both bone marrow and spleen.²² Similar results were also found in bone marrow cells following ingestion, and when exposure occurred over a five day period rather than all at once.²⁰

The first study²² also found an increase in sister chromatid exchanges in bone marrow cells. (Sister chromatid exchanges are exchanges of genetic material during cell division between members of a chromosome pair. They result from point mutations.) Similar results were found with both cypermethrin and a cypermethrin-containing product in a third study.¹

Ingestion of, or dermal exposure to, cypermethrin caused an increase in the number of micronuclei in bone marrow cells in mice.²³ Micronuclei are chromosomes (or fragments) that get left behind during cell division.²⁴ A similar increase in micronuclei was found in human blood cells.²⁴

Carcinogenicity

EPA has classified cypermethrin as a possible human carcinogen (a chemical that causes cancer) because it causes lung tumors in fe-

male mice.²⁵

Two recent studies have demonstrated molecular mechanisms by which cypermethrin might be involved in causing cancer. One study looked at "gap junctional intercellular communication."²⁶ This process plays "important roles in maintenance, growth, and differentiation of cells" and is inhibited by many carcinogenic agents. The study showed that cypermethrin, four other synthetic pyrethroid insecticides, and the organochlorine insecticide DDT all were inhibitory.²⁶ A second study showed that, in addition to inhibiting intercellular communication, cypermethrin also increased the number of "altered foci" in rat

rabbits, it caused pathological changes in the thymus, liver, adrenal glands, lungs, and skin.¹²

Occupational Exposure

In the U.S., most occupational exposure to cypermethrin comes from its uses to kill home and building pests. Structural pest control operators are exposed to cypermethrin; in California, where reporting of pesticide-related illnesses is more complete than in other states, cypermethrin was the fourth most common cause of pesticide-related illnesses among this group.²⁸ Employees can also be exposed if the building in which they work is treated with cypermethrin. For example, nine employees at a California business where cypermethrin was applied as a termiticide were exposed when they entered the building two days after treatment. Employees immediately experienced dizziness, headaches, and nausea. Six days after treatment, employees noticed a return of their symptoms when they reentered the building. Some symptoms persisted seven months.²⁹

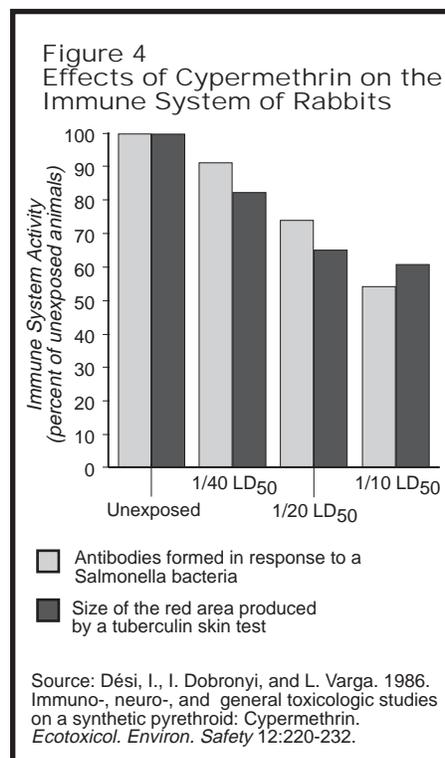
In countries where agriculture is labor intensive, agricultural workers are exposed to cypermethrin.^{30,31} For example, over 25 percent of the workers in Chinese cotton fields exhibited symptoms of pyrethroid (including cypermethrin) poisoning.³⁰

Concerns about occupational exposure are increased because laundering is not completely successful in removing cypermethrin from clothing. Experiments found that up to 19 percent of residues remained after hand washing, and up to 27 percent remained after machine washing.^{32,33}

Exposure from Household Pest Control Uses

Cypermethrin is commonly used to kill household insect pests. In California, it is the fourth most commonly-used insecticide: only chlorpyrifos, pyrethrins, and diazinon have more reported applications.⁴

Potential exposure to cypermethrin following household treatments has been studied by making applications that simulate commercial "crack and crevice" cockroach treatments in vacant dormitory rooms.³⁴ This study showed that residues persisted for 84 days (the end of the study) in the air, and on the walls, floor, and furniture. Cypermethrin moved to rooms adjacent to those treated by the



Cypermethrin inhibits the production of antibodies that fight disease-causing microbes.

livers.²⁷ Both are characteristics of tumor promoters.^{26,27}

Other Chronic Effects

Long-term feeding studies with laboratory animals have shown that cypermethrin causes adverse effects. In rats, it caused reduced growth rate and increased liver weight. In mice, it caused reduced weight gain, mild anemia, and increased liver weight. In dogs, it caused loss of appetite, incoordination, and tremors.¹ In

seventh day after treatment and persisted for 84 days.

Termiticide cypermethrin treatments are typically made to soil around or under houses. Persistence is longer than for other household applications, at least three years.³⁵

Exposure through Food

Cypermethrin residues have been found in lettuce,³⁶ and in the milk from cows wearing cypermethrin-impregnated ear tags (as a horn fly control measure).³⁷

Effects on Beneficial Insects, Spiders, and Mites

Cypermethrin is a broad-spectrum insecticide. In addition to killing the insects that are the target of a particular treatment, it can also reduce populations of insects and other arthropods that are economically desirable because they prey on unwanted insects or are useful pollinators.

Bees: Cypermethrin kills honey bees as well as leaf cutter bees (used to pollinate seed alfalfa crops). Residues on leaf surfaces are toxic (killing at least 25 percent of bees tested) for more than 3 days following treatment.³⁸ In addition, bees exposed to cypermethrin learned more slowly and less successfully than unexposed bees.³⁹

Spiders: Spiders are desirable predators in many agricultural systems because of their appetite for insects that would otherwise be agricultural pests. For example, treatment of rice with cypermethrin caused a decrease in the number of spiders and an increase in the number of whitebacked planthoppers, a pest insect. Because of the "resurgence" of the pest planthopper, yields in the cypermethrin-treated rice were the same as yields in untreated rice.⁴⁰

Cypermethrin can also have sublethal effects on spiders. Video-recording of cypermethrin-exposed spiders showed that cypermethrin caused paralysis of the hind legs and incoordination. Spiders required 9 - 12 days to return to normal.⁴¹

Parasitoids and Predators: Parasitoids lay their eggs in immature stages of other insects, which are then killed as the juvenile parasitoid develops. Predators prey on other species. Both are valuable in agriculture because they reduce populations of pest insects, but both are often killed by cypermethrin. When the Interna-

tional Organization for Biological Control surveyed cypermethrin's impact on representative parasitoid and predator species, it caused over 80 percent mortality of all parasitoid and most predator species tested.⁴²

Examples of cypermethrin's impact on parasitoids and predators include the following: predatory mites in apple orchards were killed for up to six weeks after treatment;⁴³ a buildup of a cotton pest, red spider mite, when predators were killed;⁴⁴ a decrease in the population of predatory beetles in fava beans;⁴⁵ and high mortality of two predators and a parasitoid important in the control of the pecan aphid.⁴⁶

Aquatic insects: While not usually considered beneficial insects in an economic sense, many aquatic insects are important components of aquatic ecosystems. Cypermethrin is toxic to caddisflies, mayflies, damselflies, and diving beetles.⁴⁷ Sublethal effects (abnormal swimming, etc.) have also been documented. Effects occur at low concentrations, much less than one part per billion (ppb) in some species.⁴⁸

Effects of cypermethrin on aquatic insects can be persistent and impact other species. Following spraying of a tree plantation in Australia, several streams were contaminated by cypermethrin, despite precautions taken to minimize drift. "Catastrophic" deaths of aquatic insects occurred. Recovery of some populations took six months, and an algae bloom was caused by the death of the normal herbivores. Brown trout ate the poisoned insects and showed pathological symptoms: lethargy, change in coloration, hardening of muscle tissue, and anemic appearance of blood and gills.⁴⁹

Effects on Other Animals

Earthworms: Cypermethrin is "very toxic" to the earthworm, *Eisenia foetida*.⁵⁰

Birds: Cypermethrin can impact bird populations by killing insect larvae normally used for food. A study of nesting success of blue tits following an aerial application of cypermethrin in an oak forest found a nearly 100 percent mortality of the caterpillars used as food by the blue tits. When cypermethrin spraying coincided with tit egg hatch and the early nestling stage, the result was an increase in nestling deaths, a decrease in the proportion of successful nests, and a decrease in weight of the surviving nestlings.⁵¹

Fish: Fish are particularly susceptible to cypermethrin.¹ The median lethal concentration (the concentration that kills 50 percent of a population of test animals; LC₅₀) for most fish is less than 5 ppb.¹ This is partly because fish are unable to break down pyrethroids as efficiently as mammals and birds and partly because fish nervous systems are particularly sensitive to pyrethroids.⁵²

Cypermethrin also causes sublethal effects in fish. These include an increase in cholesterol at 1/5 of the LC₅₀⁵³ and abnormal levels of blood sugars⁵⁴ at concentrations as low as 1/10 of the LC₅₀.⁵⁵

Cypermethrin bioconcentrates in fish. Bioconcentration factors (the ratio between the concentration in fish tissue and the concentration in the water in which the fish is living) in rainbow trout range from 180 to 438 depending on water type.⁵⁶ Values up to 1200 have been reported.¹⁴

Other aquatic animals: Cypermethrin kills shrimp,^{58,59} crabs,⁶⁰ crayfish,⁶¹ and lobsters⁶¹ at concentrations between 5 and 70 parts per trillion; water fleas are killed by concentrations of 5 ppb;⁵⁹ and oysters are killed by 2.3 parts per million.⁵⁹

Effects on Plants

Since cypermethrin is an insecticide, it is surprising that it also negatively impacts plants. The growth of a green algae (*Scenedesmus bijugatus*) is inhibited by concentrations as low as 5 parts per million.⁶² In addition, nitrogen-fixation (the conversion of atmospheric nitrogen into a form that can be used by plants) is decreased for 6 weeks in soybean root nodules by cypermethrin.⁶³ For nitrogen-fixing soil microbes, the cypermethrin product Ripcord was inhibitory.⁶⁴

Cypermethrin also affects plant cells. In both onion and chili roots, cypermethrin inhibited cell division and increased the number of chromosome abnormalities.^{65,66}

Persistence in Soil

The half-life (the amount of time required for half of what was originally applied to break down or move away from the test site) for cypermethrin in soil is between 4 and 12 days.¹⁴ However, it can be significantly more persistent. In agricultural soil in Ontario, Canada, cypermethrin per-

sisted for between 4 and 12 months. Persistence was less in sandy soil than in a "muck" soil. In surface layers of the soil, persistence was somewhat less (4 to 6 months).⁶⁷

Water Contamination

Cypermethrin has been found in groundwater in France⁶⁸ and in river water and sediment in the United Kingdom.⁶⁹

Resistance

Resistance to cypermethrin has developed quickly in insects exposed frequently. Both agricultural and household pest species have developed resistance. The degree of resistance is usually measured with a resistance ratio, the ratio between the amount of a pesticide required to kill a resistant insect and the amount required to kill average (non-resistant) insects. Resistance ratios from 6 to 32 have been measured in agricultural pests.⁷⁰⁻⁷² Among household pests, resistance ratios have ranged from 5 to 100.^{73,74} (The resistance ratio of 5 was enough to render synthetic pyrethroids ineffective.)

Secret "Inert" Ingredients

Virtually all cypermethrin-containing insecticide products contain ingredients that are called trade secrets by their manufacturers and classified as "inert" ingredients by EPA. However, these ingredients are neither biologically, toxicologically, or chemically inert. The following "inert" ingredients have been identified on the material safety data sheets produced for at least one cypermethrin-containing product.⁷⁵ (For molecular diagrams of some of these "inerts", see Figure 5.)

Crystalline silica is a mineral dust. The International Agency for Research on Cancer has classified evidence about its ability to cause cancer as sufficient in animals and limited in humans. In laboratory animals, inhalation of crystalline silica induced significant increases in the incidence of lung cancer. Injections induced lymphomas in the thorax and abdomen. In humans, a number of studies have shown that lung cancer occurs more frequently in workers who are exposed to silica.⁷⁶

Ethylbenzene is a solvent. It causes throat irritation, eye irritation, damage to liver and kidneys, dizziness, and incoordination. In laboratory tests, exposure to ethylbenzene has

caused fetal resorption, retardation of fetal skeletal development, and extra ribs in fetuses. It has also blocked or delayed the estrus cycle in female rats and damaged testes in a small study of monkeys. Exposure to ethylbenzene increased the number of malignant tumors in female rats.⁷⁷

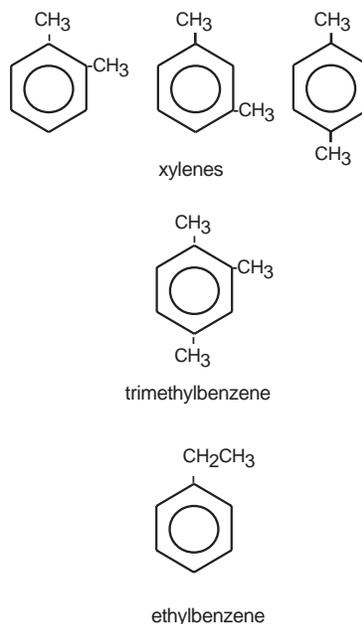
Xylenes are solvents. They cause nose, throat, and eye irritation, labored breathing, lung inflammation, nausea, vomiting, mild liver toxicity, impaired short-term memory, and hearing loss in exposed humans and/or laboratory animals. In laboratory tests, xylene exposure has also caused reduced fertility, increased number of fetal resorptions, increased

vousness, tension, bronchitis, disruptions of blood clotting, headaches, fatigue, dizziness, and loss of consciousness.⁷⁹

References

1. World Health Organization (WHO). 1989. *Cypermethrin*. Environmental Health Criteria 82. Geneva, Switzerland: United Nations Environment Programme, International Labor Organization, and WHO.
2. *Farm Chemicals Handbook '95*. 1995. Willoughby, OH: Meister Publishing Co
3. U.S. Dept. of Agriculture. National Agricultural Statistics Service. Economics Research Service. 1996. Agricultural chemical usage: 1995 field crops summary. Washington, D.C. (March.)
4. California Environmental Protection Agency. Dept. of Pesticide Regulation. Information Services Branch. 1995. Pesticide use report. Annual 1993. Indexed by chemical. Sacramento, CA. (June.)
5. Vijverberg, H.P.M. and J. van den Bercken. 1990. Neurotoxicological effects and the mode of action of pyrethroid insecticides. *Crit. Rev. Toxicol.* 21:105-126.
6. Eells, J.T. et al. 1992. Pyrethroid insecticide-induced alterations in mammalian synaptic membrane potential. *J. Pharmacol. Exper. Ther.* 262:1173-1181.
7. Ramadan, A.A. et al. 1988. Action of pyrethroids on GABA_A receptor function. *Pest. Biochem. Physiol.* 32:97-105.
8. Ramadan, A.A. 1988. Action of pyrethroids on K⁺-stimulated calcium uptake by, and [3H]nimodipine binding to, rat brain synaptosomes. *Pest. Biochem. Physiol.* 32:114-122.
9. Rao, G.V. and K.S.J. Rao. 1993. Inhibition of monoamine oxidase-A of rat brain by pyrethroids - an in vitro kinetic study. *Molec. Cell. Biochem.* 124:107-114.
10. El-Toukhy, M.A. and R.S. Girgis. 1993. In vivo and in vitro studies on the effect of larvin and cypermethrin on adenosine triphosphatase activity of male rats. *J. Environ. Sci. Health B28*:599-619.
11. He, F. et al. 1989. Clinical manifestations and diagnosis of acute pyrethroid poisoning. *Arch. Toxicol.* 63:54-58.
12. Extension Toxicology Network (EXTOXNET). 1993. Cypermethrin. Cooperative Extension offices of Cornell University, Michigan State University, Oregon State University, and University of California, Davis. (Sept.)
13. Aldridge, A.N. 1990. An assessment of the toxicological properties of pyrethroids and their neurotoxicity. *Crit. Rev. Toxicol.* 21:89-104.
14. U.S. EPA. Office of Pesticides and Toxic Substances. Office of Pesticide Programs. 1989. Pesticide fact sheet. Cypermethrin. No. 199. Washington, D.C. (Jan. 3.)
15. Cantalamessa, F. 1993. Acute toxicity of two pyrethroids, permethrin and cypermethrin, in neonatal and adult rats. *Arch. Toxicol.* 67:510-513.
16. Gaughan, L.C., J.L. Engel, and J.E. Casida. 1980. Pesticide interactions: Effects of organophosphorus pesticides on the metabolism, toxicity, and persistence of selected pyrethroid insecticides. *Pest. Biochem. Physiol.* 14:81-85.
17. U. S. EPA. 1989. "Tox one-liners." Cypermethrin. Washington, D.C. (Sept. 14.)
18. Dési, I., I. Dobronyi, and L. Varga. 1986. Immuno-, neuro-, and general toxicologic studies on a synthetic pyrethroid: Cypermethrin. *Ecotoxicol. Environ. Safety* 12:220-232.
19. Husain, R. et al. 1992. Differential responses of regional brain polyamines following in utero exposure to synthetic pyrethroids: A preliminary report.

Figure 5
Some of the "Inert" Ingredients Used in Cypermethrin-containing Products



incidence of cleft palate, and decreased fetal weight. Xylene inhalation has been associated with an increased frequency of leukemia in solvent-exposed workers. It may be a cocarcinogen; exposure to xylenes enhanced the number of skin cancers caused by other carcinogens. It "has the potential for bioaccumulation" in human fat tissue.⁷⁸

Trimethylbenzenes are highly volatile solvents that cause skin and eye irritation, ner-

- Bull. Environ. Contam. Toxicol.* 49:402-409.
20. Bhunya, S.P. and Pati, P.C. 1988. Genotoxic effects of a synthetic pyrethroid insecticide, cypermethrin, in mice *in vivo*. *Toxicol. Lett.* 41:223-230.
 21. Ramadan, A.A. 1988. Action of pyrethroids on the peripheral benzodiazepine receptor. *Pest. Biochem. Physiol.* 32:106-113.
 22. Amer, S.M., et al. 1993. Induction of chromosomal aberrations and sister chromatid exchange *in vivo* and *in vitro* by the insecticide cypermethrin. *J. Appl. Toxicol.* 13:341-345.
 23. Amer, S.M. and E.I. Aboul-ela. 1985. Cytogenetic effects of pesticides. III. Induction of micronuclei in mouse bone marrow by the insecticides cypermethrin and rotenone. *Mut. Res.* 155:135-142.
 24. Surrallés, J. et al. 1995. Induction of micronuclei by five pyrethroid insecticides in whole-blood and isolated human lymphocyte cultures. *Mut. Res.* 341:169-184.
 25. U.S. EPA. Office of Pesticide Programs. Health Effects Division. 1995. List of chemicals evaluated for carcinogenic potential. Memo from Stephanie Irene to Health Effects Division Branch Chiefs et al. Washington, D.C. (August 7.)
 26. Tateno, C. et al. 1993. Effects of pyrethroid insecticides on gap junctional intercellular communications in Balb/c3T3 cells by dye-transfer assay. *Cell Biol. Toxicol.* 9:215-222.
 27. Hemming, H., S. Flodström, and L. Wärngård. 1993. Enhancement of altered hepatic foci in rat liver and inhibition of intercellular communication *in vitro* by the pyrethroid insecticides fenvalerate, flucythrinate and cypermethrin. *Carcinog.* 14:2531-2535.
 28. Robinson, J.C. et al. 1994. *Pesticides in the home and community: Health risks and policy alternatives*. California Policy Seminar Report. Berkeley, CA: Univ. of California, Berkeley. School of Public Health. Environmental Health Policy Program.
 29. Lessenger, J.E. 1992. Five office workers inadvertently exposed to cypermethrin. *J. Toxicol. Environ. Health* 35:261-267.
 30. Chen, S. et al. 1991. An epidemiological study on occupational acute pyrethroid poisoning in cotton farmers. *Brit. J. Occup. Med.* 48:77-81.
 31. Wan, H. 1990. Pesticide exposure of applicators working in tea plantations. *Bull. Env. Contam. Toxicol.* 45:459-462.
 32. Wan, H. 1991. Removal of fenitrothion and cypermethrin from contaminated fabrics by handwashing. *Bull. Environ. Contam. Toxicol.* 47:537-539.
 33. Nelson, C. et al. 1992. Laundering as decontamination of apparel fabrics: Residues of pesticides from six chemical classes. *Arch. Environ. Contam. Toxicol.* 23:85-90.
 34. Wright, C.G., R.B. Leidy, and H.E. Dupree, Jr. 1993. Cypermethrin in the ambient air and on surfaces of rooms treated for cockroaches. *Bull. Environ. Contam. Toxicol.* 51:356-360.
 35. McDaniel, C.A. and B.M. Kard. 1994. The latest in termiticide degradation. *Pest Cont. Technol.* (May.)
 36. U.S. Dept. of Agriculture. Agricultural Marketing Service. 1994. Pesticide data program (PDP): Summary of 1992 data. Washington, D.C. (April.)
 37. Braun, H.E., R. Frank, and L.A. Miller. 1985. Residues of cypermethrin in milk from cows wearing impregnated ear tags. *Bull. Environ. Contam. Toxicol.* 35:61-64.
 38. Johansen, C.A. et al. 1983. Pesticides and bees. *Environ. Entomol.* 12:1513-1518.
 39. Taylor, K.S. et al. 1987. Impairment of a classical conditioned response of the honey bee (*Apis mellifera* L.) by sublethal doses of synthetic pyrethroid insecticides. *Apidol.* 18:243-252.
 40. Vorley, V.T. 1985. Spider mortality implicated in insecticide-induced resurgence of white planthopper and brown planthopper in Kedah, Malaysia. *Intern. Rice Res. Newsletter* 10:19020.
 41. Baatrup, E. and M. Bayley. 1993. Effects of the pyrethroid insecticide cypermethrin on the locomotor activity of the wolf spider *Pardosa amenata*: Quantitative analysis employing computer-automated video tracking. *Ecotoxicol. Environ. Safety* 26:138-152.
 42. Hassan, S.A. et al. 1988. Results of the fourth joint pesticide testing programme carried out by the IOBC/WPRS-Working Group "Pesticides and Beneficial Organisms." *J. Appl. Ent.* 105:321-329.
 43. Bostanian, N.J., A. Belanger, and I. Rivard. 1985. Residues of four synthetic pyrethroids and azinphos-methyl on apple foliage and their toxicity to *Amblyseius fallacis* (Acari: Phytoseiidae). *Can. Ent.* 117:143-152.
 44. Sandhu, S.S. 1987. Effect of insecticidal sprays on the plant and secondary pest inductions in Hirsutum cotton in Punjab. *Agric., Ecosys., Environ.* 19:169-176.
 45. Curtis, J.E. and P.A. Horne. 1995. Effect of chlorpyrifos and cypermethrin applications on nontarget invertebrates in a conservation-tillage crop. *J. Aust. Ent. Soc.* 34:229-231.
 46. Mizell, R.F. and D.E. Schiffhauer. 1990. Effects of pesticides on pecan aphid predators *Chrysoperla rufilabris* (Neuroptera: Chrysopidae), *Hippodamia convergens*, *Cycloneda sanguinea* (L.), *Olla v-nigrum* (Coleoptera: Coccinellidae), and *Aphelinus perpallidus* (Hymenoptera: Encyrtidae). *J. Econ. Entomol.* 83:1806-1812.
 47. Siegfried, B.D. 1993. Comparative toxicity of pyrethroid insecticides to terrestrial and aquatic insects. *Environ. Toxicol. Chem.* 12:1683-1689.
 48. Stephenson, R.R. 1982. Aquatic toxicology of cypermethrin. I. Acute toxicity to some freshwater fish and invertebrates in laboratory tests. *Aquatic Toxicol.* 2:175-185.
 49. Davies, P.E. and L.S.J. Cook. 1993. Catastrophic macroinvertebrate drift and sublethal effects on brown trout, *Salmo trutta*, caused by cypermethrin spraying on a Tasmanian stream. *Aquatic Toxicol.* 27:201-224.
 50. Roberts, B.L. and H.W. Dorrough. 1984. Relative toxicities of chemicals to the earthworm *Eisenia foetida*. *Environ. Toxicol. Chem.* 3:67-78.
 51. Pascual, J.A. and S.J. Peris. 1992. Effects of forest spraying with two application rates of cypermethrin on food supply and on breeding success of the blue tit (*Parus caeruleus*). *Environ. Toxicol. Chem.* 11:1271-1280.
 52. Bradbury, S.P. and J.R. Coats. 1989. Toxicokinetics and toxicodynamics of pyrethroid insecticides in fish. *Environ. Toxicol. Chem.* 8:373-380.
 53. Reddy, A.T.V. et al. 1991. Cypermethrin induced modifications in lipid metabolism of freshwater teleost, *Tilapia mossambica*. *Biochem. Intern.* 23:963-967.
 54. Ansari, B.A. and K. Kumar. 1988. Cypermethrin toxicity: Effect on the carbohydrate metabolism of the Indian catfish, *Heteropneustes fossilis*. *Sci. Total Environ.* 72:161-166.
 55. Philip, G.H., P.M. Reddy, and G. Sredevi. 1995. Cypermethrin-induced *in vivo* alterations in the carbohydrate metabolism of freshwater fish, *Labeo rohita*. *Ecotoxicol. Environ. Safety* 31:173-178.
 56. Muir, D.C.G., et al. 1994. Bioconcentration of pyrethroid insecticides and DDT by rainbow trout: uptake, depuration, and the effect of dissolved organic carbon. *Aquatic Toxicol.* 29:223-240.
 57. Coats, J.R. and N.L. O'Donnell-Jeffrey. 1979. Toxicity of four synthetic pyrethroid insecticides to rainbow trout. *Bull. Environ. Contam. Toxicol.* 23:250-255.
 58. Cripe, G.M. 1994. Comparative acute toxicities of several pesticides and metals to *Mysidopsis bahia* and postlarval *Penaeus duorarum*. *Environ. Toxicol. Chem.* 13:1867-1872.
 59. Clark, J.R. et al. 1989. Toxicity of pyrethroids to marine invertebrates and fish: A literature review and test results with sediment sorbed chemicals. *Environ. Toxicol. Chem.* 8:393-401.
 60. Mian, L. and M.S. Mulla. 1992. Effects of pyrethroid insecticides on nontarget invertebrates in aquatic ecosystems. *J. Agric. Entomol.* 9:73-98.
 61. McLeese, D.W., et al. 1980. Lethality of permethrin, cypermethrin, and fenvalerate to salmon, lobster and shrimp. *Bull. Environ. Contam. Toxicol.* 25:950-955.
 62. Megharaj, M., et al. 1987. Influence of cypermethrin and fenvalerate on a green algae and three cyanobacteria isolated from soil. *Ecotoxicol. Environ. Safety* 14:142-146.
 63. Tu, C.M. 1983. Effects of pyrethroid insecticide seed treatments on *Rhizobium japonicum* and its symbiotic relationship with, and growth of soybean. *J. Environ. Sci. Health B18*:369-378.
 64. Tu, C.M. 1991. Effect of some technical and formulated insecticides on microbial activities in soil. *J. Environ. Sci. Health B26*:557-573.
 65. Kara, M., et al. 1994. Cytogenetic effects of the insecticide cypermethrin on the root meristems of *Allium cepa* L. *Turk. J. Biol.* 18:323-331.
 66. Atale, A.S., et al. 1993. Mitodepressive and chromotoxic effects of some agrochemicals on chili. *J. Maharashtra Agric. Univ.* 18:30-31.
 67. Chapman, R.A. and C.R. Harris. 1981. Persistence of four pyrethroid insecticides in a mineral and an organic soil. *J. Environ. Sci. Health B16*:605-615.
 68. M.F. Legrand et al. 1991. Occurrence of 38 pesticides in various French surface and ground waters. *Environ. Technol.* 12:985-996.
 69. House, W.A. et al. 1991. The occurrence of synthetic pyrethroid and selected organochlorine pesticides in river sediments. In Walker, A. (ed.). *Pesticides in soils and water: Current perspectives*. Farnham, Surrey, U.K.: British Crop Protection Council.
 70. Yu, S.J. 1991. Insecticide resistance in the fall armyworm, *Spodoptera frugiperda* (J.E. Smith). *Pest. Biochem. Physiol.* 39:84-91.
 71. Kerns, D.L. and M.J. Gaylor. 1992. Insecticide resistance in field populations of the cotton aphid (Homoptera: Aphididae). *J. Econ. Entomol.* 85:1-8.
 72. Martinez-Cabrillo, J.L., et al. 1991. Responses of populations of the tobacco budworm (Lepidoptera: Noctuidae) from northwest Mexico to pyrethroids. *J. Econ. Entomol.* 84:363-366.
 73. Atkinson, T.H. et al. 1991. Pyrethroid resistance and synergism in a field strain of the German cockroach (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 84:1247-1250.
 74. Lemke, L.A., P.G. Koehler, and R.S. Patterson. 1989. Susceptibility of the cat flea (Siphonaptera: Pulicidae) to pyrethroids. *J. Econ. Entomol.* 82:839-841.
 75. *MSDS reference for crop protection chemicals*. 1992. New York: Chemical and Pharmaceutical Press.
 76. U.S. Dept. of Health and Human Services. Public Health Service. 1991. *Sixth annual report on carcinogens*. Summary. Research Triangle Park: National Institute of Environmental Health Sciences.
 77. U.S. Dept. of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. 1990. *Toxicological profile for ethylbenzene*. (November.)
 78. U.S. Dept. of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. 1993. *Toxicological profile for xylenes*. (October.)
 79. Sittig, M. 1991. *Handbook of toxic and hazardous chemicals and carcinogens*. 3rd edition. Vol. 2. Park Ridge, NJ: Noyes Publications. Pp. 1161-1162.