

● INSECTICIDE FACT SHEET

CYFLUTHRIN

Cyfluthrin is a relatively new insecticide that is classified as a synthetic pyrethroid because its chemical structure is a synthetic analog of naturally-occurring pyrethrins. (See Figure 1.) Many pesticide users and regulators agree with toxicologists who report that synthetic pyrethroids are economically successful because they have "a degree of potency not previously demonstrated in any class of insecticides,"¹ and are "generally recognized as safe to mammalian species."¹ However, a closer look at cyfluthrin reveals a variety of hazards associated with its use.

Cyfluthrin is a neurotoxin, with a mode of action similar to that of the organochlorine insecticide DDT. Acute exposures cause stinging skin, tremors, convulsions, decreased blood pressure, and labored breathing. Chronic exposure of laboratory animals to cyfluthrin has resulted in weight loss, kidney inflammation, vomiting, diarrhea, and a decrease in body temperature. Exposure through inhalation causes symptoms at very low doses; concentrations of as little as 150 parts per billion are enough to cause lethargy and a failure to gain weight.

Cyfluthrin also appears to affect reproduction. Rabbits exposed to cyfluthrin during pregnancy miscarried more frequently than unexposed rabbits. Synthetic pyrethroids as a class appear to disrupt androgen (male sex hormone) function. Consistent with this, cyfluthrin interferes with receptors that are part of this hormone system.

Cyfluthrin is highly acutely toxic to bees and fish. (Just one part per billion can kill some fish species.) Sublethal effects occur at even lower doses; less than one part per *trillion* caused adverse effects on juvenile minnows. Ecosystem-level tests have shown that cyfluthrin affects many organisms in pond ecosystems, including algae, zooplankton, nematodes, insects, and fish.

Cyfluthrin-containing insecticide products also have at least four ingredients other than cyfluthrin that are known to cause acute and chronic health hazards.

BY CAROLINE COX

Cylfluthrin (see Figure 1) was first registered for use in the United States in 1987.² It is used to kill unwanted insects in agriculture, in or around buildings, and on ornamental plants.^{2,3}

In California, where pesticide use reporting is more comprehensive than in other states, the amount used in agriculture is much smaller than that used for other purposes.⁴ (See Figure 2.) However, agricultural uses are significant: about 10 percent of the U.S. cotton acreage (over a million acres) is treated with cyfluthrin, as is about 60 percent of the U.S. pear acreage.^{5,6} (See Figure 3.)

A recent survey of household pesticide use conducted for the U.S. Environmental Protection Agency (EPA) showed that cyfluthrin

use is extensive. While cyfluthrin was used by less than 2 percent of the households surveyed, this represented almost 40 million applications annually in the U.S. The bulk of these treatments (over 33 million annually) were made indoors.⁷ (See Figure 4.)

Mode of Action

Many synthetic pyrethroids, including cyfluthrin, are complex molecules and have a variety of three-dimensional configurations called isomers. All of the isomers, however have the same mode of action.⁸

Like all synthetic pyrethroids, cyfluthrin is a neurotoxin. It causes hyperexcitation of the nervous system, which leads to convulsions and ultimately death.⁹ The peripheral nervous system appears to be the most vulnerable to synthetic pyrethroids. The notorious organochlorine insecticide DDT has structural similarities (see Figure 1), has a "broadly similar mode of action,"¹⁰ and acts on "the same, or a very similar site"⁸ in the nervous system.

On a biochemical level, cyfluthrin has a

complex mode of action and affects normal nerve function in several ways. It induces alterations in nerve membranes, causing abnormal sodium and potassium flows.¹¹ This results in the repetitive discharges from the neurons, causing convulsions and also blockage of further nerve impulses.⁸ Cyfluthrin also affects calcium concentrations in nervous tissue by inhibiting an enzyme involved in calcium transport. This in turn increases the amount of the neurotransmitter acetylcholine released at the junction between nerves.¹² In addition, two receptors found in nervous tissue, the gamma-aminobutyric acid receptors and the peripheral benzodiazepine receptors, are inhibited by cyfluthrin. Inhibition of either of these receptors can cause convulsions.^{13,14}

Acute Toxicity

The most common symptom of acute exposure to cyfluthrin (and other synthetic pyrethroids) is paresthesia (a stinging, burning, itching, and tingling of the skin particularly common on the face), progressing to numb-

Caroline Cox is JPR's editor.

Figure 1
Cyfluthrin and Other Chemically-Related Insecticides

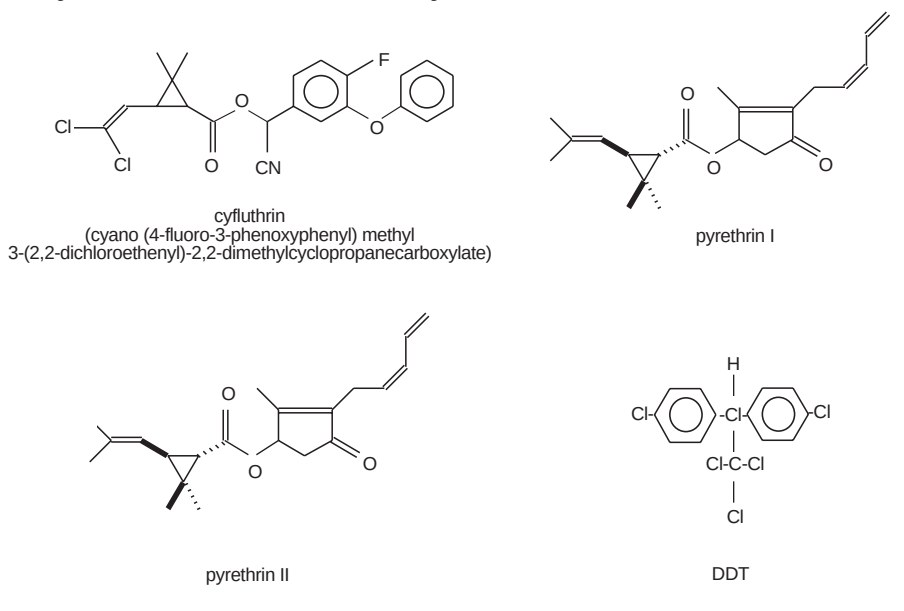
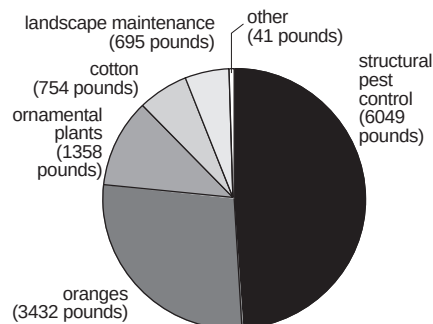


Figure 2
Cyfluthrin Uses in California (1991)



California Dept. of Pesticide Regulation.
Information Services Branch. 1993. Summary of
pesticide use report data: Annual 1991. Indexed
by chemical. Sacramento, CA (January 25.)

In California, major uses of cyfluthrin are on orange trees and for structural pest control.

ness.¹⁵ This is not an allergic or sensitizing reaction, although one cyfluthrin-containing product (Baythroid C2 EC; also called Tempo 2 and Baythroid 240) is a skin sensitizer when tested on guinea pigs.¹¹

Acute oral toxicity: Large doses of cyfluthrin cause excess salivation, irritability, tremors, incoordination, convulsions, and a fall in blood pressure.¹⁵ Larger doses, greater than 647-695 milligrams per kilogram (mg/kg) of body weight, cause death in rats.¹¹ Mice die from smaller doses (291-609 mg/kg).² In some tests, the LD₅₀ (the dose that will kill half of the population of test animals) is up to forty times smaller (16 mg/kg).¹⁶ If humans are as susceptible to cyfluthrin, the amount required to cause death in an average-sized (60 kg) adult could be from 0.03 (based on the most sensitive test) to 1.5 ounces (based on the first tests cited).

Like many pyrethroids, the acute toxicity of cyfluthrin is negatively related to temperature, so that higher toxicity is found at low temperatures. For example, cyfluthrin is 10 times more acutely toxic to cockroaches at 20°C (68°F) than it is at 30°C (86°F).¹⁷

Inhalation toxicity: Cyfluthrin is also acutely toxic when inhaled. Exposure of laboratory animals to 0.7 - 0.9 mg per liter of air

caused convulsions, excess salivation, incoordination, decreased activity, and death.¹¹ Other studies of laboratory animals who have inhaled cyfluthrin noted symptoms of labored breathing, reduced movement, nasal discharge, and ungroomed fur.¹⁸

Eye irritation: Cyfluthrin causes "mild irritation" of rabbit eyes in laboratory tests. Several cyfluthrin-containing products are more irritating to eyes. Baythroid 20% WP (similar to Tempo 20% WP) causes lesions of the conjunctive membrane, swelling around the cornea, and a discharge for up to 7 days after exposure.¹⁹ Baythroid C2 EC (Tempo 2) caused opaque corneas, lesions in the iris, and swelling around the cornea for 21 days after exposure.¹¹ According to the manufacturer, exposure to Tempo 2 EC may cause "severe eye irritation."²⁰

Chronic Toxicity

Long-term exposure of laboratory animals to cyfluthrin has caused adverse effects that range from diarrhea to reduced body temperature and weight loss. For example, in rats fed cyfluthrin for two weeks, weight loss, slight brain hemorrhages, and death of muscle fibers was observed. Cyfluthrin-contaminated diets over longer periods (four weeks) caused

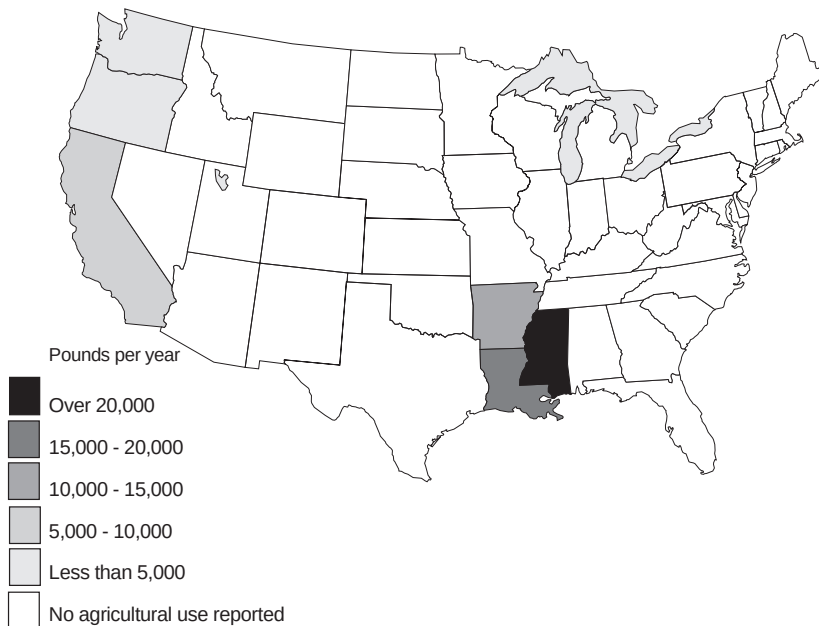
weight loss, changes in several blood chemistry parameters, and changes in liver weights. In a feeding study that lasted for two years, weight loss was also noted, as well as kidney inflammation in females. Dogs fed cyfluthrin for six months suffered from vomiting and diarrhea; in a year-long study vomiting, diarrhea, and weight loss were noted.¹⁶

Long-term inhalation of cyfluthrin can also cause adverse effects. In studies with rats, inhalation of cyfluthrin for three weeks caused a decrease in body temperature, weight loss, and changes in the weight of the liver and spleen. Inhalation over a three month period at the alarmingly low rate of 150 parts per billion (ppb), also caused a decrease in body temperature and a failure to gain weight at a normal rate.¹⁶

Neurotoxicity: Acute exposure to cyfluthrin can cause chronic symptoms of damage to the nervous system. For example, a single acute exposure of hens to cyfluthrin caused disturbed behavior, prostration, and a limping gait over two weeks later. Multiple acute exposures over a one or three week period caused "delayed neurotoxic signs and moderate fiber alterations in the sciatic nerve."¹¹

Chronic exposures at lower levels can also cause chronic symptoms of nervous system damage. Rats exposed to cyfluthrin through

Figure 3
Agricultural Uses of Cyfluthrin in the United States



Sources:

California Dept. of Pesticide Regulation. Information Services Branch. 1993. Summary of pesticide use report data: Annual 1991. Indexed by chemical. Sacramento, CA (January 25.)
U.S. Dept. of Agriculture. National Agricultural Statistics Service. Agricultural Statistics Board. 1994. Agricultural chemical usage: 1993 field crops summary. Washington, D.C.: (March).
U.S. Dept. of Agriculture. National Agricultural Statistics Service. Agricultural Statistics Board. 1992. Agricultural chemical usage: 1991 fruit and nuts summary. Washington, D.C.: (June).

Most of the cyfluthrin used by U.S. agriculture is used in cotton-growing areas. Pears in the Pacific Northwest are also commonly treated with cyfluthrin.

inhalation showed chronic symptoms of neurotoxicity at low doses. Inhaled concentrations of 150 ppb over a three month period caused the rats to exhibit unkempt fur, lethargy, and agitation. Rats fed larger amounts of cyfluthrin for two weeks showed disturbed behavior, uncoordinated walking, excess salivation, and degeneration of several nerves. Dogs fed cyfluthrin for six months developed a stiff gait, incoordination, and arched backs.¹⁶

Reproductive Effects

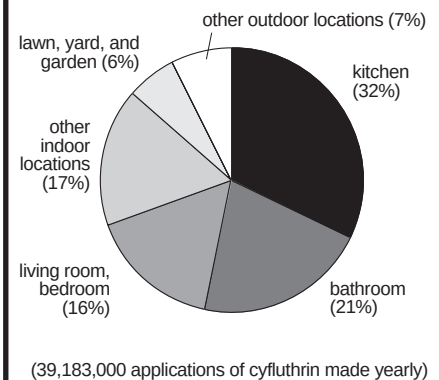
In pregnant rabbits, feeding of cyfluthrin causes both miscarriages and resorption of fetuses. In a three-generation study of rats, feeding of cyfluthrin caused pups to have "decreased viability" and decreased weight.¹⁶

Cyfluthrin may also have more subtle effects on the ability of humans and other animals to reproduce. Recent (1990) research documented the ability of six synthetic pyre-

throids, as well as the naturally occurring pyrethrins, to bind with androgen (a male sex hormone) receptors, and disrupt normal androgen function.²¹ These kinds of effects, broadly called endocrine disruption, have been linked to a variety of health problems, including breast cancer, testicular cancer, and decreased sperm counts. The researchers "advise protection from any form of contact or ingestion of the pyrethroids in order to prevent any undesirable effects on the human reproductive system."²¹ While cyfluthrin was not one of the compounds included in this study, the results are consistent with research showing that cyfluthrin binds with peripheral benzodiazepine (PBZ) receptors. PBZ receptors are found in high concentration in the testes and appear important in "hormonal responsiveness."¹⁴

Carcinogenicity and

Figure 4
Household Uses of Cyfluthrin in the United States



Whitmore, R.W., J.E. Kelly, and P.L. Reading. 1992. National home and garden pesticide use survey: Final report, Volume 1. Executive summary, results, and recommendations. Research Triangle Park, NC: Research Triangle Institute.

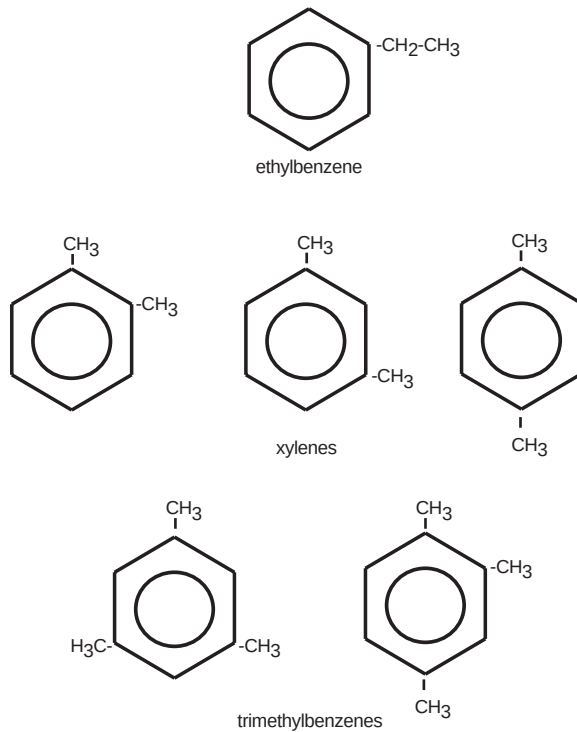
About 40 million household applications of cyfluthrin are made each year, mostly in the kitchen and bathroom.

Mutagenicity

The tests submitted in support of cyfluthrin's registration "indicate that cyfluthrin is not an oncogen" (does not cause cancer) and is "not considered to be mutagenic" (having the ability to damage genetic material).² It is not known whether cyfluthrin-containing products are carcinogenic or mutagenic because tests of the products as they are used (including all ingredients) are not required by EPA. Laboratory tests of some of the ingredients in these products other than cyfluthrin show that they are associated with increases in the incidence of some kinds of cancer. For example, crystalline silica causes increases in lung cancer in laboratory animals and in exposed workers and also induces lymphoma when injected into test animals.²² Xylenes (see Figure 5) have caused increased rates of leukemia in workers who inhaled this solvent. Xylenes also seem to be a cocarcinogen and increase the number of skin cancers caused by other carcinogens in laboratory animals.²³ Female rats exposed to ethylbenzene (see Figure 5) developed an increased number of malignant tumors.²⁴ (For more information, see "Secret 'Inert' Ingredients," p. 33.)

Human Exposure

Figure 5
"Inert" Ingredients in Cyfluthrin-containing Insecticides



Ethylbenzene, xylenes, and trimethylbenzenes are solvents used in cyfluthrin-containing products. They are all called trade secrets by the manufacturer.

People are exposed to cyfluthrin by eating contaminated food, from residues persisting after indoor or outdoor applications, and through making applications of cyfluthrin-containing products.

Food residues: Australian researchers monitored residues of cyfluthrin applied to stored wheat over a year-long period at a variety of temperature and humidity conditions. They found that much of the cyfluthrin persisted for the entire length of the study (52 weeks). The estimated half-life of the cyfluthrin varied from 23 to 114 weeks depending on temperature, humidity, and which isomer of cyfluthrin was studied.²⁵ A second study of cyfluthrin used on stored grains found that residues did not "decrease significantly" with time. In addition, losses during milling and baking were small.²⁶

A study of cyfluthrin residues on strawberries found that residues persisted for the entire length of the study (21 days after spraying).²⁷

Contamination of food with residues of cyfluthrin has made headlines recently because of some fraudulent tests conducted by Craven Laboratories of Austin, Texas. Craven contracted with a number of pesticide manufacturers to provide data on the persistence of food residues of almost 30 pesticide products, including cyfluthrin.²⁸ The data is required by EPA in order to set tolerances (allowable food contamination levels). In March 1994, Craven, its owner, and fourteen employees were sentenced to jail terms (5 years for Craven's owner), fines (15.5 million dollars), and restitution (3.7 million dollars) after pleading guilty to charges that the company had falsified residue tests.^{29,30}

Persistence (outdoor): Residents whose yards or house foundations are treated with cyfluthrin are often concerned about how long they can expect residues to remain. This is a difficult question to answer in a simple way because persistence depends on a variety of conditions. However, under laboratory con-

ditions, cyfluthrin residues in soil persisted up to 120 days, with an estimated half-life up to 75 days.³¹ EPA reports a half-life of between 56 and 63 days.²

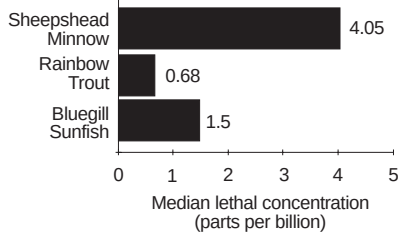
Persistence (indoor): Like persistence in soil, persistence indoors also varies considerable depending on conditions. A study that measured cyfluthrin residues following an aerosol (spray-can) application inside an apartment found that cyfluthrin persisted during the entire length of the study (60 hours). Cyfluthrin residues were constant throughout the study, so that no estimate could be made of its persistence.³² Another study found cyfluthrin-treated dormitory rooms had floor residues for three days following treatment.³³

Occupational exposure: Inhalation of cyfluthrin over a several month period caused adverse effects at lower doses than any of the other tests required for registration of cyfluthrin. As a result, EPA has been concerned about the potential exposure of pest control applicators who routinely apply cyfluthrin. In 1987, just prior to registering cyfluthrin, EPA estimated risks to pest control operators and concluded that there was not an adequate margin of safety for applicators who used cyfluthrin over a three month period. EPA's Exposure Assessment Branch suggested that exposures could be reduced by requiring applicators to wear respirators when using cyfluthrin.³⁴ However, this protective clothing was never required. Instead, EPA revised its estimates of how much cyfluthrin an applicator might use (both the number of apartments treated and the amount of cyfluthrin used per apartment) in order to achieve an adequate margin of safety.³⁵

The cyfluthrin product for which this risk assessment was done, Tempo 2, was also registered for use in hospitals, nursing homes, schools, restaurants, and food handling establishments that, according to EPA's Toxicology Branch, "may pose special exposure scenarios." The toxicologists did not believe that the pest control operator use in apartments would "necessarily represent a 'worst case' exposure scenario for the many uses listed on the label."³⁴ However, EPA appears to have taken no further action to remedy these problems.³⁵

Another concern about occupational exposure comes from studies of how well laun-

Figure 6
Acute Toxicity of Cyfluthrin to Fish



Source: U.S. EPA. Office of Pesticides and Toxic Substances. Office of Pesticide Programs. 1987. Pesticide fact sheet: Cyfluthrin. No. 164. Washington, D.C. (December 30.)

Cyfluthrin can kill fish at concentrations as low as one part per billion.

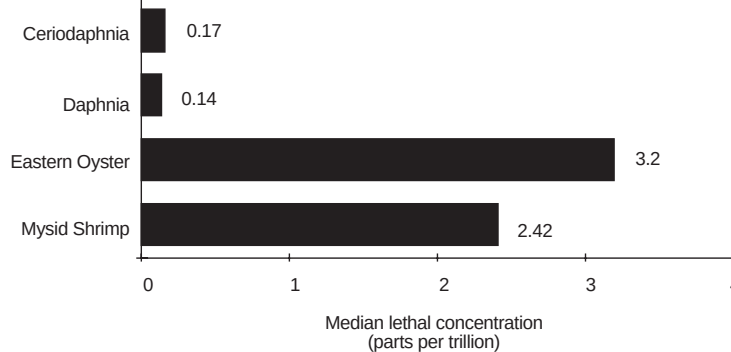
dering removes cyfluthrin residues from fabric. Depending on detergent type, fabric finish, and the type of cyfluthrin product used, between 5 and 100 percent of cyfluthrin residues were *not* removed by machine washing. The researchers state, "across all specimens as much as 90 percent ... of pesticide remained after washing. Although laundering made a difference in pyrethroid residue, it was not particularly successful."³⁶ This means pest control applicators who apply cyfluthrin may have a difficult time removing contamination from their work clothing. A second study found laundering to be somewhat more successful at removing cyfluthrin from fabric, but still found that between 20 and 30 percent of the cyfluthrin contamination was not removed.³⁷

Effects on Nontarget Organisms

Cyfluthrin affects a variety of living things in addition to the unwanted insects it is designed to kill. Such effects have been demonstrated for honey bees, spiders, fish, birds, and aquatic invertebrates. In addition, studies of model aquatic ecosystems have shown that cyfluthrin has the potential to disrupt normal ecosystem processes.

Bees: Cyfluthrin is highly toxic to bees. The median lethal dose (LD₅₀) is less than 0.04 micrograms (a millionth of a gram) per bee.³⁸ In several field tests, cyfluthrin was more acutely toxic to bees the day after it had been applied than it was at the time of application.³⁹ Cyfluthrin also appears to have sublethal effects on bees; treated bees learn at a slower rate (using an odor training test) and never achieve as high a level of

Figure 7
Acute Toxicity of Cyfluthrin to Aquatic Animals



Sources:

U.S. EPA. Office of Pesticides and Toxic Substances. Office of Pesticide Programs. 1987. Pesticide fact sheet: Cyfluthrin. No. 164. Washington, D.C. (December 30.)

Mokry, L.E. and K.D. Hoaglund. 1990. Acute toxicities of five synthetic pyrethroid insecticides to *Daphnia magna* and *Ceriodaphnia dubia*. *Environ. Toxicol. Chem.* 9:1045-1051.

Cyfluthrin kills other aquatic animals at concentrations even lower (less than a part per trillion for some species) than those that kill fish.

positive responses as do untreated bees. Cyfluthrin appears to have stronger effects on learning than do several other common synthetic pyrethroids.⁴⁰

Other Beneficial Arthropods: Kentucky entomologists have studied the impact of cyfluthrin on predators whose prey includes two turf pest species, the Japanese beetle and the fall armyworm. A single application of cyfluthrin reduced the abundance of predatory spiders, and effects persisted for five weeks following treatment.⁴¹

Birds: High exposures are required to kill the bird species on which cyfluthrin has been tested and EPA has classified cyfluthrin as "practically nontoxic"³⁸ to both upland game birds and waterfowl. However, several reproductive effects seem worthy of concern. In mallard ducks, "statistically significant reduction in production of normal hatchlings"³⁸ was observed at all levels tested. "Statistically significant impairment of reproduction"³⁸ was observed in bobwhite quail. In addition, "eggshell thinning was statistically significant at all levels tested."³⁸ Although the eggshell thinning study seems serious, particularly because of the significant consequences of eggshell thinning caused by exposure to DDT (whose mode of action is similar to that of cyfluthrin), it appears that little has been done to follow up on these studies. A second eggshell thinning study was submitted which found no thinning at any dose level, but NCAP is aware of no explanation from EPA for the inconsistent

results.³⁸

Fish: Cyfluthrin is also very highly toxic to fish. Median lethal concentrations (LC₅₀s; the concentration required to kill half of a population of test animals) are close to one part per billion for the fish species that have been tested. (See Figure 6.) As might be expected, sublethal effects occur at much lower doses; in the sheepshead minnow exposures of less than one tenth as much as the lethal dose, 84 parts per *trillion* (ppt), reduced survival of juveniles and effects were measured on juvenile rainbow trout with even lower exposures, 18 ppt.³⁸ In one study, effects on juvenile fathead minnows were measured at the startlingly low concentration of 0.14 ppt.⁴² Cyfluthrin is estimated to bioconcentrate (concentrate in animals whose diets are higher up the food chain) by a factor of over 800 times,³⁸ thus increasing its potential effects on fish.

Other aquatic invertebrates: Cyfluthrin is very highly toxic to a variety of aquatic organisms. The median lethal dose for water fleas (*Daphnia magna* and *Ceriodaphnia dubia*) was less than 1 ppt;⁴³ for mysid shrimp was less than 3 ppt;² and for Eastern oyster was about 3 parts per billion.² (See Figure 7.) Sublethal effects occurred at lower concentrations. For example, reproductive success of mysid shrimp was affected at 1.25 ppt,³⁸ and uncoordinated swimming was observed in water fleas at concentrations below the LC₅₀ of 1 ppt.⁴³

Ecosystem-level effects: EPA has recently (1992) reviewed a study designed to measure any effects of cyfluthrin on aquatic ecosystems. The study involves the use of mesocosms, small artificial ponds into which are introduced a variety of plankton, aquatic insects, and fish. While EPA found many deficiencies in the study, including the contamination of ponds that were supposed to serve as control (untreated) mesocosms, the study does point out how cyfluthrin can impact an entire ecosystem. Cyfluthrin affected "the majority of the lower tiers of the ecosystem": During most of the study, treated ponds had a lower weight of phytoplankton (algae) than did untreated ponds, and by the end of the study abundances were also lower. Zooplankton (microscopic animals) were also affected: some species were less abundant in treated ponds, while their competitors (other species of zooplankton eating the same kinds of food) increased in abundance. Nematodes increased in treated ponds, while diversity of surface-dwelling insects decreased. These effects were evident at concentrations in the water in the parts per trillion range. The study also provides evidence that these effects "cascaded throughout the pond ecosystem" and are important to the larger organisms. Fish biomass in untreated ponds was greater than treated ponds "at all test doses" and fish weight gain was "markedly greater" in untreated ponds.⁴²

Resistance

Insect resistance, the ability of unwanted insects to tolerate exposure to an insecticide in amounts that would be lethal to a typical individual, is an increasing problem. Over 500 insect species, including "most of the economically important species" have developed resistance to at least one insecticide and twelve economically important insect pests have developed resistance to nearly all available insecticides. Synthetic pyrethroids as a class have played a prominent role in recent discussions of resistance because resistance to pyrethroids has developed quickly and many insects that are resistant to other classes of insecticides easily evolve pyrethroid resistance.⁴⁴

Resistance to cyfluthrin specifically has been documented in the spotted tentiform leafminer (a pest of apples),⁴⁵ the Egyptian cotton leafworm (a pest of cotton),⁴⁶ flour

beetles (a stored products pest),⁴⁷ the German cockroach (a household pest),^{48,49} the cotton aphid (a cotton pest),⁵⁰ the tobacco budworm (a pest on a variety of crops),^{51,52} and the cat flea (a mammal pest).⁵³ In some cases, the degree of resistance is astonishing. For example, cockroaches from an apartment in Gainesville, Florida were found to be almost 90 times as resistant to cyfluthrin as a

"Recent (1990) research documented the ability of six synthetic pyrethroids ... to bind with androgen (a male sex hormone) receptors, and disrupt normal androgen function. ... The researchers 'advise protection from any form of contact or ingestion of the pyrethroids in order to prevent any undesirable effects on the human reproductive system.'"

susceptible laboratory strain. (The apartment had been treated repeatedly with cypermethrin, another synthetic pyrethroid.) The researchers warned that this "entire class of compounds may be rendered useless in a short time."⁴⁸

Secret "Inert" Ingredients

All cyfluthrin-containing insecticide products contain ingredients other than cyfluthrin that are called trade secrets by their manufac-

turers and classified as "inert" ingredients by EPA. However, these ingredients are neither biologically, toxicologically, or chemically inert. "Inerts" make up 75 percent of Baythroid 2⁵⁴ and Tempo 2 EC,²⁰ and 80 percent of Tempo 20% Wettable Powder⁵⁵ is "inert." The following "inert" ingredients have been identified on the material safety data sheets produced for at least one cyfluthrin-containing product:

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.²²

Xylenes are solvents. They cause nose and throat irritation, 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 incidence of cleft palate, decreased fetal weight. Xylene inhalation has been associated with an increased frequency of leukemia in solvent-exposed workers. In addition, it may be a cocarcinogen; exposure to xylenes enhanced the number of skin cancers caused by other carcinogens.²³

Ethylbenzene is another solvent. It causes throat irritation, eye irritation, damage to liver and kidneys, dizziness, and incoordination in humans and/or laboratory animals. 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.²⁴

Trimethylbenzenes are highly volatile solvents that can cause skin and eye irritation, nervousness, tension, bronchitis, disruptions of the ability of blood to clot, headaches, fatigue, dizziness, and loss of consciousness.⁵⁶ ♣

References

1. Bradbury, S.P. and J.R. Coats. 1989. Comparative toxicology of the pyrethroid insecticides. *Rev. Environ. Cont. Toxicol.* 108:134-177.
2. U.S. EPA. Office of Pesticides and Toxic Substances. Office of Pesticide Programs. 1987. Pesticide fact sheet: Cyfluthrin. No. 164. Washington, D.C. (December 30.)
3. *Farm Chemicals '92*. 1992. Willoughby, OH: Meister Publishing Company.
4. California Dept. of Pesticide Regulation. Information Services Branch. 1993. Summary of pesticide use report data: Annual 1991. Indexed by chemical. Sacramento, CA (January 25.)
5. U.S. Dept. of Agriculture. National Agricultural Statistics Service. Agricultural Statistics Board. 1994. *Agricultural chemical usage: 1993 field crops summary*. Washington, D.C.: (March).
6. U.S. Dept. of Agriculture. National Agricultural Statistics Service. Agricultural Statistics Board. 1992. *Agricultural chemical usage: 1991 fruit and nuts summary*. Washington, D.C.: (June).
7. Whitmore, R.W., J.E. Kelly, and P.L. Reading. 1992. *National home and garden pesticide use survey: Final report, Volume 1*. Executive summary, results, and recommendations. Research Triangle Park, NC: Research Triangle Institute.
8. Cremllyn, R.J. 1991. *Agrochemicals: Preparation and mode of action*. Chichester, U.K.: John Wiley & Sons. Pp.68-69.
9. Corbett, J.R., K.W. Wright, and A.C. Baillie. 1984. *The biochemical mode of action of pesticides*. Second edition. London, U.K.: Academic Press. p. 151.
10. Corbett, J.R., K.W. Wright, and A.C. Baillie. 1984. *The biochemical mode of action of pesticides*. Second edition. London, U.K.: Academic Press. p. 157.
11. U.S. EPA. Office of Pesticides and Toxic Substances. 1986. The review of toxicology data in support of the registration of Baythroid 240 ornamental pyrethroid insecticide Tempo 2. Memo from J.E. Whalan, Hazard Evaluation Division, to George LaRocca, Registration Division. Washington, D.C. (August 18.)
12. Al-Rajhi, D.H. 1990. Properties of $\text{Ca}^{+2} + \text{Mg}^{+2}$ - ATPase from rat brain and its inhibition by pyrethroids. *Pest. Biochem. Physiol.* 37:116-120.
13. Ramadan, A.A. et al. 1988. Action of pyrethroids on GABA receptor function. *Pest. Biochem. Physiol.* 32:97-105.
14. Ramadan, A.A. et al. 1988. Actions of pyrethroids on the peripheral benzodiazepine receptor. *Pest. Biochem. Physiol.* 32:106-113.
15. Morgan, D.P. 1989. *Recognition and management of pesticide poisonings*. Washington, D.C.: U.S. EPA. Office of Pesticide Programs. Health Effects Division.
16. U.S. EPA. Office of Pesticide Programs. 1989. "Tox one-liners": Cyfluthrin. Washington, D.C. (June 28.)
17. Wadleigh, R.W. et al. 1991. Effect of temperature on the toxicities of ten pyrethroids to German cockroach. (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 84(5):1433-1436.
18. Pauluhn, J., et al. 1988. Methodological aspects of the determination of the acute inhalation toxicity of spray-can ingredients. *J. Appl. Toxicol.* 8(6):431-437.
19. U.S. EPA. Office of Pesticides and Toxic Substances. 1987. Review of acute toxicology data in support of the registration of Tempo 20% Wettable Powder for use in food handling establishments. Memo from J.E. Whalan, Hazard Evaluation Division, to George LaRocca, Registration Division. Washington, D.C. (February 24.)
20. Miles Inc. Agriculture Division. 1991. Material Safety Data Sheet: Tempo 2EC. Kansas City, MO. (January 30.)
21. Eil, C. and B.C. Nisula. 1990. The binding properties of pyrethroids to human skin fibroblast androgen receptors and to sex hormone binding globulin. *J. Steroid Biochem.* 35(3/4):409-414.
22. 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.
23. U.S. Dept. of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. 1993. *Toxicological profile for xylenes*. (October.)
24. U.S. Dept. of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. 1990. *Toxicological profile for ethylbenzene*. (November.)
25. Noble, R.M. and D.J. Hamilton. 1985. Stability of cypermethrin and cyfluthrin on wheat and storage. *Pestic. Sci.* 16:179-185.
26. Dicke, W., H.-D. Ocker, and H.-P. Thier. 1988. Rückstandsanalyse von pyrethroid-insektiziden in getreide, mahlzerzeugnissen und brot. *Z. Lebensm. Unters. Forsch.* 186:125-129.
27. McEwen, F.L. 1986. Residues of synthetic pyrethroid insecticides on horticultural crops. *Pestic. Sci.* 17:150-154.
28. CRC Press. 1991. EPA lists 14 more pesticides linked to possibly faulty data. *Pesticide & Toxic Chemical News* (August 7): 8-9.
29. U.S. EPA. Communications, Education, and Public Affairs. 1993. Craven Laboratories case concludes with guilty pleas for falsifying pesticide tests. Press Advisory. Washington, D.C. (December 17.)
30. U.S. EPA. Communications, Education, and Public Affairs. 1994. Craven Laboratories, owner, and 14 employees sentenced for falsifying pesticide tests. Press Advisory. Washington, D.C. (March 4.)
31. Shehata, A.F., et al. 1987. Some factors influencing persistence, hydrolysis, downward movement and leachability of cyfluthrin in Egyptian soils. *Annals Agric. Sci. (Fac. Agric., Ain Shams Univ., Cairo, Egypt)* 32(3):1677-1687.
32. Class, T.J. and J. Kintrop. 1991. Pyrethroids as household insecticides: analysis, indoor exposure and persistence. *Fresenius J. Anal. Chem.* 340:446-453.
33. Stout, D.M., C.G. Wright, and R.B. Leidy. The determination of cyfluthrin in air and on surfaces. *Abs. Papers Amer. Chem. Soc.* 207: AGRO #36.
34. U.S. EPA. Office of Pesticides and Toxic Substances. 1987. Registration of Tempo™ 2 (containing cyfluthrin) and risk assessment of pest control officer (PCO) use in buildings. Memo from J.E. Whalan, Hazard Evaluation Division, to G. LaRocca, Registration Division. Washington, D.C. (August 27.)
35. U.S. EPA. Office of Pesticides and Toxic Substances. 1987. Revised risk assessment of pest control officer (PCO) use of Tempo™ 2 insecticide in buildings. Memo from J.E. Whalan, Hazard Evaluation Division, to G. LaRocca, Registration Division. Washington, D.C. (November 10.)
36. Laughlin, J., K. Newburn, and R.E. Gold. 1991. Pyrethroid insecticides and formulations as factors in residues remaining in apparel fabrics after laundering. *Bull. Environ. Cont. Toxicol.* 47:355-361.
37. 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.
38. U.S. EPA. Office of Pesticide Programs. Ecological Effects Branch. 1989. EEB review: Proposed §18 for use on pears and interplanted apples. Washington, D.C. (January 30.)
39. Estes, B.J. et al. 1992. Residual life and toxicity to honey bees (Hymenoptera: Apidae) of selected insecticides applied to cotton in Arizona. *J. Econ. Entomol.* 85(3):700-709.
40. Taylor, K.S., Waller, G.D., and L.A. Crowder. 1987. Impairment of a classical conditioned response of the honey bee (*Apis mellifera* L.) by sublethal doses of synthetic pyrethroid insecticides. *Apidologie* 18(3):243-252.
41. Terry, L.A., D.A. Potter, and P. Spicer. 1993. Insecticides affect predatory arthropods and predation on Japanese beetle (Coleoptera: Scarabaeidae) eggs and fall armyworm (Lepidoptera: Noctuidae) pupae in turfgrass. *J. Econ. Entomol.* 87:872-877.
42. U.S. EPA. Office of Prevention, Pesticides and Toxic Substances. 1992. Completion of the review of cyfluthrin mesocosm study. Memo from D.J. Urban, Environmental Fate and Effects Division, to G. LaRocca, Registration Division. Washington, D.C. (July 29.)
43. Mokry, L.E. and K.D. Hoaglund. 1990. Acute toxicities of five synthetic pyrethroid insecticides to *Daphnia magna* and *Ceriodaphnia dubia*. *Environ. Toxicol. Chem.* 9:1045-1051.
44. Georgiou, G.P. 1990. Overview of insect resistance. In Green, M.B., H.M. LeBaron, and W.K. Moberg (eds.). *Managing resistance to agrochemicals: From fundamental research to practical strategies*. p. 18-41. ACS Symposium Series #421.
45. Marshall, D.B. and D.J. Pree. 1986. Effects of pyrethroid insecticides on eggs and larvae of resistant and susceptible populations of spotted tentiform leafminer. *Can. Ent.* 118:1123-1130.
46. Lagadic, L. et al. 1993. Pharmacokinetics of cyfluthrin in *Spodoptera littoralis* (Boisd.). I. In vivo distribution and elimination of [^{14}C] cyfluthrin in susceptible and pyrethroid-resistant larvae. *Pest. Biochem. Physiol.* 45:105-115.
47. Reidy, G.F., et al. 1990. Increased glutathione s-transferase activity and glutathione content in an insecticide-resistant strain of *Tribolium castaneum* (Herbst). *Pest. Biochem. Physiol.* 36:269-276.
48. Atkinson, T.H. et al. 1991. Pyrethroid resistance and synergism in a field strain of the German cockroach (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 84(4):1247-1250.
49. Cochran, D.G. 1991. Extended selections for pyrethroid resistance in the German cockroach (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 84(5):1412-1416.
50. Kerns, D.L. and M.J. Gaylor. 1992. Insecticide resistance in field populations of the cotton aphid (Homoptera: Aphididae). *J. Econ. Entomol.* 85(1):1-8.
51. Martinez-Carrillo, J.L., L.P. Schouest, Jr., and T.A. Miller. 1991. Responses of populations of the tobacco budworm (Lepidoptera: Noctuidae) from northwest Mexico to pyrethroids. *J. Econ. Entomol.* 84(2):363-366.
52. Martinez-Carrillo, J.L. 1991. Monitoreo de resistencia a piretroides en gusano tabacalero *Heliothis virescens* en el noroeste de Mexico. *Southwestern Entomologist* (Suppl. 15):59-67.
53. Lemke, L.A., P.G. Koehler, and R.S. Patterson. 1989. Susceptibility of the cat flea (Siphonaptera: Pulicidae) to pyrethroids. *J. Econ. Entomol.* 82(3):839-841.
54. Mobay Corporation. Agricultural Chemicals Division. 1991. Material Safety Data Sheet: Baythroid 2. Kansas City, MO.
55. Miles Inc. Agriculture Division. 1991. Material Safety Data Sheet: Tempo 20% Wettable Powder. Kansas City, MO. (January 30.)
56. Sittig, M. 1991. *Handbook of toxic and hazardous chemicals and carcinogens*. 3rd edition. Park Ridge, NJ: Noyes Publications. v.2 p.1161-1162.