A LITTLE LESS GREEN?

Are Pyrethroid Insecticides Dangerous?

Studies challenge the benign image of pyrethroid insecticides

By Janet Raloff

Rachel Carson turned the pest-control world upside down in 1962. In Silent Spring, she documented how long-lived organochlorine pesticides, most notoriously DDT, were not only ridding croplands of insects, streets of mosquitoes, and homes of spiders but also exacting a high toll on songbirds and other nontargeted species. The chemicals' broad-spectrum potency and resistance to breakdown, advantages in their use against pests, emerged as hazards.

Shortly after the publication of Carson's book, industrialized countries began phasing out such persistent organic pollutants, or POPs. There's now a United Nations treaty aiming at their global elimination (SN: 11/8/03, p. 301: Available to subscribers at http://www.sciencenews.org/articles/20031108/note14.asp).

In the wake of organochlorine pesticides came organophosphate agents. Although these agents are highly effective, their toxicity to nontarget animals -- including people -- echoed the perils of DDT. Regulators responded, and by the middle 1990s, once-popular members of this class of agents -- such as dursban, malathion, and chlorpyrifos -- were being phased out or severely restricted in their uses.

In recent years, farmers and others have increasingly turned to products based on pyrethrins, chemicals made by certain members of the chrysanthemum family. Farmers in various parts of the world have for millennia used preparations from these flowers to protect crops from insects. Since the 1960s, manufacturers have produced synthetic analogs -- called pyrethroids -- of the herbal products' active ingredients.

Although pyrethroids have greater toxicity to insects and somewhat more resistance to breakdown than their natural counterparts do, studies have demonstrated that these synthetic chemicals pose little risk to most vertebrates, from songbirds to people.

Pyrethroids stand poised to overtake organophosphate insecticides for farm use and are already the leading insecticides sold to homeowners. However, emerging data show that even pyrethroids can pose serious environmental hazards. At concentrations found in streams, the chemicals can kill beneficial insects and crustaceans and may even be acting -- below the radar screen -- to poison fish and lizards.

Most of these findings came to light in some dozen presentations in Baltimore last November at the Society of Environmental Toxicology and Chemistry (SETAC) annual meeting. The research described there suggests that, at least where the mum-based pesticides might enter streams, these compounds should be used sparingly.

"The Environmental Protection Agency needs to take a closer look at pyrethroids" with an eye toward changing how the 22 such compounds that it has registered are marketed and used, argues Michael J. Lydy, an environmental toxicologist at Southern Illinois University in Carbondale. Ample and growing data, he says, challenge "the suggestion that in the environment, pyrethroids will be innocuous."

Hunting thrins

"Walk down the pesticide aisle of your local hardware store and read the active ingredients in insecticides. Nearly every one ends in 'thrin,'" a dead giveaway that it is a pyrethroid, observes Donald P. Weston, an environmental toxicologist at the University of California, Berkeley. Only a few pyrethroids -- most notably esfenvalerate -- lack that suffix.

Although many of these compounds have been used for decades, especially on farms, "no one had looked for them in the environment," Weston notes. In the past few years, he and his colleagues launched several surveys to check whether pyrethroids were causing harm in streams. Because these pesticides don't readily dissolve, but instead glom on to particles and quickly settle out of water, his team focused its analyses on sediments.

Their findings proved eye-opening, Weston told Science News. In one study of creeks adjacent to farmlands across a 10-county area in California's Central Valley, researchers looked for five pyrethroids and found one or more in at least three-quarters of the 70 sediments sampled.

The researchers then tested two stream dwellers: the amphipod Hyalella azteca, which is a small, shrimplike crustacean, and a larval midge of the species Chironomus tentans. Ecologists use these tiny "lab rats of the sediment-testing world" for toxicity assessments, Weston explains.

At 42 percent of the sampled sites, the sediment proved deadly to at least one of two species, his group reported 2 years ago.

In a follow-up study, the scientists spiked sediment samples from clean sites with six common pyrethroids to compare their toxic effects on H. azteca. They measured each compound's LC50 -- the concentration lethal to 50 percent of animals exposed in a test.

In the April 2005 Environmental Toxicology and Chemistry (ET&C), the team reported that permethrin's LC50 was 60 to 110 parts per billion (ppb), depending on how much organic carbon the sediment contained. The LC50 for the remaining pyrethroids was far lower, indicating greater toxicity. The most toxic: lambda-cyhalothrin and bifenthrin, which have an LC50 of 2 to 6 ppb.

The crustaceans' growth was significantly retarded at concentrations just one-third of a pyrethroid's LC50.

Lawn pollution Farm runoff isn't the only -- or perhaps even the most important -- way in which these agents get into streams. Weston and his Berkeley colleague Erin L. Amweg reported data at the SETAC meeting showing that pyrethroids are washed into waterways from suburban yards by rain and lawn watering.

RUNAWAY RUNOFF. Lawn-watering runoff at this home in Roseville, Calif., illustrates how pyrethroids used on the yard would be washed into storm drains, which are a direct conduit to neighborhood streams. Amweg

In one recent study, Weston, Lydy, and others surveyed streams in Roseville, a suburb of Sacramento, Calif. Only a decade earlier, land along these creeks had been arid grassland. Since then, much of it has been converted to subdivisions sporting four homes per acre, most with manicured lawns.

Roughly 90 percent of the stream sediments sampled contained bifenthrin, and the majority of them had bifenthrin concentrations toxic to Hyalella, the scientists report in the Dec. 15, 2005, Environmental Science & Technology. Often, one to five more pyrethroids were present.

In contrast, the pesticides didn't show up in waters draining Roseville sites free of residential development.

In toxicity, bifenthrin dominated the suburban sediments. Indeed, Lydy told Science News, "80 percent of our samples had enough toxicity due to bifenthrin alone to cause at least half of our [amphipods] to die." The team recorded pesticide concentrations as high as 437 ppb—that's about 100 times as great as its LC50 for H. azteca and 15 times the highest bifenthrin concentration seen in sediments of creeks running through Central Valley croplands.

This indicates, Weston says, that the highest concentrations of pyrethroids in creek sediments trace to "classic suburbia -- we're talking Mom, Dad, two kids, and a dog."

Although pesticides applied by professional exterminators around the perimeters of homes are a possible source of the creek contamination, the research group strongly suspects that much of the bifenthrin comes from lawn-care products. Some fertilizers even include bifenthrin, so that homeowners can feed their grass and kill bugs in one pass.

In the Roseville study, the pesticides didn't appear to travel far once they reached a creek, with the high concentrations appearing only within 100 yards or so of storm-drain outfalls.

What's not clear, Weston and others observe, is whether the California data reflect what's occurring nationally or might instead represent a worst-case scenario. For instance, Amweg presented data at the SETAC meeting indicating that creeks near Sacramento and San Francisco showed substantial sediment contamination but streams in Nashville didn't.

The California sites, unlike Nashville, get little summer rainfall to dilute stream pollutants. Moreover, many of California's urban areas rely on concrete storm drains to channel lawn runoff directly into streams, whereas the Nashville sites were separated from waterways by a corridor of greenery.

Too excited Joel R. Coats of Iowa State University in Ames and his colleagues have been probing why pyrethroids "are as nasty as DDT [is] to a lot of aquatic life -- including fish."

HOW NEAT? Aquatic caddis fly nymphs build protective cases from plant debris. Ordinarily, a nymph cuts and stacks materials, log-cabin style, into an orderly, well-aerated covering (top inset). Pyrethroid-exposed nymphs, however, make chaotically structured dwellings from uncut parts (bottom inset) or forgo such protection altogether. Johnson/OSU

Pyrethroids poison pests by wreaking havoc on their nervous systems, as most insecticides do. When nerves transmit an impulse, Coats explains, "there's an electrical ripple that's triggered by sodium gates in [each cell] opening in sequence." Pyrethroids perturb the nerve cells' sodium gates, however, so that once open, they never fully close, Coats says. The resulting sodium leaks maintain nerve cells in a state of overexcitation that kills the insects.

Because the nervous systems of crustaceans and many other soft-bodied aquatic animals resemble those of insects, these nontargeted animals are also vulnerable to pyrethroids.

Coats observes that mammals and birds gain some protection from pyrethroid poisoning by two mechanisms: production of esterase enzymes that inactivate the poisons by splitting them in half, and another metabolic process that employs oxidation. He reported at the SETAC meeting that although rainbow trout, bluegill, and fathead minnows can all oxidize pyrethroids, their esterase enzyme activity doesn't break apart the pesticides.

Although these pesticides may induce ill effects that fall short of lethality, toxicologists have generally been forced to focus on their deadliness, Weston says, because fatal concentrations tend to be at or near the minimum value at which current technology can detect the pesticides. If the pesticides cause sickness, therefore, it's likely to happen at concentrations too low to measure, he says. To get around this difficulty, some scientists have added minute amounts of the compounds to tanks of water containing aquatic animals.

At Oregon State University (OSU) in Corvallis, Katherine R. Johnson and her colleagues administered esfenvalerate to aquatic nymphs of the caddis fly (Brachycentrus americanus) -- an insect eaten by many fish.

For protection from predators, these nymphs enshroud themselves in hard cases. As the OSU researchers increased pyrethroid concentrations above 0.05 ppb, formerly resting animals began fleeing their cases in increasing numbers, notes coauthor Jeffrey J. Jenkins. Among nymphs that fled, three-quarters of those exposed to as little as 0.2 ppb esfenvalerate didn't rebuild their cases. Rebuilt cases were disordered and much weaker than the originals, the scientists reported at the SETAC meeting.

Conditional toxicity Environmental stressors can sabotage pesticide-detoxification systems, even in animals that would otherwise withstand the chemicals, notes Larry G. Talent. At Oklahoma State University in Stillwater, he studied adult green anole lizards (Anolis carolinensis), 6 to 8 inches long, exposed to a pyrethroid product used to treat birds for mites and lice.

When he doused the lizards with a solution of the pesticide and then maintained the reptiles at a comfortable 95°F, none died. However, 70 percent of treated lizards died within 2 days when they were instead housed at a cool 68°F. Without pesticide exposure, the lizards showed no mortality at the lower temperature, Talent reports in the December 2005 ET&C.

Low temperatures, which might mimic night or winter environments, pose a double whammy for pyrethroid effects: Not only is the lizard's nervous system more vulnerable to poisoning but its metabolic breakdown of pollutants also slows.

Mark A. Clifford last year reported a similar synergy between two environmental stressors—pyrethroid exposure and a viral infection --in young salmon. The University of California, Davis fish pathologist exposed 2-month-old chinook salmon for 4 days to either esfenvalerate or chlorpyrifos, an organophosphate pesticide. He then seeded some of the aquariums holding the fish with infectious hematopoietic necrosis virus, which can kill juveniles.

Fish exposed to low doses of the virus survived, as did those exposed to either pesticide alone, Clifford's team reported in the July 2005 ET&C. Deaths occurred only in fish exposed to high concentrations of the virus or to both the pyrethroid and virus. Within 3 days of being exposed to either dose of virus, roughly 70 percent of the pesticide-exposed salmon fry were dead.

The pyrethroid's impact "was totally unexpected," Clifford says. Two follow-up trials confirmed that the initial observation was not a fluke.

Winds of change? EPA considers new data when it periodically reviews its approvals of pesticides registered before 1984. Reevaluations for permethrin, resmethrin, and cypermethrin are slated for completion this year, and three other pyrethroids are to be reviewed by 2008.

Because bifenthrin was registered in late 1985, it's not scheduled for such a reevaluation. In a statement to Science News, however, EPA's Office of Pesticide Programs (OPP) notes that this pesticide's manifestation of "certain toxic properties at the level of detection [makes it] challenging for the agency to determine whether risks from the use of this pesticide are acceptable."

In fact, the statement says, to better understand pyrethroids' toxicity and bioavailability to nontarget organisms, OPP is "reviewing the sediment toxicity studies on bifenthrin, cypermethrin, cyfluthrin, and esfenvalerate that were recently submitted [by Weston's group and others]." These pesticides were chosen as "surrogates," the statement says, for assessing the exposures and toxicity of other pyrethroids.

Indeed, OPP notes, despite their use on some 50 agricultural crops, some pyrethroids have only "conditional" approval from EPA, pending future evaluation of their sediment toxicity and of the value of buffer zones in keeping treated areas from tainting streams.

OPP says that it anticipates completing a "comparative assessment for pyrethroids" by December.

Pyrethroid manufacturers are already bracing for change.

Jim Fitzwater, a spokesman for bifenthrin-maker FMC Corp. of Philadelphia, says that homeowners need to be educated about how and when to apply lawn-care products containing pyrethroids. He notes that his company sells to consumer-products companies rather than consumers and says, "We're looking at working with [these] end-use manufacturers to do a better stewardship job."

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