Insecticide Market Trends and Potential Water Quality Implications

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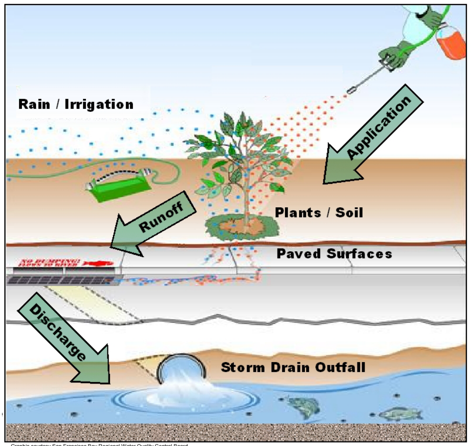
Background

Insecticides Cause Urban Surface Water Toxicity

Until the 1990s, water quality managers generally did not actively consider the potential for urban pesticide use to harm surface water quality. In the mid-1990s, California water quality agencies found widespread toxicity in water bodies receiving urban runoff. The toxicity was linked to two commonly used pesticides—diazinon and chlorpyrifos (SFBRWQCB, 2002).

A national water quality survey conducted by the U.S. Geological Survey (USGS) frequently detected the insecticides diazinon, chlorpyrifos, carbaryl, and malathion in urban streams, and often at concentrations that exceeded water quality criteria (Gilliom *et al*., 1999). The USGS survey found that urban surface water insecticide levels are similar to—and in some cases higher than—insecticide concentrations in agricultural surface waters (Hoffman *et al*., 2000). These surprising findings have caused water quality managers to redesign urban runoff management programs to address potential surface water impacts from urban pesticide use.

Urban Runoff Carries Pesticides to Creeks



Graphic courtesy San Francisco Bay Regional Water Quality Control Board.

Most Urban Diazinon and Chlorpyrifos Use to End

In the San Francisco Bay Area, diazinon and chlorpyrifos were identified as the primary causes of toxicity in urban runoff, urban creeks, wastewater treatment plant effluent, rivers, and the Bay margins (SFBRWQCB, 2002). In 2000, the U.S. Environmental Protection Agency (U.S. EPA) announced agreements with manufacturers to phase out most urban uses of diazinon and chlorpyrifos (U.S. EPA, 2000; U.S. EPA, 2001). While the planned phase out is likely to end most (if not all) of the previously identified toxicity, it brings new water quality management challenges as different insecticides enter the urban pesticide marketplace.

Urban Insecticide Market is Shifting—Pyrethroids are the Primary Substitutes for Diazinon & Chlorpyrifos

Of the 45 insecticides that are possible replacements for urban uses of diazinon and chlorpyrifos, ten insecticides (bifenthrin, carbaryl, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, imidacloprid, malathion, permethrin, and pyrethrins) appeared to be most likely to gain significant market share in the coming years and may pose concerns for water quality; these were selected for detailed review.

Recent store shelf surveys and manufacturer product line reviews found that pyrethroids (including lambda cyhalothrin, which was not included in this study) are the primary alternative in the urban marketplace (TDC Environmental, in preparation).

Other alternatives commonly available in the urban marketplace are carbaryl, malathion, imidacloprid, and pyrethrins.

Aquatic Toxicity

Pyrethroids are More Toxic than Diazinon

Pesticide	Lowest Toxicity Data Identified: Fresh Water	Salt Water
Pyrethroids		
Bifenthrin	0.07 ppb *Ceriodaphnia dubia*, 48-H LC50	0.00397 ppb *Americamysis bahia*, 96-H LC50
Cyfluthrin	0.14 ppb *Ceriodaphnia dubia*, 48-H LC50 0.025 ppb *Daphnia magna*, 48-H EC50	0.00242 ppb *Americamysis bahia*, 96-H LC50
Cypermethrin	0.36 ppb *Daphnia magna*, 48-H LC50 0.5 ppb *Oncorhynchus mykiss*, 96-H LC50	0.005 ppb *Americamysis bahia*, 96-H LC50
Deltamethrin	0.01 ppb *Daphnia magna*, 96-H LC50 0.003 ppb *Daphnia magna*, 96-H EC50	0.017 ppb *Americamysis bahia*, 96-H LC50
Esfenvalerate	0.07 ppb *Oncorhynchus mykiss*, 96-H LC50	0.038 ppb *Americamysis bahia*, 96-H LC50
Permethrin	0.075 ppb *Daphnia magna*, 48-H LC50	0.046 ppb *Americamysis bahia*, 96-H LC50
Organophosphorous Pesticides		
Chlorpyrifos	0.038 ppb *Ceriodaphnia dubia*, 96-H LC50	0.04 ppb* *Americamysis bahia*, 96-H LC50
Diazinon	0.20 ppb Gammarus fasciatus, 96-H LC50 0.44 ppb* *Ceriodaphnia dubia*, 96-H LC50	0.0056 ppb* *Americamysis bahia*, 96-H LC50
Malathion	0.27 ppb *Daphnia magna*, 24-H LC50 0.098 ppb *Daphnia magna*, 24-H EC50	0.03 ppb *Menidia beryllina*, 96-H LC50
Other Substitutes		
Carbaryl	1.1 ppb *Daphnia magna*, 24-H LC50 0.0115 ppb *Daphnia pulex*, 48-H EC50	5.7 ppb *Americamysis bahia*, 96-H LC50 5.5 ppb *Penaeus sp.* 24-H EC50
Imidacloprid	10,440 ppb *Daphnia magna*, 48-H LC50	34 ppb *Americamysis bahia*, 96-H LC50
Pyrethrins	5.2 ppb *Oncorhynchus mykiss*, 96-H LC50	1.4 ppb *Americamysis bahia*, 96-H LC50

*Species mean acute value from DFG, 2000.
Sources: U.S. EPA Ecotox (U.S. EPA, 2002), DPR Ecotox (DPR, 2002), and DFG, 2000.

Many Aquatic Toxicity Data Gaps Exist (X = Data Gap)

Pesticide	Invertebrates: *Ceriodaphnia dubia*	*Daphnia magna*	*Daphnia pulex*	*Hyalella azteca*	*Gammarus lacustris*	*Gammarus fasciatus*	*Americamysis bahia*	*Penaeus sp.*	*Crassostrea virginica*	*Crassostrea gigas*	Vertebrates: *Pimephales promelas*	*Oncorhynchus mykiss*	*Salvelinus fontinalis*	*Lepomis macrochirus*	*Cyprinodon variegatus*	*Menidia beryllina*	Plants: *Selenastrum capricornutum*	*Skeletonema costatum*
Bifenthrin			X	X	X	X		X		X			X		X	X	X	X
Carbaryl				X						X						X		
Cyfluthrin			X	X	X	X		X		X			X			X	X	X
Cypermethrin	X		X	X	X	X					X		X			X	X	X
Deltamethrin	X		X	X	X	X		X		X	X		X			X	X	X
Esfenvalerate	X		X		X	X		X	X	X			X			X	X	X
Imidacloprid	X		X	X	X	X		X		X	X		X			X	X	X
Malathion				X						X							X	X
Permethrin				X	X	X											X	X
Pyrethrins	X		X	X	X	X		X		X	X		X			X	X	X

Salt water species are in the shaded areas of the table.
Source: Evaluation of data in U.S. EPA Ecotox (U.S. EPA, 2002), and DPR Ecotox (DPR, 2002).

Future Risks

Pyrethroids are a Threat to Surface Water Quality

Pyrethroids are increasing in market share rapidly. Since several different pyrethroids are coming into widespread use, the environmental effects of pyrethroid mixtures, rather than individual chemicals, will need to be considered

Although pyrethroids are generally applied in much smaller quantities than organophosphorous pesticides, these quantities are environmentally meaningful because pyrethroids are very highly toxic to aquatic organisms.

In surface waters, pyrethroids are expected to partition primarily into sediments. The speed of that partitioning, which will depend on flow, mixing, and sediment quality in individual water bodies, will be very relevant for their significance to aquatic ecosystems.

Pyrethroids have been detected in many environmental water samples and have been found to cause toxicity to aquatic species in some water and sediment samples (Kim *et al*., 2001; Werner *et al*., 2002; Dabrowski *et al*., 2002; Laabs *et al*., 2002; USGS, 2002; Carroll *et al*., 1981, Anderson, 2003; Weston, 2003). This suggests that the environmental water column concentrations are sufficient (and persist for a sufficiently long time period) to cause toxicity and/or that particulate- or sediment-bound pyrethroids contribute to toxicity.

The limited available data do not allow a conclusion as to whether the measurements are anomalies or are indicative that environmentally relevant concentrations may commonly remain in the water column for sufficient time periods to cause aquatic toxicity (Casjens, 2002).

Given their hydrophobicity, pyrethroids are likely to appear in sediments at concentrations several thousand times their water column concentrations. Pyrethroids may decompose slowly enough in sediments for residuals to last for years; if so, sediment concentrations may gradually increase with continued pyrethroid use. In sediments, the accumulated pyrethroids may concentrate sufficiently to cause toxicity to benthic organisms (Maund *et al*., 2002; Weston, 2002).

While currently available data are insufficient for proof of environmental harm, the available information strongly suggest that widespread use of pyrethroids as substitutes for diazinon and chlorpyrifos is likely to cause environmentally relevant concentrations to be exceeded in surface waters, sediments, or both for meaningful time periods.

Other Insecticides May Also Cause Aquatic Toxicity

Carbaryl is one of the most widely used broad-spectrum insecticides. The USGS National Water Quality Assessment (NAWQA) found it to be the second most commonly detected insecticide in surface water. In the NAWQA data, streams draining urban areas had more frequent detections and higher concentrations of carbaryl than streams draining agricultural or mixed land use areas (Gilliom *et al*., 1999).

The presence of carbaryl in surface waters has important implications—the U.S. EPA environmental risk assessment for carbaryl found significant risks to aquatic species (U.S. EPA, 2002).

Malathion, like carbaryl, is one of the most widely used broad-spectrum insecticides. Together with diazinon, chlorpyrifos, and carbaryl, the USGS NAWQA found malathion frequently in surface water, particularly in urban creeks, where the highest concentrations were measured (Gilliom *et al*., 1999).

Malathion is toxic to aquatic organisms at observed concentrations—many fish kills have been confirmed (U.S. EPA, 2000). According to the U.S. EPA malathion environmental risk assessment, malathion poses significant acute and chronic risks for aquatic invertebrates and some fish. Even at the lowest application rates, the U.S. EPA risk assessment found that levels of concern are exceeded by factors of up to 160 for certain invertebrate groups (U.S. EPA, 2000). Additional significant risks may exist in urban areas (where concentrations are higher)—but urban areas were not evaluated in the U.S. EPA environmental risk assessment.

Malathion and carbaryl are among the most frequently detected pesticides in urban surface waters and are commonly detected at concentrations known to cause adverse effects to aquatic ecosystems. Use of these two insecticides as substitutes for diazinon and chlorpyrifos will only exacerbate existing aquatic toxicity problems.

Depending on application locations, use of two other substitutes–imidacloprid and pyrethrins—as replacements for urban uses of diazinon and chlorpyrifos may cause adverse effects in aquatic ecosystems receiving urban runoff. Extensive data gaps preclude a more definitive conclusion.

Next Steps

Regulatory Changes Could Prevent Future Toxicity

The following changes would maximize the ability of the pesticide registration process to prevent potential water quality problems associated with pesticide use:

- *Make all information necessary to evaluate and prevent surface water quality impacts from pesticides publicly available for every registered pesticide.* Procedures need to be modified such that data call-ins for all pesticides include complete and practical pesticide chemical analysis methods with detection limits below the lowest environmentally relevant concentration and toxicity test results for all standard water quality test species.
- *Use California and Federal water quality agency expertise during the pesticide registration process to ensure that pesticide applications comply with the Clean Water Act and the Porter-Cologne Water Quality Control Act.* Current pesticide regulatory processes are not designed to prevent surface water toxicity from pesticide use.
- *Identify and/or develop methods appropriate for ecological risk assessment of surface water quality impacts of pesticides.* Pesticide registration risk assessments normally do not address urban pesticide use—even though as much as half of all pesticide use occurs in urban areas.

Monitoring Could Identify Environmental Effects of New Insecticides—But Only if Practical Test Methods Become Widely Available

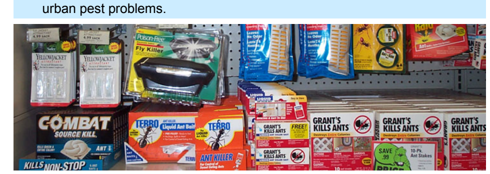
The following actions would establish the environmental relevance of diazinon & chlorpyrifos replacements in Bay Area urban surface waters:

- *Develop methods for chemical analysis of pyrethroids and imidacloprid suitable for use by commercial laboratories with detection limits below environmentally relevant concentrations.* Currently, few laboratories can measure these pesticides at environmentally relevant concentrations. No published methods exist for some pyrethroids or for imidacloprid.
- *Monitor urban surface waters for pyrethroids and other urban insecticides.* Monitoring should include samples from urban creeks and from San Francisco Bay. Given the sensitivity of salt water species to many diazinon and chlorpyrifos replacement pesticides, monitoring at creek discharge points ("the Bay margins") is recommended. Both the water column and sediments should be monitored. Toxicity testing—rather than chemical concentration measurements—will probably be the simplest and most cost-effective primary monitoring strategy.

Education and Integrated Pest Management Can Reduce Risks

To minimize the potential risks associated with the transition in the insecticide market, the following educational measures are recommended:

- Discourage use of pyrethroids as replacements for urban uses of diazinon and chlorpyrifos.
- Until further information is available, refrain from recommending imidacloprid and pyrethrins as substitutes for urban uses of diazinon and chlorpyrifos.
- Strengthen efforts to promote pest management methods that use non-chemical and least-toxic chemical alternatives to pesticides to manage urban pest problems.



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