Lethal Lawns:

Oregon Pesticide Education Network

Diazinon Use Threatens Salmon Survival

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Lethal Lawns: Diazinon Use Threatens Salmon Survival

By Caroline Cox
June 2000

U.S. Army Corps of Engineers

About the Author:

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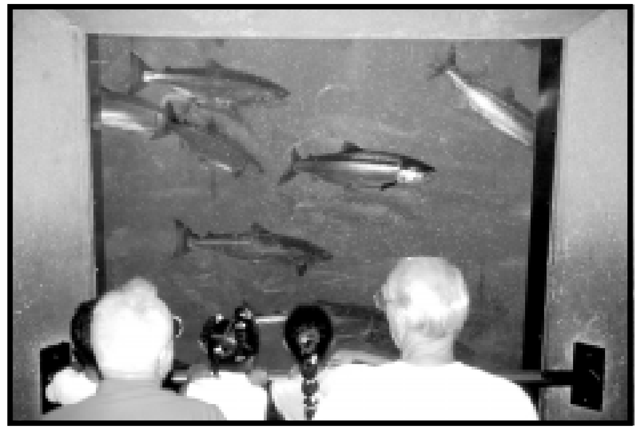
Executive Summary

Diazinon, a common organophosphate insecticide, frequently pollutes Pacific Northwest rivers and streams. It is found both in agricultural and urban areas where diazinon is used. Runoff of a fraction of one percent of the amount of diazinon applied can result in significant levels in nearby streams. Water quality agencies have measured diazinon pollution resulting from applications made to yards according to label directions.

Diazinon and other pesticide pollution threatens our efforts to restore healthy salmon runs. The levels of diazinon currently found in Northwest streams can impact salmon in at least four ways: disruption of behaviors that juveniles use to avoid predators; reduction of populations of aquatic animals that salmon use for food; disruption of behaviors and physiology that are critical to successful reproduction; and damage to genes.



U.S. Army Corps of Engineers

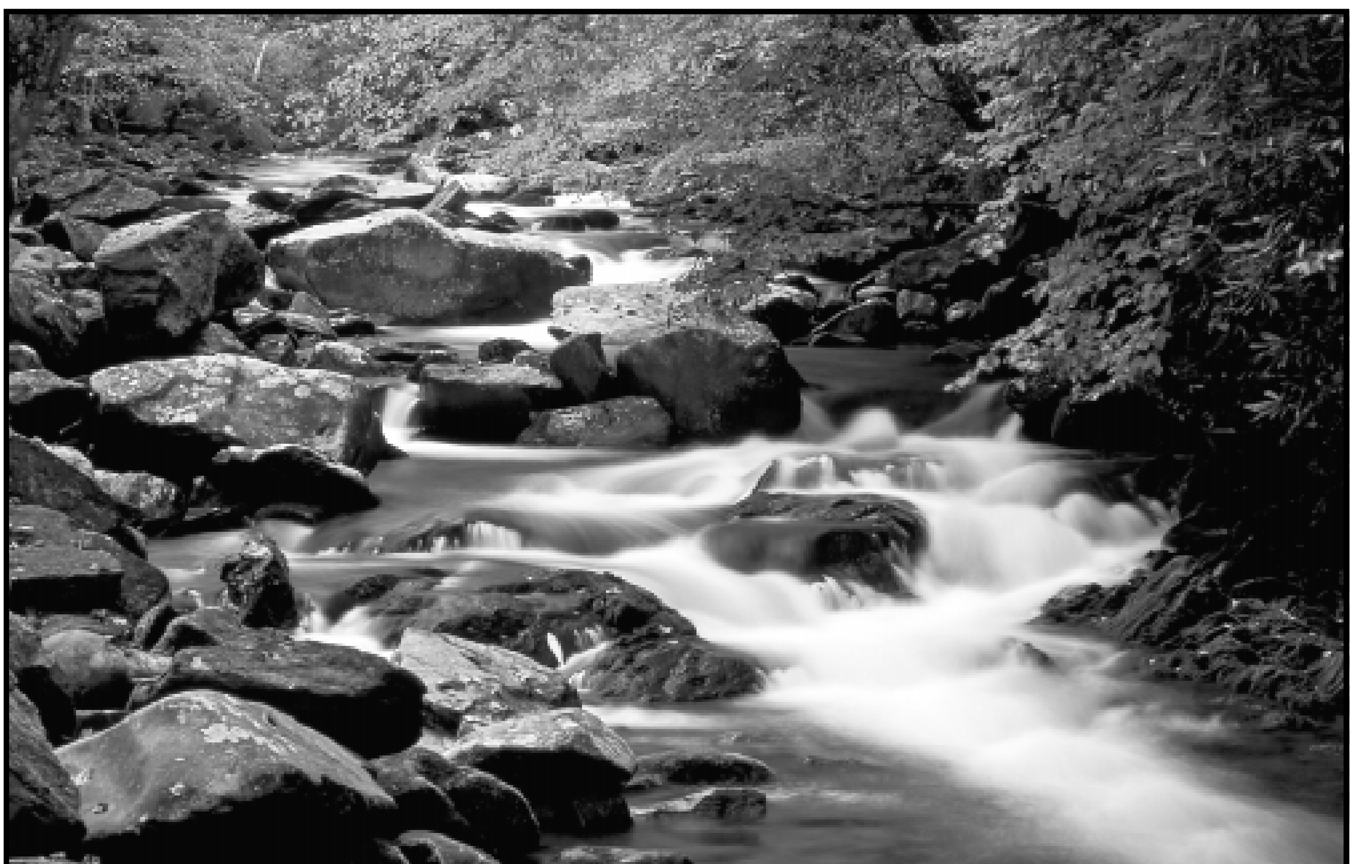
The U.S. Environmental Protection Agency (EPA) has not yet set an "aquatic life criterion" for diazinon as required under the Clean Water Act. Neither has the agency complied with the consultation requirements of the Endangered Species Act. Both of these actions are crucial. In addition, the Northwest needs accurate, comprehensive tracking of pesticide use so that effective plans for salmon restoration can be developed. Information about nonchemical strategies for managing the pests for which diazinon is frequently used should also be readily available. These simple but decisive actions will help restore the Northwest salmon heritage for generations to come.

Introduction

During the last decade the U.S. Geological Survey (USGS) has been studying water quality in river basins across the country. Results from the first phase of the study are, in a word, startling. Almost every stream sample “contained two or more pesticides”[1] according to the USGS, and “at least one pesticide was found in almost every … fish sample.”[1]

The USGS found that pesticide pollution was widespread regardless of how watersheds were used; pesticides were found in all samples from major rivers, 99 percent of the samples from urban streams, and 92 percent of the samples from streams in agricultural areas. The kind of pesticide detected varied according to land use: herbicides were most common in agricultural areas while urban streams had “among the highest insecticide concentrations of all streams and rivers sampled.”[1] The insecticides that the USGS found frequently in these urban streams were those “commonly used around homes and gardens and in commercial and public areas,” including diazinon (the most commonly detected insecticide), chlorpyrifos, malathion, and carbaryl.[1]

Does this water contamination affect the health of fish, insects, other animals, and plants in our streams? The answer appears to be yes. The USGS has already found compelling evidence that the levels of pesticide pollution they measured in rivers and streams nationwide are changing levels of sex hormones in fish.[2] These



hormones control crucial aspects of fish biology: growth, development, and reproduction. Thus, the impact of the pesticides may be far-reaching.

As many salmon populations in the Pacific Northwest near extinction, public and government concern to protect these fish increases. However, the national studies about pesticides and water quality provide an important warning for the Northwest as restoration of declining salmon runs begins. This article uses the example of the contamination of streams and rivers in the Pacific Northwest by the insecticide diazinon to illustrate this warning. We show that diazinon pollution is pervasive and that the national patterns of contamination are reflected on regional and local scales. We show that both agricultural and urban uses of diazinon contribute to water pollution, but that household uses are particularly important. We also show that the levels of diazinon currently found in Northwest streams are hazardous to fish, with likely impacts on salmon. Finally, we show that current laws and regulations are not able to protect rivers and streams from diazinon, and suggest critical improvements.

> **"The uncertainty about whether present-day levels of pesticide contamination are a threat to human health or the environment makes it imperative that we document and understand the nature of pesticide exposure, the causes of contamination, and the actions we can take to reduce pesticide levels in streams and ground water."**
>
> **— U.S. Geological Survey**

What is Diazinon?

Diazinon is an insecticide in the organophosphate family. Like all insecticides in this family, it is toxic to the nervous system and kills insects by interfering with their nerves' normal function. Organophosphate insecticides inhibit the activity of an enzyme (acetylcholinesterase) that normally deactivates one of the chemicals that transmits nerve impulses from one nerve to another. As a result, nerve impulses are repeatedly transmitted and overstimulate muscles and other organs controlled by the nerves. Organophosphates have the same type of effect on animals other than insects because of the similarity of their nervous systems.[3]

"The U.S. Environmental Protection Agency estimates that diazinon (along with its chemical cousin, chlorpyrifos) is the home and garden insecticide used in the largest quantity."

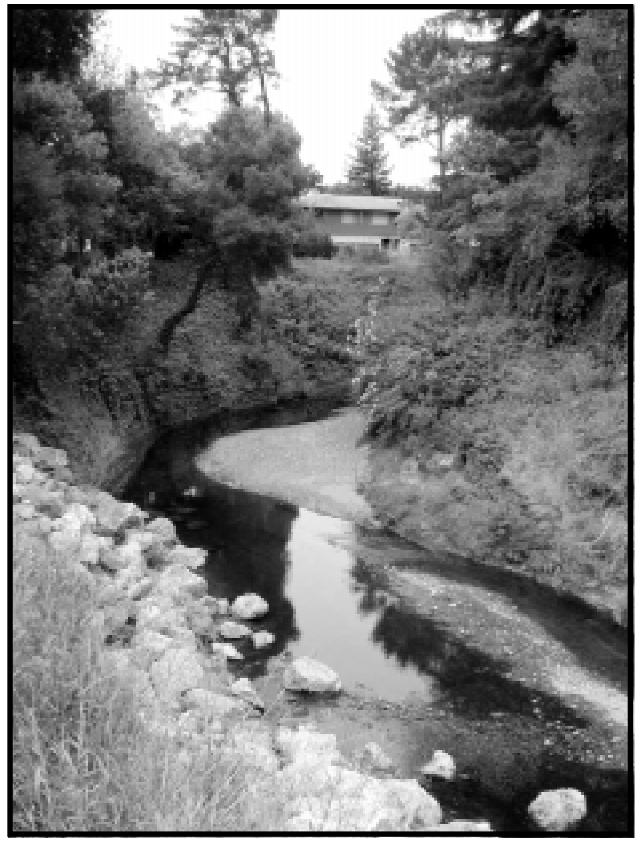
Diazinon is widely used in yards and gardens: the U.S. Environmental Protection Agency estimates that diazinon (along with its chemical cousin, chlorpyrifos) is the home and garden insecticide used in the largest quantity.[4] It is a broad-spectrum insecticide, and can be used to kill a wide variety of insects. In the Pacific Northwest, common pests treated with diazinon include ants, aphids, carpenter ants, crane flies, and fleas.[5,6] Diazinon also has agricultural uses: Northwest crops on which the largest quantities are used are hops and beets in Idaho; cherries and hops in Oregon; potatoes and hops in Washington; and almonds, plums, and lettuce in California.[7]

Diazinon Contamination of Pacific Northwest Rivers and Streams

The national water quality survey by the USGS included four Northwest river basins: the Willamette Basin (in Oregon), the Upper Snake River Basin (in Idaho and Wyoming), the Central Columbia Plateau (in Washington and Idaho), and the San Joaquin-Tulare Basins (in California).[8-11] In two of these four basins, diazinon was the most frequently detected insecticide: the Willamette Basin in which 35 percent of samples were contaminated with diazinon and the San Joaquin-Tulare Basins, in which 71 percent of the samples contained diazinon.[8,11] Overall, the studies show that river basins that drain urban areas, or agricultural areas with crops on which diazinon is used, are likely to be polluted with diazinon.

Other studies that cover relatively large geographical areas had similar results. A survey of 13 agricultural, forest, and urban streams in the Puget Sound Basin (Washington) found diazinon in almost half of the streams sampled.[12] A survey of storm water in urban creeks draining into the San Francisco Bay found "potentially toxic levels of diazinon" in 27 percent of the storm samples.[13]

These frequent detections of diazinon have inspired further research about diazinon in smaller geographical areas. These studies highlight diazinon in urban



Geoff Brosseau

San Francisquito Creek, in Palo Alto, California, is one of many urban creeks frequently polluted with diazinon.

watersheds as a particular concern. For example, a study of urban streams in King County (Seattle), Washington, found diazinon at all 12 study sites.[14]

In Oregon, Aloha's Beaverton Creek and Salem's Pringle and Claggett Creeks were contaminated with diazinon on four out of five sample dates. Dixon Creek in Corvallis was contaminated with diazinon on three out of five sample dates.[15] In Eugene's Amazon Creek, diazinon was found at all four sites sampled.[16]

In California, Castro Valley Creek in Alameda County was contaminated with diazinon during all 22 storms sampled.[13] In three creeks in Palo Alto (Adobe, Barron, and Matadero) diazinon was found in all samples tested and in a fourth creek (San Francisquito) diazinon was found in three out of four samples.[17] In Modesto, diazinon contaminated all stormwater samples collected from five different sites.[18] In Sacramento, diazinon was found in all samples tested over a two and a half year period.[19]

Agricultural uses of diazinon can be important sources of water contamination in areas with crops on which diazinon is used. In California's Central Valley, for example, diazinon is used as a winter season spray (typically in January) in stone fruit orchards. Sampling after February rains found diazinon in both the San Joaquin and the Sacramento Rivers, the major rivers draining the Central Valley. Highest concentrations occurred a few days after the first rainstorm that followed the spray season, and researchers were able to follow this "pulse" of diazinon as it moved downstream towards San Francisco Bay.[20] In Oregon's Willamette Valley, diazinon contaminated four out of the five creeks studied in agricultural watersheds where the USGS estimated diazinon use of over 100 pounds per year.[15]

Chauncey Anderson

Agricultural streams, like this one in Oregon's Willamette Valley, are often contaminated with diazinon when it is used on crops grown in the watershed.

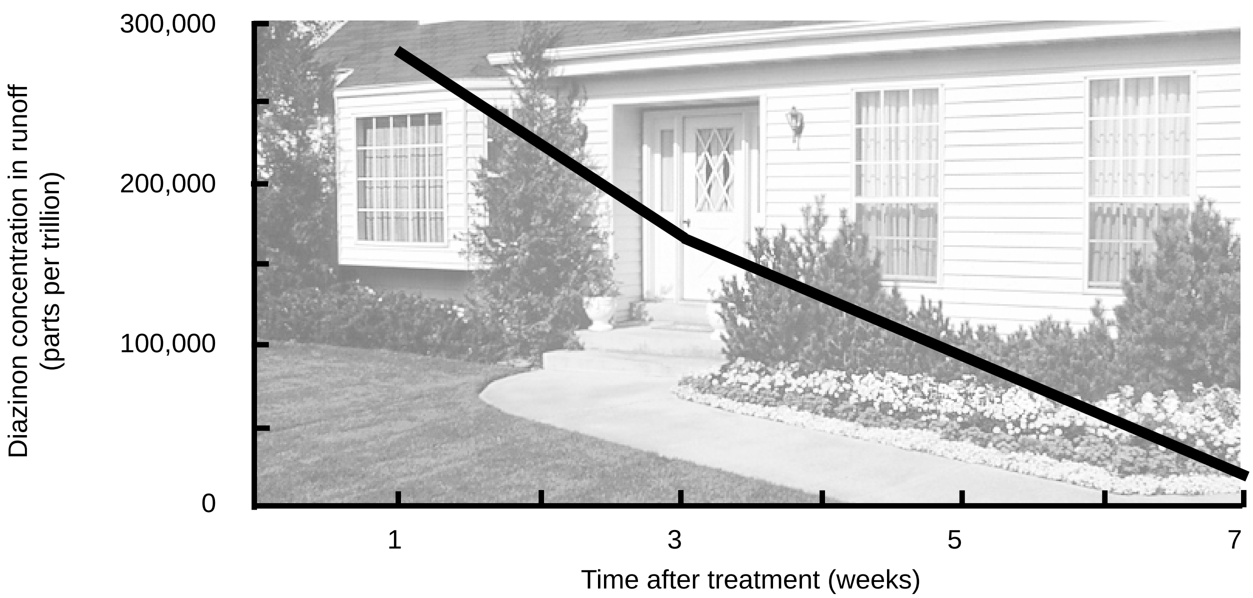
Relationships between Diazinon Use and Water Pollution

Some of the studies of local-scale diazinon contamination have also collected data about diazinon use. The relationships between these statistics provide important details about how diazinon enters aquatic ecosystems, and also provide essential information if pollution prevention is to be successful.

In King County, Washington, diazinon was the insecticide with the largest retail sales, and also the most common insecticide found in local streams.[14]

In Alameda County, California, a block-by-block sampling of rainwater in street gutters showed that the diazinon pollution originated from a tiny number of homes (less than 4 percent of the total homes). Researchers followed up this monitoring study by hiring commercial applicators to apply diazinon to two home lawns in the watershed. This research verified that applications of diazinon at recommended rates and in accordance with directions on the product label caused contamination at the levels that had been measured in the block-by-block monitoring study.[13]

Figure 1
Diazinon Concentrations in Runoff Following Ant Treatments



Source: Ref. # 13

Following treatments to control ants made at recommended rates and according to label directions, diazinon was found in runoff from patios, driveways, and roof drains. Seven weeks after applications, concentrations in runoff were still over 200 times the aquatic life guideline recommended by the International Joint Commission.

Another striking relationship is that only a minuscule fraction of applied diazinon needs to end up in rivers and streams in order to cause the levels of contamination that have been measured by monitoring agencies. In Palo Alto, California, runoff of less than one percent of purchased diazinon would result in the observed concentrations in Palo Alto creeks.[17] A similarly small percentage (.03%) was calculated for the watershed of Castro Valley Creek (Alameda County, California).[13]

The findings of these studies lead directly to the conclusion that yard and garden use of diazinon, even applied as directed on the pesticide label by a relatively small number of households in a watershed, is frequently contaminating urban streams.

U.S. Geological Survey

Diazinon was the insecticide with the largest retail sales in King County, Washington, and also was found in all streams tested in a USGS study, including Des Moines Creek (pictured).

Diazinon Harms Fish, Especially Salmon

Levels of diazinon currently found in our streams are high enough to harm fish, including salmon. This conclusion is supported by four types of research evidence:

1) Diazinon disrupts behaviors that protect young fish from predators. Since diazinon is toxic to the nervous system, effects on behavior are an obvious focus of research. A new study from the National Marine Fisheries Service looked at the effect on juvenile chinook salmon of diazinon at levels "that are commonly measured in many western river systems." They found that the olfactory system (sense of smell) is particularly sensitive to diazinon and that diazinon causes "substantial and significant" disruption of antipredator behaviors which are normally initiated by smelling alarm chemicals.[21]

OAR/National Undersea Research Program

Behaviors that protect young fish from predators, the abundance of insects and other animals that serve as food for young fish, spawning behavior, and the integrity of fish genes can all be impacted by diazinon.

In another example, a USGS study of lakes in Washington's Central Columbia Plateau measured the activity of the enzyme inhibited by organophosphate insecticides, acetylcholinesterase (AChE), in common carp. The carp lived in Royal Lake, a lake that is contaminated with a variety of insecticides, including diazinon. Researchers compared these measurements with AChE activity in fish living in Billy Clapp Lake, a lake with no detectable insecticide contamination. They found that AChE activity of fish living in Royal Lake was only about two-thirds the activity of fish in Billy Clapp Lake.[22] A second experiment suggests that this disruption of the nervous system significantly affects the behavior of fish. Juvenile rainbow trout exposed to organophosphate insecticide concentrations enough to decrease AChE activity between 25 and 80 percent were hyperactive, did not avoid light (they normally gather in shadowed areas), and reacted weakly to being touched.[23] These abnormal behaviors seem likely to make them more vulnerable to predators. Because the levels of insecticides in Royal Lake were comparable (maximum of 200 parts per trillion) to the diazinon levels measured in urban streams throughout the Northwest, equivalent disruption of the nervous system could be expected in many of the streams and rivers in the region.

These studies indicate that diazinon can threaten survival by disrupting behaviors that normally help young salmon survive.

2) Diazinon impacts the insects and other animals on which young salmon feed. Diazinon is a broad-spectrum

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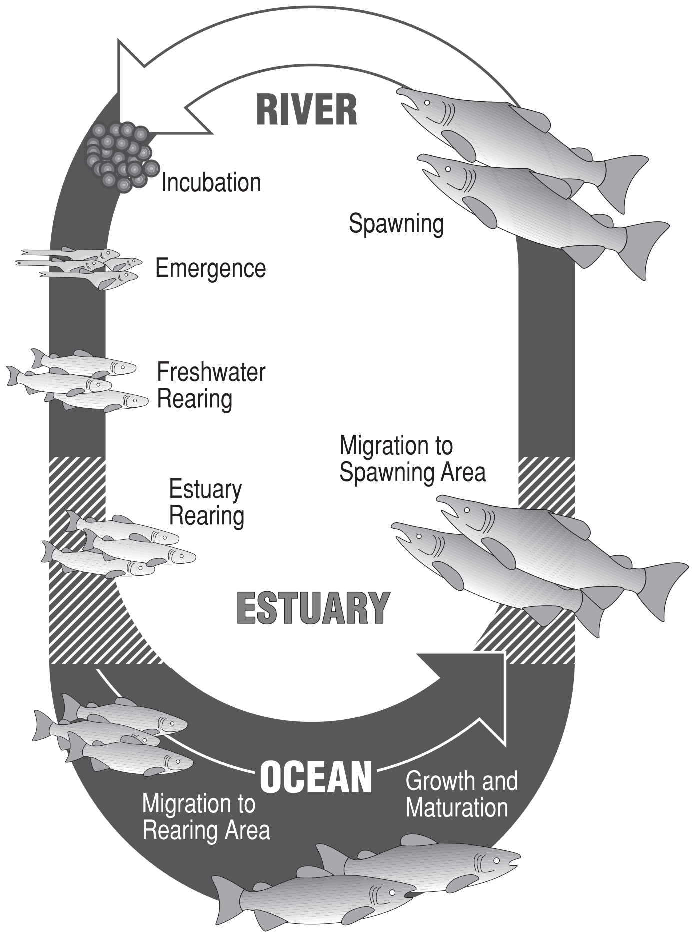


Salmon are anadromous. This means juveniles migrate from the streams in which they are born to the sea where they feed and grow. Mature adults return to the stream where they were born to spawn. Salmon can be harmed by diazinon contamination of rivers and streams both as juveniles and as spawning adults.

insecticide; thus, it would not be surprising that relatively low concentrations could have adverse effects on fish that rely on insects or their relatives as a food resource.

In free-flowing rivers, young salmon feed mostly on caddisfly larvae as their preferred prey.[24] Caddisflies belong to the insect order Trichoptera, and are one of the insect groups whose population dynamics have been studied in artificial ponds treated with parts per billion of diazinon. In this experiment, "Trichoptera was the most sensitive order, with significant reductions at all treatment levels throughout most of the treatment period."[25] In reservoirs, as opposed to free-flowing rivers, juvenile salmon feed on *Daphnia* (water fleas).[24] *Daphnia* are significantly impacted by remarkably low concentrations of diazinon. In laboratory studies, less than one part per trillion of diazinon reduced survival, growth, and reproduction.[26,27] Taken together, this evidence suggests that widespread diazinon contamination of streams could reduce the food available to juvenile salmon.

3) Diazinon inhibits behaviors important in reproduction. A study of Atlantic salmon found that diazinon inhibited normal sexual physiology in males,[28] suggesting that similar effects could occur in Pacific salmon species. In mature males, the smell of urine from female salmon who have ovulated increases the levels of sex hormones in the males' blood and increases their production of milt (sperm).[28] Concentrations of diazinon equal to or greater than 300 parts per trillion reduced these responses in males[28]; this threshold was exceeded in 62 percent of the stream samples from Sacramento, California; 6 percent of the samples from Palo Alto, California; 5 percent of the samples from the Willamette Valley, Oregon; and 3 percent of the samples from King County, Washington.[14,15,17,19]

4) Diazinon can cause genetic damage in fish. Healthy genes, the inheritance that parents pass on to their offspring, are vital for maintaining a healthy population.

Although NCAP located no publicly available studies of diazinon's ability to cause genetic damage in salmon, a study of genetic damage in another fish, the central mudminnow, suggests at least the potential for such problems.[29] The type of genetic damage researchers observed in the mudminnow is called sister chromatid exchanges, and involves an increased exchange of genetic material between parts of a duplicating chromosome.[30] Diazinon caused this genetic damage at concentrations equal to or greater than 160 parts per trillion.[30] In monitoring of urban Northwest streams, concentrations of diazinon exceeded this threshold in 25 percent of the Palo Alto, California, stream samples, 100 percent of the Sacramento, California, stream samples, 5 percent of the Willamette Valley, Oregon, samples, and 16 percent of the King County, Washington samples.[14,15,17,19] The prospect that diazinon similarly damages the genes of threatened salmon is a serious call for action to protect them from exposure to this insecticide.

Concentrations of diazinon equal to or greater than 300 parts per trillion reduced production of milt (sperm) in male salmon.

Not Just Bad for Fish

Diazinon is hazardous to human, as well as salmon health. Some of the significant health hazards that have been identified for diazinon include the following:

• **Diazinon is toxic to human nervous systems.** Symptoms of acute (short-term) diazinon poisoning in people are similar to the symptoms of any organophosphate insecticide poisoning: headache, nausea, dizziness, tearing, sweating, salivation,[a] drowsiness, and agitation.[b] Recently (1997), an Environmental Protection Agency (EPA) review found that "symptoms may persist for months or years after the initial exposure."[c]

• **Diazinon can harm developing nervous systems.** An EPA-funded study using mice exposed to low levels of diazinon in their food found that offspring exhibited subtle behavioral problems. Their endurance and coordination was impaired compared to mice born to unexposed mothers.[d]

• **Exposure to diazinon has been associated with increased cancer risks**. Garden diazinon use by parents was associated with an increased risk of brain cancer in their children in a Missouri study.[e] In two studies of farmers conducted by the National Cancer Institute, use of diazinon was associated with an increased risk of non-Hodgkin's lymphoma.[f,g]

• **Diazinon can damage genes.** Three studies of human blood cells found that damage to chromosomes, the genetic material in the nucleus of human cells, was more common in cells exposed to diazinon than in unexposed cells.[h-j]

• **Diazinon poisonings are frequent.** Data collected by poison control centers nationwide between 1985 and 1992 showed that diazinon was the second most frequent cause of insecticide poisoning. Almost one-quarter of the poisonings were caused by diazinon.[c] Nearly half involved children under six years of age.[k]

Agencies Are Not Protecting Endangered Salmon from Diazinon

Under the Clean Water Act, EPA sets "aquatic life criteria" that define the agency's acceptable levels of water contamination. The Clean Water Act requires states to improve water quality in rivers, streams, and lakes that do not meet water quality standards, including aquatic life criteria.[31] Unfortunately, although a draft criterion for diazinon was completed in 1998, EPA has not yet established a final one.[32] Instead, most water quality studies must use guidelines recommended for diazinon by either the National Academy of Sciences (NAS) or the International Joint Commission (IJC), an international agency that oversees the health of the Great Lakes. These guidelines are not legally enforceable under the Clean Water Act.[18] While they vary considerably, (the NAS guideline is 9 parts per trillion (ppt)[18] and the IJC guideline is 80 ppt[1]), established guidelines at such low concentrations clearly demonstrate that small amounts of diazinon can impact aquatic life.

Both guidelines were frequently exceeded in Northwest streams. Local surveys in California, Oregon, and Washington found diazinon concentrations that exceeded the NAS guideline in 60 to 100 percent of the samples and exceeded the IJC guideline in 10 to 100 percent of the samples.[14,15,17,19] (See Table 1.)

Since EPA has not yet acted to set aquatic life criteria for diazinon, most states do not list diazinon-contaminated streams as "impaired" under the Clean Water Act. This means that the restoration procedures required under the act will not occur.

EPA is also charged with protecting salmon from diazinon under the

Table 1
Diazinon Concentrations in Northwest Streams Frequently Exceeded Guidelines Recommended by a Federal and an International Agency

	Percent of samples that exceeded guideline recommended by	
Location	National Academy of Sciences (9 ppt)	International Joint Commission (80 ppt)
Palo Alto, California	94	50
Sacramento, California	100	100
Willamette Valley, Oregon	60	10
King County, Washington	80	50

Sources: 14,15,17,19

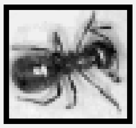
Note: ppt=parts per trillion

Endangered Species Act (ESA).[33] The law sets up a process in which federal agencies are required to make sure that any action "authorized, funded, or carried out"[34] by an agency does not jeopardize threatened or endangered species. Actions of federal agencies also must not "result in the destruction or adverse modification of habitat"[34] that is critical for these species. This process is called "consultation"[34] under ESA, and should occur between EPA and the National Marine Fisheries Service for threatened salmon. With respect to EPA's registration of diazinon as a pesticide, no consultations have been made.[35]

It is worth noting that these are not problems just for diazinon. Aquatic guidelines are missing for most pesticides. While "almost every urban stream sampled had concentrations of insecticides that exceeded at least one guideline"[1] for protection of aquatic life in the USGS's national water monitoring study, guidelines were available for only 28 of the 76 pesticides monitored by the USGS. To even find guidelines for 28 pesticides, USGS had to combine assessments from three agencies.[1] EPA's endangered species protection program for pesticides is similarly incomplete: the agency has information for less than half (23) of the states,[36] and has not consulted about salmon for any pesticide.[35]

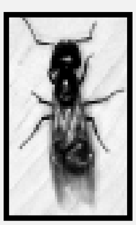
If we are to successfully restore Northwest salmon runs, regulatory agencies will need to comply with both the Clean Water Act and the Endangered Species Act.

Alternatives

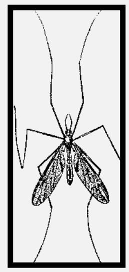


Ants usually come into a house while foraging for food and water. Ant problems can be controlled by cleaning up or removing food sources (the honey jar, the cat food dish, etc.) Keep food in containers with tight lids. Empty garbage daily. Use soap and water to remove ants and to erase the chemical trail they are following. Caulk or otherwise close the entry point that the ants are using to come into your house. Be as persistent as the ants!

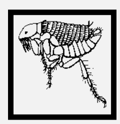
Aphids don't often thrive on healthy plants. Make sure you use plant varieties that are well-adapted to your area and that irrigation and fertilization are optimal for each plant in your yard or garden. Aphids can be controlled by encouraging beneficial insects that prey on aphids. If aphid populations get too large, wash them off plants with a strong stream of water.



Carpenter ants enter houses to forage for food and water, but in addition they can nest in wooded parts of a house. Keeping the wooden parts of a house dry and making sure that carpenter ants do not have easy access is key to preventing problems. Repairing leaky plumbing, storing firewood away from the house, and trimming tree branches so they don't touch your house are all important steps. It's crucial to caulk the exterior of your house, and seal potential entry points like holes where utility lines enter your house. If possible, locate and remove problematic carpenter ant nests.



Crane flies are often noticeable even when their populations aren't high enough to actually damage lawns. The first step if you think you might have a crane fly infestation is to dig up a small section of lawn and count crane fly larvae. Unless there are more than 15 to 20 larvae per square foot, no treatment is necessary. If you need to treat a crane fly problem, nonchemical strategies include deep infrequent watering, aeration of the lawn, and the use of parasitic nematodes.



Fleas should be controlled with techniques that focus on your pet and the areas where the pet sleeps rather than broadcast insecticides. Flea combing is an effective technique for removing fleas from your pet. Since flea eggs and larvae are mostly found off the pet and often are in the pet's bedding, frequent vacuuming or washing of the bedding that your pet uses is important. Commercial flea traps that use a light to attract fleas to a sticky surface are also available.

Factsheets with more detailed and referenced discussions of alternative management techniques for these pests are available on NCAP's website, www.pesticide.org.

Unniversity of Nebraska-Lincoln Entomology Department

Taking Action

Diazinon's impacts on water quality and fish health in urban and rural areas give us a remarkable incentive to change the techniques used to manage pests in the Northwest. Simple nonchemical solutions are available for managing the major pests for which diazinon is used (For examples, see Alternatives, p.17). Now we need concerted action to insure that these alternatives are widely adopted. To that end, The Oregon Pesticide Education Network recommends the following:

"Clean water and thriving salmon are an integral part of the Pacific Northwest's heritage. Simple but decisive action to protect salmon from pesticides now can restore this heritage for generations to come."

• **Each state in the Pacific Northwest should comprehensively track pesticide use.** Site-specific data about which pesticides are used where and in what amounts is essential if we are to successfully and efficiently monitor streams for pesticide contamination and reduce hazards to fish. Collection of sales information from businesses that retail household pesticide products is a crucial part of this effort.

• **EPA must comply with both the Clean Water Act and the Endangered Species Act in order to protect our waterways and the salmon that depend on them.** EPA should establish aquatic life criteria for diazinon and other pesticides that commonly pollute water. These criteria should be adopted by states in the Pacific Northwest and elsewhere. Cleanup and pollution prevention measures should then be initiated. EPA should also complete the "consultations" required under the Endangered Species Act, and regulate use of diazinon and other pesticides to protect salmon.

• **Information about nonchemical strategies for managing the pests for which diazinon is frequently used should be readily available.** Master gardening programs, county extension agents, and water quality agencies should produce educational materials for distribution at garden stores and other places where consumers seek advice about pest problems. State departments of agriculture and land grant universities should provide farmers, school districts, and local governments with information and assistance to encourage alternatives to diazinon use.

Clean water and thriving salmon are an integral part of the Pacific Northwest's heritage. Simple but decisive action to protect salmon from pesticides now can restore this heritage for generations to come.

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