● INSECTICIDE FACTSHEET

DIAZINON: ECOLOGICAL EFFECTS AND ENVIRONMENTAL CONTAMINATION

Diazinon is an organophosphate insecticide that is toxic to birds and has caused what the U.S. Environmental Protection Agency calls "widespread and repeated mortality." Exposure to diazinon also reduces the number of eggs birds lay and the survival of eggs and nestlings.

Diazinon is toxic to many species of fish. In addition to killing fish, exposure to low concentrations (one part per billion or less) also causes genetic damage, disrupts behaviors that are crucial for reproduction and protection from predators, and kills aquatic animals on which fish depend for food.

Exposure to diazinon also causes abnormalities in developing tadpoles at concentrations of several parts per billion. The abnormalities include stunting of their tails and underdevelopment of their gills.

Diazinon reduces the ability of soil organisms to transform (fix) atmospheric nitrogen into a form that is usable to plants.

Rivers and streams are frequently contaminated with diazinon. In a national monitoring study, diazinon was the most commonly detected insecticide in both urban and agricultural watersheds. Research has shown that residential diazinon applications made according to label directions contaminate surface water. Diazinon is a frequent air contaminant; a compilation of U.S. air monitoring studies found diazinon in 90 percent of the samples tested.

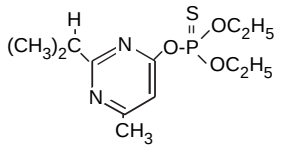
BY CAROLINE COX

Diazinon (see Figure 1) is a commonly used insecticide in the organophosphate chemical family. The hazards of diazinon to human health were summarized in the first part of this factsheet (JPR 20(2):15-21). This article discusses diazinon's hazards to birds, fish, beneficial insects, and plants, as well as diazinon contamination of water and air.

Effects on Birds

Acute toxicity: Diazinon is notorious because of its acute (short-term) toxicity to birds. For many species, its acute toxicity is less than 10 milligrams per kilogram (mg/kg), placing it in the U.S. Environmental Protection Agency's (EPA's) highest acute toxicity category. Sensitive species include Canada goose, house sparrow, mallard duck, bobwhite quail, red-winged blackbird,[1] and American wigeon.[2]

Figure 1
Diazinon



diazinon
(O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate)

Symptoms of acute poisoning in birds are lack of coordination, wing spasms, diarrhea, salivation, and seizures.[3]

Diazinon-related bird kills are common. According to EPA, "Diazinon has caused widespread and repeated mortality of birds."[4] Only the carbamate insecticide carbofuran has caused more pesticide-related bird kills than diazinon.[5] These hazards led to cancellation of diazinon's uses on golf courses and sod farms, where diazinon-caused bird kills were frequent, in 1988.[6] Even though these uses have ended, EPA's incident reporting system indicates that the number of diazinon-caused bird kills has increased steadily since the 1980s.[5]

Both liquid and granular diazinon products are hazardous to birds. Liquid products leave residues on vegetation, which can then be eaten by birds. Diazinon also washes into puddles during rainfall or irrigation, and birds drink the contaminated water. Birds eat granular products when they stick to food or pick them up directly as grit.[7] A single diazinon granule has killed house sparrows in laboratory tests, and five granules have killed blackbirds.[8]

EPA's assessment of diazinon's acute risks to birds concluded that the agency's "levels of concern"[9] were exceeded for all uses evaluated. EPA stated that its past efforts to mitigate these risks by lowering application rates and adding label warnings "are not adequate to prevent mortality."[10]

Problems with Reproduction: In addition to its acute toxicity, diazinon re-

Caroline Cox is JPR's editor.

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duces the reproductive success of birds. Examples include the following problems:

• *A decrease in the successful hatching of eggs.* Robin eggs in Christmas tree plantations sprayed with diazinon hatched at a lower rate than did eggs in unsprayed nests.[11] In a laboratory study, the hatching rate of eggs from chickens fed 0.1 parts per million (ppm) in their food was 87 percent, compared to 94 percent from birds fed uncontaminated food.[12]

• *A decrease in the survival of nestlings.* Mortality of song sparrow nestlings in Christmas tree plantations sprayed with diazinon was greater than mortality in unsprayed nests.[11] (See Figure 2.) In a laboratory study, survival of mallard ducklings whose mothers were fed 16 ppm of diazinon in their food was significantly less than the survival of ducklings whose mothers were fed uncontaminated food.[13]

• *A decrease in the number of eggs laid.* The number of eggs produced by bobwhite quail fed 35 ppm of diazinon in their food was reduced compared to quail fed uncontaminated food.[14]

• *An increase in the number of deformities in developing chicks.* Injection of small amounts of diazinon (6.25 micrograms (µg)) into developing eggs caused the chicks to develop twisted necks.[15] Higher amounts of diazinon caused additional defects in quail and chicken including folding of the spinal chord,[15] shortening of the neck,[15] fusing and twisting of vertebrae,[16] abnormal development of ribs and breastbone,[16] reduced calcification of bones,[17] curled claws,[18] and reduced growth of leg and wing bones.[18]

Endangered species: EPA's assessment of diazinon's hazards concluded that the agency's "levels of concern" for endangered bird species were exceeded by all the uses of diazinon evaluated, including liquid and granular diazinon products used in both agricultural and urban settings.[19] These concerns are supported by a study of loggerhead shrikes in Virginia. Diazinon contaminated 29 percent of the kidney, liver, and brain samples tested.[20]

Exposure: Studies of diazinon exposure to birds are rare. However, the few studies obtained by NCAP indicate that diazinon exposure could be widespread. In California's Central Valley, diazinon was found on the feathers of 45 percent of the hawks studied.[21] Diazinon also was found in a goose that died after a condominium lawn was treated with diazinon.[22]

Lack of ability to detoxify organophosphates: Birds have lower levels of a group of enzymes used to break down diazinon than do mammals.[23] According to researchers, "this appears to be the main reason why birds are much more susceptible than mammals"[23] to diazinon and related insecticides.

Special susceptibility of juveniles: Young birds appear to be more susceptible to diazinon poisoning than mature birds. In a study of starlings, newly hatched nestlings were 20 times more sensitive than birds that had fledged.[24]

Effects on Fish

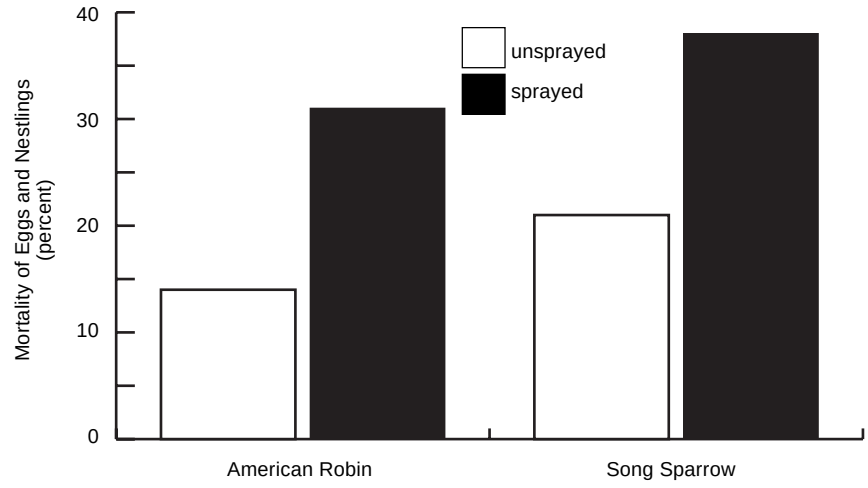
Acute toxicity: According to EPA, diazinon is highly toxic (median lethal concentration, LC_{50}, less than 1 ppm) or very highly toxic (LC_{50} less than 0.1 ppm) to about 60 percent of the fish species for which the agency has data. These include bluegill sunfish; brook, cutthroat, lake, and rainbow trout; and striped mullet.[25] Fish species that are sensitive to diazinon have enzymes that activate diazinon more quickly, enzymes that break it down more slowly, or nerves that are more affected by diazinon.[26]

EPA has calculated that acute risks to fish from diazinon's use on urban lawns and many of its agricultural uses exceed the agency's "levels of concern."[27]

Genetic damage: Diazinon has caused genetic damage in the central mudminnow, a fish used as a model for testing of genetic effects. In aquarium studies, diazinon at the low concentration of 160 parts per trillion caused an increase in genetic damage called sister chromatid exchanges (SCEs).[28] SCEs are exchanges of genetic material between parts of a chromosome as it duplicates.[29]

Effects on reproduction: Diazinon can disrupt the physiology of reproducing fish. Male Atlantic salmon returning to spawning streams normally react to the smell of urine from female salmon who have recently ovulated. In response to this smell, the levels of sex hormones in males'

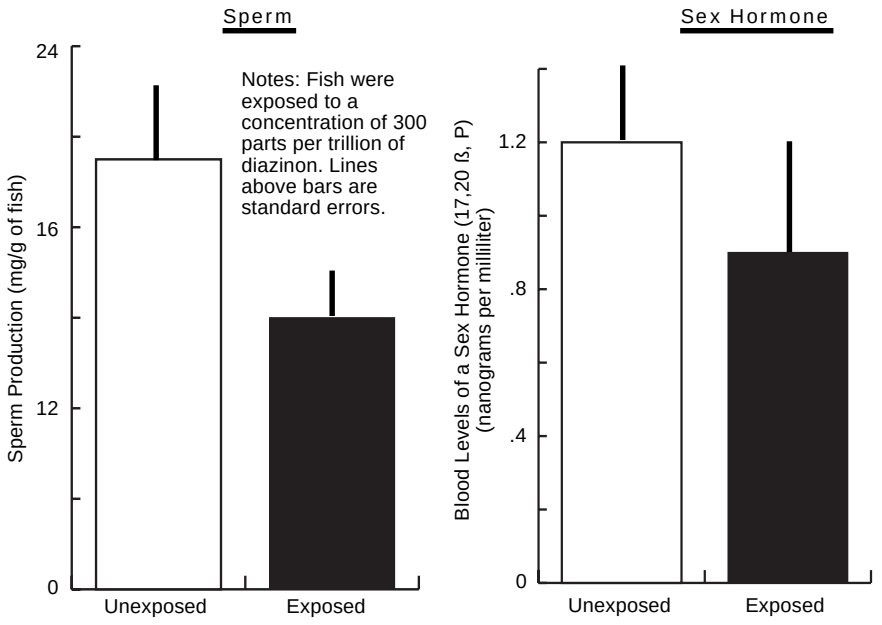
Figure 2
Diazinon Spraying Increased the Mortality of Robin and Sparrow Eggs and Nestlings



Source: Rondeau, G. and J. Desgranges. 1995. Effects of insecticide use on breeding birds in Christmas tree plantations in Quebec. *Ecotoxicol.* 4:281-298.

In nests from Christmas tree plantations sprayed with diazinon, mortality of eggs and nestlings was nearly twice the mortality in nests from plantations not sprayed during nesting season.

Figure 3
Effect of Diazinon on Salmon Sperm Production and Sex Hormone Levels



Source: Moore, A. and C.P. Waring. 1996. Sublethal effects of the pesticide diazinon on olfactory function in mature male Atlantic parr. *J. Fish. Biol.* 48:758-775.

Male Atlantic salmon exposed to diazinon produced less sperm than unexposed salmon. Levels of one of their sex hormones were also reduced.

blood rise and their production of milt (sperm) increases. Concentrations of diazinon above 300 ppt reduced these responses.[30] (See Figure 3.)

Diazinon also impaired reproduction at only slightly higher concentrations (560 ppt) in a study of sheepshead minnows.[31] Reproduction was impaired during diazinon exposure and for up to a month after exposure. In a similar study of brook trout, diazinon reduced the growth of offspring at concentrations of 550 ppt.[32]

Effects on antipredator behavior: A study by the National Marine Fisheries Service found that diazinon affects the behavior of young chinook salmon. Concentrations (1 and 10 ppb) which "emulate diazinon pulses in the natural environment"[33] affect the olfactory system (their sense of smell) and disrupt antipredator behaviors that are normally initiated when the fish smell alarm chemicals given off by other fish in the water.[33]

Effects on food: As an insecticide, diazinon kills insects and other aquatic animals on which many fish feed. For details about effects on these food resources, see "Effects on Aquatic Insects and Crustaceans," below.

Bioconcentration: Diazinon bioconcentrates in fish, meaning that the concentration in fish is greater than that in the water in which the fish lives. Bioconcentration factors (the ratio between the concentration in the fish and that in the water) vary from 18 to 300.[34-38]

Damage to gills: Concentrations of diazinon as low as 15 ppb have damaged gills of the bluegill sunfish. At higher concentrations, diazinon "may result in severe physiological problems, ultimately leading to the death of fish."[39] Gills may be particularly susceptible to diazinon because diazinon bioconcentrates more strongly in gills (bioconcentration factor 2300)[40] than in some other fish tissues.[41]

Liver damage: Another organ in which diazinon bioconcentrates is the liver. Bioconcentration factors as high as 1850 have been measured.[42] In the livers of exposed fishes, concentrations of 150-200 ppb cause cell membranes to rupture[43] and cavities to form.[43,44]

Effects on Vision: Exposure of eggs to diazinon causes areas of dead cells to form in the retina of developing medaka.[45]

Hazards to Endangered Species: EPA's risk assessment considered 19 agricultural uses and 1 household use (broadcast treatment of lawns). The agency's "levels of concern" for endangered freshwater and marine fish species were exceeded by all 20 uses evaluated.[27]

Effects on Frogs

Low concentrations of diazinon affect the survival and development of frog eggs and tadpoles. About 3 parts per billion (ppb) of the diazinon-containing insecticide Basudin 500 EC caused half of tested green frog eggs to fail to hatch. Slightly higher concentrations (5 ppb) of diazinon alone had a similar effect. Even lower concentrations (0.5 ppb Basudin 500 EC and 1 ppb diazinon) produced swelling and blistering of the head or abdomen, stunting of the tail, and underdevelopment of gills. Since the researchers measured diazinon contamination up to .78 ppb in wetlands in four orchards, they believe that it impacts tadpoles at "environmentally relevant concentrations."[46]

Effects on Earthworms

Application of the diazinon-containing insecticide Diazinon 14G to turf reduces earthworm populations about 60 percent.[47] (See Figure 4.) Supporting evidence comes from the LC_{50} (the median lethal concentration, the concentration needed to kill 50 percent of test animals) for a common earthworm, 18 ppb.[48]

Effects on Aquatic Insects and Crustaceans

Diazinon is "very highly toxic" to most many aquatic insects and crustaceans, according to EPA. For example, LC_{50}s for waterfleas, scuds, and larval caddisflies are less than 1 ppb.[49-51] Other effects occur at lower exposures: 0.5 ppb reduced

waterflea feeding[52]; 1 ppt reduced growth and reproduction of waterfleas; 0.1 ppb disrupted shrimp feeding[53]; and 0.6 ppb induced stress proteins in a crustacean.[54]

In a field study, cadddisflies and waterfleas were the two groups of animals most sensitive to diazion.[55]

Diazinon can be surprisingly persistent in aquatic animals. For example, diazinon was found in fiddler crabs 6 weeks after a mosquito treatment.[56]

Effects on Beneficial Insects and Mites

Given that diazinon is an insecticide, it is not surprising that it harms beneficial insects and mites, those that are useful in agriculture.

For example, diazinon is classified by EPA as "highly toxic" to honeybees.[57] It also shortens the life span of worker honey bees.[58,59] (See Figure 5.) Newly emerged bees are most sensitive.[59] Alfalfa leafcutting bees and alkali bees, also used as pollinators, are as sensitive to diazinon as honey bees are.[60]

In an international screening program of beneficial insects and mites, diazinon was in the highest toxicity category for most of the species tested: parasitic wasps and predatory mites, as well as lacewings, ladybugs, and other predatory insects.[61] Diazinon has similar effects on predators and parasites of the pecan aphid; diazinon caused 100 percent mortality of the four species studied.[62]

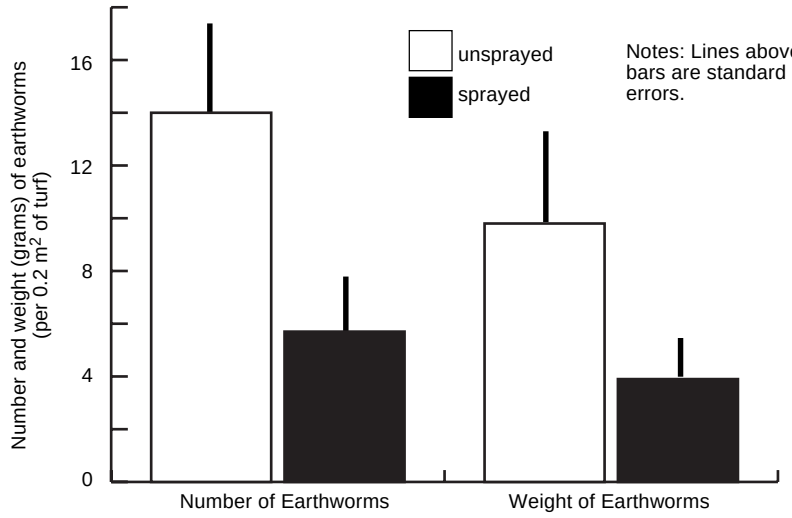
Effects on Pest Insects

Diazinon increases the economic damage caused by the brown plant hopper, an important pest of rice in tropical areas. Treatment with diazinon increased planthopper populations and rice damage. The planthoppers' feeding rate and egg production also increased on treated rice.[63]

Effects on Plant Growth

Although perhaps unexpected for an insecticide, diazinon can reduce plant growth. The most sensitive species studies in tests submitted to EPA for diazinon's registration was cucumber. A reduction in shoot height[64] occurred at applications of less than the recommended 4 pounds per acre.[65] EPA assessed diazinon's risks to endangered plant species using this data and concluded that the agency's "levels of concern" were exceeded for many agricultural uses.[66]

Figure 4
Effect of a Diazinon Turf Treatment on Earthworm Populations



Source: Potter, D.A. et al. 1990. Toxicity of pesticides to earthworms (Oligochaeta: Lumbricidae) and effect on thatch degradation in Kentucky bluegrass turf. *J. Econ. Entomol.* 83:2362-2369.

Treatment of turf with diazinon caused significant earthworm mortality.

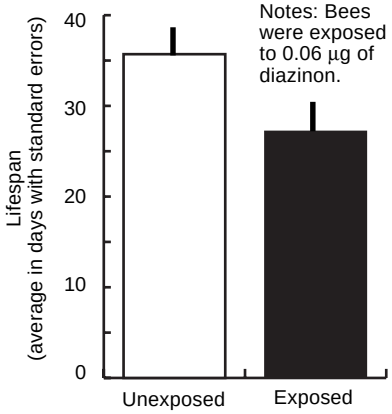
Genetic Damage in Plants

Diazinon has also caused genetic damage in plants. In onions[67] and barley[67,68] diazinon treatment resulted in abnormal chromosomes. In addition, seeds from diazinon-treated plants grew into seedlings with mutations that reduced the chlorophyll in their cells.[67] Abnormal chromosomes in pollen cells were also caused by diazinon treatment of barley seeds or seedlings.[69]

Effects on Nitrogen Fixation

Diazinon can reduce the ability of soil organisms to fix nitrogen, an important plant nutrient. Nitrogen fixation is the process that transforms atmospheric nitrogen into a form that is usable by plants. In a study of *Rhizobium*, a nitrogen-fixing bacteria that lives on the root of the soybean, diazinon treatment at the recommended rate reduced the activity of an important nitrogen-fixing enzyme. The nitrogen content of the soybean was reduced by about half.[70] A study of nitro-

Figure 5
Effect of Diazinon on the Lifespan of Honey Bees



Source: Smirle, M.J., M.L. Winston, and K.L. Woodward. 1984. Development of a sensitive bioassay for evaluating sublethal pesticide effects on the honey bee (Hymenoptera: Apidae). *J. Econ. Entomol.* 77:63-67.

Exposure of bees to diazinon (1/5 of the amount that will kill a bee) shortens their lifespan.

gen-fixing bacteria on water hyacinth had similar results: diazinon reduced the growth of the bacteria by almost half.[71] The activity of an enzyme found in soil microorganisms that "plays an important role" in nitrogen cycling was inhibited by diazinon.[72] Diazinon also reduced the amount of nitrogen compounds in soil.[73]

Contamination of Rivers and Streams

Diazinon was the most commonly detected insecticide in the U.S. Geological Survey's National Water-Quality Assessment Project (NAWQA). NAWQA is a nationwide monitoring program that eventually will study 60 river basins across the country. Currently (2000), data from 20 basins are available.[74] Diazinon contaminated rivers or streams in all of the basins studied so far.[75] (See Figure 6.)

NAWQA also found associations between pesticide pollution and land use. Diazinon was the most commonly detected insecticide in both agricultural and urban areas. About 75 percent of samples from urban watersheds were contaminated with diazinon, as were almost 20 percent of samples from agricultural watersheds,[74] but concentrations were highest in agricultural areas with heavy diazinon use.[76]

This widespread contamination has led to studies on local or regional scales which have documented several important patterns. These include the following:

• *Diazinon applications made at recommended rates and following label directions contaminate streams.* In Castro Valley, California, researchers treated two single family homes with diazinon in accordance with the product label, then measured diazinon contamination in runoff from patios, driveways, and roof drains. Runoff was contaminated for seven weeks after application.[77] (See Figure 7.)

• *Diazinon pollution is not limited seasonally or to certain weather conditions.* A study in the Hudson River Basin, New York, found that diazinon contamination was more frequent in the spring and summer, when applications are typically made, but 60 percent of the fall and winter samples analyzed were also contaminated.[78] A study of the South Platte River Basin (Colorado and Nebraska) found diazinon in samples taken after rain storms, when runoff might be expected, but also found "substantial" contamination during dry weather.[79]

• *Pollution of rivers and streams by diazinon is related to the amount of use.* This is true both in urban and agricultural areas. For example, in King County, Washington, diazinon was the insecticide with the most retail sales, and was found in 100 percent of the streams sampled.[80] In the Tuolumne River Basin, California, diazinon was the insecticide with the highest reported use, and was also found in the highest concentration.[81]

• *Diazinon use does not have to be widespread in order to contaminate streams.* In Castro Valley, California, researchers calculated that use of diazinon by four percent of the homes would account for the contamination they observed.[77]

• *Pollution of urban streams is related primarily to residential use of diazinon, not use on commercial properties.* In Stockton and Sacramento, California, researchers compared stormwater from a residential and a commercial drainage. Concentrations were two times higher in the residential area than in the commercial area.[82]

Contamination of Wells

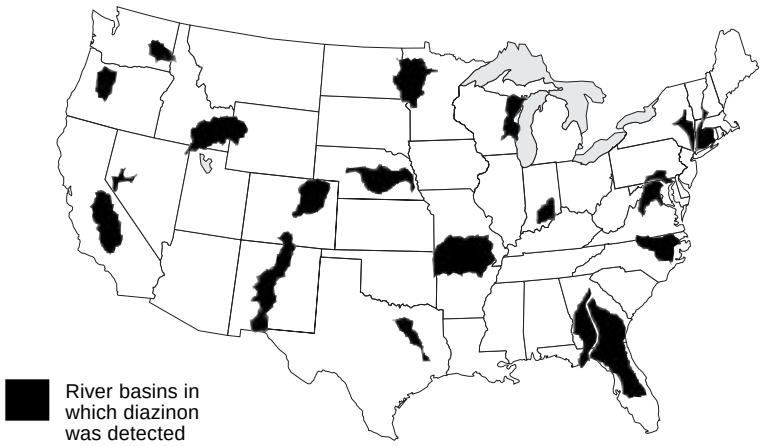
Diazinon contaminates wells, but not as frequently as it contaminates surface water. NAWQA found diazinon in about 2 percent of tested wells.[83] Contaminated wells were located in 10 of the 20 basins studied so far.[75]

It is striking that deep wells are as vulnerable as shallow wells to diazinon. In the NAWQA study, contamination was as common in deep wells in major aquifers as it was in shallow wells.[84] Diazinon was found in Missouri drinking water wells that were 80 feet deep; a similar study in Virginia found diazinon in wells that were 200 feet deep.[85]

Toxic Effluent from Wastewater Treatment Plants

Diazinon is a major cause of toxicity in the effluent from wastewater treatment plants. A nationwide survey found that 65 percent of effluent samples were con-

Figure 6
Contamination of U.S. Rivers and Streams with Diazinon: Results of the U.S. Geological Survey's National Water-Quality Assessment Program



Source: U.S. Geological Survey. National Water-Quality Assessment (NAWQA) Program. 1998. Circulars 1144,1150, 1151, 1155-1171. http://water.usgs.gov/pubs/nawqasum/.

The U.S. Geological Study found diazinon in all twenty river basins they have studied as part of the National Water-Quality Assessment Program.

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taminated. Across the country, 47 treatment plants have failed Clean Water Act toxicity tests because of diazinon contamination.[86] Although researchers believe that this contamination comes from diazinon's varied commercial and residential uses,[87] one study identified pet kennels as a source of wastewater with high concentrations of diazinon.[88]

Diazinon is not removed from wastewater by the standard techniques used at wastewater treatment plants.[89]

Contamination of Air

Diazinon frequently pollutes air. In 1998, the USGS compiled local, state, multi-state, and national air monitoring studies from the U.S and found that nearly 90 percent of the samples were contaminated with diazinon. Diazinon was the fifth most frequently detected pesticide.[90]

As with diazinon's contamination of water, both urban and agricultural uses contribute significantly to contamination of air, with urban uses being particularly important. A 1998 study along the Mississippi River found diazinon in every sample tested, regardless of land use. However, concentrations were highest in "reaches of the river that included a major metropolitan area."[91]

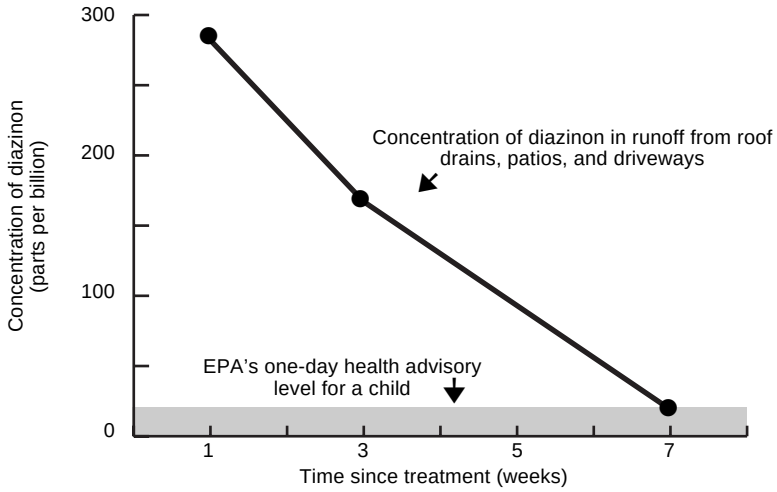
Airborne diazinon can travel large distances. In California, diazinon has been found in the air in the Sierra Nevada Mountains, 15 miles (25 kilometers, km) from the application site.[92]

Contamination of Rain, Snow, and Fog

Diazinon contaminates rain and snow along the Mississippi and in California's Sierra Nevada mountains.[92-94] One California study found diazinon in rain 25 miles (40 km) from the application site.[92]

During the last two decades, diazinon has been repeatedly found in fog in California's Central Valley and in coastal areas.[95-98] Diazinon in fog water that drips from trees is transformed into diazoxon, a more biologically active and toxic molecule than diazinon, resulting in "enhanced toxicity"[98] to orchard workers.

Figure 7
Levels of Diazinon in Runoff after Household Treatments



Sources:
Schueler, T.R. 1999. Diazinon sources in runoff from the San Francisco Bay region. *Watershed Protection Techniques* 3:613-616.
U.S. EPA. Office of Water. 2000. Drinking water standards and health advisories. Washington D.C.

Diazinon concentrations in runoff following a household application made according to label directions were above EPA's acceptable level for a child to drink. Concentrations remained above this level for seven weeks after application.

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