● INSECTICIDE FACTSHEET

CARBARYL

Carbaryl is a widely used insecticide in the carbamate chemical family. It is used in dozens of products; one well-known brand name is Sevin. About 2 million pounds of carbaryl are used every year on 140 agricultural crops. Between 2 and 4 million pounds are used every year in yards and gardens.

Symptoms of carbaryl poisoning in exposed people include stinging eyes, wheezing, sweating, and nausea.

The National Institute of Occupational Safety and Health labels carbaryl as a mutagen (a compound that causes genetic damage) based on a series of laboratory tests spanning decades. Similarly, carbaryl's ability to disrupt hormone function and the immune system were first documented decades ago. Current research supports the results of the older studies.

The U.S. Environmental Protection Agency classifies carbaryl as "likely to be carcinogenic [cancer-causing] in humans." Use of carbaryl has also been linked with cancer in studies of farmers.

Exposure of men to carbaryl (measured by the amount of its breakdown product in the body) is linked with sperm problems, including low sperm counts and sperm that can't move normally.

In laboratory tests, exposure to carbaryl during pregnancy caused offspring to have smaller brains than are found in unexposed animals.

Carbaryl frequently contaminates air, rain, and streams.

Carbaryl is toxic to birds, fish, tadpoles, salamanders, shrimp, bees, and other animals. Small amounts have caused adverse effects. These effects include reduced production of eggs, reduced ability to run, deformed legs, reduced swimming speed, and mortality.

BY CAROLINE COX

Carbaryl (see Figure 1) is a popular insecticide that has been used since 1956. It is a broad spectrum insecticide, killing most insects, and is also used as a molluscide to kill slugs and snails. It is the oldest commercially viable insecticide in the carbamate chemical family.[1]

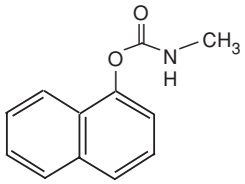
Dozens of products manufactured by over 30 companies contain carbaryl,[2] but Bayer CropScience is the primary manufacturer.[3] One well-known brand name is Sevin.[3]

This article focuses on research published since 2000.

Use

The U.S. Environmental Protection Agency (EPA) estimates that about two million pounds of carbaryl are used every year for agricultural purposes.[4] Use in yards and gardens is at least as much, and perhaps significantly more; EPA's estimates range from two to four million pounds per year.[5] There are over 140 food crops on which carbaryl can be used; crops on which over 100,000 pounds of carbaryl per year are used include apples, pecans, grapes, alfalfa, oranges, and corn.[4] Pests targeted by home and garden carbaryl products include fleas, fruit tree insects, lawn insects, garden insects, ornamental plant insects, slugs, snails, fire ants, and grasshoppers.[2,3]

Figure 1
Carbaryl



1-naphthyl N-methylcarbamate

How Does Carbaryl Kill Insects?

Carbaryl, like all insecticides in its chemical family, kills insects by disrupting the normal function of their nervous system. Nerve impulses are transmitted from one nerve to another by a chemical called acetylcholine. Under normal circumstances, an enzyme called acetylcholinesterase destroys the acetylcholine so that another nerve impulse can be transmitted. Carbaryl stops the functioning of this enzyme, so acetylcholine builds up, resulting in restlessness, tremors, convulsions, paralysis, and death.[6]

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The way carbamate insecticides kill insects is similar to another common class of insecticides, the organophosphates. The major difference is that organophosphates inhibit the enzyme for days, while the effect of carbamates lasts a shorter period of time (a few hours).[6]

Carbamates affect human nerves in much the same way as they affect insect nerves. The nerves they affect are different, however. In insects carbamates affect the central nervous system. In humans they affect the interactions between nerves and muscles. This means that the symptoms of carbaryl poisoning in humans are different than the symptoms in insects.[6] (See "Symptoms of Carbaryl Poisoning," right.)

Inert Ingredients

Most commercial carbaryl products contain ingredients other than carbaryl. According to U.S. pesticide law, many of these ingredients are called "inert."[7] There is not much public information about the identity of these ingredients.

For information about the hazards of some of the inert ingredients in carbaryl-containing pesticides, see "Inert Ingredients," left.

In this article, we identify which studies use carbaryl and which use commercial carbaryl products. Most studies conducted to satisfy registration requirements at EPA use carbaryl alone.[8]

Symptoms of Carbaryl Poisoning

Symptoms of poisoning in people exposed to carbaryl include irritated, swollen, congested, stinging or burning eyes as well as sore or burning throat, chest tightness, wheezing, sweating, dry heaves, nausea, and vomiting, according to reports collected by the California Environmental Protection Agency.[9]

Effects on the Nervous System

Given that carbaryl's pesticidal activity results from disrupting nerve function, it is not surprising that the nervous system is affected in laboratory tests. In a study sponsored by a carbaryl manufacturer, exposure to a single dose of carbaryl caused behavioral changes (decreases in activity) as well as decreases in the activity of acetylcholinesterase. These effects occurred at all dose levels tested in this experiment.[10]

Ability to Cause Genetic Damage (Mutagenicity)

The National Institute for Occupational Safety and Health labels carbaryl as a mutagen and has identified over 20 studies conducted in the 1970s and 1980s documenting carbaryl's ability to cause genetic damage.[11]

A recent study provided more details about this ability to cause genetic damage. A group of scientists led by a toxicologist from the Institut National de la Recherche Agronomique (France) studied carbaryl in 2001. They found, in human cells, that carbaryl stimulates the activity of an enzyme that transforms carbaryl into a compound

"INERT" INGREDIENTS

Some inert ingredients in commercial carbaryl products, with examples of their health hazards, include the following:

- **Amyl acetate**[1] caused eye irritation and behavior changes in laboratory tests.[2]
- **1,2-Benzisothiazolin-3-one**[3] caused skin allergies in laboratory tests.[4]
- **Propylene glycol**[5] caused genetic damage and miscarriages in laboratory tests.[6]
- **Quartz (crystalline silica)**[7] caused cancer and genetic damage in laboratory tests.[8]
- **Sodium dioctyl sulfosuccinate**[3] caused severe eye irritation and diarrhea in laboratory tests.[9]
- **Sodium salt of lignosulfonic acid**[3,10] caused genetic damage and muscle weakness in laboratory tests.[10]
- **Sodium sulfate**[3,11] caused skin tumors and abnormal development of fetuses in laboratory tests.[12]
- **Trimethylbenzene**[3,13,14] caused genetic damage in laboratory tests.[15-17]

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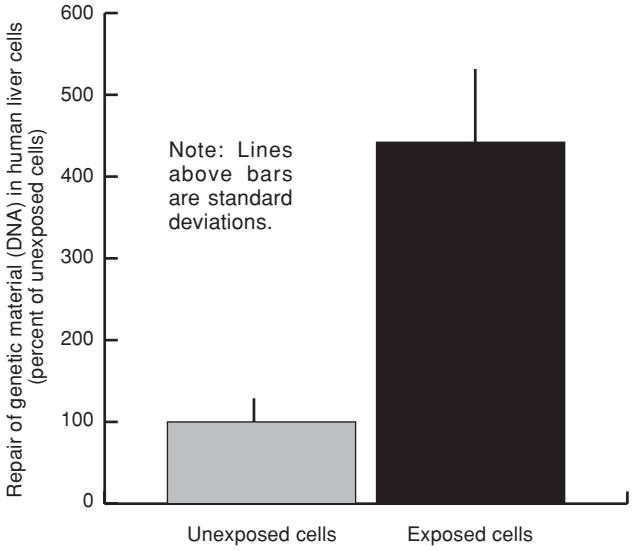
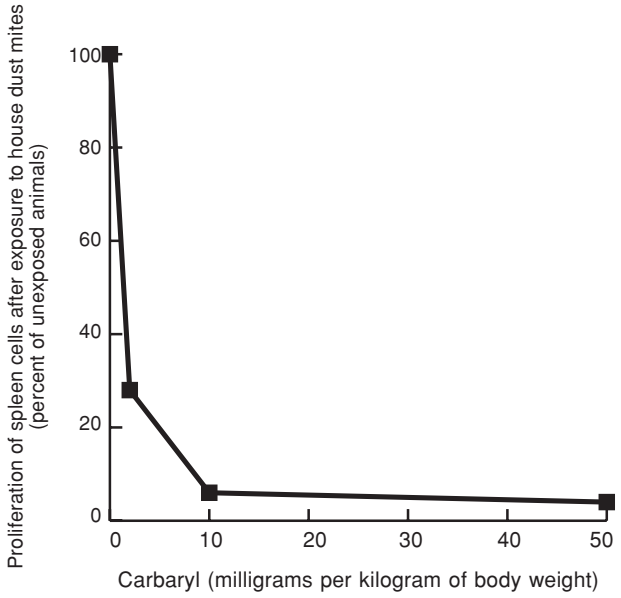
Figure 2
Ability to Cause Genetic Damage



Source: Delescluse, C. et al. 2001. Induction of cytochrome P450 1A1 gene expression, oxidative stress, and genotoxicity by carbaryl and thiabendazole in transfected human HepG2 and lymphoblastoid cells. *Biochem. Pharmacol.* 61:399-407.

Figure 3
Ability to Disrupt the Immune System



Source: Dong, W, et al. 1998. Enhanced allergic responses to house dust mite by oral exposure to carbaryl in rats. *Toxicol. Sci.* 44:63-69.

Carbaryl exposure caused genetic damage in tests with human cells, and disrupted the response of the immune system to house dust mites.

that causes damage to DNA, the genetic material in living organisms, (see Figure 2).[12]

Effects on Hormones

Hormones are chemical messengers that regulate all biological processes in people, other mammals, birds, and fish. These processes include "blood sugar levels, growth and function of the reproductive system, and the development of the brain and nervous system."[13] Hormones are mostly produced by endocrine glands like the ovaries, testes, pituitary gland, and thyroid gland.[13]

Carbaryl's ability to disrupt hormones and the endocrine system was first demonstrated only a decade after its marketing began when researchers from the USSR Academy of Medical Sciences described carbaryl's effects on the endocrine glands of rats.[14]

Recent research supports these conclusions. For example, in 1997, researchers from Tulane University showed that carbaryl inhibited the activity of two sex hormones, estradiol and progesterone, in human cells.[15] EPA's Science Policy Council, in 2005, described two different evaluations that have identified carbaryl as an endocrine disruptor.[16]

Despite this long history of concern, EPA's Office of Pesticide Program's 2004 evaluation of carbaryl took no action with respect to effects on hormones except to state that "carbaryl may be subjected to additional screening and/or testing to better characterize effects related to endocrine disruption."[17]

Effects on the Immune System

Carbaryl's ability to disrupt the immune system was first demonstrated about the same time that effects on hormones were first published; Soviet researchers showed that exposure to carbaryl reduced immunity to tetanus in laboratory animals.[18] Recent research has come to similar conclusions; EPA and University of North Carolina toxicologists showed that carbaryl suppressed the immune system while increasing house dust mite allergies in laboratory animals. (See Figure 3.)[19]

Ability to Cause Cancer (Carcinogenicity)

In 2001, EPA classified carbaryl as "likely to be carcinogenic in humans," based on a study sponsored by a carbaryl manufacturer which found that carbaryl caused malignant blood vessel tumors in laboratory mice. In this study, as well as in an additional study of laboratory rats, carbaryl also caused kidney and liver tumors.[20]

Consistent with these laboratory experiments, two recent studies have found an association between use of carbaryl by farmers and an increased risk of the cancer non-Hodgkin's lymphoma (NHL).[21,22]

One study, conducted by researchers from Yale University, the National Cancer Institute, and the University of Nebraska, found that farmers in four Midwestern states who used carbamate

pesticides "had a 30% to 50% increased risk of NHL"[21] The most consistent association was for farmers who used the carbaryl-containing insecticide Sevin. (See Figure 4.)[21]

The second study, led by a researcher from the University of Saskatchewan, found that the risk of NHL in Canadian farmers was significantly increased by exposure to carbaryl.[22]

Effects on Sperm

Two recent studies indicate that carbaryl can damage sperm.[23,24]

One of these studies, from the Harvard School of Public Health and the Centers for Disease Control and Prevention, showed that men with higher amounts of a carbaryl breakdown product in their bodies were more likely to have low sperm counts than men with lower amounts. In addition, sperm from men in the higher exposure group were more likely to have sperm that didn't move normally. None of the exposure to carbaryl in these men resulted from exposure at work. (See Figure 5.)[23]

The second study, conducted by physicians at Nanjing Medical University (China) and the University of California, Los Angeles, looked at workers at a carbaryl manufacturing plant who were exposed to the insecticide and compared them with unexposed workers and with men who worked elsewhere. The study showed that sperm from exposed workers had more fragmented DNA and abnormal chromosomes than did sperm from unexposed men.[24]

Miscarriage

A study of Ontario (Canada) farm families found that use of carbaryl by male farmers was associated with an increased risk of their wives' pregnancies ending in a miscarriage. The research was part of the Ontario Farm Family Health Study and was done by researchers from the University of North Carolina and Health Canada.[25]

Effects on the Developing Brain

A study sponsored by a carbaryl manufacturer showed that carbaryl exposure during pregnancy and nursing affects the developing brain. The study showed that two parts of the brain were smaller in offspring of exposed animals than in unexposed offspring.[26]

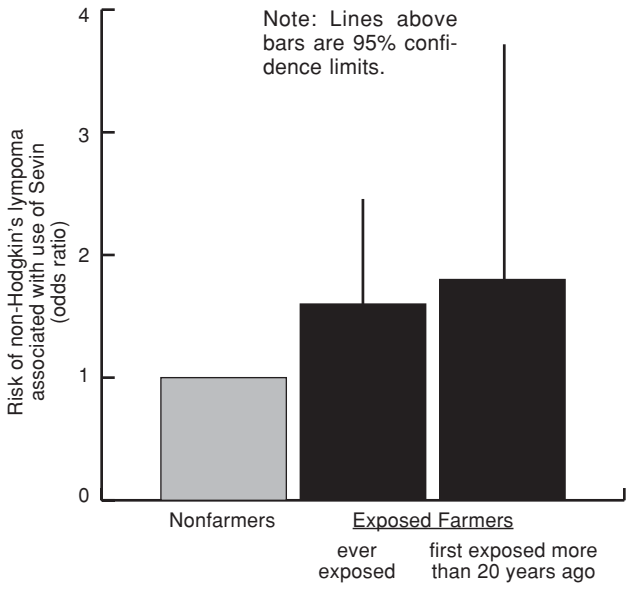
Carbaryl on Skin

Carbaryl is absorbed through skin and ends up in a variety of tissues and organs. Scientists from the Institute of Agricultural Medicine (Poland) showed that carbaryl applied to skin of laboratory animals ended up in the liver, blood, and brain.[27]

Contamination of Streams

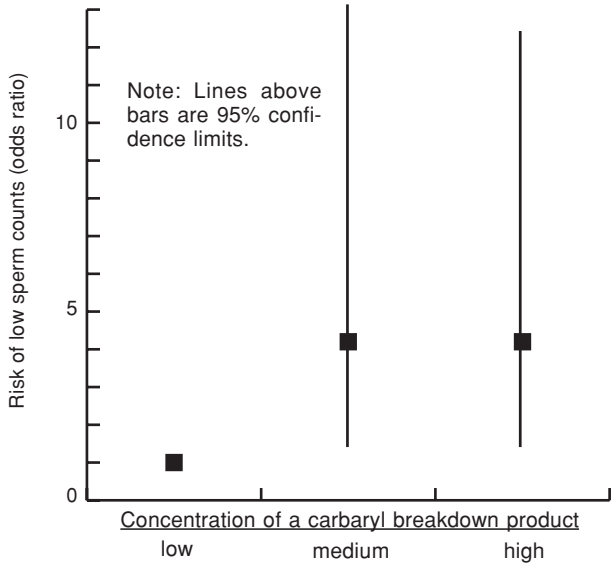
A decade of water monitoring shows that carbaryl frequently contaminates streams, especially in cities and towns. Between 1992 and 2001, the U.S.

Figure 4
Ability to Cause Cancer



Source: Zheng, T. et al. 2001. Agricultural exposure to carbamate pesticides and risk of non-Hodgkin lymphoma. *J. Occup. Environ. Med.* 43:641-649.

Figure 5
Low Sperm Counts



Source: Meeker, J.D. et al. 2004. The relationship of urinary metabolites of carbaryl/naphthalene and chlorpyrifos with human semen quality. *Environ. Health Persp.* 112:1665-1670.

Use of Sevin by farmers is linked with increased incidence of the cancer non-Hodgkin's lympnoma. Exposure to carbaryl is also linked with low sperm counts.

Geological Survey's (USGS's) national water quality monitoring program found carbaryl in almost 10 percent of the agricultural streams sampled, over 15 percent of the streams with mixed land uses, and almost 45 percent of urban streams. Carbaryl is the second most commonly detected insecticide in urban areas, and the third most common in agricultural areas.[28]

Contamination of Rain

Carbaryl, at least in some areas, is often found in rainwater. In a study of 3 rural towns and 3 cities in the Mississippi River Valley, USGS found carbaryl in 10 to 60 percent of the rain samples tested. Only a handful (between 1 and 3) of insecticides were found more often than carbaryl.[29]

USGS also sampled rainwater in a town far away from both urban and agricultural areas. Even there, the agency found carbaryl in the rain, indicating that pesticides like carbaryl are "relatively stable in the environment and have the potential to be transported hundreds of kilometers."[29]

Contamination of Air

The USGS study mentioned in the previous paragraph also found, with the exception of one agricultural town, that carbaryl frequently contaminated air. Between 5 and 40 percent of the samples tested were contaminated with carbaryl. Samples from cities were more frequently contaminated than samples from rural towns.[30]

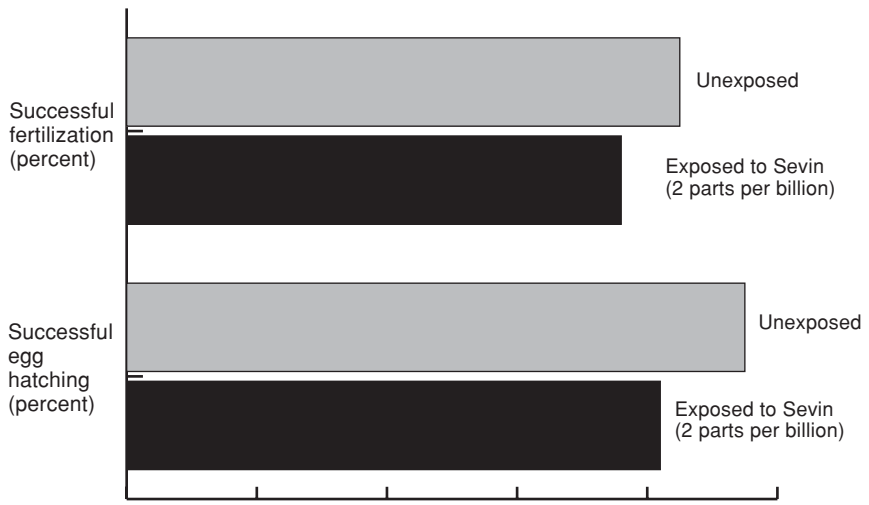
Persistence

There are rarely satisfactory answers to questions about how long a pesticide will persist after it is applied. For carbaryl, there is even less information about persistence than is typical. According to EPA, most of the tests of persistence sponsored by carbaryl manufacturers were unacceptable. The one study EPA accepted was done in a young pine plantation in Oregon. The half-life (time required for half of the applied carbaryl to break down or move away from the application site) was between 65 and 75 days.[31]

Effects on Birds

When EPA assessed the risks of carbaryl to birds in 2002, the agency concluded that use of both granular and liquid products posed significant risks. Over half of the uses of liquid products pose long-term risks to birds because exposure can reduce egg production. All uses of granular products pose short-term risks to small songbirds because the amount of carbaryl applied to one or two square feet is enough to kill these birds. EPA estimates that lawn applications, and applications to trees and shrubs, are more risky than other uses.[32]

Figure 6
Effects on Fish



Source: Kaur, K. and A. Dhawan. 1996. Effect of carbaryl on tissue composition, maturation, and breeding potential of *Cirrhina mrigala. Bull. Environ. Contam. Toxicol.* 57:480-486.

Low concentrations of carbaryl reduce fertilization and hatching of eggs in fish.

Effects on Bees

According to EPA, carbaryl "is categorized as highly toxic"[33] to honey bees. It is also toxic to leaf-cutter bees, alkali bees,[33] and bumble bees.[34] EPA's databases show that "numerous bee kill incidents also have been reported in several states."[35]

Effects on Jumping Mice

Because carbaryl is used in grasshopper baits, there is concern for the harm these baits might cause to the small mammals who share grasshopper habitat. A biologist at the University of Tampa observed the behavior of jumping mice after they were fed Sevin-treated wheat bran. He found that Sevin-exposed mice ran more slowly and were more apt to cannibalize their offspring than unexposed mice.[36]

Effects on Frogs and Salamanders

Two recent studies show that low concentrations of carbaryl harm amphibians.

One experiment, conducted by biologists at the University of Pittsburgh, studied the interactions between carbaryl, predatory salamanders, and tree frog tadpoles. One of their experiments showed that about 60 percent of tadpoles exposed to 50 parts per billion (ppb) of carbaryl died. If predatory salamanders were nearby, adding a second stress to the tadpoles, carbaryl mortality increased to 97 percent.[37]

Another experiment, this one from the University of Kentucky, showed that salamanders are harmed by a concentration of 50 ppb of carbaryl. The survival of salamander larvae decreased when exposed to carbaryl. In addition, carbaryl exposure caused salamanders

to develop deformed legs.[38]

Effects on Fish

According to EPA, carbaryl can "range from highly to slightly toxic to freshwater fish on an acute basis" and is moderately toxic to ocean and estuary fish. Salmon, trout, and perch are the most sensitive species and are killed by concentrations between 250 and 970 ppb.[39]

However, recent research has shown that lower concentrations of Sevin and carbaryl cause significant problems for fish. A study from Punjab Agricultural University showed that Sevin reduced egg production, fertilization, and hatching of a fish called the mrigal.[40] (See Figure 6.) The U.S. Geological Survey showed that carbaryl reduced the swimming speed of rainbow trout, leaving them vulnerable to predators.[41] A third study, from Manhattanville College, showed that Sevin reduced the size of zebrafish embryos.[42] These effects occurred at concentrations between 2 and 188 ppb, but all 3 studies found effects at the lowest concentrations tested.[40-42] This means that the lowest concentration of carbaryl that is harmful to fish has not yet been identified.

Effects on Other Aquatic Animals

In EPA's recent evaluation of carbaryl, the agency used the results from studies of water fleas, stoneflies, and scuds to represent effects on all freshwater animals. In these studies, all sponsored by a carbaryl manufacturer, both carbaryl and a commercial carbaryl insecticide were "very highly toxic"[43] to all three animals tested. Carbaryl and a commercial carbaryl insecticide are also very highly toxic to shrimp, crab, and oysters.[43]

Resistance

Insecticide resistance refers to a reduction in the sensitivity of a pest to an insecticide, resulting in repeated failure of the insecticide to control the pest as expected.[44]

Over 50 pest insects have developed resistance to carbaryl, including many agricultural pests, lice, ticks, fleas, and mosquitos.[45]

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