TRADE OR OTHER NAMES

Brodan, Detmol UA, Dowco 179, Dursban, Eradex, Lorsban, Piridane, Stipend.

REGULATORY STATUS

The EPA has established a 24-hour reentry interval for entering crop areas treated with emulsifiable concentrate or wettable powder formulations of chlorpyrifos without protective clothing (40). Products containing chlorpyrifos must bear the signal word "Warning" or "Caution," depending on the toxicity of the formulation (46). Check specific state regulations for local restrictions which may apply.

INTRODUCTION

Chlorpyrifos is a broad spectrum insecticide, a chemical used to kill a wide variety of insects. It was introduced in 1965 (45). While originally used primarily to kill mosquitoes in the immature, larval stage of development, chlorpyrifos is no longer registered for this use. Chlorpyrifos is effective in controlling a variety of insects, including cutworms, corn rootworms, cockroaches, grubs, flea beetles, flies, termites, fire ants, and lice (38). It is used as an insecticide on grain, cotton, field, fruit, nut and vegetable crops, and well as on lawns and ornamental plants (40, 2). It is also registered for direct use on sheep, turkey, for horse site treatment, for treatment of dog kennels, and for domestic dwellings, farm buildings, storage bins, and commercial establishments (40). Chlorpyrifos is available in emulsifiable concentrate, dust, flowable, pellet, spray, granular and wettable powder formulations (46).

Chlorpyrifos acts on pests primarily as a contact poison, with some action as a stomach poison. It is a nonsystemic contact chemical, meaning that it is acts only
where it comes into direct contact with plant tissues, and is not transported to other plant parts.

Chlorpyrifos is one of a class of insecticides referred to as organophosphates. These chemicals act by interfering with the activities of cholinesterase, an enzyme that is essential for the proper working of the nervous systems of both humans and insects. Please refer to the Toxicology Information Brief on cholinesterase-inhibition for a more detailed description of this topic.

**TOXICOLOGICAL EFFECTS**

**ACUTE TOXICITY**

Chlorpyrifos is moderately toxic to humans (50). Poisoning from chlorpyrifos may affect the central nervous system, the cardiovascular system, and the respiratory system (31). It is also a skin and eye irritant (49). While some organophosphates are readily absorbed through the skin, studies in humans suggest that skin absorption of chlorpyrifos is more limited (45). Skin which has come in contact with this material should be washed immediately with soap and water and all contaminated clothing should be removed. The acute dermal LD50 for chlorpyrifos in male and female rats is greater than 2,000 mg/kg (53).

Three hundred and nineteen human exposure incidents were reported by the Pesticide Incident Monitoring System (PIMS) from 1970 through 1981, most resulting from inhalation and dermal exposure. Three human deaths were caused by chlorpyrifos and/or chlorpyrifos combined with other active ingredients (41). Persons with respiratory ailments, recent exposure to cholinesterase inhibitors, cholinesterase impairment, or liver malfunction are at increased risk from exposure to chlorpyrifos.

The organophosphate insecticides are cholinesterase inhibitors which may be absorbed through all routes of exposure. When toxic amounts are inhaled, the first effects are usually respiratory and may include bloody or runny nose, coughing, chest discomfort, difficult or short breath, and wheezing due to constriction or excess fluid in the bronchial tubes. Skin contact with organophosphates may cause localized sweating and involuntary muscle contractions. Eye contact may cause pain, bleeding, tears, pupil constriction, and blurred vision. Following exposure by any route, other systemic effects may begin within a few minutes or be delayed for up to 12 hours. These may include pallor, nausea, vomiting, diarrhea, abdominal cramps, headache, dizziness, eye pain, blurred vision, constriction or dilation of the eye pupils, tears, salivation, sweating, and confusion. Severe poisoning will affect the central nervous system, producing incoordination, slurred speech, loss of reflexes, weakness, fatigue,
involuntary muscle contractions, twitching, tremors of the tongue or eyelids, and eventually paralysis of the body extremities and the respiratory muscles. In severe cases there may also be involuntary defecation or urination, psychosis, irregular heart beats, unconsciousness, convulsions and coma. Death may be caused by respiratory failure or cardiac arrest (39).

Some organophosphates may cause delayed symptoms beginning 1 to 4 weeks after an acute exposure which may or may not have produced immediate symptoms. In such cases, numbness, tingling, weakness and cramping may appear in the lower limbs and progress to incoordination and paralysis. Improvement may occur over months or years, and in some cases residual impairment will remain (39).

Since chlorpyrifos is absorbed through the skin, especially through cuts and scratches, dermal contact should be avoided (40). In addition to causing inhibition of cholinesterase, acute exposure to chlorpyrifos may cause skin irritation. Absorption through the skin may result in systemic intoxication, or general poisoning in a bodily system. The severity of poisoning will determine the amount and range of symptoms which are experienced (31).

Inhalation of chlorpyrifos may cause absorption of the insecticide through the mucous membranes, resulting in systemic intoxication (31). Plasma cholinesterase levels activity has been shown to be inhibited when chlorpyrifos particles are inhaled (1).

The amount (dose) of a material that causes death in one-half (50%) of the test population, when it is given on a short-term basis by mouth is referred to as its oral lethal dose (LD50). The oral LD50 for chlorpyrifos in rats is 82 to 270 milligrams per kilogram (mg/kg) (21, 41, 2). This indicates that it takes 82 to 270 mg of chlorpyrifos for each kg of body weight to kill 50 percent of the experimental animals tested (14, 49). The LD50 for chlorpyrifos in mice is 60 mg/kg, 1000 mg/kg in rabbits, 32 mg/kg in chickens, 500 to 504 mg/kg in guinea pigs, and 800 mg/kg in sheep (2, 14, 17, 49). The dermal LD50 in rats is greater than 2000 mg/kg (53), and 1000 to 2000 mg/kg in rabbits (2, 17).

The lethal concentration fifty, or LC50, is that concentration of a chemical in air or water that kills half of the experimental animals exposed to it for a set time period. The 4-hour inhalation LC50 for chlorpyrifos in rats is greater than 200 mg/m3 (54).

**CHRONIC TOXICITY**

Repeated or prolonged exposure to organophosphates may result in the same effects as acute exposure including the delayed symptoms. Other effects reported in workers repeatedly exposed include impaired memory and concentration, disorientation,
severe depressions, irritability, confusion, headache, speech difficulties, delayed
reaction times, nightmares, sleepwalking and drowsiness or insomnia. An influenza-
like condition with headache, nausea, weakness, loss of appetite, and malaise has also
been reported (49).

When technical chlorpyrifos was fed to dogs at doses of 0.01, 0.03, 0.1, 1 and 3
mg/kg/day for 2 years, increased liver weight occurred at 3.0 mg/kg. Signs of
cholinesterase inhibition occurred at 1 mg/kg. Rats and mice given technical
chlorpyrifos in the diet for 104 weeks showed no adverse effects other than
cholinesterase inhibition (50). An occupational study on 22 pest control operators
exposed to an 8 hour level of 27.6 microgram per cubic meter (ug/m3) of Dursban
showed inhibition of plasma cholinesterase when compared to a control group of the
same age and sex (37). A measurable change in plasma and red blood cell
cholinesterase levels was seen in spray workers exposed to 0.5% chlorpyrifos
emulsion in field trials for malaria control. Human volunteers who ingested 0.1 mg/kg
of chlorpyrifos daily for four weeks showed significant plasma cholinesterase
inhibition (1). A low blood cholinesterase level can sometimes persist from two to six
weeks with long-term exposure to chlorpyrifos (31).

Two-year feeding studies of 1 and 3 mg/kg/day of chlorpyrifos to rats produced
moderate depression of plasma and red blood cell cholinesterase. Brain cholinesterase
was decreased with the larger dose. Cholinesterase levels recovered when the
experimental feeding was discontinued (18). Identical results occurred in a 2-year
feeding study with dogs. No long-term health effects were seen in either the dog or rat
study (1, 45). In some animal species, chlorpyrifos may produce neurotoxicity, or
harm to nerve tissue (14).

Reproductive Effects

EPA has determined that chlorpyrifos does not adversely affect reproduction (40, 50).
In two studies reviewed by the EPA, no effects were seen in the animals tested at dose
levels up to 1.2 mg/kg/day (40). No effects on reproduction occurred in a 3-generation
study with rats fed dietary doses as high as 1 mg/kg/day (1, 50). In another study in
which rats were fed 1.0 mg/kg/day for two generations, the only effect observed was a
slight increase in the number of deaths of newborn offspring (18). Once in the
bloodstream, chlorpyrifos may cross the placenta (49).

Teratogenic Effects

EPA has determined that chlorpyrifos is not teratogenic. No teratogenic or other
adverse effects to offspring were found when pregnant rats were fed doses as high as
15 mg/kg/day for 10 days. When pregnant mice were given doses of 1, 10 or 25
mg/kg/day for 10 days, minor skeletal variations and a decrease in fetal length occurred at the highest dose tested. The developmental NOEL was 10 mg/kg/day (35, 40, 50). No birth defects were seen in the offspring of male and female rats fed 1.0 mg/kg per day during a three-generation reproduction and fertility study (18, 1).

Mutagenic Effects

EPA has determined that chlorpyrifos is not mutagenic. No evidence of mutagenicity was found in any of 4 tests reviewed by EPA (50). Mutagenic effects were observed in fruit flies given oral concentrations of 50 parts per billion (ppb) of chlorpyrifos for 3 days (27).

Carcinogenic Effects

EPA has determined that chlorpyrifos is not carcinogenic. There was no increase in the incidence of tumors when rats were fed 10 mg/kg/day for 104 weeks nor when mice were fed 2.25 mg/kg for 105 weeks (50).

Organ Toxicity

Chlorpyrifos primarily affects the nervous system through inhibition of cholinesterase, an enzyme required for proper nerve functioning.

Fate in Humans and Animals

In humans, chlorpyrifos and its principal metabolites are eliminated relatively rapidly following a single dose (30). It is readily absorbed into the bloodstream through the gastrointestinal tract if it is ingested, through the lungs if it is inhaled, or through the skin if there is dermal exposure (40).

After a single oral dose, its half-life in the blood appears to be about one day (29). Chlorpyrifos was found in its original form in the blood, brain and liver of a 61-year-old man who lived only one day after accidentally eating this material (18).

Chlorpyrifos is eliminated primarily through the kidneys in urine (38). Following oral intake of chlorpyrifos by rats, 90% was removed in the urine and 10% was excreted in the feces (17). It is detoxified quickly in rats, dogs and other animals (44). The major metabolite found in rat urine after administration of a single oral dose of 0.5 or 25 mg/kg was TCP. TCP does not inhibit cholinesterase and it is not mutagenic (50). Following intake, some chlorpyrifos becomes stored in fat tissues. It is eventually moved out of the fat tissue and eliminated from the body, with a half-life of about 62 hours (18, 45).
Research indicates that chlorpyrifos does not build up or persist in body tissues. It does not have a significant bioaccumulation potential (29). When formulated chlorpyrifos (Dursban) was fed to cows, unchanged pesticide was found in the feces, but not in the urine or milk (37). Chlorpyrifos was detected in the milk of cows for 4 days following spray dipping with a 0.15% emulsion. The maximum concentration in the milk was 0.304 ppm. This concentration was decreased by 26 to 47% by pasteurization (45). In a rat study, chlorpyrifos did not accumulate in any tissue except fat (26). Residues of granular formulations of chlorpyrifos were found in salt marsh snails immediately after they were treated with the material and for up to five weeks after treatment. When an emulsion formulation was used, residues were found immediately following treatment, and for up to 3 weeks afterwards (23).

**ECOLOGICAL EFFECTS**

The US EPA requires precautionary language on chlorpyrifos product labels, warning of the hazard that this insecticide poses to birds, wildlife and aquatic organisms. It should not be applied directly to water. Drift and runoff from treated areas may be hazardous to aquatic organisms in adjacent aquatic sites (2, 40).

**Effects on Birds**

Chlorpyrifos is moderately to very highly toxic to birds (50). Its oral LD50 in pheasants is 8.41 mg/kg, 112 mg/kg in mallard ducks, 21.0 mg/kg in house sparrows, and 32 mg/kg in chickens (17, 37, 50). The LD50 for a granular product (15G) in bobwhite quail is 108 mg/kg (50).

Two one-generation reproductive studies resulted in NOELs of 125 ppm (the highest dose tested) for bobwhite quail and 25 ppm for mallard ducks. At 125 ppm, mallards laid significantly fewer eggs (50).

There was no evidence of changes in weight gain, or in the number, weight and quality of eggs produced by hens fed dietary levels of 50 parts per million (ppm), or about 5.12 mg/kg, of chlorpyrifos (18). Bird deaths have not been observed in repeated mosquito control efforts (17).

**Effects on Aquatic Organisms**

Chlorpyrifos is very highly toxic to freshwater fish, aquatic invertebrates and estuarine and marine organisms (50). Cholinesterase inhibition was observed in acute toxicity tests of fish exposed to very low concentrations of this insecticide (29). Precautions and restrictions are being imposed by EPA to decrease potential hazards.
Application of concentrations as low as 0.01 pounds of active ingredient per acre may cause fish and aquatic invertebrate deaths (50).

Chlorpyrifos accumulates in the tissues of aquatic organisms. Studies involving continuous exposure of fish during the embryomic through fry stages have shown BCF values of 58 to 5100 (52).

Chlorpyrifos toxicity to fish may be related to water temperature. Its 96-hour LC50 varied in rainbow trout from 7.1 micrograms per liter (ug/l) to 51 ug/l at three different temperatures (34). The 24-hour LC50 for chlorpyrifos in goldfish is 180 ug/l, and less than 1,000 ug/l in mosquito fish (46). The 96-hour LC50 for chlorpyrifos in mature rainbow trout is 9 ug/l, 98 ug/l in lake trout, 806 ug/l in goldfish, 10 ug/l in bluegill, and 331.7 ug/l in fathead minnow (38).

Due to its high acute toxicity and its persistence in sediments, chlorpyrifos may represent a hazard to sea bottom dwellers (34). Smaller organisms appear to be more sensitive than larger ones (38).

When fathead minnows were exposed to Dursban for a 200-day period during which they reproduced, the first generation of offspring had decreased survival and growth, as well as a significant number of deformities. This occurred at approximately 2.68 microgram per liter (ug/l) exposure for a 30 day-period (37).

**Effects on Other Animals (Nontarget Species)**

Aquatic and general agricultural uses of chlorpyrifos may be extremely poisonous to wildlife and honeybees (40, 17). Treated areas should not be used for grazing, nor should the chemical be used when bees are actively collecting pollen or nectar (2, 25, 36). Studies indicate that with continuous exposure over time, chlorpyrifos may accumulate to toxic levels in test animals (36).

While one study did not detect any negative effect to nontarget insects when chlorpyrifos was applied to rice fields at 0.01 to 0.02 kilogram per hectare (kg/ha), another study reported that practically all nontarget insects died after a similar application (15).

**ENVIRONMENTAL FATE**

Chlorpyrifos is moderately persistent, but relatively immobile in the environment (50). Chlorpyrifos may bioconcentrate at very low levels in ecological systems (BCF = 2.50 to 3.54) (48).
Breakdown of Chemical in Soil and Groundwater

Chlorpyrifos adsorbs strongly to soil particles and it is not readily soluble in water (47, 52). It is therefore immobile in soils and unlikely to leach or to contaminate groundwater (32, 50, 52). It is not mobile in sandy loam and loamy sand soils (41). TCP, the principle metabolite of chlorpyrifos, adsorbs weakly to soil particles and appears to be moderately mobile and persistent in soils. EPA has required additional testing to determine the environmental fate of TCP (50).

In aerobic soils, the soil half-life of chlorpyrifos was from 11 to 141 days in seven soils ranging in texture from loamy sand to clay and with soil pHs from 5.4 to 7.4. Chlorpyrifos was less persistent in the soils with a higher pH. Soil half-life was not affected by soil texture or organic matter content. In anaerobic soils, the half-life was 15 days in loam and 58 days in clay soil (50). Adsorbed chlorpyrifos is subject to degradation by UV light, chemical hydrolysis and by soil microbes. When treated on moist soils, the volatility half-life of chlorpyrifos was 45-163 hours, with 62-89% of the applied chlorpyrifos remaining on the soil after 36 hours. In another study, 2.6 and 9.3% of the chlorpyrifos applied to sand or silt loam soil remained after 30 days (52). The half-life of chlorpyrifos in soil, or the time that it takes for half of the insecticide to be broken down, is usually between 60 and 120 days, but can range from 2 weeks to over 1 year, depending on the soil type, climate and other conditions (17, 40, 48).

Breakdown of Chemical in Water

The current label for this material states that it is not to be applied directly to bodies of water. In open waters, the concentration and persistence of chlorpyrifos will vary depending on the type of formulation. For example, immediately after entering open waters, emulsifiable concentrates and wettable powders tend to produce a large increase in chlorpyrifos concentrates in water. As the pesticide adheres, or (adsorbs) to sediments and suspended organic matter, however, concentrations rapidly decline. Granules and controlled- release formulations do not produce as rapid an increase in the concentration of insecticide in the water, but the resulting concentration persists longer (38). Slow desorption from sediments can also maintain low (ppb) residual concentrations of chlorpyrifos in open waters for long periods of time (48).

Chlorpyrifos enters freshwater and saltwater ecosystems primarily as spray drift. It is also carried on eroded soil particles from treated areas (38). If soil with adsorbed chlorpyrifos is carried by runoff, surface water may be contaminated (32).

In water, chlorpyrifos readily adsorbs to suspended sediment and bottom materials. Volatilization is probably the primary route of loss of chlorpyrifos from water. Volatility half-lives of 3.5 and 20 days have been estimated for pond water (52). The
photolysis half-life of chlorpyrifos is 3 to 4 weeks during midsummer in the U.S., but photodegradation of chlorpyrifos is not expected to be significant in deep waters, during winter, or in waters which sunlight can not penetrate (48). Its change into other natural forms (biotransformation) is slow (34). Research suggests that this insecticide is unstable in water, and the rate at which it is hydrolyzed increases with temperature, decreasing by 2.5 to 3-fold with each 10 degrees C drop in temperature. The rate of hydrolysis is constant in acidic to neutral waters, but increases in alkaline waters. In water at pH 7.0 and 25 degrees C, it had a half-life of 35 to 78 days (48). The half-life of chlorpyrifos in water of an unknown pH was about 80-100 days (37).

Breakdown of Chemical in Vegetation

Chlorpyrifos may be toxic to some plants, such as head lettuce (23). Residues remain on plant surfaces for approximately 10-14 days (36, 16). Data indicate that this insecticide and/or its soil metabolites, can accumulate in certain crops (41).

Information is limited on chlorpyrifos toxicity to freshwater plants, although algal blooms frequently follow its field application (38).

PHYSICAL PROPERTIES AND GUIDELINES

Technical chlorpyrifos is an amber to white crystalline solid with a mild sulfur (mercaptan) odor (18, 2, 50). Volatile components or contaminants, such as diethyl sulfide and diethyl disulfide, are partly responsible for the offensive odor of the technical grade of chlorpyrifos (37). Chlorpyrifos may undergo violent decomposition at temperatures above 130 degrees C (266 degrees F), causing a build-up of heat and pressure that may lead to violent rupture of containers. Thermal decomposition of chlorpyrifos may release toxic or hazardous gases (49, 50).

Chlorpyrifos is corrosive to copper and brass (17). It is compatible with most fungus-killing chemicals (fungicides) and other insecticides (16). Chlorpyrifos is stable in neutral or acidic aqueous solutions. Non-aqueous solutions of chlorpyrifos can be stored indefinitely under appropriate storage conditions. It is, however, unstable under alkaline conditions (18, 41).

Technical-grade chlorpyrifos has generally been found to be more toxic than an equal amount of active ingredient in a formulated product. The effects of inert ingredients can not, therefore, be ignored (38). Avoid eye and skin contact with chlorpyrifos as well as inhalation of its vapors, dusts, or sprays (17). A pesticide face mask (respirator) is recommended (2). Chlorpyrifos should not be used near water (17).
Persons who work with organophosphate materials for long periods of time should have frequent blood tests of their cholinesterase levels. If the cholinesterase level falls below a critical point, no further exposure should be allowed until it returns to normal (51).

Protective clothing must be worn when handling chlorpyrifos. Before removing gloves, wash them with soap and water. Always wash hands, face and arms with soap and water before smoking, eating or drinking.

After work, remove all work clothes and shoes. Shower with soap and water. Wear only clean clothes when leaving the job. Wash contaminated clothing and equipment with soap and water after each use. Keep contaminated work clothes separate from regular laundry.

**Exposure Guidelines:**

- **OSHA TWA (skin)**: 0.2 mg/m3 (49)
- **ACGIH TWA (skin)**: 0.2 mg/m3 (49)
- **TLV/TWA**: 0.2 mg/m3. Occupational intake at 0.028 mg/kg/day is considered safe (1, 18)
- **NOEL**: 0.10 mg/kg/day (rats); 0.03 mg/kg/day (dogs) (18); 100 ug/kg/day (human, rat, dog) (29)
- **ADI**: 0.003 mg/kg/day based on a human cholinesterase study with a NOEL of 0.03 mg/kg/day and a 10-fold safety factor (40, 50)
- **STEL**: For skin = 0.6 mg/m3 (1)

**Physical Properties:**

- **CAS #**: 2921-88-2
- **Specific gravity**: 1.398 at 43 degrees C (49)
- **H2O solubility**: low; 2 ppm at 35 degrees C (29, 18, 23); 2 ppm water at 2 degrees C (44)
- **Solubility in other solvents**: In benzene 790, acetone 650, chloroform 630, carbon disulfide 590, diethyl ether 510, xylene 645, methylene chloride 714, isoctane 79, methanol 45 (all in g/100 g at 25 degrees C) (17)
- **Melting Point**: 41.5 to 44 degrees C (106 to 108 degrees F) (52)
- **Flash point**: greater than 200 degrees F (54).
- **Vapor pressure**: 1.87 x 10 to the minus 5 power mm Hg at 25 degrees C (35b)
- **Kow**: 66,000 at 23 degrees C (29)
  - log Kow = 4.7 (35a); 3.06, 5.11 (22); 4.82 (42)
Koc: 6070 g/ml (47); 7,000-25,000 ml/g (52)
Kd: $pc = 128,000$ (20); 13,490 (32)
Chemical Class/Use: Organophosphate insecticide

BASIC MANUFACTURER

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