Paraquat

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What is paraquat?

Paraquat, or paraquat dichloride, is a synthetic (human-made) herbicide.[1] It is a member of the bipyridylnium or dipyridylnium chemical family.[2,3] Paraquat kills all vegetation that it touches. This is called a nonselective contact herbicide. It is also used as a desiccant, which dries out the crop before harvest. Paraquat is sometimes used as a plant growth regulator.[3] For example, it can control unwanted growth in trees and vines. It may induce or delay flowering. It has no residual activity in soil. This means paraquat is not expected to keep killing plants after it is first applied.[2]

Paraquat is widely used throughout the United States.[3] It was first registered in the United States in 1964. The U.S. Environmental Protection Agency (U.S. EPA) classified all paraquat products as restricted-use pesticides in 1978 because of paraquat's high acute toxicity.[2] Many paraquat products contain a dye and/or an emetic (which causes vomiting) to reduce the risk of people accidentally drinking it.[4] The U.S. EPA has added additional training requirements for people who use paraquat, and requires special packaging to help prevent exposure.

Technical Grade Paraquat: This fact sheet refers to the technical grade, or "pure" paraquat only. Products you buy from the store include other ingredients as well. While many of the chemicals used as other ingredients may not pose health or environmental risks, some of them can be toxic. In some cases, the other ingredients can pose greater risks than the active ingredient itself.

What are some products that contain paraquat?

In the United States, there are currently 24 registered pesticide products that contain paraquat.[5] Paraquat is only formulated as a liquid. All paraquat products are restricted-use pesticides. Restricted-use pesticides are not available for the public to buy or use. Only people who have gone through special training and certification can buy or use paraquat. There are no products for home or residential uses.[3]

Paraquat is used on a wide variety of crops, including grains, vegetables, peanuts, and animal feed crops. It is used as a plant growth regulator for sucker control on orchard crops, hops, and grapes. Paraquat is used as a desiccant on crops such as potatoes and cotton before they are harvested.[3] It is also used in pastures and non-crop areas including fencerows, airports, and electric substations.[2,3]

Paraquat is not used in organic agricultural production.[6]

Seek medical attention immediately if anyone is exposed to paraquat. Always follow label instructions and take steps to minimize exposure. If any exposures occur, be sure to follow the First Aid instructions on the product label carefully. For additional treatment advice, contact the Poison Control Center at 800-222-1222. If you wish to discuss a pesticide problem, please call 800-858-7378.

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How does paraquat work?

Paraquat is a nonselective contact herbicide and affects all plants.[3] Paraquat is quickly taken up by leaves and stems.[7] It destroys cell membranes in the plant tissue it touches. This stops photosynthesis.[2]

It is absorbed quickly by foliage but kills plant tissue so quickly that it is not likely to move throughout the entire plant. It is most effective against healthy, actively growing plant tissue.[7] The plant can still grow from undamaged parts if it is a perennial.[2]

How might I be exposed to paraquat?

You may be exposed to a pesticide such as paraquat if you get it on your skin, breathe it in, or if you eat or drink it. For a pesticide exposure to harm you, you must be exposed to enough of it. If a pesticide is very toxic, it may cause harm from only a small exposure. You may be exposed to very low levels of paraquat residues on or in food because it is used on crops and pastures. These residues are expected to be well below the level that could cause harm. **See the text box on pesticide tolerances.**

If you are very close to an application site and there is spray you could get paraquat on your skin or breathe it in. People have died from being exposed to paraquat by accidentally drinking paraquat that had been stored in beverage containers.[3]

What are pesticide tolerances?

The EPA sets legal limits for how much pesticide is allowed in food and drinking water. In food, those limits are called "tolerances." Every pesticide has its own tolerance for each crop it can be used on. In water, those limits may be called Maximum Contaminant Levels (MCLs), health advisories (HA), or other names. The amount allowed in water is specifically regulated for some pesticides. Health advisories are issued for others.

The U.S. EPA requires pesticide handlers to wear chemical-resistant gloves and respirators when handling paraquat. Handlers must also use closed loading or transfer systems when putting paraquat into application equipment. People who apply paraquat must be certified applicators and must take specific training before they can use it.[3] These requirements are meant to protect workers from exposure.

What are some signs and symptoms from a brief exposure to paraquat?

Paraquat is low in toxicity if it gets on skin and causes slight skin irritation. It is moderately to severely toxic to eye tissue. Paraquat is highly toxic if inhaled[2] and highly toxic if swallowed.[1] The onset of signs and symptoms depends on the dose and the route of exposure.[1] **See the text box on pesticide risk.**

Pesticide Risk: Any chemical, including any pesticide, can pose risks to people, pets, or the environment. Understanding *pesticide risk* will help you take *steps to minimize it*. The risk of a pesticide depends on two things, exposure (how much?) and toxicity (how poisonous?). The exposure is the amount you get in or on your body, or the amount that is released into the environment. The toxicity of a pesticide is a measure of how poisonous it is to people or the environment. Even products that are low in toxicity can be hazardous if the exposure is high enough. Take steps to lower your chance of exposure to reduce your risk.

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Seek medical attention immediately if anyone is exposed to paraquat. Swallowing small amounts of paraquat can be fatal and there is no antidote.[8] See EPA's resource *Paraquat Dichloride: One Sip Can Kill.*

Skin exposure to paraquat can cause pain, itchiness, redness, welts, hives, irritation, peeling skin, swelling, blisters, discharge, and lesions.[4] Agricultural workers who got paraquat on their skin developed dry, cracked skin. Their fingernails developed horizontal ridges.[1]

People who **inhaled** a fine mist of paraquat have had nosebleeds, skin irritation, irritated upper respiratory tract, cough, chest pain, vomiting, and headaches.[9] Paraquat is not expected to cause systemic toxicity if inhaled because of the amount people are likely to inhale. This is because paraquat is not likely to turn into a vapor and low concentrations are used during spraying.[1] However, paraquat is moderately to severely irritating to mucous membranes. It can cause severe damage to tissue in the nose, mouth, throat, and voice box.[10]

Paraquat is fatal if ingested!

See EPA's resource *Paraquat Dichloride: One Sip Can Kill.*

People who accidentally **drank** paraquat experienced burning in their mouth, throat, esophagus, chest, and upper abdomen due to the damage to the mucosal lining. Other early signs and symptoms after swallowing paraquat include headache, giddiness, fever, lethargy, and coma. Paraquat ingestion may cause swelling of the brain and brain damage.[1] People who have ingested or swallowed it may develop a very rapid, uneven heartbeat, and may die from circulatory failure within the first 24 hours.[11]

Paraquat builds up in lung tissue no matter how the person or animal was exposed. Paraquat damages the lung tissue by causing inflammation and scarring which leads to pulmonary fibrosis. The damage can occur starting from a few hours to 14 days after exposure. How soon this happens depends on the amount of the exposure. Within 2-4 days, the person may develop rapid, short breaths and coughing. As the lung damage increases, breathing becomes more difficult. Patients eventually die because they cannot breathe and their tissues cannot get enough oxygen.[1]

Paraquat also causes damage in the liver and kidneys.[11] Although the U.S. EPA classified paraquat as moderately toxic by ingestion (see table below), people who swallowed as little as 14 mg/kg of a product containing paraquat died from the exposure.[9] **See the text box on mg/kg.**

Based on reported exposures, the LD_{50} in humans is roughly 3-5 mg/kg.[1] This is considered highly toxic. **See the text box on LD_{50}.**

What is milligrams per kilogram (mg/kg)?

"Mg/kg" is a way to measure a chemical dose. This can tell us how toxic a chemical is. "Mg" means milligrams of a chemical. "Kg" means one kilogram of an animal's body weight. Something that is highly toxic may kill a person with a very small amount of chemical. If something is very low in toxicity, it may take much more for that same person to become very sick or die.

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LD_{50}/LC_{50}:A common measure of acute toxicity is the lethal dose (LD_{50}) or lethal concentration (LC_{50}) that causes death (resulting from a single or limited exposure) in 50 percent of test animals. LD50 is generally expressed as the dose in milligrams (mg) of chemical per kilogram (kg) of body weight. LC_{50} is often expressed as mg of chemical per volume (e.g., liter (L)) of medium (i.e., air or water) the animal is exposed to. Chemicals are considered highly toxic when the LD_{50}/LC_{50} is small and less toxic when the value is large.

The highlighted/shaded boxes in the table below reflect the toxicity classification (high, moderate, low, or very low) of exposure by the route indicated in the left-hand column.

TOXICITY CLASSIFICATION - PARAQUAT[1,2] (see the text box about **mg/kg**)

	High Toxicity	Moderate Toxicity	Low Toxicity	Very Low Toxicity
Acute Oral LD_{50}	**≤ 50 mg/kg[2]**	> 50 – 500 mg/kg	> 500 – 5000 mg/kg	> 5000 mg/kg
Inhalation LC_{50}	**≤ 0.05 mg/L**	> 0.05 – 0.5 mg/L	> 0.5 – 2.0 mg/L	> 2.0 mg/L
Dermal LD_{50}	≤ 200 mg/kg	> 200 - 2000 mg/kg	**> 2000 – 5000 mg/kg**	> 5000 mg/kg
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue) or corneal involvement or irritation persisting for more than 21 days	**Corneal involvement or other eye irritation clearing in 8 - 21 days**	Corneal involvement or other eye irritation clearing in 7 days or less	Minimal effects clearing in less than 24 hours
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring)	Severe irritation at 72 hours (severe erythema or edema)	Moderate irritation at 72 hours (moderate erythema)	**Mild or slight irritation at 72 hours (no irritation or erythema)**

You may be wondering why the "High Toxicity" column has smaller numbers than the "Low Toxicity" column. This is because if a smaller amount of the pesticide caused a health effect, it's more toxic. If it takes a larger amount of the pesticide to cause a health effect, it's less toxic.

Modeled after the U.S. Environmental Protection Agency, Office of Pesticide Programs, Label Review Manual, Chapter 7: Precautionary Statements. epa.gov/sites/default/files/2018-04/documents/chap-07-mar-2018.pdf.

What happens to paraquat when it enters the body?

Absorption

Absorption of paraquat by the gastrointestinal tract happens quickly. Scientists observed peak concentrations of paraquat in blood plasma of various animal species within an hour to under 6 hours after exposure.[9]

Paraquat is not well absorbed through the gastrointestinal tract.[10] However, paraquat is corrosive to its mucosal lining.[1] In one study, rats absorbed 8-14% of a dose they swallowed.[10]

Paraquat is poorly absorbed across undamaged skin. Skin of human volunteers absorbed only 0.3% of paraquat over 24 hours.[2] Because paraquat may damage skin, causing blisters, chemical burns, and lesions, the amount absorbed may increase.[10]

Distribution

Paraquat given to test animals including rats, dogs, and mice was distributed rapidly throughout the animals' bodies, especially to the kidneys and lungs. Only the lungs retained the paraquat.[2]

In one study, scientists fed rats 126 mg/kg of paraquat. The lung tissue had increasing amounts of paraquat over 32 hours. The amount of paraquat in the blood remained the same.[9]

In humans, paraquat affects the lungs regardless of the exposure route.[10] Paraquat concentrates in lung tissue.[12,13]

Rats fed low levels of paraquat at 250 parts per million (ppm) for 8 weeks did not concentrate the paraquat in any of their tissues. Researchers did not find any paraquat in the rats' bodies 7 days after they fed the last dose of paraquat to the rats.[9,14] **See the text box about parts per million (ppm).**

Paraquat crossed the placenta in pregnant women who intentionally drank it.[15]

Parts per million (ppm): Parts per million (ppm) measures very small concentrations. It is how many parts of a contaminant are present per million parts of soil, water, or other substance like food. It may sometimes be equivalent to mg/kg or mg/L if it refers to how much of the substance was consumed relative to body weight (see text box on mg/kg). However, if ppm refers to a concentration in food or water, it is not the same as the dose given to a test animal or eaten by a person because it does not account for their body weight.

Metabolism

Paraquat causes damage when it is broken down into free radicals called superoxides.[1,16] Free radicals are molecules with an unpaired electron. Free radicals damage cell structures.[17] Although the lungs are the organ most affected in people exposed to paraquat, paraquat also damages most organs in the body.[16]

Rats did not metabolize paraquat when it was given to them by a tube inserted into their stomach.[18] Up to 30% of the paraquat in the feces had been degraded by gut microbes.[2,18]

Excretion

Scientists found 69-86% of an oral dose of paraquat in the rats' feces.[9] Rats excreted most of the dose within 2-3 days.[2,18] Rats excreted 4-22% of the dose in their urine. The amount excreted in urine varied depending on the strain of rat used and the chemical form of paraquat.[18] Rats excreted 90-100% of a dose of paraquat within 2 days.[19]

Hens drank water containing low concentrations of 40 ppm of paraquat for two weeks. They laid eggs with residues of 0.1 ppm of paraquat. The eggs continued to contain residues for 6 days after dosing stopped. The treated hens laid the same number of eggs. However, treated hens laid slightly more abnormal eggs than control hens.[20]

Scientists force-fed cows with a single dose of 8.0 mg/kg paraquat. Concentrations of paraquat in the cows' milk peaked the day after dosing and had only 0.015% of the original dose.[9,21]

Is paraquat likely to contribute to the development of cancer?

The U.S. EPA classified paraquat into Category E, "evidence of non-carcinogenicity for humans."[10] This means that there is evidence that paraquat does not cause cancer in people.

The U.S. EPA concluded that "there is no concern for mutagenicity" for paraquat.[10]

Has anyone studied non-cancer effects from long-term exposure to paraquat?

Some animal experiments that involved feeding paraquat to rats including pregnant rats did not find developmental effects. Other experiments found effects to both the mothers and their young.[2,7] The U.S. EPA reviewed a variety of studies and concluded that the studies did not show evidence of developmental toxicity, unless the mother was also visibly harmed by the exposure.[10]

- In one study, scientists force-fed pregnant rats 0, 1, 3, or 8 mg/kg per day of paraquat on days 7-16 of their pregnancies. Neither the mothers nor their pups were affected.[2] **See the text box on mg/kg.**
- In another study, scientists fed paraquat to two generations of rats of both sexes before mating, during pregnancy, and after birth. They then repeated those exposures in the next generation. Neither the mother rats nor their babies showed any ill effects.[7]
- Scientists force-fed pregnant rats 0,1, 5, or 10 mg/kg of paraquat during days 6-15 of their pregnancies. Mothers in the two groups with the highest doses gained less weight, had trouble breathing, and had damage to their lungs and kidneys. Their fetuses had less bone formation in their toes than fetuses from mother rats not fed paraquat.[2]
- In another study, scientists gave pregnant female rats low doses of paraquat by stomach tube on days 6-15 of their pregnancy. The mother rats did not gain weight during pregnancy. They had a hunched appearance, their fur stood up, and they made croaking noises. The unborn pups of these rats weighed less and had less bone development. Mothers given the higher dose showed these signs more quickly. Some of the mother rats died before the end of the dosing period at the higher dose.[7]

No studies on the developmental and reproductive effects of paraquat on humans were found.

Has anyone studied other non-cancer effects from long-term exposure to paraquat?

Pesticide exposure may contribute to other chronic health effects aside from cancer or developmental effects. Epidemiology looks at what people have been exposed to and what health problems they have later to see if the two are related. Researchers have studied relationships between paraquat exposure and several health effects. They have looked at Parkinson's disease, respiratory illness, and end-stage renal disease.[10]

The U.S. EPA reviewed 74 published epidemiology studies that looked for possible links between paraquat and human health effects. This included 26 studies examining Parkinson's disease, 17 that looked at respiratory effects, eight cancer studies, and 25 studies of other health effects.[22] They also examined studies using live animals and studies of cells in the laboratory in the case of Parkinson's disease.[23]

The U.S. EPA concluded that there was some evidence that people exposed to paraquat on the job may have a higher risk of developing Parkinson's disease. However, they determined that the data are not strong enough to conclude that paraquat exposure causes Parkinson's disease. This means that although a few studies reported that paraquat exposure was associated with Parkinson's disease, more research is needed to show that paraquat exposure actually causes Parkinson's disease. The U.S. EPA concluded that the evidence did not support a relationship between non-occupational exposure to paraquat and Parkinson's disease.[23]

Other scientists have also conducted reviews of studies that look at the relationship between exposure to paraquat at work or at home and Parkinson's Disease. They used different combinations of studies and different methods than used by the U.S. EPA. They also concluded that there is evidence of a relationship between Parkinson's disease and paraquat exposure.[24,25] All reviews concluded that more studies and better data are necessary to determine if paraquat can cause Parkinson's disease.

The U.S. EPA also reviewed studies looking at paraquat and other health outcomes. The agency felt that current knowledge does not support that paraquat exposure could be associated with chronic bronchitis or cancer. However, the agency concluded that there is "limited but insufficient evidence at this time to conclude that" paraquat exposure is associated with end stage renal disease.[22]

Are children more sensitive to paraquat than adults?

The U.S. EPA concluded that there is no evidence paraquat is more toxic to children than adults.[10]

As with any pesticide, young children may act in ways that put them at greater risk of being exposed to pesticides. For example, they may spend more time near the floor. They may also be more likely to place their hands in their mouths after touching treated surfaces or pets.

What happens to paraquat in the environment?

The form of paraquat used in pesticides is paraquat dichloride. Paraquat dichloride is a salt form that breaks apart into a positively charged ion, called a cation, that is the active form of the herbicide.[7] It is highly soluble in water.[7,26]

The vapor pressure of paraquat is very low.[7,27] This means it is unlikely to turn into a vapor. Paraquat did not vaporize from soil in laboratory tests.[7]

Plants do not break paraquat down into other chemicals.[19] However, sunlight will break down paraquat residues on vegetation even after the plants are dead.[26] Microbes on the plants also break down residues of paraquat.[28]

UV radiation intensity affects paraquat. In strong sunlight, two-thirds of an application of paraquat broke down within 3 weeks.[26] In another study, sunlight broke down 50% of paraquat in surface soils in 3 weeks.[29] Paraquat breaks down into chemicals that are low in toxicity and that degrade easily.[26]

Paraquat will break down in alkaline waters.[2] Sunlight does not help break paraquat down if it is in water.[2,10] It may enter surface waters if it is bound to soil that washes into streams or ponds.[2]

Paraquat binds tightly to clay and organic matter in soil.[2,10] This limits its availability to plants and animals in the soil.[7] Microbes may break down paraquat in soil if it is not bound to soil particles or organic matter.[26] This process is very slow because so little paraquat is available to the microbes. The half-life of paraquat in soils ranged from 1.4-7.2 years.[30]

Paraquat is corrosive to metals.[2]

Can paraquat affect birds, fish, or other wildlife?

Because paraquat binds so strongly to soil, sediments, and organic material, it is thought to have low potential for wildlife or non-target plant exposure if there is no spray drift. However, impacts to non-target plants and animals have occurred.[7] Sensitivity to paraquat varies widely among different kinds of animals, even among closely related species.[7,29,31]

Plants

The seeds of different plant species appear to have different sensitivities to paraquat.[29]

Aquatic vascular plants were less sensitive than aquatic non-vascular plants such as algae. Although aquatic plants can be affected, how much paraquat is actually available for uptake is hard to predict.[7]

Aquatic invertebrates

Invertebrates, especially marine or estuarine crustaceans such as amphipods, are the most sensitive aquatic animals.[29] Paraquat is highly toxic to them. It is moderately toxic to freshwater crustaceans. Marine and estuarine crustaceans are also more affected than freshwater crustaceans when exposed to paraquat for longer periods of time. It is slightly to moderately toxic to estuarine and marine mollusks.[7]

Currently, scientists are not sure if differences in sensitivity among aquatic invertebrates to paraquat is a result of differences in their behavior and life history or innate sensitivity.[7]

Fish

Paraquat is slightly toxic to marine and estuarine fish but is moderately toxic to freshwater fish for acute, short-term exposures. However, estuarine and marine fish are more affected than freshwater fish for chronic, longer-term exposures.[7]

Reptiles

Adult frogs and toads do not seem to be affected by paraquat at concentrations below 3 mg/L. However, far lower concentrations of 0.5 mg/L affected northern leopard frog eggs and larvae.[29]

Soil microbes and terrestrial invertebrates

Soil microbes and small invertebrate animals living in soil are not expected to be harmed by paraquat residues bound to soil.[26] Earthworms that ate soil treated with paraquat did not absorb it from their guts.[29]

Paraquat is considered practically non-toxic to honeybees based on acute oral and contact exposure. There was no data available on the toxicity of chronic exposure to honeybee larvae or to adult bees.[7] No other information was found for other species of pollinators.

Birds

Paraquat ranges from moderately toxic to highly toxic to birds, depending on the species.[7] Chickens and turkeys were much more sensitive than Japanese quail, northern bobwhite quail, ring-necked pheasants, and mallards.[31] Paraquat was highly toxic to zebra finches.[7]

Wild birds could be exposed by eating contaminated prey. Kestrel nestlings given doses of 10, 25 or 60 mg/kg of paraquat per day died more often than unexposed nestlings. Death rates were 22%, 18% and 44% for the 10, 25, and 60 mg/kg groups, respectively. The death rate for unexposed nestlings was 9%. Kestrel nestlings in the highest dose groups also weighed less by the end of the 10-day study.[31]

Paraquat is also toxic to embryos in the eggs of chickens, Japanese quail, and mallard ducks at levels used in the field when the mother bird has chronic exposure.[31] Mallard ducks fed paraquat in their diet at 101 mg/kg ate less food, laid fewer eggs, and the eggs had fewer live embryos.[7]

Mammals

Paraquat is moderately toxic to mammals based on studies of acute exposure in rats.[7] Chronic exposure effects can be found in the section above for effects on reproduction and development. No other information on mammals was found.

Paraquat is not expected to bioaccumulate up the food chain.[7,29]

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Where can I get more information?

For more detailed information about paraquat please visit the list of referenced resources, call us Monday - Friday, between 8:00am and 12:00pm PT (11:00am to 3:00pm ET) at 800-858-7378, email us at npic@oregonstate.edu, or visit us on the web at npic.orst.edu. NPIC provides objective, science-based answers to questions about pesticides.

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