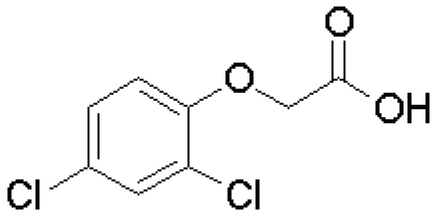
2,4-DICHLOROPHENOXY (2,4-D)

Overview



2,4-D (2,4-dichlorophenoxy) is a systemic phenoxy herbicide developed in the 1940s and still in use today. 2,4-D was the first widely used herbicide used to control broadleaf plants, and it has significantly contributed to modern weed control in agriculture. Different formulations vary widely in levels of toxicity, health effects, and environmental impact, leading to debate over regulations and the formation of a 2,4-D Industry Task Force. Currently, more than 46 million pounds of 2,4-D are applied annually, with the global marketplace for the herbicide accounting for more than US$300 million (EPA RED Facts, 2005 and PAN-UK, 1997).

Chemical Description

2,4-D is chemically classified as a chlorophenoxy herbicide and is an odorless, crystalline powder that is colorless or white to yellow. 2,4-D is a strong oxidizer and is a non-combustible solid; however, it can be dissolved in flammable liquids (CDC NIOSH 2005.)

In addition to 2,4-D itself, there are eight salts and esters of 2,4-D. The most common form is the acid form, which is the subject of the majority of toxicity tests (Journal of Pesticide Reform, 2005).

2,4-D has a chemical half-life in soil between seven and ten days, depending on temperature, moisture, sterility, nutrient composition, and oxygenation of the soil. Despite the short half-life, low levels of 2,4-D have been detected in groundwater supplies in at least 5 states in the United States.

Use

2,4-D is a post-emergence systemic herbicide used widely for selective control of broadleaf plants in a variety of food, forest, aquatic, and residential sites. On average, 4.6 million pounds are used annually: 66% on agriculture, 23% on pasture/ rangeland, and 11% by homeowners.

In the US 2,4-D is used predominantly in the Midwest, Great Plains, and Northwest (EPA RED FACTS, 2005).

2,4-D is commonly found in lawn care products; wheat, corn, and other grass family herbicides; forestry products; treatments for roadside weeds; and aquatic weed control products (NPTN).

Application
2,4-D can be sprayed from many different applicators such as fixed-wing aircraft, truck-mounted sprayers, and backpack sprayers (EPA RED Decision, 2005).

Formulations
2,4-D can be formulated as emulsifiable concentrates, granules, soluble concentrate and solids, water-dispersable granules, and wettable powders. 2,4-D is used alone, but is commonly formulated with dicamba, mecoprop,mecoprop-p, MCPA, and clopyralid (EPA RED FACTS, 2005).

Amount
2,4-D is a High Production Volume (HPV) chemical with annual usage around 46 million pounds, making it one of the most widely used Herbicides in the world (#Scorecard and #EPA RED FACTS, 2005). Approximately two-thirds of use is for agricultural purposes and one-third is for residential purposes.

History

2,4-D was developed during World War II at British Rothamsted Experimental Station by Judah Hirsch Quastel and sold commercially in 1946. 2,4-D was developed by a British team during World War II and first saw widespread production and use in the late 1940s. It is easy and inexpensive to manufacture, and it kills many broadleaf plants while leaving grasses largely unaffected (although high doses of 2,4-D at crucial growth periods can harm grass crops such as maize or cereals). 2,4-D's low cost has led to continued usage today and it remains one of the most commonly used Herbicides in the world.

Role in Agent Orange
The herbicide and defoliant Agent Orange, by far the most toxic of the Army's Rainbow Herbicides, was widely used in the Vietnam War to destroy foliage in an effort to expose the enemy by destroying their cover. It was roughly a mixture of two chemicals, 2,4-D and 2,4,5-T. 2,4,5-T becomes contaminated with dioxin during its production. Though 2,4-D composed 50% of Agent Orange, the health effects of Agent Orange are related to the dioxin (EXOTOXNET, 1996).

Routes of Exposure and Metabolism

In humans, 2,4-D exposure can occur through inhalation, skin absorption, ingestion, and skin/eye contact. Once absorbed in the body, there is little evidence that 2,4-D is accumulated and only a small percentage is transformed in 2,4-D conjugates with sugars or amino acids. A single dose of 2,4-D is excreted within a few days, mainly through the urine, but also in the bile and feces (International Programme on Chemical Safety, WHO Geneva, 1984).

In plants, 2,4-D affects double-leaf seeds rather than single-leaf seeds, explaining why it is selective against broadleaf plants. 2,4-D is absorbed by the leaves of the plant and eventually enters the meristems of the plant. From the meristems, 2,4-D acts as an auxin and increases the following three characteristics of the plant: plasticity of cell walls, amount of proteins being made, and ethylene production. Collectively, this causes cells to divide and the plant to grow uncontrollably, resulting in tissue damage and ultimately death.

Human Health Effects

2,4-D is reported to have negative effects on the endocrine system (specifically the thyroid and gonads) and immune system.

Research in the Netherlands suggests that 2,4-D displaces sex hormones from the protein that normally transports these hormones in the blood. More specifically, a study done at the University of Missouri reported a strong correlation between low sperm counts, high numbers of abnormal sperm, and atrophy of the testes with high levels of 2,4-D (measured in urine). Additionally, a University of Minnesota study found that 2,4-D acts like estrogens in breast cancer cells (CDC NIOSH, 2005).

University of Saskatchewan researchers demonstrated that "environmentally realistic" amounts of 2,4-D reduce the activity of several proteins important to immune system function. Researchers at NIOSH have demonstrated a decreased production of cells responsible for making antibodies in mice bone marrow, in addition to decreased T-cells, produced in the thymus.

Acute Toxicity

The different formulations of 2,4-D may have different toxicities; for instance, the acid and salt formulations are severe eye irritants while the ester forms are not (EPA RED Decision, 2005). 2,4-D is slightly toxic to humans and at high doses is a central nervous system depressant that can cause stiffness of arms and legs, incoordination, lethargy, anorexia, stupor, and coma

(EPA, 2007). It is also a respiratory system irritant that can cause prolonged difficulty breathing, coughing, burning, dizziness, and temporary loss of muscle coordination (EXOTOXNET, 1996). Other symptoms of 2,4-D poisoning include irritation, inflammation, itching, and headache (CDC NIOSH, 2005). The primary target organs of the chemical are the eye, thyroid, kidney, adrenals, ovaries, and testes (EPA RED Decision, 2005).

Chronic Toxicity

Long-term animal studies of 2,4-D's chronic exposure have shown effects on the blood, liver, and kidneys (#EPA, 2007). Studies have also revealed slight chronic symptoms including a reduction in weight and changes in blood chemistry (#NPTN).

Developmental Toxicity

It is observed to be a developmental toxicant. Some observed effects are increased gestation length, skeletal abnormalities, and effects on the thyroid and gonads (#EPA RED FACTS, 2005).

Carcinogenicity

2,4-D is not classified as a human carcinogen, but some studies have shown it to be a carcinogen in rats that were fed high levels of 2,4-D over two years (EPA RE FACTS, 2005 and EXTOXNET, 1996). Recently, several human studies have shown an association between exposure to 2,4-D and an increased risk of tumor formation, but it is not yet clear that "this represents a true association, and, if so, whether it is specifically related to 2,4-D" (EPA, 2007). Several university studies done in the US have confirmed that rapid and repeated division of blood cells occurs in pesticide applicators using 2,4-D, in addition to increased activity of a tumor gene in the liver. It should be noted that NIOSH lists the acid, sodium salt, and dimethylamine salt formations as mutagens and that chromosomal rearrangement and breaks are both correlated with increased levels of 2,4-D in the urine (CDC NIOSH, 2005).

Environmental Health Effects

Persistence

2,4-D's persistence depends on its formulation as it enters the environment, but "under most environmental conditions 2,4-D esters and 2,4-D amines will degrade rapidly to form 2,4-D acid," which generally has a low persistence under normal conditions (EPA RED Facts, 2005). The half-life in normal soil conditions is seven days and microorganisms readily degrade 2,4-D under normal aquatic conditions (EXTOXNET, 1996).

Effect on Animals and Organisms

2,4-D is slighly toxic to wildfowl, moderately toxic to birds, and highly disruptive to honeybees

(EXTOXNET, 1996).
Several notable toxicity experiments have been conducted uniquely on animals. Important results with possible human applications include: decreased litter size in animals drinking 2,4-D contaminated water, contaminated breast milk in 2,4-D-contaminated mothers (in both rats and goats), and effects on neurotransmitters, brain size, and development of neural connections in lab animals (CDC NIOSH, 2005).

Regulation

2,4-D has been in pre-Special Review status by the EPA since 1986, due to carcinogenicity concerns. The herbicide has been the subject of several Data Call-Ins (1980, 1994, 1995), requiring studies on toxicity, carcinogenicity (specifically non-Hodgkin's Lymphoma), reproduction, metabolism, re-entry, residential exposure, and chemistry to be submitted. A link could not be established between 2,4-D exposure and non-Hodgkin's Lymphoma, deferring the initiation of a Special Review. Instead, the 2,4-D Task Force agreed to risk-reduction measures in September, 1992. In 2004 the EPA concluded that there is no additional epidemiological evidence to implicate 2,4-D as a cancer-causing agent. As a result, 2,4-D has been classified as a Group D Carcinogen (not classifiable to human carcinogenicity). Risk-reduction measures, such as modified product labels and a user-education program, are still in place (EPA RED FACTS 2005).

Precautions

According to the EPA, 25% of samples of 2,4-D were contaminated with dioxin (2,3,7,8-TCDD), which is mutagenic, carcinogenic, and causes reproductive problems at very small doses (CDC NIOSH, 2005).

Sources of Potential Exposure

Exposure most likely would result from inhalation or dermal contact during 2,4-D's manufacture, formulation, or application, but it has been found in low levels in five states' groundwater supplies

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