ChemicalWatch Factsheet: Malathion

ChemicalWATCH Stats:

CAS Registry Number: 121-75-5
Trade Names: Celthion, Karbofos, Maltox, Cythion
Use: Organophosphate insecticide used for control of mosquitoes, aphids, mites, and other insect species in residential areas and food and non-food field crop sites.
Toxicity rating: Toxic
Signal words: Caution
Health Effects: Eye and skin irritation, associated with neurological and neuromuscular effects.
Environmental Effects: Toxic to bees, fish, and birds with low toxicity to mammals.

General Use and Registration Status

Malathion is a registered organophosphate insecticide with the U.S. Environmental Protection Agency (EPA), first introduced by American Cyanamid Company and registered for use by EPA in 1956.[1] Malathion is a non-systemic, broad-spectrum organophosphate insecticide.[2] It is widely used to control mosquitoes, aphids, mites, and many other insect species, and is applied to alfalfa, clover, pasture and rangeland, nonagricultural land, cereal crops, cotton, soybeans, corn, blueberries, stored grain, and inside homes. Estimated use of malathion is currently 15 million pounds of active ingredients used annually.[3] Malathion is used in the United States Department of Agriculture's Cotton Boll Weevil Eradication Program and Fruit Fly (Medfly) Control Program, and by mosquito control districts around the United States for mosquito-borne disease control. According to EPA, less than 1% of spraying for mosquitoes is malathion aerial spray.[4] Malathion, like all other organophosphate insecticides, works to kill insects by inhibiting important enzymes of the nervous system, specifically acetylcholinesterase (AChE). This inhibition causes a buildup of acetylcholine, resulting in restlessness, convulsions, and paralysis.[5]

Acute Toxicity

The U.S. Environmental Protection Agency (EPA) has classified malathion as a toxicity class III pesticide, bearing the signal word "Caution."[6] Malathion has a rat oral LD50 of 5400 milligrams per kilogram of body weight (mg/kg).[7] Malathion is rapidly absorbed through the gastrointestinal tract, skin, and lungs.[8] Symptoms of acute exposure to malathion and other organophosphate or cholinesterase-inhibiting compounds may include the following: numbness, tingling sensations, headache, dizziness, tremor, nausea, abdominal cramps, sweating, incoordination, blurred vision, difficulty breathing, and slow heartbeat. Very high doses may result in unconsciousness, incontinence, and convulsions or fatality. All organophosphate pesticides act on the body in the same way and their effects are can be additive.

Chronic Toxicity

Malathion is a nerve poison, which acts by inhibiting the enzyme acetylcholinesterase (AchE). Cases of long-lasting polyneuropathy[9] and sensory damage[10] have been reported in humans, as well as behavioral changes. Corresponding indications of neurotoxicity are seen in animal studies. Malathion has shown to damage DNA in humans, particularly for those in frequent contact with the chemical.[11] Another study reports that malathion exposures induce cytotoxic and

genotoxic effects in HepG(2) cells.[12] It has also been associated with birth defects in domestic and laboratory animals.[13] Studies have indicated that repeated malathion exposure causes "depressant-like behavior and oxidative damage to the brain of rodents" and when administered chronically for 28 days caused such behavior in the forced swimming test in animals.[14]

Previous research has already suggested that organophosphates, like malathion, cause a variety of serious neurological health problems, including Parkinson's disease.[15] This is not surprising, as organophosphates are known to be extremely toxic to nerve cells and fatal at high doses. There is also research into long-term effects, including a 2012 meta-analysis that found that long-term, low-dose exposure to organophosphates can damage neurological and cognitive functions.[16]

Metabolites

Malaoxon is the oxygen degradate of malathion and its principal metabolite. Like malathion, malaoxon is active in acetylcholinesterase inhibition, but more potent than malathion. In the 2006 organophosphate (OP) cumulative assessment EPA stated that malathion uses (agriculture, residential, public health) were not a significant contributor to the cumulative risk assessment, and as a result, refinement for brain cholinesterase inhibition from the metabolite, malaoxon, not necessary. In the 2016 human health assessment for malathion, EPA evaluated the ratio of toxicity between malathion and malaoxon and found that malaoxon is 22 times more toxic than malathion.[17] Malathion and malaoxon have also been detected in multiple ambient air in agricultural areas, posing potential risks to bystanders.[18] Malathion and malaoxon may also pose risks through food and drinking water as agricultural applications leave residues on food and runoff may contaminate sources of drinking water. According to EPA, there is limited environmental fate information for malaoxon, but it is expected to have similar environmental properties to malathion.

The International Agency for Research on Cancer (IARC) assessed the carcinogenicity of malathion in 2015 and classified it as probably carcinogenic to humans (Group 2A).[19] This was based on limited evidence from exposure studies for non-Hodgkin lymphoma and prostate cancer and rodent studies in which malathion caused tumor development. EPA has classified malathion as having "suggestive evidence of carcinogenicity,"[20] a category which does not require a quantitative cancer dose-response assessment to be completed. Malathion's determination was made based upon human agricultural studies and strong evidence of DNA or chromosomal damage.

Occupational and Residential Exposure

Malathion is not a restricted use pesticide and thus can lead to exposures in both residential and occupational use scenarios, especially from adulticide applications. It is also registered for "pick-your-own" farm applications which means that the public, including children, can be exposed to agricultural use concentrations. An investigation of reported illnesses associated with exposure to insecticides used for mosquito control in nine states during 1999-2002 indicated that 95 of the 133 reported cases were associated with organophosphates. Of these 95 incidents, malathion was associated with 64 (67.4%) of the cases.[21] In California, malathion was the third most common cause of pesticide related illness from 1981 – 85, especially among applicators exposed during indoor application, usually due to inhalation of fumes.[22] Malathion is second on the list of the 16

pesticide active ingredients thought to be responsible for the largest number of acute occupational pesticide-related illnesses, using 1999 data. Of the 56 cases reported, drift and spray application accounted for 34% and 25% of the cases, respectively.[23] A comprehensive evaluation of pesticides in relation to wheeze led by North Carolina State researchers found that malathion, which is widely used in mosquito control programs, was associated with both allergic and non-allergic wheeze.[24] Additionally, a 2014 study found a positive relationship between the use of malathion and depression in farmers[25], which echoed the conclusion from an earlier French study which also reported that farmers using pesticides face a greater risk of developing depression.[26]

The widespread use of malathion in Florida in 1999 led the Centers for Disease Control (CDC) to release a memo which recommended that Florida find alternatives to malathion to fight the Mediterranean fruit fly (Medfly). According to the CDC report, over 230 people had reported being sick after malathion was sprayed aerially during the Medfly Eradication Program in 1998 with 123 of these incidents listed as probably or possible cases.[27]

The regulatory decisions in the early 2000s to phase out the use of other organophosphates, chlorpyrifos and diazinon for residential use did not apply to malathion. A study assessing longitudinal trends in incident reports following the phase-out of these OPs found that there was a significant decrease in the number of incidents observed for chlorpyrifos and diazinon, but no significant difference for malathion.[28] The average annual number of reports for chlorpyrifos was 214 and 39.3 incidents in the pre- and post- phase out periods, respectively, and for diazinon there was a reduction from an average of 80.6 reports pre-announcement to 19.6 incidents post-announcement. According to the study, the average annual number of reports received by the National Pesticide Information Center for malathion was 51.3 and 56.9 in the pre- and post-phase out periods, respectively, demonstrating the need for a similar phase out.

According to EPA in its 2016 human health risk assessment, risks for dermal and inhalation residential exposures were identified, especially those associated with adulticide applications. Additionally, spray drift as a result of aerial applications results in major risk concerns.[29] The assessment also identified risks for occupational exposures including mixing/loading, handheld and airblast applications.

Environmental Effects

Malathion is known to be highly toxic to aquatic larvae of non-target insects along with a range of mortality for non-target insects and spiders.[30] Malathion is highly toxic to honey bees. Residues on plants and other surfaces indirectly expose bees to malathion, which is also systemically absorbed by plants, translocating throughout the plant and into pollen and nectar, further exposing foraging bees.[31] Bees carrying contaminated pollen back to the hive unwittingly expose the entire colony to malathion residues. Honey bees, pollen, wax and honey have all been found to be contaminated with malathion residues.[32] It has a wide range of toxicities in fish, extending from very highly toxic in the walleye and the brown trout to moderately toxic in fathead minnows. According to EPA, there have been numerous fish kills resulting from malathion use followed by heavy rainfall and runoff into aquatic areas such as streams and ponds.[33]

In April 2016, EPA released a first of its kind national assessment which reviewed the impact of certain OP pesticides as required under the Endangered Species Act Section 7. The review

determined that pesticide impacts are pervasive, and specifically found that chlorpyrifos and malathion are "likely to adversely affect" 97% of listed and candidate species.[34] While these chemicals are currently allowed for use in agriculture, chlorpyrifos and malathion's impact is broader due to their allowance as mosquito insecticides. EPA's analysis required consideration of both direct impacts through dietary exposure as well as indirect impacts through consumption of contaminated prey.

Concerns continue to be raised over the current monitoring methods used for determining the true impact of insecticides, including organophosphates like malathion. A group of researchers called into question the fact that as insecticides are applied less frequently than herbicides, the current monitoring procedures do not detect the occurrence of peak concentrations of these chemicals in the environment.[35]

Environmental Fate

Malathion is moderately to highly mobile in soil, is very soluble in water, and has been detected in groundwater in wells in Mississippi, Virginia, and California, which is likely due to its movement through sandy soils and soils with little organic matter.[36] Malathion is of low persistence in soil with reported field half-lives of several hours to 11 days, depending on moisture levels, pH, and microbial activity. Degradation in soil is rapid and related to the degree of soil binding, plant uptake, and surface runoff. In aerobic aquatic conditions, the half-life varies from 1 day to two weeks, whereas malathion photodegrades slowly in distilled water, with reported half-lives of up to 42 days.[37] If released into the atmosphere, malathion can be transported due to fog, wind, and volatilization. According to a study of west-central Mississippi in 2007, malathion was present in approximately 24% of air samples and 15% of rain samples collected and tested, despite having no estimated local use. This was a reduction compared to 1995 where researchers detected presence of malathion in approximately 29% of air samples and 43% of rain samples tested.[38]

Malathion and Mosquito Control

Community mosquito-spraying varies by state and locality. Many states allow spraying by mosquito abatement districts, which operate based on perceived need, during periods when there are public health concerns and mosquito-transmitted diseases are high. However, with elevated concerns surrounding mosquito-borne viruses like Zika and others, many communities are quick to resort to spraying potentially harmful pesticides. The CDC has stated that spraying pesticides intended to kill adult mosquitoes is usually the least efficient mosquito control technique.[39] A large part of this has to do with the inability, especially in an urban environment, to hit target insects with typical ground spraying from trucks or by aerial application. Given the potential health risks and environmental impacts of adulticiding, monitoring and prevention techniques must be heavily emphasized.[40]

According to EPA, most malathion mosquito adulticide applications (about 90%) are made by ground application (fogging equipment mounted on trucks). EPA states that ground applications do not exceed levels of concern for the agency while aerial applications do. Common mosquito pesticides, like malathion, are highly toxic to bees, other insect pollinators, as well as birds and aquatic organisms. Widespread spraying of malathion and other designated mosquito-control insecticides is not a long-term solution for controlling mosquito populations. Adulticiding fails to

sufficiently control mosquito populations, promotes pesticide resistance, and kills other species that act as natural predators to mosquitoes. There is documented resistance amongst mosquito populations to malathion, as well as other organophosphates used in mosquito control. In Sri Lanka, where antimalarial activities depend largely on the use of malathion, a high level of resistance was detected among the A. culicifacies population.[41]

Organophosphate Class Should Be Phased Out

Organophosphate insecticides, like malathion, are neurotoxic cholinesterase inhibitors that cause the buildup of acetylcholine (AChE), leading to uncontrolled rapid twitching of some muscles, paralyzed breathing, convulsions, and, in extreme cases, death. They have also been linked to developmental delays, impaired cognitive development, and a host of learning/behavioral problems in young children.[42,43] Despite numerous organophosphate poisonings of farmworkers, homeowners, and children, EPA has allowed the continued registration of many of these products. In some cases, such as chlorpyrifos and diazinon, household uses of the products have been cancelled because of the extreme health risks to children, but agricultural, golf course, and "public health" (mosquito control) uses remain on the market. EPA's 2006 cumulative risk assessment document considered the cholinesterase inhibition mechanism for neurotoxic effects of OPs.[44] However studies show that there are other mechanisms at work, resulting in nervous system toxicity. Studies show that at very low levels OPs can induce additional neurotoxic effects at concentrations below those for inhibition of AChE. These studies find that OP-mediated toxicity is a combination of various enzyme-inhibitory, metabolic, and transcriptional events acting at the cellular and molecular level.[45,46,47]With OPs' common mechanism of toxicity and aggregate exposures from food, water and pesticide drift from applications, coupled with their low-level potency, the agency must act with urgency to formally revoke all registrations and uses of this class of pesticide.

Registration Review

EPA released its draft human health risk assessment in 2016. Beyond Pesticides submitted comments on this draft assessment, stating that EPA's assessment of residential and occupational exposures from malathion shows that there are risks of concern that cannot be ignored, and given the legacy of OPs, all uses must finally be phased out. EPA has identified several risks of concern related to malathion use which cannot be ignored or successfully mitigated. Dermal and inhalation exposures continue to pose the most risks from residential and occupational uses. Spray drift, which is inevitable given the current allowable uses of malathion, also raises concern. Continued allowable uses for wide-area mosquito control (aerial and ground applications) poses risks to applicators and the general public, especially the most vulnerable. In light of concerns raised from aerial applications of malathion, EPA has proposed to make modifications to current label directions including adjusting the height of the application and the droplet size of the spray.[48] However, while these measures may reduce one-time residue levels in the environment, repeated applications ensure that exposures remain elevated in areas being sprayed.

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