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Toxicity overview- Pyrethroids

(Permethrin, Bifenthrin, Cypermethrin, Deltamethrin)

{Report citing in brief an overview of the toxicological aspects of conventional pyrethroids used for pest control in polymeric applications and the hazards associated with them}

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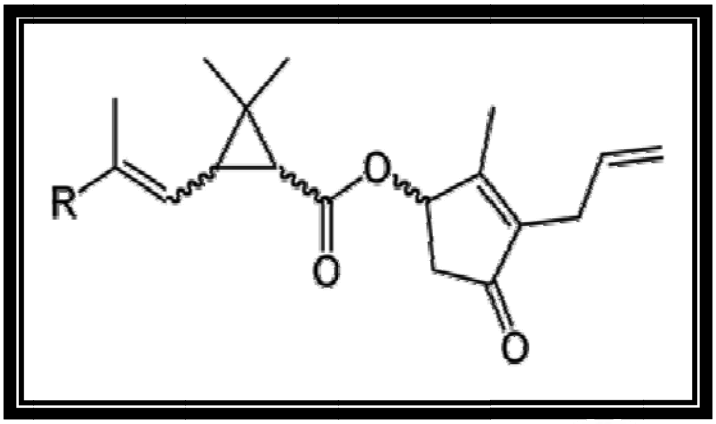

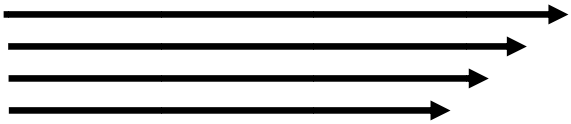

Pyrethroids- A brief description

Pesticide products particular for insect and rodent repellence are many a times based on pyrethroids which are synthetic in nature and it is a myth indeed that they are often touted by pest control operators, community insect management bureaus and even the manufacturers or suppliers themselves as being 'as safe as chrysanthemum flowers' **While pyrethroids are a synthetic version of an extract from the chrysanthemum plant, they were chemically engineered to be more toxic with longer breakdown times, and are often formulated with synergists, increasing potency and compromising the human body's ability to detoxify the pesticide.**

What are Synthetic Pyrethroids?

Synthetic pyrethroids are synthesized derivatives of naturally occurring pyrethrins, which are taken from pyrethrum, the oleoresin extract of dried chrysanthemum flowers (the term "pyrethrum" is often used as a generic term to describe either natural pyrethrins or synthetic pyrethroids). The insecticidal properties of pyrethrins are derived from ketoalcoholic esters of chrysanthemic and pyrethroic acids. These acids are strongly lipophilic and rapidly penetrate many insects and paralyze their nervous system (Reigart et al., 1999).

Various formulations of these pesticides are often combined with other chemicals, known as synergists, to increase potency and persistence in the environment. **While chemically and toxicologically similar, pyrethrins are extremely sensitive to light, heat and moisture. In direct sunlight, half-lives that can be measured in hours**.

Both pyrethrins and synthetic pyrethroids are sold as commercial pesticides used to control pest insects in agriculture, homes, communities, restaurants, hospitals, schools, and as a topical head lice treatment. **Thus it should be noted here that they were traditionally never developed for use as a masterbatch**

Pyrethroids- the different types:

Bifenthrin

Bifenthrin is an off-white to pale tan waxy solid, characterized by its slightly sweet smell. **As a Restricted Use Pesticide**, Bifenthrin may only be purchased or applied by certified applicators or persons under the direct supervision of a certified applicator. **EPA has classified products containing Bifenthrin as toxicity class II (I = most toxic, IV = least toxic), and the word WARNING must appear on all product labels.** Bifenthrin is toxic to mammals when ingested (oral rat LD50 = 54 to 70 mg/kg), and like all pyrethroids affects the central nervous system. Symptoms of poisoning include in-coordination, tremor, salivation, vomiting, diarrhea, and irritability to sound and touch (ETN Bifenthrin, 1995). Of concern in the environment, Bifenthrin is very highly toxic to fish, crustaceans, other aquatic animals and bees, and is moderately toxic to birds. Scientists are particularly concerned about possible bioaccumulation in birds.

A study on laboratory mice shows that Bifenthrin causes gene mutation in white blood cells (ETN, Bifenthrin, 1995). **EPA classifies Bifenthrin as a Class C (possible human) carcinogen (EPA, 1997).**

Cypermethrin

Cypermethrin is registered to control cockroaches, fleas and other indoor pests in homes, restaurants, hospitals, schools and food processing plants, and also in agriculture to control pests on cotton, fruits and vegetables. **Depending on the specific product formulation, EPA classifies pesticides containing Cypermethrin as toxicity class II (I = most toxic, IV = least toxic) and must display the word WARNING or CAUTION on the labels.** Cypermethrin is considered to be toxic (oral male rat LD50 = 187 to 326 mg/kg, dermal rat LD50 = 1600 mg/kg) and like all pyrethroids, affects the central nervous system (ETN, Cypermethrin, 1996). Symptoms of Cypermethrin poisoning in humans include numbness, burning, loss of bladder control, vomiting, in-coordination, seizures, coma and death. In California, Cypermethrin is the fourth most

common cause of pesticide-related illness in pest control operators. **EPA classifies Cypermethrin as a class C (possible human) carcinogen (EPA, 1997). Studies in laboratory animals have shown exposure to Cypermethrin to cause reproductive effects, including abnormal sperm and disruption of sex hormones (Cox, 1996). Cypermethrin should not be applied near water, because it is very toxic to fish and other aquatic organisms.**

Deltamethrin

Deltamethrin is pyrethroid insecticide that kills insects on contact and through digestion. It works by paralyzing the insects' nervous system and therefore giving a quick knock-down effect. **Deltamethrin pesticides may range in toxicity from EPA toxicity class I to class III (I = most toxic, IV = least toxic), bearing the words DANGER-POISON, WARNING or CAUTION on the label (PANNA, 2000). Deltamethrin products may be general or Restricted Use Pesticides.** Deltamethrin produces different signs of poisoning than other pyrethroids. When exposed to Deltamethrin, mammals exhibit typical type II motor symptoms, which include a writhing syndrome in rodents, as well as copious salivation. **The acute oral LD50 in male rats has been reported as low as 128 mg/kg to greater than 5,000 mg/kg depending on the carrier and conditions of the study (ETN, Deltamethrin, 1995).** Some studies have shown Deltamethrin to cause skin irritation. Especially characteristic of Deltamethrin poisoning is rolling convulsions. The sequence of the signs of poisoning is clearly defined, progressing from chewing, salivation, and pawing to rolling convulsions, tonic seizures, and death (ETN, Deltamethrin, 1995). In humans, symptoms of poisoning include ataxia, convulsions leading to muscle fibrillation and paralysis, dermatitis, edema, diarrhea, dyspnea, headache, hepatic microsomal enzyme induction, irritability, peripheral vascular collapse, rhinorrhea, serum alkaline phosphatase elevation, tremors, vomiting and death due to respiratory failure. Deltamethrin is a suspected endocrine disruptor. Deltamethrin is also toxic to fish, aquatic organisms, amphibians and bees.

Permethrin

Permethrin resembles pyrethrins chemically, but is chlorinated to increase its stability. There are four isomeric forms, two cis- and two trans- of technical permethrin. Although the acute toxicity of the mixture (oral rat LD50 > 5000 mg/kg, oral mouse LD50 = 500) is less than that of natural pyrethrins, the cis-isomer is considerably more toxic (oral mouse LD50 = 100), and in rats, the metabolites of the cis-isomer are more persistent biologically. (The cis and trans isomers differ in the spatial arrangement of the atoms.) Product formulations of permethrin can vary greatly in isomeric content. **Permethrin receives an EPA toxicity class rating of II or III (I = most toxic, IV = least toxic), and carries either the word WARNING or CAUTION on its label, depending on the formulation.** While it is not extremely toxic to humans, there are numerous reports of transient skin, eye and respiratory irritation. Like all pyrethroids, permethrin is a central nervous system poison. Workers and researchers report tingling in face and hands, and some report allergic reactions. Based on studies demonstrating carcinogenicity, EPA ranks permethrin as a class C, or possible human carcinogen (U.S. EPA, 1997). Other studies have shown effects on the immune system, enlarged livers and at high doses, decreased female fertility and endocrine disruption. Permethrin is extremely toxic to aquatic life, bees and other wildlife. It should not be applied in crops or weeds where foraging may occur (ETN, Permethrin, 1996).

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Hazards overview- causes of concern!

Pyrethroids have irritant and/or sensitizing properties. They are not easily absorbed through the skin, but are absorbed through the gut and pulmonary membrane. Tests of some pyrethroids on laboratory animals reveal striking neurotoxicity when administered by injection or orally. The acute toxicity, calculated by LD50's, ranges from low to high, depending on the specific formulation Pyrethroids interfere with the ionic conductance of nerve membranes by prolonging the sodium current. This stimulates nerves to discharge repeatedly causing hyper-excitability in poisoned animals. **The World Health Organization explains that synthetic pyrethroids are neuropoisons acting on the axons in the peripheral and central nervous systems by interacting with sodium channels in mammals and/or insects.** The main systems for metabolism include breakage of the ester bond by esterase action and oxidation at various parts of the molecule. Induction of liver microsomal enzymes has also been observed (WHO, 1999).

Signs and symptoms of poisoning by pyrethroids may take several forms. Because of the similarities to crude pyrethrum, pyrethroids may act as dermal and respiratory allergens. Exposure to pyrethroids has resulted in contact dermatitis and asthma-like reactions. Persons, especially children, with a history of allergies or asthma are particularly sensitive, and a strong cross-reactivity with ragweed pollen has been recognized. Severe anaphylactic (allergic) reactions with peripheral vascular collapse and respiratory difficulty are rare. Other symptoms of acute toxicity due to inhalation include sneezing, nasal stuffiness, headache, nausea, in-coordination, tremors, convulsions, facial flushing and swelling, and burning and itching sensations. The most severe poisonings have been reported in infants, who are not able to efficiently break down pyrethroids (ETN, Pyrethroids, 1994). With orally ingested doses, nervous symptoms may occur, which include excitation and convulsions leading to paralysis, accompanied by muscular fibrillation and diarrhea (ETN, Pyrethroids, 1994). Death in these cases is due to respiratory failure. Symptoms of acute exposure last about 2 days.

Endocrine Disruption and Breast Cancer

Many pyrethroids have also been linked to disruption of the endocrine system, which can adversely affect reproduction and sexual development, interfere with the immune system and increase chances of breast cancer. Pyrethroids contain human-made, or xenoestrogens, which can increase the amount of estrogen in the body (Garey et al., 1998). When tested, certain pyrethroids demonstrate significant estrogenicity and increase the levels of estrogen in breast cancer cells (Go et al., 1999). Because increased cell division enhances the chances for the formation of a malignant tumor in the breast, artificial hormones, like those found in pyrethroids, may increase breast cancer risk (PCBR, 1996). Some pyrethroids are classified by EPA as class C (possible human) carcinogens.

Pyrethroids and the Environment

While the development of the synthetic pyrethroids was heralded with claims of selective toxicity to insects, both pyrethroids and pyrethrins are extremely toxic to aquatic organisms, including fish such as the bluegill and lake trout, with LC50 values less than 1.0 parts per billion. Lobster, shrimp, mayfly nymphs and zooplankton are the most susceptible non-target aquatic organisms (Mueller-Beilschmidt, 1990). The nonlethal effects of pyrethroids on fish include damage to the gills and behavioral changes. Pyrethroids are toxic to birds, with most LD50 values greater than 1000 mg/kg. Birds can also be indirectly affected by pyrethroids, because of the threat to their food supply. Waterfowl and small insectivorous birds are the most susceptible (Mueller-Beilschmidt, 1990). Because pyrethroids are toxic to all insects, both beneficial insects and pests are affected by pyrethroid applications. In some cases, predator insects may be susceptible to a lower dose than the pest, disrupting the predator-prey relationship.

Pyrethroids Residues / Persistence

As mentioned before, pyrethroids are designed to breakdown more slowly than the naturally occurring pyrethrins. While pyrethrins, extremely sensitive to light, heat and moisture, break down in a few hours, the synthetic pyrethroids are stable and persist in the environment much longer. With a few exceptions, pyrethroids break down most

quickly in direct sunlight, usually just a few days after application, with a few exceptions. However, in areas with limited sunlight, such as grain silos and subway tunnels, pyrethroids can persist for months. For more specific breakdown times see the sections below on Bifenthrin, Cypermethrin, Deltamethrin, Permethrin and so on

Synergists

Both pyrethroids and pyrethrins are often formulated with oils or petroleum distillates and packaged in combination with synergists, such as piperonyl butoxide (PBO) and n-octyl bicycloheptene dicarboximide (Gosselin et al., 1984). Synergists are added to increase the potency of the pesticide. A range of products from repellants to foggers to pediculicides (lice killers) to garden sprays contain synergists. PBO inhibits important liver enzymes responsible for breakdown of some toxins, including the active ingredients of pesticides. Specifically, it has been shown to inhibit hepatic microsomal oxidase enzymes in laboratory rodents and interfere in humans. Because these enzymes act to detoxify many drugs and other chemicals, a heavy exposure to an insecticidal synergist may make a person temporarily vulnerable to a variety of toxic insults that would normally be easily tolerated. Symptoms of PBO poisoning include anorexia, vomiting, diarrhea, intestinal inflammation, pulmonary hemorrhage and perhaps mild central nervous system depression. Repeated contact may cause slight skin irritation. Chronic toxicity studies have shown increased liver weights, even at the lowest doses, 30 mg/kg/day. While not considered a carcinogen by EPA, animal studies have shown hepatocellular carcinomas, even treatments as low as 1.2% (Takahashi et al., 1994).

Chemicals		Rats	Bees	Birds	Fish	Human Life
Pyrethroid						
	Permethrin	4	6	3	5	5
	Deltamethrin	4	6	3	6	4
	Bifenthrin	5	6	3	6	4

	Cypermethrin	4	6	2	6	4
	Resmethrin	4	5	3	5	3
Dieldrin		5	4	5	5	4
Chlorpyrifos		4	5	5	6	4

6-Extremely Toxic, 5-Highly toxic, 4-Toxic, 3-Slightly Toxic, 2-Practically Non toxic, 1-Relatively Harmless

The above table provides us with the toxicological data of these conventional pyrethroids with respect to toxicity to birds, bees, rats, fish and human life.

Occupational hazards

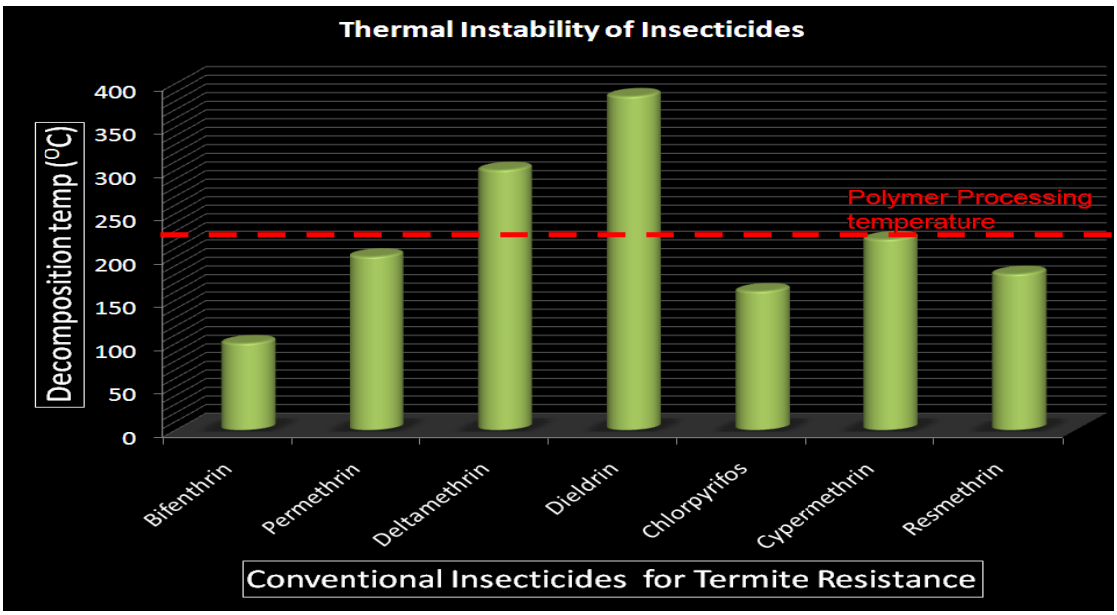
Synthetic analogs of the pyrethrins, extracts from the ornamental Chrysanthemum cineraiaefolium, have been developed to circumvent the rapid photodegradation problem encountered with the insecticidal natural pyrethrins. The pyrethroids are widely used in field pest control and household use and as veterinary and human pediculicides and are among the most potent insecticides known (Smith and Stratton, 1986). The widespread use of these pesticides consequently leads to the exposure of manufacturing workers, field applicators, the ecosystem, and finally the public to the possible toxic effects of these pesticides.

Excessive exposure to pyrethroids like Bifenthrin, Permethrin, Deltamethrin and Cypermethrin can cause nausea, headache, muscle weakness, excessive salivation, shortness of breath, and seizures. Worker exposure to the chemical can be monitored by measurement of the urinary metabolites, while severe over dosage may be confirmed by quantitation of permethrin in serum or blood plasma. These harmful insecticide additives volatilize at polymer processing temperatures and release extremely toxic fumes. These toxic fumes are many times more lethal than the original .This poses fatal hazards to workers handling such products at the shop floor. As (air) temperature increases, vapor hazards will increase. The vapors from many pesticides increase three to four times for each 10° C increase in temperature. This is one reason why pesticide should be stayed away from sunlight and why it is typically recommended that

pesticides not be applied when air temperatures are above 30° C. Extrusion temperatures are as high as 100-300° C.

Toxic Vapors:

Pyrethroids have a low thermal decomposition temperature **of around 200-300°C**. When such chemicals are used in extrusion for manufacturing of wire and cables, pipelines etc, they decompose during the process only. The decomposition leads to the formation of toxic fumes. These fumes are highly toxic especially for the personnel working on the shop floor. The graph below shows the thermal instability of various pesticides currently used worldwide.



Elevated as well as localized temperatures in an extruder can go as high as 400°C and even beyond. This can result in serious problems for workers which will be handling the product. Moreover the temperatures are quite high near the tube exits of the extruder which could be a major source of toxic fumes. In case of insufficient ventilation which is normally the case in case of compact arrangements near the exits, these fumes can accumulate thus increasing the toxicity in general 30° C. Extrusion temperatures are as high as 100-400° C.

Conclusion

Thus it can be seen that pyrethroids are extremely toxic to animals, human health and life and the environment. Moreover they are not meant for polymeric applications as they are not designed for use as a masterbatch as they pose problems during processing via extrusion and also on account of leachability, compatibility and toxicity.