Environmental Fate of Imidacloprid

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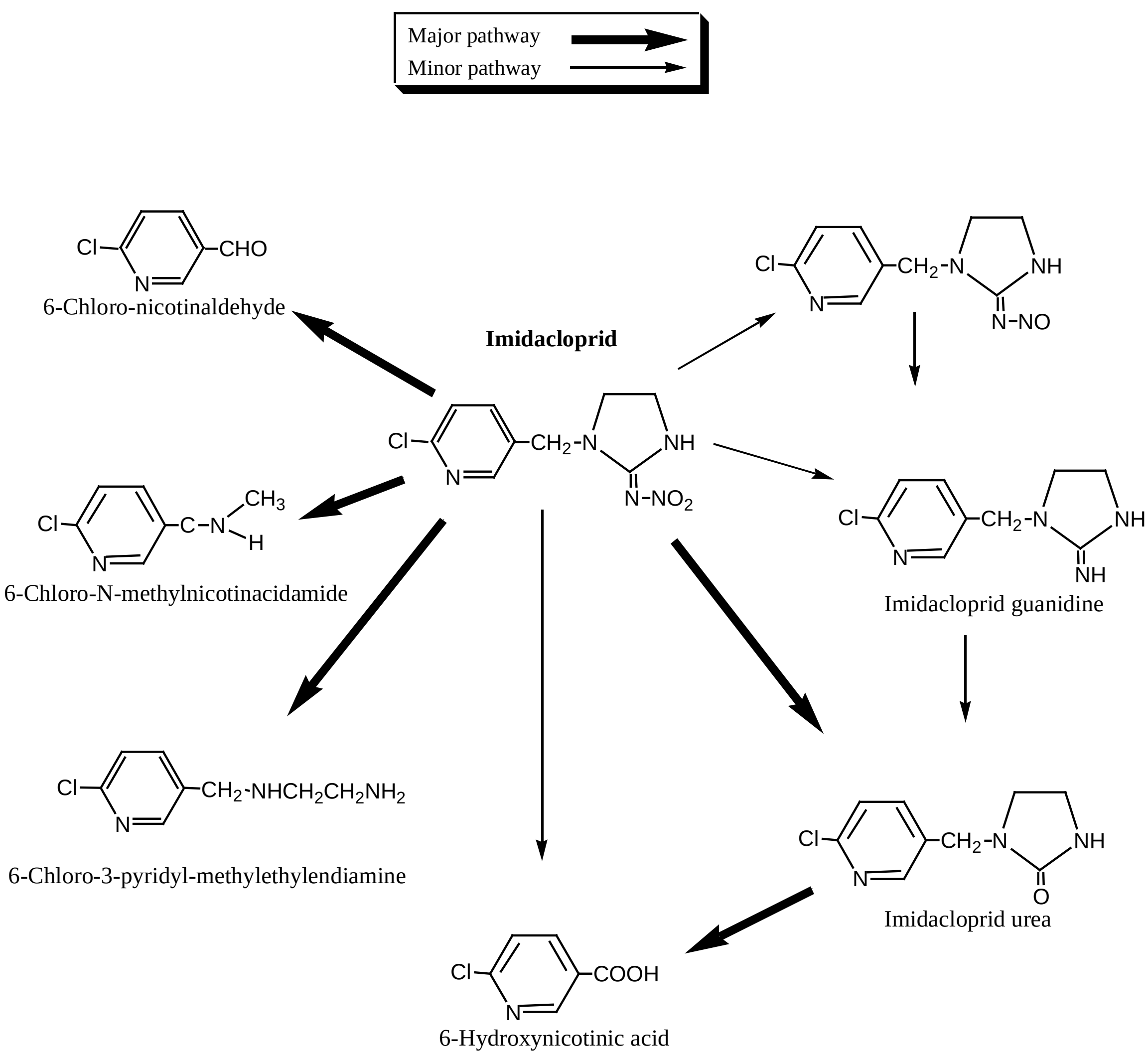
This document reviews all routes of environmental fate for imidacloprid under field conditions for its potential use in controlling the glassy-winged sharpshooter. Imidacloprid is a chloronicotinoid insecticide. Chemical name: 1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine).

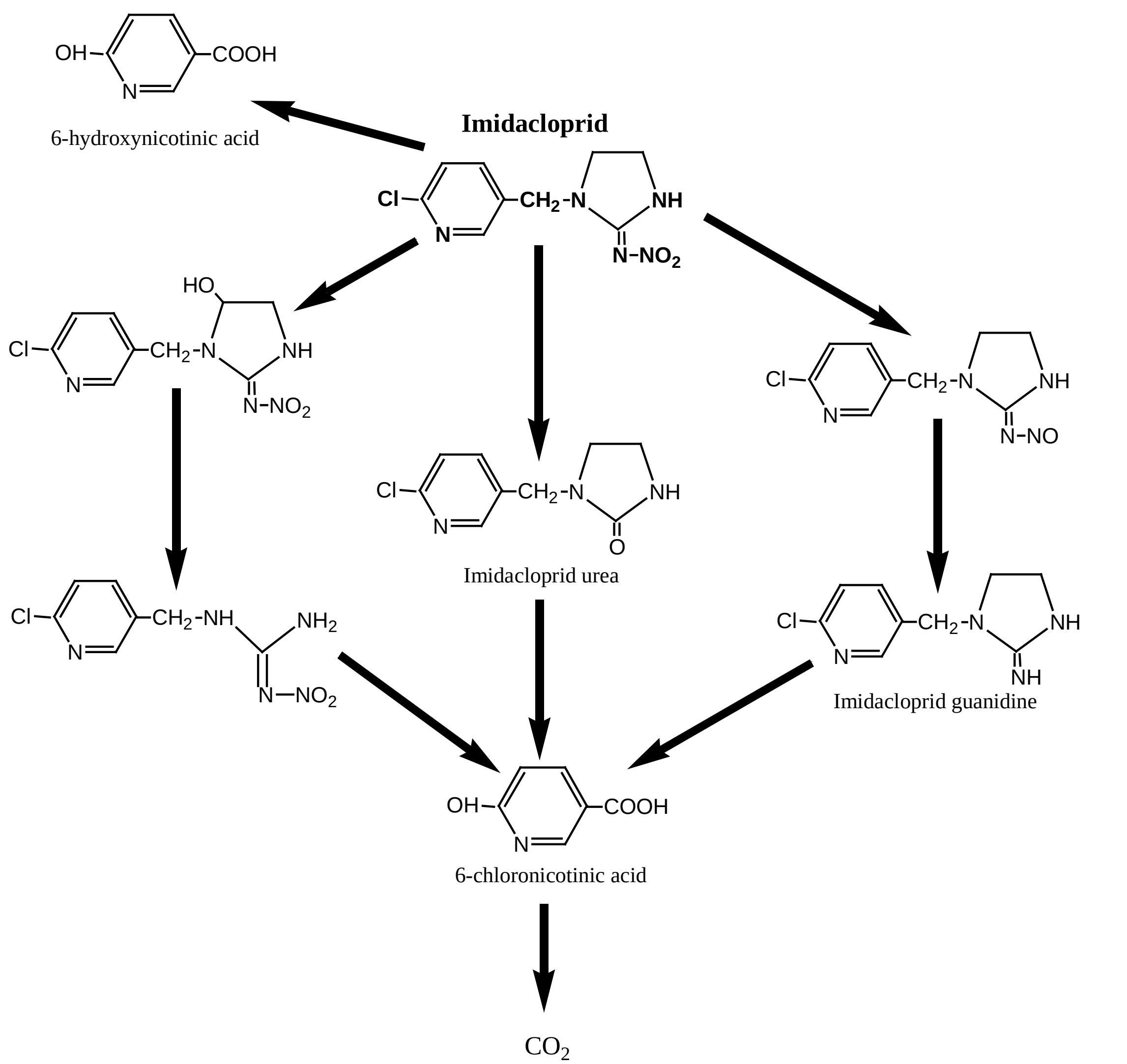
Imidacloprid Degradation

Photolysis in water



SOIL DEGRADATION

Probable degradation pathway in soil (main metabolites).



Physical-Chemical Properties[a]

Molecular weight	255.7
Water solubility	5.14×10^2 ppm (20ºC at pH 7)
Vapor pressure	1.00×10^{-7} mm Hg (20ºC)
Hydrolysis half-life	>30 days (25ºC at pH 7)
Aqueous photolysis half-life	3.98×10^{-2} days (24ºC at pH 7)
Anaerobic half-life	27.1 days
Aerobic half-life	9.97×10^2 days
Soil photolysis half-life	38.9 days
Field dissipation half-life	26.5 to 229
Henry's constant	6.5×10^{-11} atm m^3/mole (20ºC)
Octonal-water coefficient (K_{ow})	3.7
Soil adsorption coefficient:	
K_d	.956 to 4.18
K_{oc}	132 to 310

Toxicity[b]

Daphnia magna LC_{50} (48 h)	85 ppm
Mysid shrimp LC_{50} (96 h)	34 ppb
Rainbow trout LC_{50} (96 h)	>83 ppm
Bobwhite quail LD_{50}	152 ppm
Mallard duck LD_{50}	283 mg/kg
Rat acute oral LD_{50}	450 ppm
Honeybee LD_{50} (48 h)	0.008 ug/bee

a Data from the DPR PestChem Database (Kollman and Segawa, 1995)
b Department of Pesticide Regulation, EXTOXNET Database (2000)

General Information and Mode of Action

Imidacloprid has many trade names: Gaucho, Admire, Confidor, Advantage, Merit, Provado, Imicide, Imisol, Vision and Premise. Imidacloprid is a chloronicotinoid insecticide. This systemic insecticide kills insects via ingestion or contact by disrupting the nervous system of an insect pest.

Imidacloprid controls sucking insects, soil insects, termites, and some chewing insects, and is effective against adult and larval stages. It is used as a seed, soil, crop and structural treatment. It is also used as a flea control treatment on domestic pets (Farm Chemical Handbook, 2000).

Environmental Fate

The low K_{oc} of 132 to 310, combined with a high water solubility of 514 ppm, suggests a potential to leach to ground water, although earlier field studies, under normal weather conditions, have found imidacloprid to be relatively immobile in silt loam soils (Rouchaud et al., 1994; Miles Inc., 1993). The moderate K_{ow} value of 3.7, combined with its rapid photodegradation in water, (half-life ($t_{1/2}$) < 3 hours) and on soil ($t_{1/2}$ 39 days), suggests a low potential for bioaccumulation (DPR Pestchem Database, 1995).

Air: Some formulations of this pesticide are applied by spraying in an upward direction allowing for possible offsite movement through drift. The low vapor pressure of 1.0 x 10^{-7} mm Hg indicates that this insecticide is relatively non-volatile. Since, imidacloprid also has a low soil adsorption coefficient, it has a relatively low potential to be dispersed in air over a large area via air-borne soil particles. The low Henry's law constant of 6.5 x 10^{-11} atm m^3/mole also indicates that it has low potential of volatizing from water.

Water: There is a potential for imidacloprid to enter streams and ponds via drift during application or in runoff water. Rouchaud et al. (1994) and Miles Inc. (1993) found that imidacloprid did not leach to ground water in their field studies. But in a recent study conducted in 1997 to 1998, Bayer Corporation found imidacloprid in ground water, 18 feet below ground surface (sandy loam soil). Concentrations ranged from < .1 ppb to 1 ppb.

Hydrolysis of this pesticide is greater than 30 days at pH 7 and 25^{o}C. Sarkar et al., (1999) reported that the hydrolysis half-life varies from 33 to 44 days at the same pH and temperature. Imidacloprid was found to be stable in acidic and neutral water, but more readily hydrolyzed in alkaline water (Zheng et al., 1999).

The formulation of the insecticide can affect the half-life. In wetable powder formulations persistence increased by 3 to 6 days compared to liquid formulations (Sarkar et al., 1999).

Mobay (1989) found the two major metabolites via hydrolysis were 1-[(6-chloro-3pyridinyl)methyl]-4,5-dihydro-1H-imidazol-2-amine] (imidacloprid-guanidine) and 6-chloro-3-pyridyl-methylethylendiamine. Zheng et al. (1999) found the only main metabolite was 1-[(6-chloro-3pyridinyl)methyl]-2-imidazolidone.

The aqueous photolysis half-life is less than 3 hours (Wamhoff et al., 1999; Moza, 1998). The prime degradation products resulting from photolysis in water were found to be:

- 1-[(6-chloro-3-pyridinyl)methyl]-2-imidazolidinoe (imidacloprid urea)
- 6-Chloro-nicotinaldehyde
- N-methylnicotinacidamide
- 6-chloro-3-pyridyl-methylethylendiamine

Soil: The high water solubility and low Koc, indicate a low tendency to be adsorbed to soil particles. Field studies show that imidacloprid can persist in soil, with a half-life ranging from 27 to 229 days (Miles Inc., 1993). Half-life in soil varies depending on soil type, use of organic fertilizers, and presence or absence of ground cover. Scholz et al. (1992) found that imidacloprid degraded more rapidly under vegetation, $t_{1/2}$ 48 days, versus 190 days without vegetation. Degradation on soil via photolysis has a $t_{1/2}$ of 39 days. In the absence of light, the longest half-life of imidacloprid was 229 days in field studies and 997 days in laboratory studies (Miles Inc., 1993). This persistence in soil, without the presence of light, makes imidacloprid suitable for seed treatment and incorporated soil applications because it allows continual availability for uptake by roots (Mullins, 1993).

In field experiments, low application rates showed high sorption (Cox et al., 1998). The sorption level of imidacloprid is also affected by soil properties such as organic carbon and minerals. As the organic carbon levels and laminar silicate clay content in the soil increases, the potential for imidacloprid to leach would decrease (Cox et al., 1997, 1998). Organic fertilizers, such as chicken and cow manure, increased the pesticide adsorption to the organic matter and also increased its half-life. Half-lives ranged from 40 days when no organic fertilizers were used to 124 days when cow manure was used. However, residual insecticide soil concentrations were low at the time of harvest, similar to those not treated with organic fertilizers (Rouchaud et al., 1996). Plants readily absorb imidacloprid through the roots, and metabolize it (Westwood et al., 1998). No correlation was found between K_{oc} and the soil carbon content (Rouchaud et al., 1996).

The prime breakdown products from imidacloprid in soil include:

- 1-[(6-chloro-3-pyridinyl)methyl]-2-imidazolidinoe (imidacloprid urea)
- 6-chloronicotinic acid
- 6-hydroxynicotinic acid

CO_2 is then formed from 6-chloronicotinic acid (Scholz 1992, Miles Inc., 1993).

Biota

Even with imidacloprid's potential to persist in soil, the high photodegradation tendency and high water solubility indicate there is low potential for bioaccumulation in the environment.

Plants readily absorb imidacloprid through the roots. In one study, at 97 days after sowing, the metabolites in sugar-beet leaves represented 44.5% of the applied parent compound (Westwood et al., 1998). In the same study the main metabolites in plants were found to be 6-hydroxynicotinic acid, an olefinic compound and an unidentified metabolite. Koester (1992) found the main metabolites to be 1-[(6-chloro-3-pyridinyl)methyl]-5-hydroxy-4,5-dihydro-N-nitro-1H-imidazol-2-amine and 1-[(6-chloro-3-pyridinyl)methyl]-N-nitro-1H-imidazol-2-amine.

If imidacloprid were to enter surface water, the photodegradation half-life in water is less than 3 hours. Without light, hydrolysis can range from 33 to 44 days. When applied according to label directions the potential for toxicity to fish is low with a LC_{50} level of 211 ppm for the rainbow trout. No studies have been done to determine or identify imidacloprid in fish.

Summary

Imidacloprid is a systemic, chloronicotinoid insecticide, which kills insects via ingestion or contact. It is effective by disrupting the nervous system of an insect pest. It is used for controlling sucking insects, soil insects, termites, and some chewing insects. It is applied as a seed and soil treatment, crop and structural treatment, and a topical flea control treatment on domestic pets.

The low vapor pressure of 1.0×10^{-7} mm Hg indicates that this insecticide is non-volatile. Also, the low Henry's law constant of 6.5×10^{-11} atm m^3/ mole, indicates that it has low volatility from water. Therefore, it is unlikely to be dispersed in air over a large area from volatilization.

Hydrolysis of imidacloprid can range from 33 to 44 days at pH 7 and 25^{o}C. The aqueous photolysis half-life is less than 3 hours. The soil surface photolysis of imidacloprid has a half-life of 39 days, and in soil the half-life ranges from 26.5 to 229 days. This persistence in soil allows continual availability for uptake by roots.

The soil adsorption coefficient of 132 to 310, combined with a high water solubility of 5.14×10^2 ppm, suggests a potential to leach to ground water.

The potential for toxicity to fish is low with a LC_{50} level of 211 ppm for the rainbow trout. Even with a potential to persist in soil, the potential for imidacloprid to bioaccumulate in the environment is low due to the high photodegradation tendency and high water solubility.

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