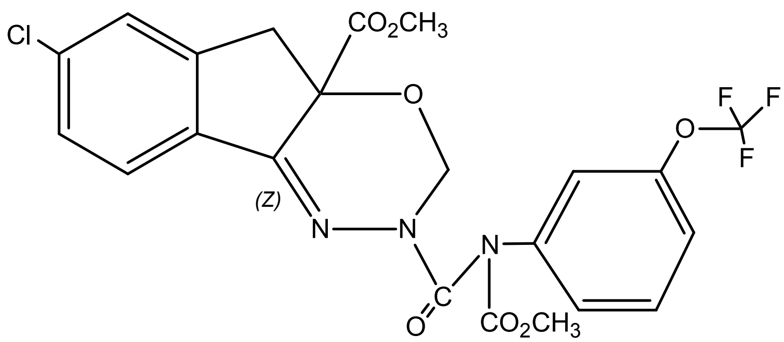
ENVIRONMENTAL FATE OF INDOXACARB

Adriana Moncada
Environmental Monitoring Branch
Department of Pesticide Regulation
1001 I Street
Sacramento, CA 95812-4015

March 6, 2003

This document reviews the environmental fate and environmental effects of the oxadiazine insecticide indoxacarb. The chemical name of indoxacarb is (S)-methyl 7-chloro-2, 5-dihydro-2- [[(methoxycarbonyl) [4 -(trifluoromethoxy) phenyl] amino] carbonyl] indeno[1,2-e][1,3,4] oxadiazine-4a(3H)-carboxylate ($C_{22}H_{17}ClF_3N_3O_7$). This relatively new pesticide was registered in California, January 2001. The current products that contain indoxacarb are Avaunt and Steward. Indoxacarb was developed by E. I. du Pont de Nemours and Company.



Indoxacarb

General Information and Mode of Action

Indoxacarb is formulated as a wettable granule and a soluble concentrate. The technical material is a white powered solid (Farm Chemicals Handbook, 2002). The name indoxacarb refers to the S-isomer of the molecular structure above which has also been designated as DPX-KN128 by Dupont. The R-stereoisomer, designated DPX-KN127, does not display insecticidal activity. DPX-MP062 is a 75:25 mixture of the two isomers, while DPX-JW062 is a 50:50 mixture of DPX - KN128 and DPX-KN127 DPX-JW062 is a less effective insecticide than DPX - MP062 due to the lower levels of the active isomer, DPX - KN128, present in the compound. Most of the physicochemical and field trial data were obtained using the 50:50 isomer mixture, DPX-JW062 (Brugger, 1997). However, these data are expected to be representative of the environmental fate of the S-stereoisomer indoxacarb.

Indoxacarb is a non-systemic, synthetic organophosphate replacement insecticide used to control sucking insects. Indoxacarb affects insects from direct exposure and through ingestion of treated foliage/fruit. Once indoxacarb is absorbed or ingested, feeding cessation occurs almost immediately. It kills by binding to a site on sodium channels and blocking the flow of sodium ions into nerve cells. The result is impaired nerve function, feeding cessation, paralysis, and death (Brugger, 1997). It may take days for insects to die. Indoxacarb is used on a range of crops, which include fruits (apples, pears, and tomatoes), vegetables (broccoli, Brussels sprouts, cabbage, cauliflower, eggplant, potato, and lettuce), soybeans, alfalfa and peanuts. It is used to control or suppress the many insects, including Beet armyworm, Cabbage looper, Corn earworm, Diamondback moth, Fall armyworm, Imported cabbageworm, Southern armyworm, Tomato pinworm, and the Tomato fruitworm (Dupont, 2002).

Table 1. Physical-Chemical Properties

Molecular weight [a]	527.87 g/mole
Water solubility [b]	0.2 mg/L (25º C at pH 7.0)
Vapor pressure [b]	<1.0 X 10^{-7} mmHg (25º C)
Hydrolysis half-life [b]	>30 days (pH 5)
	38 days (pH 7)
	1 day (pH 9)
Aqueous photolysis half-life [b]	3.16 days (pH 5.0)
Aerobic soil degradation [b]	4.5-117 days
Anaerobic soil degradation [b]	12.8-402 days
Soil photolysis half-life [b]	139 days
Field dissipation half-life [b]	6-114 days (Median 20.1)
Henry's law constant [a]	<6 X 10^{-10} atm-m^3/mol(25ºC)
Octanol-water coefficient (log Kow) [b]	4.5
Soil adsorption coefficient: Koc [a]	2200-8200

[a] Brugger, 1997.
[b] DPR Pesticide Chemistry database.

Table 2. Ecological Toxicity (DPX - MP062)

Bluegill LC_{50}	900 ppb
Daphnia magna 21-day NOEC	75 ppb
Daphnia magna 48-hr EC_{50}	600 ppb
Honey Bee 48-hr Contact LD50	0.18 ug/bee
Mallard Duck LC50	>5620 ppm
Mysid Shrimp 96-hr LC_{50}	54.2 ppb
Oyster (Larvae or shell growth)	218 ppb
Quail Oral LD 50	98 ppm
Quail Bobwhite LC50	808 ppm
Rat Oral LD50 Male	1730 ppm
Rat Oral LD50 Female	268 ppm
Rainbow trout LC_{50}	650 ppb
Sheephead Minnow 96-hr LC50	374 ppb

[a] Brugger and Kannuck, 1997

ENVIRONMENTAL FATE

Air

Indoxacarb is relatively non-volatile with a low vapor pressure of $<1.0 \times 10^{-7}$ mmHg at 25 ºC. The low vapor pressure indicates vaporization is not a significant dissipation mechanism in the environment (Cobranchi and Schmuckler, 1997). The Henry's law constant of $<6 \times 10^{-10}$ atm-m^3/mol at 25º indicates that indoxacarb has almost no tendency to volatilize from aqueous solution or moist soils. A study of DPX-JW062 volatilization from plant and soil found that a spray application of 600 g of active ingredient (AI) per hectare to lettuce, resulted in volatilization of <3 % of the total applied over a time period of 7 days. (Kubiak, 1996).

Water

Indoxacarb hydrolysis rates increase with increasing pH. The half-life at pH 5, 7 and 9 were calculated to be approximately 500 days, 38 days, and 1 day, respectively (Ferraro and McEuen, 1996).

Radiolabel DPX-JW062 was rapidly degraded by simulated sunlight, suggesting that photolysis likely plays a major role in dissipation of DPX-JW062 in aquatic environments. The short aqueous photolysis half-life of 3.16 days suggests low persistence in aquatic systems. This indicates chronic exposures in aquatic systems may not be significant (Ferraro and McEuen, 1997).

Soil

Indoxacarb is moderately hydrophobic with a low water solubility of 0.2 mg/L and a log Kow of 4.6. This, coupled with a moderately high soil sorption coefficient Koc of 2200 – 8200, indicates a relatively low probability of leaching into groundwater. In a soil column leaching study, recovery for the 15 cm (15 to 30 cm depth including the aged soils) ranged from 82 to 95 % radioactivity. The lower 15-30 cm of the soil columns contained < 3 % of the applied radioactivity. The glass columns were eluted with at least 200 mm of 0.01 M $CaCl_2$ over a 7-day period (Chrzanowski and Fetterman, 1997).

A laboratory soil photolysis study found degradation on Tama silt soil samples when applied at a rate of 1 kg of active ingredient per hectare was slow under exposure to simulated sunlight. The half-life in soil photolysis using natural sunlight was calculated to be 139 days. Given the rapidity at which DPX-JW062 is degraded hydrolytically (38 days at pH 7) soil photolysis probably plays only a minor role in the environment (Berg, 1997).

Microbial degradation of indoxacarb is an important degradation pathway in soil. Indoxacarb undergoes rapid decomposition in terrestrial environments through microbial degradation (Brugger, 1997). Under aerobic conditions, the hydrolysis product INJT333 is rapidly formed (Figure 1). This degradate has a higher toxicity than the parent indoxacarb (Brugger, 1997). The reported field dissipation half-lives of indoxacarb are variable, ranging from 16 to 114 days.

Biota

Vegetation. Indoxacarb has no reported adverse effect on non-target terrestrial plants. Indoxacarb had no phytotoxic effect on 8 crops observed in field efficacy testing, at application rates approximately equivalent to its intended field use rate of 0.065 lbs active ingredient per acre in vegetables.

DPX-MP062 degrades moderately rapidly in and on plant leaves and fruits. The measured DT50 (disappearance time for 50 % of the chemical) on leaves and fruits of the vegetable crops ranged from 2-34 days (average 18 days). Based on the low use rate of DPX-MP062 and its rapid dissipation in plants, dietary exposure to non-target organisms inside and outside the application area is expected to be very low (Brugger, 1997). Studies with aquatic algae and duckweed indicate no measurable toxicity at levels >1.93 ppm and >84 ppb, respectively. No studies were found on metabolic fate in plants.

Birds. In birds, indoxacarb, is "moderately toxic" to avian species on an acute dietary basis. The lowest LC50 is 808 mg/kg-diet for bobwhite quail. The metabolite JT333 is "slightly toxic" on an acute oral basis with an LC50 =1618 mg/kg (US EPA, 2000).

Fish and Insects. Indoxacarb, the DPX-KN127 isomer and associated degradates are "moderately to very highly toxic" to freshwater and estuarine/marine fish on an acute basis with LC50s ranging from 0.024 to >1.3 mg/L. They are also "moderate to very highly toxic" in freshwater and estuarine/marine invertebrates on an acute basis with EC50s ranging from 0.029 to 2.94 mg/L. Chronic toxicities range from 0.0006 to 0.0184 ml/L for estuarine fish and invertebrates and from 0.004 to 0.15mg/L for freshwater fish and invertebrates (US EPA, 2000).

Bees. In bees, indoxacarb is considered "highly toxic" by contact (US EPA, 2000). DPX-MP062 is predicted to be highly toxic to bees, based on laboratory studies with a similar compound, DPX-JW062. Although the pesticide is highly toxic to honeybees upon direct contact (treatment), DuPont states that there is a low impact on honeybees after the spray has dried. For instance, a study of honeybees exposed to residues in alfalfa at the maximum proposed single use rate (0.11 AI/A) reported that bees were not affected after 3 hours post-application (Brugger, 1997).

Summary

Indoxacarb is a nonsystemic insecticide and is considered a "reduced risk" pesticide by the U.S. EPA (EPA Fact sheet, 2000). This insecticide is used to control sucking insects. The insecticidal activity occurs via blockage of the sodium channels in the insect nervous system and the mode of entry is via the stomach and contact routes. The result is impaired nerve function, feeding cessation, paralysis, and death. Indoxacarb is primarily used in agriculture. There are no registered residential uses at this time.

Indoxacarb is relatively non-volatile with a low vapor pressure and a low Henry's law constant. Consequently volatilization is not a significant factor in dissipation. The low water solubility, high Kow, and moderately high Koc suggest that indoxacarb will have a moderately tostrong tendency to partition from water to soil and therefore be relatively immobile in soil. Hydrolysis is an important degradation route at alkaline or neutral pH (s), but much less important under more acidic conditions. In vegetation, indoxacarb does not appear to have an adverse effect on non-target terrestrial plants. Indoxacarb is moderately to very highly toxic to freshwater, estuarine/marine fish and insects. In bees, it is highly toxic" by contact, but has lesser post-application toxicity after drying on vegetation.

References

Berg, D.S. 1997. Photodegradation of Radiolabeled DPX-JW062 (A Racemic Mixure of DPX- KN128 and IN-KN127) on Soil under Simulated Sunlight. DuPont Agricultural Products Document No. AMR 2818-93.

Brugger, K.E. 1997. DPX-MP062: Prospective Tier I Ecological Effects Assessment for Non-target Organisms. DuPont Agricultural Products Document No. AMR 4782-97.

Brugger, K.E., and Kannuck, R.M. 1997. Tier 1 Environmental Risk Assessment of DPX- MP062 and Competitive Insecticides in the USA. Dupont Agricultural Products Document No. AMR 4635-97.

Chrzanowski, R.L., and Fetterman, D.E. 1997. Soil Column Leaching Study of C-DPX-MP062 (A 3:1 Mixture of DPX-KN128 and IN-KN127) on Four Aged Soils. DuPont Agricultural Products Document No. AMR 3845-96.

Cobranchi, D.P., and Schmuckler, M.E. 1997. Vapor Pressure of DPX-KN128 and Calculation of Henry's Law Constant. DuPont Agricultural Products Document No. AMR 4169-96.

DPR Pesticide Chemistry database. Environmental Monitoring Branch, Department of Pesticide Regulation. 2003.

Dupont Product Profile. 2002. Indoxacarb. Available Online: http://www.avaunt.dupont.com.

Farm Chemicals Handbook. 2002. Meister Publishing Company. 230.

Ferraro, P., and S.F. McEuen. 1996. Hydrolysis of DPX-JW062 (A Racemic Mixture of DPX-KN128 and DPX-KN127) in Buffer Solutions of pH 5, 7, and 9. DuPont Agricultural Products Document No. AMR 2789-93.

Ferraro, P., and S.F. McEuen. 1997. Photodegradation of DPX-JW062 (A Racemic Mixture of DPX-KN128 and IN-KN127) in pH 5 Buffer Solution and Natural Water by Stimulated Sunlight. DuPont Agricultural Products Document No. AMR 2788-93.

Kubiak, Roland. 1996. Investigation of the Volatilization of [$_{14}$C] DPX-JW062 from

Plant and Soil Surfaces under Laboratory Conditions. DuPont Agricultural Products Document No. AMR 3711-95.

Rhodes, B.C. 1997. Aerobic Soil Metabolism of ^{14}C-DPX-JW062. DuPont Agricultural Products Document No. AMR 2803-93.

U. S. EPA Pesticide Fact Sheet: Indoxacarb. 2000.

FIGURE 1. PROPOSED DEGRADATION PATHWAYS FOR INDOXACARB IN AEROBIC SOIL (Rhodes, 1997)

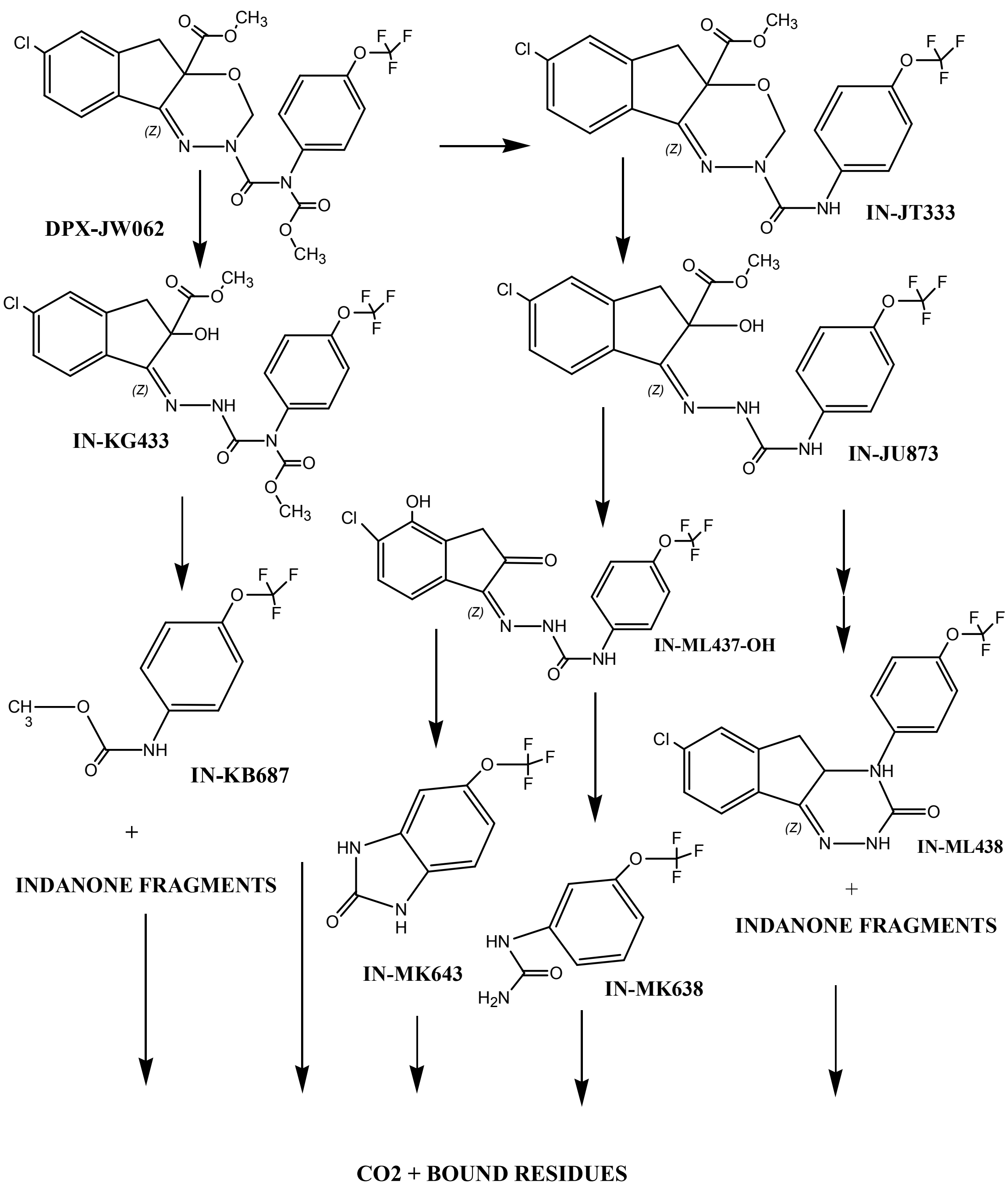


FIGURE 2. PHOTODEGRADATION PATHWAY OF INDOXACARB
(Ferraro and McEuen, 1997)