Environmental Fate of Carbaryl

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Contents

I. Introduction

Carbaryl (1-naphthyl-*N*-methyl carbamate; Fig. 1) is a carbamate insecticide introduced in 1956 by Union Carbide Corporation. The insecticide is used worldwide and is a substitute for some organochlorine pesticides (Ribera et al., 2001). Carbaryl controls a broad spectrum of insects on more than 120 different crops (Ware, 2000). It has also been used to prevent bark beetle attacks in pine trees (Hastings et al., 2001) and as a general garden insecticide (Ware, 2000). In 2004, approximately 110,000 kg of the insecticide was applied in California alone (CDPR, 2004). Annual use in the U.S. is reported to be 4.5-6.8 million kg (Cox, 1993). Several trade names are associated with carbaryl; the most common being Sevin®. Active ingredient (a.i.) use rates for carbaryl range from 0.57-4.5 kg/ha (Rajagopal et al., 1984). It is available in the form of a wettable powder, pellets, granules, suspensions, and solutions. The insecticide is the second most widely detected insecticide in surface waters in the U.S. (Martin et al., 2003).
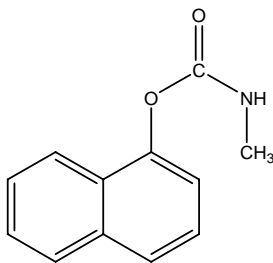

Fig. 1. Chemical structure of carbaryl.

II. Chemistry

Carbaryl, like most carbamates, inhibits the enzyme that degrades acetylcholine - acetylcholinesterase. Inhibition of this enzyme promotes the buildup of acetylcholine at synapses resulting in uncontrolled movement, paralysis, convulsions, and possible death (Tomlin, 2000).

The physical chemical properties of carbaryl are listed in Table 1. Carbaryl is a low molecular weight compound that is moderately soluble in water and does not readily volatilize. The compound is not compatible with alkaline materials such as lime (Tomlin, 2000).

Table 1. Physical-chemical properties of carbaryl.

Pure physical state [a]	Colorless or tan crystal
Chemistry Abstracts Service registry number (CAS #) [b]	63-25-2
Molecular weight (g/mol) [a]	201.2
Molecular formula [a]	$C_{12}H_{11}NO_2$
Melting point (°C) [a]	142
Vapor pressure (mPa at 23.5°C) [a]	0.041
Octanol-water partition coefficient (log K_{ow}) [a]	2.36
Density (20°C) [a]	1.23
Henry's law constant (atm m³ g/mol at 25°C) [a]	2.74×10^{-9}
Organic-carbon normalized partition coefficient (K_{oc}) [b]	290
λ_{max} (nm) [c]	280
Water solubility (mg/L) 20°C [a]	120
25°C [d]	104
40°C [e]	40

[a] Tomlin, 2003; [b] Phillips and Bode, 2004 [c] Sheng et al., 2001; [d] Arroyo et al., 2004; [e] Meister, 2001.

III. Chemodynamics

A. Air

The low vapor pressure measured for carbaryl makes the possibility of volatilization unlikely (Table 1). Additionally, its low Henry's law constant suggests that it will not volatilize from aqueous solutions (Table 1). However, carbaryl could become airborne from binding to particulates or as a spray drift immediately following application. Drift monitoring from aerial spraying of carbaryl at a rate of 2250 g a.i./ha on a Vermont apple orchard revealed concentrations of 0.70-7.20 µg/plate (1 mm thick Teflon sheet covered the 15 cm diameter petri plate), which corresponds to 0.4-4.1 g a.i./ha, as far out as 305 meters with 8-12 km/h winds (Currier et al. ,1982). Higher concentrations (481 µg/plate) were observed at 76 meters

downwind and 12 meters upwind (45.9 μg/plate) in the same study. But, the study noted that all detections decayed to relatively low concentrations within 2 hours after application (< 2 ug/m^3; Currier et al., 1982). Airborne carbaryl degrades after reaction with hydroxyl radicals in the atmosphere (Kao, 1994). Sun et al. (2005) determined the reaction rate constant for carbaryl hydroxyl radical reactions at 3.3×10^{-11} cm^3/second.

Low drift concentrations were reported in a California study with concentrations up to 1.12 μg/m^3 in the air after ground spraying to control the glassy-winged sharpshooter, *Homalodisca coagulate* (Walters et al., 2003). Although below the adverse health effect concentration (51.7 μg/m^3), the study indicated that the insecticide was present in the air up to 47 hours after application (Walters et al., 2003). Shehata et al. (1984) also reported atmospheric concentrations that ranged from 0.0035 to 0.107 μg/m^3 in a Maine forest treated with carbaryl to control the spruce budworm.

In eastern France, air concentration measurements for carbaryl at remote (non-populated), rural (population = 80,000), and urban (population = 300,000) sites were on average 280, 348, and 577 pg/m^3 with highest detections at 1800, 696, and 1420 pg/m^3, respectively (Sanusi et al., 2000). The increased urban and rural carbaryl concentrations were primarily due to local agricultural use (Sanusi et al., 2000). Similar concentrations were observed in 1995 at three urban and agricultural sites along the Mississippi River (Foreman et al., 2000). However, carbaryl was detected more frequently in urban sites than agricultural sites in Mississippi and Iowa and possibly reflective of its growing domestic use (Foreman et al., 2000).

B. Water

Carbaryl is moderately soluble in water and its solubility increases with increasing temperature and amount of organic solvents. Detections of carbaryl have been found in surface waters of 42 U.S. states at low concentrations (μg/L). In many states, detections were found in both agriculture and urban environments (Table 2). Several state reported higher frequency of detections in urban than in agricultural environment. In California, detections in urban environments are less than in agricultural areas (Table 2). Carbaryl ranked 8th nationally among pesticides for outdoor home-and-garden use in 1992 (Whitmore et al., 1992), and one of four insecticides most commonly detected in urban streams in 2001 (Gilliom et al., 2007). Agricultural inputs of carbaryl to water systems have also been reported. In Florida, Wilson et al. (2006) detected carbaryl in eight of 457 samples collected from Ten Mile Creek located in an agricultural watershed at concentrations that ranged from 0.33-0.95 μg/L. Lower concentrations of carbaryl (10-100 ng/L) were detected in the Pinios River in Greece with seasonal use of the insecticide in the Thessaly agricultural area (Fytianos et al., 2006). Higher concentrations have been detected in several locations after carbaryl was used across central California to control the newly introduced glassy-winged sharpshooter pest, *Homalodisca coagulate*. For instance, 6.94 μg/L in a goldfish pond and 1737 μg/L in rain runoff in a drain were detected adjacent to where carbaryl was sprayed (Walters et al., 2003).

Groundwater detections are also reported by LaFleur (1967) who found the presence of carbaryl within two months after application to Congaree soil (well drained loamy soil on river bed) with detections continuing up to eight months. Table 2 shows that New Jersey had the highest number of carbaryl detections in groundwater across all land use types. Several other states also had groundwater detections mainly in urban and mixed-use areas.

Table 2. Detection of carbaryl in U.S. surface and ground water according to the U.S. Geological Survey [*].

State	Type of Land use	Carbaryl		
		Surface Water Detections	Ground Water Detections	Concentration Range (µg/L)
Alabama	Urban	61	1	0.002-0.422
	Agriculture	19	2	
	Mixed	41	1	
California	Urban	166	-	0.0005-5.20
	Agriculture	251	1	
	Mixed	432	1	
Alaska	Urban	20	-	0.002-0.332
Colorado	Urban	190	-	0.0005-16.5
	Agriculture	27	-	
	Mixed	126	3	
Florida	Urban	39	-	0.003-0.441
	Agriculture	21	-	
	Mixed	39	-	
Georgia	Urban	208	1	0.001-1.90
	Agriculture	20	-	
	Mixed	177	-	
Hawaii	Mixed	8	-	0.007-0.370
	Urban	9	-	
Indiana	Urban	119	-	0.001-0.460
	Agriculture	69	-	
	Mixed	62	-	
New Jersey	Urban	122	5	0.001-1.50
	Agriculture	24	5	
	Mixed	89	9	
Pennsylvania	Urban	119	-	0.001-2.41
	Agriculture	82	1	
	Mixed	82	9	
Texas	Urban	164	7	0.001-5.18
	Agriculture	13	-	
	Mixed	138	4	
Virginia	Urban	165	2	0.002-2.0
	Agriculture	14	-	
	Mixed	45	3	
Washington	Urban	46	-	0.001-33.5
	Agriculture	267	1	
	Mixed	106	2	
Wisconsin	Urban	27	-	0.002-0.267
	Agriculture	8	-	
	Mixed	40	-	

[*] U.S.G.S., 2007.

C. Soil

Organic compound sorption to soils, in general, may prevent surface and groundwater contamination and in this section the sorptive processes of carbaryl are reviewed. Carbaryl sorption to soil is rapid at 0.5 hours (Ahmad et al., 2001a) and 3 hours (Jana and Das, 1997) but persistent (from two to 16 weeks) with a $t_{1/2}$ of ~8 days for concentrations ranging from 1-14 mg/L (Rajagopal et al., 1984). Carbaryl has been found to adsorb more readily to acidic soil (Rajagopal et al., 1984). Both mineral and organic matter in soils has been found to contribute to carbaryl sorption. The mineral interactions are clearly reported in several recent studies. For instance, Sheng et al. (2001) found that potassium (K) saturated smectite clay (a non-ionic, expandable, hydrophilic clay) is a better sorbent for carbaryl than soil organic matter (SOM); the distribution coefficient (K_d) for carbaryl was five times greater in clay (235) than SOM rich soil (muck; 54.2). Sheng et al. (2001) estimated that K saturated clay contributes approximately 35 times more to carbaryl retention than a soil with 2% SOM. De Oliveira et al. (2005) found that its sorption is dependent on the surface charge density and is site-specific. For example, the amount of carbaryl sorbed was strongly dependent on the presence of specific exchangeable cations and followed the order of Ba ~ Cs ~ Ca > Mg ~ K > Na ~ Li. The carbonyl group in carbaryl was found to directly interact with the exchangeable cations; Mg^{2+} and Na^+ interacted strongly with the partial negative charge of the double-bonded oxygen atom on the insecticide (De Oliveira et al., 2005). A positive correlation between carbaryl sorption with surface area, cation exchange capacity (CEC), and free Al_2O_3 content in Ultisol and Inceptisol soils was made by Jana and Das (1997). Sorption isotherms of carbaryl sorption to Indian soils followed reversible S-shaped curves which suggest multilayer adsorption on the sorbent surface (Jana and Das, 1997).

Organic matter is another contributor to sequestering carbaryl in soils. For example, carbaryl movement through soil was found to be a function of SOM content; ~52% carbaryl was leached in ten rinses from organic rich soil while it took only one rinse to leach the same amount from a sandy soil (Sharom et al., 1980). The positive contribution of SOM to carbaryl sorption is evident in Table 3 where the sorption capacity (K_f) increases with SOM content in Indian soils (Jana and Das, 1997).

Table 3. The relationship between soil organic matter (SOM) and the sorption capacity (K_f) in four different soils from India (Jana and Das, 1997).

Soil	SOM (%)	$K_f (\mu g/g)/(\mu g/mL)$
Ultisol 1	0.40	0.308
Inceptisol 2	1.10	1.916
Ultisol 2	1.16	2.175
Inceptisol 1	1.70	2.490

Table 4 summarizes a large data set on the sorption of carbaryl to soils from four countries (Ahmad et al., 2001a). While the table shows that organic carbon influences the sorption (K_d) of carbaryl, a positive correlation between the two was not observed by Ahmad et al. (2001a). However, in a similar study by the same group (Ahmad et al., 2001b), a positive, highly significant, correlation of organic carbon normalized sorption capacity (K_{oc}) and aromatic content of SOM was observed. Similar K_d values to those presented in Table 4 are reported elsewhere (Bondarenko and Gan, 2004) and indicate the sorption of carbaryl to soils is not very significant.

Sorption processes are predicted to be highly reversible for carbaryl since the binding is proposed to be nonspecific sorptive binding unlike chemisorption (Rajagopal et al., 1984). This, along with reported low K_d values, indicate that soils do not have a significant potential to stop carbaryl movement, with time, into water systems and other environmental fate processes (i.e., abiotic or biotic degradation) may play an important role in its dissipation.

Table 4. Distribution coefficients (K_d) for carbaryl in several soils with different organic carbon (OC) content.

Soil	OC (g/kg)	K_d	Sand:Silt:Clay (%)
Pakistan 2 [a]	2.79	0.99	22:60:18
Australian 2 [a]	3.0	0.19	92:5:3
United Kingdom 2 [a]	8.9	1.09	10:67:23
Pakistan 1 [a]	13.82	59.67	22:51:27
Australian 1 [a]	58	23.02	63:16:21
United Kingdom 1 [a]	83.8	8.80	18:39:43
California 1 [b]	-	43.4	-
California 2 [b]	-	47.7	-

[a] Ahmad et al., 2001a; [b] California 1 and 2 represent sediment from San Diego Creek and Bonita Creek in California, USA (Bondarenko and Gan, 2004).

IV. Degradation

A. Abiotic

1. Hydrolysis

Carbaryl is effectively hydrolyzed in water and undergoes 50% loss at 20ºC and pH 8 in 4 days (Rajagopal et al., 1984). Earlier studies reported similar degradation times: 6 days in flowing canal water (Osman and Belal, 1980) and one week in river water (Eichelberger and Lichtenberg, 1971). These and other investigators (Ghauch et al., 2001) showed that hydrolysis of the compound increases with elevated temperature. Hydrolytic degradation was shown to be mediated by hydroxyl radical oxidation (Fig. 2; Wang and Lemley, 2002). 1-naphthol was identified as the primary degradation product of carbaryl (Osman and Belal, 1980).

2. Photolysis

Carbaryl was photolyzed into 1,2-naphthoquione, 1,4-naphthaoquinone, 2-hydroxy-1,4-naphthoquinone, and 7-hydroxy-1,4-naphthoquinone (Brahimia and Richard, 2003). Carbaryl in water produced naphthoxyl radicals and demonstrated the hemolytic cleavage of the carbon-oxygen bonds. In oxygen rich water, however, solvated electrons could be transformed into

super-oxide anions that can recombine with radical cations or with 1-naphthoxyl radicals. Both

reactions are expected to produce naphthoquinones after reduction (Brahmia and Richard, 2003).
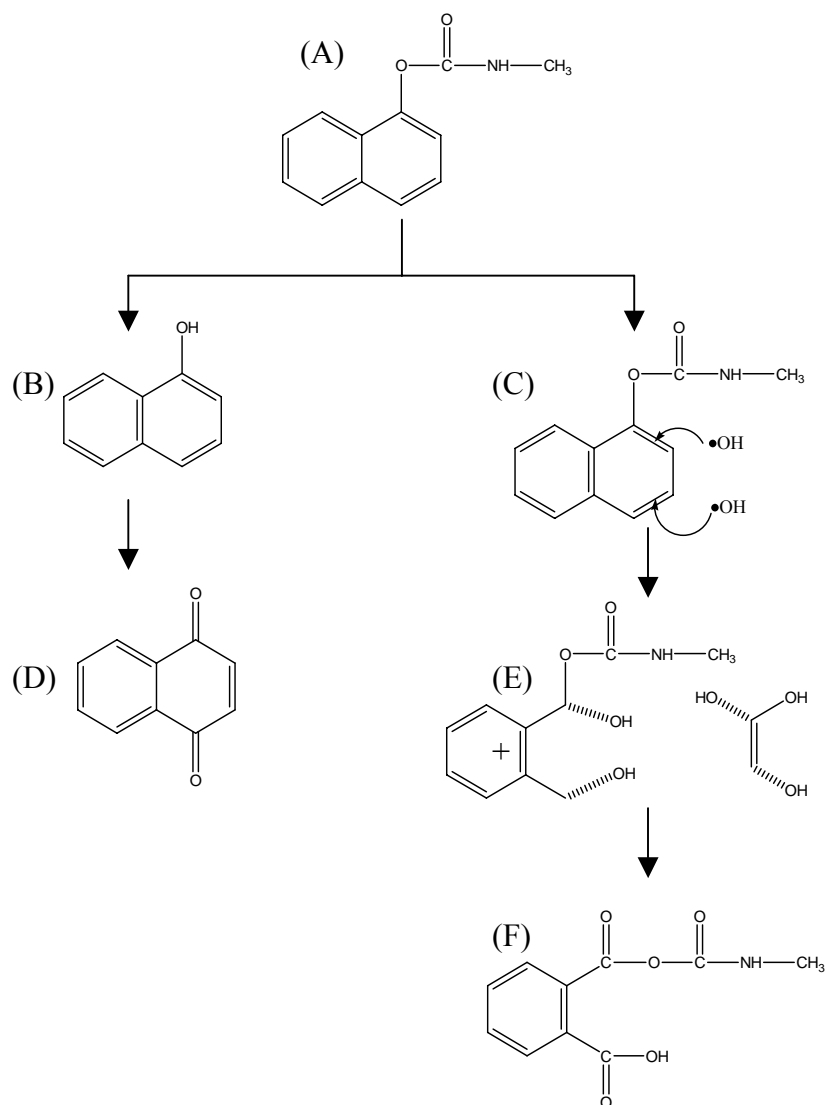

Fig. 2. The degradation pathways of carbaryl (A) by hydroxyl radical attack (C and E) showing the degradation products; 1-naphthol (B), 1,4-naphthoquinone (D), and (F) (phthalic acid-*O*-)yl *N*-methylcarbamate (Wang and Lemley, 2002).
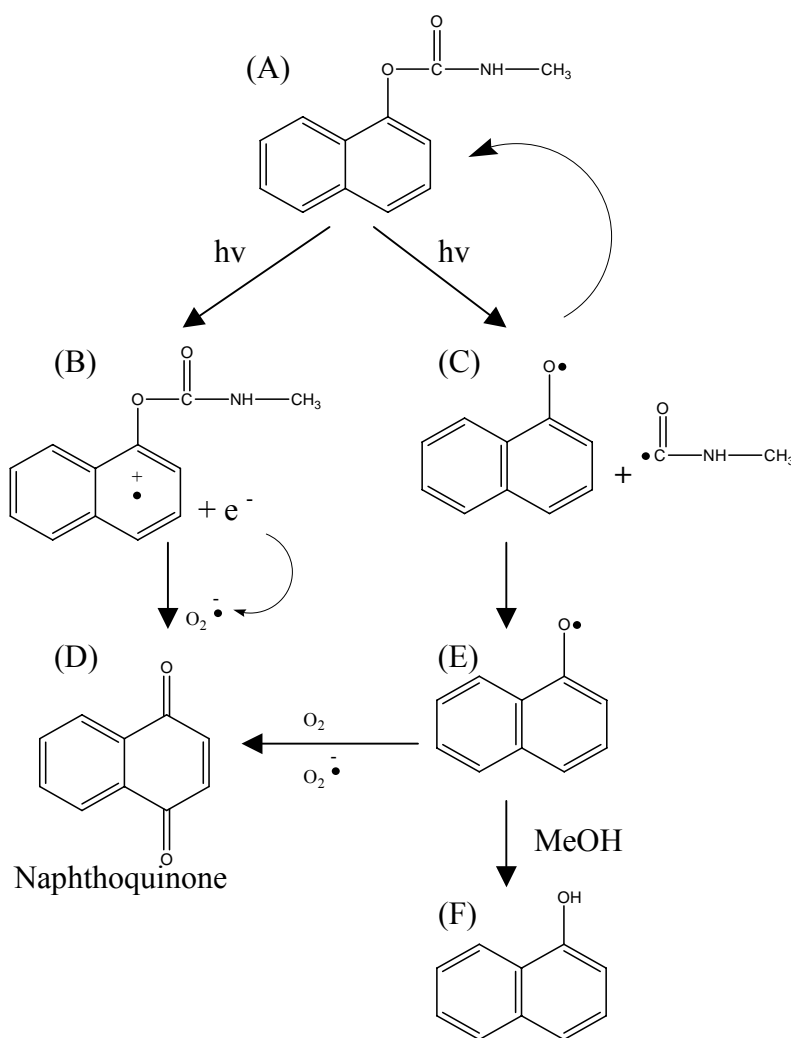
Fig. 3. Proposed (Brahmia and Richard, 2003) photolytic degradation pathway for carbaryl (A). The parent compound is distributed into radicals (B and C) via photolytic processes. 1-naphthoxyl (C) may then react with oxygen to yield naphthoquionone (D) or 1-naphthol (F). 2003). Proposed photolysis is shown (Fig. 3). Photo-conversion of carbaryl to 1-naphthol (Fig. 3 F) was also observed in organic solvents; acetonitrile and methanol.

Indirect photolysis of carbaryl has been reported by Miller and Chin (2002). They found that photo-enhanced degradation was seasonally and spatially dependent. Nitrate and dissolved organic matter (DOM) were primary constituents responsible for the formation and reaction of hydroxyl radicals with carbaryl (Miller and Chin, 2002).

B. Biotic

1. Microbial

The microbial degradation of carbaryl has been reported in several studies. For instance, ring ^{14}C-labeled carbaryl degraded at a constant rate in 120 days leaving behind 15-20% of the parent compound in the soil as monitored by the release of ^{14}C carbon-dioxide (Rodriguez and Dorough, 1977). Shorter degradation times have been observed by Menon and Gopal (2003) that carbaryl dissipated in 45 days (DT_{50} = 14.93). However, this relatively rapid degradation was attributed to high temperatures and precipitation. Still shorter DT_{50}'s have been reported that ranged from 0.15 (Wolfe et al., 1978) to several days (Tomlin, 2003). In aerobic soils the DT_{50} was 7-14 days in sandy loam and 14-28 days in clay loam soils (Tomlin, 2003). Bondarenko and Gan (2004) observed aerobic $t_{1/2}$ values of 1.8 and 4.9 days in soils containing 1.8 % (sand:silt:clay = 76:15:9) and 1.25 % (sand:silt:clay = 46:32:22) organic matter, respectively. First-order kinetics described the microbial degradation of carbaryl in most soils (Venkateswarlu et al., 1980). Inhibition of carbaryl can occur when ammonium nitrogen is added to the enrichment cultures (Rajagopal et al., 1983) indicating that nitrogen on the carbamate chain may provide an essential element to microbes.

Degradation has been observed to be more rapid in flooded (anaerobic) soils than aerobic soils; $t_{1/2}$ was 13-14 days in flooded soils while it was 23-28 days in aerobic soils (Venkateswarlu et al., 1980). Rajagopal et al. (1983) observed a DT_{50} of 10-15 days in submerged laterite and sodic soils. They also observed that degradation was faster in soils previously treated with carbaryl. Recently however, Bondarenko and Gan (2004) reported different findings. Under anaerobic conditions, carbaryl was found to be slowly degraded with $t_{1/2}$ values from 125-746 days depending on soil conditions, sorption capacity, and ageing of the soil with the insecticide.
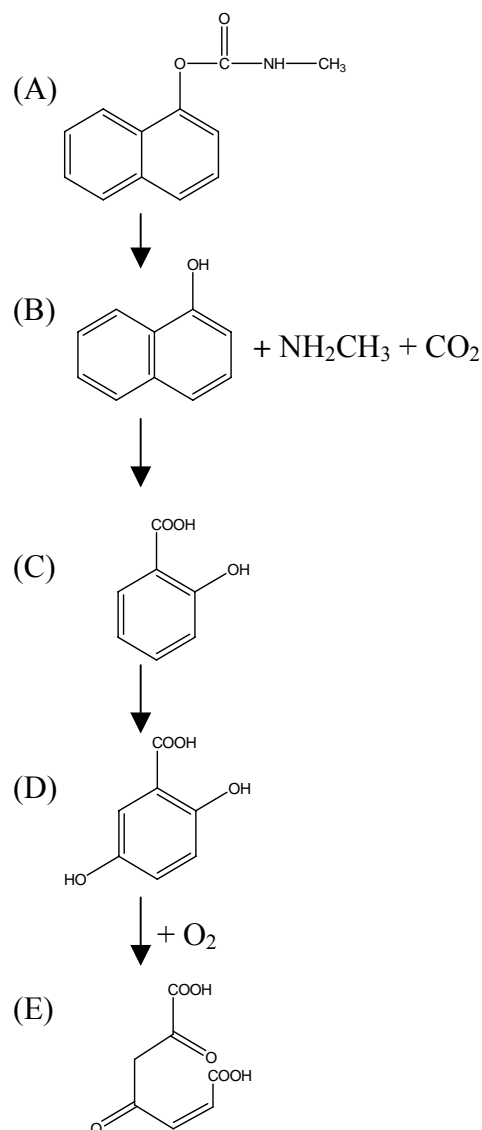
Fig. 4. Proposed degradation pathway of carbaryl by *Micrococus* sp. (Doddamani and Ninnekar, 2001). Carbaryl (A) is reduced to 1-naphthol and methylamine (B) which is then degraded to salicylic (C) and gentrisic (D) acid. The acids are then oxidized to maleylpyruvate (E).

The mechanisms of degradation have also been reported. Karinen et al. (1967) showed

carbaryl ring degradation to CO_2 from 1-naphthol, its primary degradate. Thus, ring structure

hydroxylation of carbaryl is the first step in microbial dissipation. Such findings are supported by

Rajagopal et al. (1983) where it was noted that hydrolysis at the carbamate bond was the major

pathway of degradation in flooded (anaerobic) soils (Fig. 4). The primary degradation product, 1-

naphthol, has a DT_{50} of approximately 12-14 days (Menon and Gopal, 2003) and can be further

transformed to phenolic radicals which polymerize to organic matter in soils (Rajagopal et al.,

1984). Complete degradation from carbaryl to maleylpyruvate is reported for an isolated

Micrococcus species (Fig. 4) by Doddamani and Ninnekar (2001).

Other microbial strains capable of degrading carbaryl have been identified. These include

bacterial species *Achromobacter*, *Pseudomonas*, *Arthrobacter*, *Xanthomonas* (Rajagopal, 1984),

and *Pseudomonas cepacia* (Venkateswarlu et al., 1980). Degradation by a fungus *Penicillium*

implicatum has also been demonstrated (Menon and Gopal, 2003). However, the insecticide has

been shown to be inhibitory to the growth of several strains of rhizobia (Rajagopal et al., 1984).

2. Higher-order organisms

The metabolism of carbaryl has been extensively studied and evaluated for mammals. In

general, the compound does not accumulate in mammalian tissue and is rapidly metabolized to

non-toxic substances, particularly 1-naphthol, which are eliminated in the urine and feces

(Tomlin, 2000). The main metabolic pathways in higher-order organisms are hydroxylation,

hydrolysis, and expoxidation (Carpenter et al., 1961; Dorough and Casida, 1964). Hydrolysis of

carbaryl by earthworms forms 1-naphthol according to Stenersen (1992). A hydrolytic

degradation mechanism has been proposed by Sogorb et al. (2002). According to this pathway,

carbaryl reacts with tyrosine residues on rabbit serum albumin molecules to yield 1-naphthol and

carbamylated rabbit serum albumin. Water molecules than attack the carbamylated complex,

releasing carbamic acid and free enzymes, the latter of which is subject to a new catalytic cycle.

Carbamic acid is expected to decompose to CO_2 and methylamine (Sogorb et al., 2002).

Metabolites detected in urine of human workers exposed to the carbaryl were 1-naphthyl-

glucoronide and 1-naphthylsulphate (Sogorb et al., 2004). Carbaryl metabolism in human liver

microsomes and by cytochrome P450 isoforms was investigated by Tang et al. (2002). They

found three major metabolites: 5-hydroxycarbaryl, 4-hydroxycarbaryl, and carbaryl methylol

(Fig. 5). Interestingly, these are the same metabolites in plants (Tomlin, 2003).
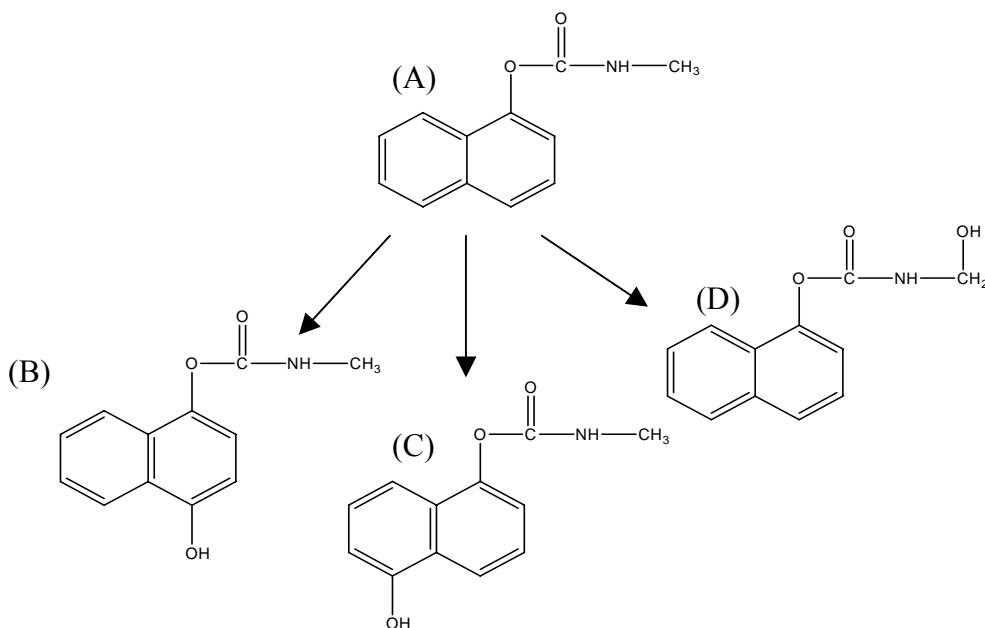

Fig. 5. The cytochrome P450-dependent metabolism of carbaryl (A) to 4-hydroxycarbaryl, 5-hydroxycarbaryl (C), and (D) carbaryl methylol (Tang et al., 2002).

Factors inhibiting enzymatic carbarylase-driven hydrolysis has also been noted. For

instance, data collected by Sogorb et al. (2004) suggest that long chain fatty acids are better

inhibitors of carbarylase than shorter ones. Several organic compounds can inhibit carbarylase as

well. For example, chlorpyrifos inhibits carbaryl metabolism (Tang et al., 2002) and paraoxon

inhibits carbalylase by 44% (Sogorb et al., 2004).

V. Toxicity

Carbaryl is a highly effective insecticide for controlling insect pests. For example, it is

used to control several animal ectoparasites, specifically the cattle tick *Boophilus microplus*. This

tick is endemic to Mexico, having been eradicated from the U.S. in 1961 according to Li et al.

(2005). Several strains of *B. microplus* were highly susceptible to carbaryl; LC_{50} ranged from 0.0025 to 0.0031% (Li et al., 2005). Carbaryl is highly toxic to the bee at 1 μg (LD_{50}) topical dose (Tomlin, 2003).

Although carbamate pesticides do not persist in the environment, there may still be short-term cumulative effects on the reproduction of aquatic organisms. For instance, Tripathi and Singh (2004) found that doses of 2, 5, and 8 mg/L carbaryl altered the biochemical parameters in nervous, hepatopancreatic, and ovotesticular tissues of the snail, *Lymnaea acuminate*. Specifically, glycogen, pyruvate, total protein, and nucleic acid levels were reduced after 96 hours of exposure to carbaryl while lactate and free amino acid levels increased (Tripathi and Singh, 2004). Carbaryl can also affect embryo development. For example, Tripathi and Singh (2004) reported that the number of eggs for the freshwater snail, *Lymnaea acuminate*, were reduced by 49% at 2 mg/L while no eggs were laid at 5 and 8 mg/L. The rate of neonatal survival was also reduced significantly by 53% after exposure of hatchling for 28-day at 2 mg/L. In a similar study Todd and Van Leeuwan (2002) found that the average mortality of zebrafish eggs (*Danio rerio*) was reduced (~20%) after low-level exposures (<0.05 mg/L). Although the insecticide did not directly kill embryos, it had a significant effect on embryo size.

When zebrafish were exposed to 0.017 mg/L of carbaryl, they developed more slowly and hatched later compared to the controls. Delayed hatching exposes zebrafish embryos to predations. The toxicity results of carbaryl to several aquatic animals are summarized in Table 5. Note that carbaryl is toxic to the water flea, shrimp, and freshwater snail at ppb (μg/L) levels while to fish at ppm (mg/L). The results suggest that the insecticide should not be used in bodies of water or in fields adjoining those bodies, particularly in the rainy season.

Table 5. The aquatic animal toxicology of carbaryl.

Aquatic organism	Test	Concentration (mg/L unless noted)
Juvenile trout [a]	96 h LC_{50}	4.27-6.18
Toad larvae [a]	96 h LC_{50}	17.68-34.77
Juvenile trout [a]	IC_{50}	19 µg/L
Toad larvae [a]	IC_{50}	7.580
Rainbow trout [b]	96 h LC_{50}	1.3
Sheephead minnow [b]	96 h LC_{50}	2.2
Bluegill sunfish [b]	96 h LC_{50}	10
Mysid shrimp [b]	96 h LC_{50}	5.7 µg/L
Eastern oyster [b]	48 h LC_{50}	2.7
Shrimp larvae [c]	96 h LC_{50}	30 µg/L
Common carp [d]	96 h LC_{50}	7.85
Freshwater snail [e]	24 h LC_{50}	20.05
Freshwater snail [e]	96 h LC_{50}	14.19
Water flea (*B. longirostris*) [f]	24 h LC_{50}	8.6 µg/L
Water flea (*B. fatalis*) [f]	24 h LC_{50}	4.1 µg/L
Water flea predator (*L. kindtii*) [f]	24 h LC_{50}	3.6 µg/L

[a] Ferrari et al., 2004; [b] Tomlin, 2003; [c] Reyes et al., 2002; [d] De Mel and Pathiratne, 2005, [e] Tripathi and Singh, 2001; [f] Sakamoto et al., 2005.

Rats and dogs tolerate carbaryl at 200 and 400 mg/kg, respectively (Carpenter et al., 1961). Table 6 summarizers LD_{50} data of carbaryl to several birds having a greater tolerance to the compound compared to other animals such as rats and dogs.

Table 6. The oral LD_{50} of carbaryl to birds.

Bird	Concentration (mg/kg)
Mallard duck [a]	>2179
Pheasant [a]	>2000
Japanese quail [a]	2230
Pigeon [a]	1000-3000

[a] Tomlin, 2003.

VI. Summary

Carbaryl is an agricultural and garden insecticide that controls a broad spectrum of insects. It is moderately soluble and does not volatilize readily nor easily vaporize. The compound is susceptible to drift after spray application, unstable under alkaline conditions, and easily hydrolyzed. It has been detected in water at µg/L concentrations but degradation of

carbaryl in this environmental medium is relatively rapid with 1-naphthol identified as the major

degradation product. Indirect and direct photolysis of carbaryl produces different

naphthaquinones as well as some hydroxyl substituted naphthaquinones.

The pesticide's sorption to soil is kinetically fast and both the mineral and organic

fractions of soil contribute to its relatively low sorption. Sorption to soil minerals was strongly

dependent on the presence of specific exchangeable cations and increased with the soil organic

matter aromaticity and age. Microbes in soils (bacteria and fungi) are capable of degrading

carbaryl and the process is more rapid in anoxic than aerobic systems and with increased

temperature and moisture.

In mammals, the compound does not accumulate and is rapidly metabolized to non-toxic

substances which are eliminated in the urine and feces. Several studies have shown that a

cumulative effect may exist with respect to the reproduction of aquatic organisms. Therefore, its

application near water bodies must be carefully evaluated prior to its use.

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