NATIONAL TOXICOLOGY PROGRAM

EXECUTIVE SUMMARY OF SAFETY AND TOXICITY INFORMATION

DICYCLOPENTADIENE

CAS Number 77-73-6

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Submitted to:

NATIONAL TOXICOLOGY PROGRAM

Submitted by:

Arthur D. Little, Inc.

Executive Committee Draft Report

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OVERVIEW1

Nomination History: Dicyclopentadiene was nominated for carcinogenicity testing by the National Cancer Institute (NCI) in 1987. The nomination was based on the high and increasing production and use of this compound, its presence in ground water and surface water sources and the lack of subchronic, chronic/carcinogenic and mutagenic data.

<u>Chemical and Physical Properties</u>: Dicyclopentadiene is a colorless, flammable liquid with a boiling point of 170° C (338° F). This substance is essentially insoluble in water and soluble in alcohol, acetic acid and ether. Dicyclopentadiene has a vapor pressure of 1.4 mm Hg @ 20° C and a vapor density of 4.60.

Production/Uses/Exposure: Production of dicyclopentadiene (including cyclopentadiene) was reported to be 130,410,000 pounds in the United States in 1988, by the United States International Trade Commission. In the same year, the volume of this compound imported to the United States was reported to be 43,416,216 pounds, by the U.S. Department of Commerce. Dicyclopentadiene is used as an intermediate in the manufacture of ethylene-propylene diene monomer elastomers, hydrocarbon resins, and unsaturated polyester resins. Miscellaneous applications for this compound include its use in flame retardants, pesticides, agricultural chemicals, fuel and lube additives and adhesives.

Data from the National Occupational Exposure Survey (NOES) indicate that 1,122 workers, including 85 women, were potentially exposed to dicyclopentadiene between 1981 and 1983. Dicyclopentadiene has been detected in drinking water, ground water and soil, and waste water in certain locations in the United States. In Colorado, ground water supply contamination resulted from the disposal of pesticide wastes at the Rocky Mountain Arsenal before 1966. The OSHA permissible exposure limit (PEL) is 5 ppm (30 mg/m³) averaged over an eight-hour work shift. The ACGIH-recommended

¹The information contained in this Executive Summary of Safety and Toxicity Information (ESSTI) is based on data from current published literature. The summary represents information provided in selected sources and is not claimed to be exhaustive.

threshold limit value-time weighted average (TLV-TWA) is 5 ppm (27 mg/m 3).

Toxicological Effects:

Human: Symptoms following acute exposure to dicyclopentadiene may include eye, skin, mucous membrane and respiratory tract irritation, nausea, vomiting, headaches and dizziness. No data were found on the prechronic, chronic, carcinogenic or reproductive and teratogenic effects of dicyclopentadiene in humans.

Animal: Application of dicyclopentadiene to the skin of rabbits produced minimal irritation and no signs of systemic toxicity. In the Draize eye irritation test, dicyclopentadiene caused only temporary irritation. Inhalation exposure to this compound induced eye and nose irritation, dyspnea, narcosis, muscular incoordination, tremors and hypersensitivity as well as lung, liver and kidney congestion in rats. Oral administration of dicyclopentadiene to calves at a concentration of 500 mg/kg caused excess salivation, ataxia, falling and clonic spasms. In addition to these toxic effects, calves administered 1000 and 2000 mg/kg developed congestion of the small intestine, lung and liver. The reported oral LD_{50} values in rats range from 378 mg/kg to 820 mg/kg, and the LC_{50} for rats, based on a four-hour inhalation exposure, ranges from 359 ppm to 385 ppm. Prechronic inhalation exposure to dicyclopentadiene has been found to cause an increase in kidney and liver weights in male rats. Kidney abnormalities including round-cell accumulations, dilated tubules and tubular degeneration were observed. However, no liver alterations were noted. Male juvenile pastel minks exposed prechronically to dicyclopentadiene via inhalation exposure were found to have significant decreases in heart, spleen and liver weights. Dicyclopentadiene was not found to induce chronic effects in Mallard ducks, Bobwhite quails or dark variety minks. Dicyclopentadiene was not found to cause reproductive effects in Mallard ducks or Bobwhite quails. However, a significant depression in neonate weight gain was observed in the offspring of minks exposed to dicyclopentadiene (200, 400, and 800 ppm) by dietary administration. A significant reduction in testicular weight was observed in male minks fed 800 ppm dicyclopentadiene.

<u>Genetic Toxicology</u>: Dicyclopentadiene was non-mutagenic to <u>Salmonella typhimurium</u> strains TA98, TA100, TA1535, and TA1537 with and without metabolic activation. No other data on genetic toxicology were found.

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<u>Structure Activity Relationships</u>: A structurally related chemical, endodicyclopentadiene dioxide was found to be non-tumorigenic in skin painting studies in mice. No other data on structure activity relationships were found.

I. NOMINATION HISTORY AND REVIEW

A. Nomination History

- 1. Source: National Cancer Institute [NCI, 1987, a,b]
- 2. Date: July, 1987
- 3. Recommendations: Carcinogenicity
- 4. Priority: Moderate
- 5. Rationale/Remarks:
 - High and increasing production and use
 - Presence in ground water and surface water sources
 - Limited subchronic data available
 - Lack of chronic toxicity data for dicyclopentadiene and structurally related compounds
 - Need for additional mutagenicity testing
 - Absence of carcinogenicity data
 - Exo-tetrahydrodi(cyclopentadiene) has been found to induce kidney tumors in male rats; the kidney was found to be the target site for dicyclopentadiene in rats (90 day inhalation study)
 - Dicyclopentadiene contains potentially reactive double bonds

B. Chemical Evaluation Committee Review

- 1. Date of Review: September 12, 1990
- 2. Recommendations:
 - Carcinogenicity
 - Reproductive and teratogenicity studies
- 3. Priority: Moderate
- 4. NTP Chemical Selection Principle(s): 3, 8
- 5. Rationale/Remarks:
 - High and increasing production and use
 - Found in ground water and surface water
 - Potential for exposure
 - Lack of toxicological data

C. Board of Scientific Counselors Review

- 1. Date of Review: October 15, 1990
- 2. Recommendations:
 - Carcinogenicity
 - Reproductive and teratogenicity studies

3. Priority: Moderate

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- 4. Rationale/Remarks:
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 - High and increasing production and use Identified in ground water and surface water Potential for exposure Need to fill toxicological data gaps Previous chronic, reproductive and teratogenicity studies used mammals not usually used for risk evaluation for human health ٠

D. Executive Committee Review

- 1. Date of Review:
- 2. Decision:

II. CHEMICAL AND PHYSICAL DATA

A. Chemical Identifiers

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DICYCLOPENTADIENE

Molecular formula: $C_{10}H_{12}$

Molecular weight: 132.22

CAS No. 77-73-6 RTECS No. PC 1050000

B. Synonyms and Trade Names

Synonyms: 4,7-methanoindene,3a,4,7,7a-tetrahydro- (8CI); 4,7-methano-1H-indene,3a,4,7,7a-tetrahydro- (9CI); bicyclopentadiene; DCP; DCPD; 1,3-cyclopentadiene, dimer

Trade Names: No data available

C. Chemical and Physical Properties

Description:	Colorless liquid or solid crystals with a camphor odor [Kirk-Othmer, 1979; U.S. Coast Guard, 1985] (odor threshold < 0.003 ppm [U.S. Coast Guard, 1985])
Melting Point:	32°C (89.6°F) [Weast, 1989]
Boiling Point:	170°C (338°F) [Aldrich, 1988; Weast, 1989] 172°C (342°F) [NFPA, 1986]
Specific Gravity:	1.071 @ 20°/4°C [Aldrich, 1988]/0.9302 @35/4°C [Weast, 1989]
Refractive Index:	1.5100 [Aldrich, 1988] 1.5050 [Weast, 1989]
Solubility in Water:	Insoluble [NFPA, 1986]; 40 ppm (estimated) [USEPA, 1987]
Solubility in Other Solvents:	Soluble in alcohol [Sax and Lewis, 1987; Weast, 1989], acetic acid, ether [Weast, 1989]

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Log Octanol/ Water Partition:

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2.894 [USEPA, 1987]

Reactive Chemical Hazards:

Incompatible with strong oxidizing agents, strong acids, strong bases [Lenga, 1988]. Decomposition products include toxic fumes of carbon monoxide and carbon dioxide [Lenga, 1988].

Flammability Hazards:

- Flammable [NFPA, 1986] with a flash point of 32°C (90°F) O.C. [NFPA, 1986; U.S. Coast Guard, 1985]
- Vapor pressure: 1.4 mm Hg @ 20°C [ACGIH, 1986]
- Vapor density: 4.60 (air=1) [Lenga, 1988]
- Autoignition temperature: 503°C (937° F) [NFPA, 1986]; 505°C (941°F) [U.S. Coast Guard, 1985]
- Flammable limits in air: LEL 0.8%; UEL 6.3%
 [U.S. Coast Guard, 1985]

III. PRODUCTION/USE

- A. Production
 - 1. Manufacturing Process

Dicyclopentadiene is formed when cyclopentadiene spontaneously polymerizes at ordinary temperatures, with the rate of polymerization increasing with increasing temperature. Cyclopentadiene is produced during the carbonization of coal, and as a by-product of thermal cracking of hydrocarbons such as gas oil and naphtha in the presence of steam. Cyclopentadiene and other C₅-hydrocarbons are recovered from the cracked product by a series of distillations. The distillate that remains is heated to a temperature of approximately 100°C to remove the lower boiling hydrocarbons and to increase the rate of polymerization of cyclopentadiene. Depending on the temperature and concentration, the heat soaking operation requires 5 to 24 hours. Dicyclopentadiene, which boils at a higher temperature than the unreacted hydrocarbons of the distillate, is recovered as distillation bottoms. Dicyclopentadiene normally occurs as a very low percentage of a stream, and is concentrated by a series of distillations. Following the distillations, high purity dicyclopentadiene is obtained by cracking the dicyclopentadiene in the crude stream, separating the low-boiling cyclopentadiene by distillation, and allowing the concentrated cyclopentadiene to dimerize under controlled conditions [Kirk-Othmer, 1979].

- 2. Producers and Importers
- U. S. Producers:
- Atlantic Richfield Company, Lyondell Petrochemical Company, Division, Channelview, Texas [SRI, 1989; USITC, 1988]

- Chemical Exchange Industries, Inc., Texmark Resins, Subsidiary Galena Park, Texas [SRI, 1989]
- Dow Chemical U.S.A. Freeport, Texas [SRI, 1989; USITC, 1988]
- Exxon Chemical Americas Baton Rouge, Louisiana [SRI, 1989]
- Shell Oil Company, Shell Chemical Company, Division Deer Park, Texas [SRI, 1989; USITC, 1988]
- Jonas Chemical Corp., Specialty Chemical Division Brooklyn, New York [SRI, 1989]
- Velsicol Chemical Corp. Rosemont, Illinois [USITC, 1989]

European Producers:

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- Dow Chemical (Nederland) BV Terneuzen, (Zeeland) Netherlands [SRI, 1989]
- Rütgerswerke AG Duisburg, Germany [SRI, 1989]
- Shell Nederland Chemie BV Moerdijk, (Noord Brabant) Nederland/Rotterdam-Pernis, (Zuid Holland) Netherlands [SRI, 1989]

Importers:

- Dow Chemical Company Midland, Michigan [USEPA, 1990c]
- Mitsubishi New York, New York [USEPA, 1990c; USEPA, 1987]
- Neville Chemicals Santa Fe Springs, California [USEPA, 1990c; USEPA, 1987]
- Ashland Chemical Dublin, Ohio [USEPA, 1990c; USEPA, 1987]

3. Volume

The United States International Trade Commission (USITC) reports the following production data for dicyclopentadiene (including cyclopentadiene):

Year	Production (pounds)
1985	63,607,000
1986	98,946,000
1987	99,255,000
1988	130.410.000
	[USITC, 1986-1989]

The production volume of dicyclopentadiene is reported in the public file of the EPA Toxic Substances Control Act (TSCA) inventory. In 1977, 11 manufacturers listed as producers of dicyclopentadiene reported a total production volume ranging from 53,200,000-282,000,000 pounds [USEPA, 1990c].

The following maximum production levels of dicyclopentadiene in 1980 at the following plants have been reported:

Plant

<u>Capacity (pounds)</u>

Carbide Isoprene, Penuelas, Puerto Rico60,000,000Chemical Exchange, Houston, Texas60,000,000Dow, Freeport, Texas25,000,000Exxon, Baton Rouge, Louisiana45,000,000Monsanto, Chocolate Bayou, Texas18,000,000[Kavaler, 1980]

At the time these data were published, it was predicted that Exxon's capacity would rise to 50 million pounds per year in mid 1981 and to 80,000,000 pounds by 1982. Carbide and Exxon were the only producers of high purity dicyclopentadiene in 1980.

The demand for dicyclopentadiene in 1979 was 90 million pounds. In 1980, the demand for this compound had remained unchanged, and in 1984 the demand had risen to 115 million pounds. The historical growth for dicyclopentadiene (1969 - 1979) was 4.8% per year. In 1980, growth was predicted to be 4.9% through 1984. In 1980, it was reported that the markets for ethylene propylene diene monomer elastomers had remained among the strongest of the available rubber products, and that dicyclopentadiene's use as an intermediate in the production of unsaturated polyester resins was expected to grow. At the same time, this compound's use in pesticides was declining and several competing dienes which can be used in the vulcanization of ethylene propylene diene monomer elastomers were on the market [Kavaler, 1980].

The United States Department of Commerce reported that the total

volume of dicyclopentadiene imported between 1985 and 1988 increased by 30%. The major exporters of dicyclopentadiene to the United States during this period included the Netherlands, Japan, and Belgium [U.S. Department of Commerce, 1986-1989]. A breakdown of the net quantity of dicyclopentadiene exported to the United States by country for the years 1985 through 1988 is presented in Table 1.

TABLE 1 Net Quantity of Dicyclopentadiene Exported to the United States by Country 1985—1988

Source	<u>Countries</u>	<u>Net Quantity (lbs)</u>
U.S.Imports for Consumption*1985	United Kingdom Netherlands Japan Other	1,169,224 9,909,179 19,519,878 45,856
	Total	30,644,137
U.S. Imports for Consumption 1986	Netherlands Belgium Japan Other	16,161,396 6,256,571 18,294,317 41,711
	Total	40,753,995
U.S. Imports for Consumption 1987	Netherlands Belgium Japan Other	12,609,890 3,430,402 25,455,912 41,998
	Total	41,538,202
U.S. Imports for Consumption 1988	Netherlands Belgium Japan	22,054,741 1,090,234 20,271,241
	Total	43,416,216

Imports for consumption is a measure of the total of merchandise that has cleared through Customs, whether such merchandise enters consumption channels immediately, or is withdrawn for consumption from warehouses under Customs custody, or is entered into U.S. Customs territory from Foreign Trade Zones.

4. Technical Product Composition

Dicyclopentadiene exists in two stereoisomeric forms, the endo- and the exo-isomers. The commercial product is primarily the endo-isomer [Kirk-Othmer, 1979].

Dicyclopentadiene is available from Aldrich Chemical company at 95% purity [Aldrich, 1988]. Dicyclopentadiene is also available at 97% purity [U.S. Coast Guard, 1985]. Dicyclopentadiene is available in a crude form at ≥ 50 wt%. A high purity form is available in the United States and Europe between 70 to 95 wt%. Depending on the distillation process, impurities may include light C₅-hydrocarbon fractions [Kirk-Othmer, 1979]. Industrial grade dicyclopentadiene consists of approximately 95% endo-dicyclopentadiene. The other constituents are predominantly the

exo-isomer, methyldicyclopentadienes and tricyclopentadiene [Van Breemen, et al., 1987].

- B. Use
- Production of hydrocarbon resins that result in the end-use manufacture of adhesives, rubber tackification, surface coatings, and resin replacements [Kirk-Othmer, 1979].
- A precursor in the production of elastomers [Kirk-Othmer, 1979], polymers, and perfumes [Van Breemen, et al., 1987].
- An intermediate in the production of chlorinated derivatives for the production of pesticides [Sax and Lewis, 1987]; however, this use is limited to termite control substances [Kirk-Othmer, 1979].
- Stabilizer for organophosphorus insecticides [USEPA, 1987].
- An intermediate used in flame and fire retardant chemicals [Kirk-Othmer, 1979; Sax and Lewis, 1987].
- Jet fuel component [Kirk-Othmer, 1979].
- The following pattern of use was reported in 1980 [USEPA, 1987]:
 Ethylene-propylene diene monomer elastomers: 40%
 - Hydrocarbon resin systems: 30%
 - Unsaturated polyester resins: 10%
 - Miscellaneous (e.g., flame retardants, pesticides and agricultural chemicals, fuel and lube additives, adhesives): 20%.

IV. EXPOSURE/REGULATORY STATUS

A. Consumer Exposure

No data were found on consumer exposure to dicyclopentadiene. However, because this compound is used in a variety of consumer products, there is potential for consumer exposure.

B. Occupational Exposure

Wildlife officers monitoring a basin contaminated with dicyclopentadiene were reportedly exposed to this compound [NIOSH, 1981]. In addition, laboratory research personnel were accidentally exposed to dicyclopentadiene while performing toxicity testing [Kinkead, et al., 1971]. The concentrations of dicyclopentadiene to which the wildlife officers and researchers were exposed were not reported.

Data from the National Occupational Exposure Survey (NOES) conducted by NIOSH between 1981 and 1983 indicate that 1,122 workers, including 85 female employees, were potentially exposed to dicyclopentadiene in the workplace [NIOSH, 1990].

C. Environmental Exposure

The presence of dicyclopentadiene in the environment is caused by the land disposal of pesticide wastes [Spanggord, et al., 1979]. Dicyclopentadiene has been detected in drinking water, groundwater, soil, and in wastewater effluents near user facilities in certain locations in the United States [NIOSH, 1981; Spanggord, et al., 1979]. Dicyclopentadiene is a contaminant of certain ground water supplies in Colorado, as a result on the disposal of pesticide wastes in unlined ponds, and from deep-well injection at the Rocky Mountain Arsenal. Although the disposal of such wastes had ended by 1966, dicyclopentadiene residues in sub- to low-ppm ranges are still detectable in some well water supplies [Ivie and Oehler, 1980].

Because many derivatives of dicyclopentadiene have been detected in ground water extracts from the Rocky Mountain Arsenal, it is evident that extensive transformation of this compound can occur in the environment. In one study of this area, eight derivatives of dicyclopentadiene were detected by gas chromatography-mass spectrometry (GC/MS) in direct methylene chloride extracts of ground water. Five derivatives were observed in methylene chloride extracted charcoal, which had been used to filter ground water in a water treatment system at the Rocky Mountain Arsenal. Three derivatives were found in both extracts. The majority of the derivatives found were oxygenated, with the addition of one, two, or three oxygen atoms, and in other cases with the loss or addition of two hydrogen atoms. Incorporation of sulfur or one carbon and two hydrogen atoms had also occurred. The authors stated that spontaneous oxidation of dicyclopentadiene by atmospheric oxygen might occur, but that bacterial metabolism is probably responsible for the derivatives observed [Van Breemen, 1987].

A study on the environmental fate of dicyclopentadiene has been conducted by the Department of the Army. From the results of this study, it was concluded that the photolysis of dicyclopentadiene occurs in the presence of natural water sensitizers. This indirect photolysis occurs slowly, with a halflife of approximately 76 days. In addition, biotransformation occurs very slowly in water and soil. Biodegradation in both soil and water appears to slow with decreasing temperature, and only very small amounts of biodegradation have been found to occur at 10°C [Spanggord, 1979]. It is estimated that the biodegradation half-life ranges from 4 to 7 years in soil and from 1 to 2 years in water at 25°C. The estimated volatilization half-life for dicyclopentadiene is 5 years and therefore, volatilization is considered to be a primary fate of this compound [Spanggord, 1979]. In 1977, The U.S. Army Medical Bioengineering Research and Development Laboratory recommended temporary guidelines for dicyclopentadiene in the accessible environment. The following guidelines were based on the results of mammalian toxicity tests:

Food	1.3 ppm
Drinking water	1.3 ppm
Water: for recreation	13.0 ppm
Water: to protect aquatic life	0.5 ppm
Water: for irrigation	20.0 ppm

[Burrows, 1977]

D. Regulatory Status

- The OSHA permissible exposure limit (PEL) is 5 ppm (30 mg/m³) averaged over an eight-hour work shift. A short-term exposure limit (STEL) has not been determined [OSHA, 1989].
- The Food and Drug Administration (FDA) has approved the use of dicyclopentadiene in adhesives, rubber articles intended for repeated use, and in polymers for inclusion in food packaging [Office of the Federal Register, 1990].
- E. Exposure Recommendations
- The ACGIH-recommended threshold limit value-time weighted average (TLV-TWA) is 5 ppm (27 mg/m³) [ACGIH, 1989].
- There is no NIOSH-recommended exposure limit (REL) for dicyclopentadiene.

V. TOXICOLOGICAL EFFECTS

- A. Chemical Disposition
 - 1. Human Data

No information was found on the chemical disposition of dicyclopentadiene in humans.

- 2. Animal Data
- Dicyclopentadiene radiolabeled with carbon-14 was rapidly absorbed after oral administration to rats, mice and dogs (strain and number of animals not reported). Blood plasma concentrations peaked in 2 hours in mice and dogs, and in 6 hours in rats. The radioactivity was widely distributed in all three species in 1 to 2 hours, with high values in the urinary bladder, gall bladder and body fat of mice, in the gall bladder, and bile of dogs and in body fat, adrenals, and urinary bladder of rats. Urination was the primary mode of excretion in all three species: about 85% of the administered radioactivity was accounted for in urine and

feces within 24 hours. No other information was provided [Hart and Dacre, 1978].

A study was conducted to examine the disposition of C-14 radiolabeled dicyclopentadiene in a 293 kilogram lactating Jersey cow. The cow was initially given one oral dose containing 2.93 grams of non-radiolabeled dicyclopentadiene in a gelatin capsule daily for 5 consecutive days. This dose was the equivalent of 10 mg/kg of body weight per day. Twentyfour hours after the final dose, the cow was moved to a pen, catheterized, and given an oral dose of C-14 radiolabeled dicyclopentadiene to which had been added sufficient unlabeled dicyclopentadiene to make the total dose equivalent to 2.93 grams of dicyclopentadiene. The total radiocarbon given was 4.00 x 10⁸ dpm; the specific activity was 137 dpm/µg. Blood samples were taken from the cow at frequent intervals, and the cow was milked every 12 hours. Ninety-six hours after dosing with the radiolabeled dicyclopentadiene, the cow was sacrificed and tissues and organs were removed for radiocarbon analysis. Feces and urine were analyzed when collected.

Radioactive material was excreted rapidly after oral administration. Approximately 81% of the administered dose was eliminated in urine, 4% in feces, and <0.1% in milk. Radioactivity was not detected in milk after 48 hours. Carbon-14 in the blood reached maximum levels within 2 hours after dosing and then diminished rapidly such that blood levels were not detectable 24 hours after treatment. None of the tissue samples collected contained detectable amounts of radiocarbon residues. Tissues collected included brain, fat, gall bladder, heart, kidney, liver, muscle, ovary, lung, adrenals, skin, spleen, urinary bladder, and udder. Metabolites were detected in urine, primarily in the form of glucuronide conjugates. No other data were available concerning the chemical nature of the metabolites formed [Ivie and Oehler, 1980].

Twenty-four Bobwhite quails (*Colinus virginianus*) and 24 Mallard ducks (*Anas platyrhynchos*) were dosed *per os* with ¹⁴C-dicyclopentadiene in a corn-oil carrier. The final solution of corn-oil for dosing contained 0.39 μ Ci/ml of ¹⁴C-dicyclopentadiene for the ducks and 1.23 μ Ci/ml of ¹⁴Cdicyclopentadiene for the quails. The calculated dose for administration was based on 100 mg/kg body weight, and a target of 1 μ Ci of ¹⁴C per quail or duck. In addition, 36 quail and 36 ducks were also given ¹⁴Cdicyclopentadiene in the diet at a concentration of 100 ppm for 5 days.

High ¹⁴C-dicyclopentadiene residues were detected in all tissues sampled (plasma, liver, adipose, skin, kidney, brain, and muscle) except the red blood cells 2 hours after dosing. Maximum residues ranged from 5.6 ppm to 50.1 ppm, depending on the tissue and species. Radioactivity was detected in most tissues from both quails and ducks by 48 hours after dosing. The carbon-14 equivalents (ppm), adjusted for body weight, from quails and ducks obtained two hours after dosing are presented below:

	Adipose	Kidney	Liver	Skin	Plasma	BrainN	fuscle	RBCs
Quail.	50.1	26.1	17.4	13.7	19.1	6.9	5.6	0.0
Duck	34.3	40.9	31.7	20.8	12.1	10.8	11.8	0.0

After administration of 100 ppm of ¹⁴C-dicyclopentadiene in the diet of ducks and quails, carbon-14 residues obtained at days 3 and 5 were less than 1 ppm in all tissues. The following ¹⁴C-equivalents (ppm) were obtained on day 5:

	Adipose	Kidney	Liver	Skin	Plasma	BrainM	uscle	RBCs
Quail	0.17	0.25	0.19	0.0	0.0	0.0	0.0	0.0
Duck	0.99	0.68	0.21	0.16	0.27	0.13	0.25	0.0

Five days post- 14 C-dicyclopentadiene feeding, only the skin from quails and kidneys from ducks had detectable residues which ranged from 0.05 to 0.07 ppm. Most samples procured on the third day after withdrawal were already at or below detection limits, with an average detectable residue level of 0.04 ppm.

The rate of elimination of carbon-14 residues from ducks and quails dosed with ¹⁴C-dicyclopentadiene was calculated. The average rate of elimination ($t_{1/2}$ -hours) for quail and duck tissues was determined to be 12.7 hours. The following elimination times (hours) were calculated:

	Plasma	Liver	Adipose	Skin	RBCs	Kidney F	Brain M	luscle
Quail	11.1	14.7	10.4	11.9	NC	14.5	12.5	14.4
Duck	NC	13.6	14.8	15.1	NC	10.9	13.5	8.3

NC- Value could not be calculated.

The authors concluded that dicyclopentadiene consumed with food is not retained for long periods and is readily depleted from the bodies of quails and ducks. In addition, dicyclopentadiene was not concentrated in adipose tissue of either species. Therefore, the rapid biological half-life and lack of binding to fat indicate that this compound is not retained for passage along the food chain [Aulerich, 1979].

B. Acute

1. Human Data

Exposure to dicyclopentadiene may result from dermal absorption, inhalation or ingestion [Lenga, 1988]. Symptoms observed following exposure to dicyclopentadiene include mucous membrane and respiratory

tract irritation, nausea, vomiting, headache and dizziness [U.S. Coast Guard, 1985]. This compound causes eye and skin irritation [Lenga, 1988].

- 2. Case Reports
- In order to determine the odor threshold of dicyclopentadiene vapor for humans, three volunteers between the ages of 24 and 47 were exposed to various concentrations of this compound for 10 seconds per exposure, with a period of 45 minutes between exposures. The concentration levels tested were 0.0006, 0.003 and 0.006 ppm. The odor threshold was determined to be slightly less than 0.003 ppm, with a 67% incidence of odor detection.

Two volunteers inhaled concentrations of 1.0 ppm and 5.5 ppm for 30 minutes to determine the human sensory response to dicyclopentadiene. During the 30 minute exposure to 1 ppm, one volunteer experienced slight eye and throat irritation after 7 minutes of exposure, and one volunteer reported olfactory fatigue after 24 minutes. No olfactory fatigue was reported by either subject from the 5.5 ppm, 30-minute exposure. However, eye irritation was reported by one subject after 10 minutes of exposure, and another subject could taste dicyclopentadiene for 1 hour after the 5.5 ppm exposure. In addition, some inadvertent exposures to dicyclopentadiene occurred during the five-month study resulting in transitory headaches [Kinkead, et al., 1971].

• Three researchers conducting inhalation toxicity experiments for dicyclopentadiene experienced inadvertent exposures to the vapor. All three workers reported transitory headaches during the first two months of the experiments, but similar exposures during the next three months did not result in further headaches.

In another instance, three wildlife officers investigating a pond located at the Rocky Mountain Arsenal reported severe headaches, throat irritation, and skin irritation as the result of handling sick and dead ducks that had been exposed to pond contaminants. Dicyclopentadiene was later identified as a contaminant, and was considered to be responsible for the headaches and throat and eye irritation [NIOSH, 1981].

3. Acute Animal Data

The principal effects in rats dosed orally with dicyclopentadiene were general congestion and hyperemia and focal hemorrhages in many organ tissues including the kidney, intestine, stomach, bladder, and particularly the lungs [Clayton and Clayton, 1981].

• Application of dicyclopentadiene to the skin of albino rabbits at doses up to 2.0 g/kg produced minimal skin irritation and no signs of systemic intoxication. Following application to the conjunctival sacs of rabbits and irrigation at 2 or 4 seconds after the application, the Draize eye irritation test revealed signs of temporary irritation. No irritation was present after three days [Hart and Dacre, 1978].

- Two male and two female Alderly Park rats received one, 1- hour inhalation exposure to dicyclopentadiene at a concentration of 2,500 ppm. In addition, a second groups of rats (2 males and 2 females) received one, 4-hour exposure at a concentration of 1,000 ppm. Symptoms following exposure in the first group included eye and nose irritation, dyspnea, and narcosis. One of the rats died following exposure. Histological examination revealed lung, liver and kidney congestion. In the second group of rats, eye and nose irritation, dyspnea, muscular incoordination, tremors, and hypersensitivity were observed. All of the animals died after treatment. Histological evaluation revealed lung, liver, and kidney congestion [Gage, 1970].
 - A study was conducted using 16 eight-to-ten week-old calves of mixed breeding. Each group consisted of two male and two female calves for a total of four groups. The calves in each group were observed each day after treatment for clinical toxicity and responses over the next 14 days including urine and blood analyses on days 1, 3, 7, and 14. Each calf was administered a single oral dose of 95% pure dicyclopentadiene via gastric intubation (the administration vehicle was not reported). The dose levels used per group were 250, 500, 1,000, and 2,000 mg/kg of body weight. Mild signs of intoxication including partial anorexia, ataxia, and excess salivation were noted in the 250 mg/kg group, 24 hours after dosing. All animals from this group survived, and all four were sacrificed 14 days after dosing. Responses for the higher dosed groups became more severe with increased dose. Calves given 500 mg/kg dicyclopentadiene developed moderate signs of intoxication (excess salivation, ataxia, falling, clonic spasms) within 24 hours after dosing. Calves given 1,000 and 2,000 mg/kg dicyclopentadiene developed severe signs of intoxication within 8 hours and 1 hour after dosing, respectively. The toxic effects in both groups were similar to those observed in the 500 mg/kg group, but were more severe. One calf given 1,000 mg/kg of dicyclopentadiene died three days after dosing. One of the remaining three calves in the 1,000 mg/kg group was sacrificed on day 7 and the other 2 calves were sacrificed on day 14 after dosing. The calves that received 2,000 mg/kg died on days 2, 3, 4 and 6 after dosing.

Blood and urine analyses revealed no significant changes in total serum protein, serum protein fraction, prothrombin time, partial thromboplastin time, platelet count, and clotting time. Within the first 24 hours after dosing there were slight increases in erythrocyte count and hemoglobin and hematocrit levels. These returned to normal levels by day 3. There was no significant change in glucose-6-phosphate dehydrogenase activity, mean cell volume, mean cell hemoglobin and mean cell hemoglobin concentration, reticulocyte count, and erythrocyte osmotic fragility values. The leukocyte count increased in the first 24 hours from 9,000 to 37,000 per mm³ for one calf in each of the 1,000 and 2,000 mg/kg groups. Similar changes were noted in the other six calves of the same two groups (two calves in the 500 mg/kg group, and one in the 250 mg/kg group), but all to a lesser degree. In all cases, the morphology appeared normal without toxic changes in the neutrophils. There was no apparent change in the lymphocyte values for calves in the 250 mg/kg dose group. Between days 3 through 7 the enzymes creatine phosphokinase, glutamic oxalacetic transaminase, and glutamic pyruvic transaminase were significantly elevated (p>0.05) in the 1,000 and 2,000 mg/kg dose groups, but returned to normal levels by day 14.

Gross pathological examination revealed lesions in calves in the 1,000 and 2,000 mg/kg dose groups, consisting primarily of congestion of the small intestine, lung, and liver. Gross lesions were not found in the lower dose groups.

Histopathologic examination of tissues from three calves given 1,000 mg/kg of dicyclopentadiene revealed that one of the three calves had an increase in the perivascular space in both the gray and white matter, indicative of mild cerebral edema. Also, there was an apparent mild gliosis in the fiber tracts of the thalamus of this calf. The other calves from the same dose group exhibited no significant lesions. Twelve sections of brain and spinal cord were examined from each of the four calves given 500 mg of dicyclopentadiene. Two small foci of gliosis were observed in one of the sections of cerebral cortex from one calf, and a few small scattered hemorrhages were observed in sections of internal capsule, thalamus, and medulla oblongata from another calf. Significant lesions were not observed in the other sections from these two calves or in any of the sections examined from the other two calves.

The authors concluded that dicyclopentadiene exerted "detrimental effects" to calves at 250 mg/kg and would therefore be classified as moderately toxic [Cysewski, et al., 1981].

• A study was conducted to determine the oral LD₅₀ of dicyclopentadiene in female juvenile pastel minks. The number of animals per dose group varied from 2 to 4, with a total of 26 animals used for the study. Animals were assigned to dose groups and received dicyclopentadiene at concentrations of 0, 30, 60, 120, 240, 480, 600, 720, and 960 mg/kg of body weight. Dicyclopentadiene was administered by gelatin capsule for minks dosed at 30, 60, and 120 mg/kg. Doses of 240 mg/kg and above were administered by gavage. Mortality and signs of intoxication were recorded 2 hours following dosing, and daily for 14 days. After 14 days, the animals were sacrificed and examined for gross pathomorphological changes.

All of the animals survived the study, and the oral LD_{50} was determined to be greater than 1,000 mg/kg. Clinical signs of intoxication following dosing included hyperactivity, high-pitched vocalizations, dyspnea, diarrhea, opisthotonus, convulsions, vomiting, and paresis of the hind limbs. Recovery generally occurred within one to one and one-half hours after dosing.

In addition, five female minks were each given a single dose of dicyclopentadiene by intraperitoneal injection, and observed for one hour. The doses administered were 960, 1,200, 1,680, and 1,920 mg/kg (no control group was assigned). The administration vehicle for dicyclopentadiene was not reported. Each of the minks died within minutes after administration of the compound. The authors reported that the data suggest a lower LD_{50} for intraperitoneal administration than by the oral route of administration in mink [Aulerich, et al., 1979].

• A study was conducted to determine the oral LD₅₀ of dicyclopentadiene in adult Mallard ducks (strain not reported). A total of 40 ducks were divided into two groups of twenty, each consisting of 10 male and 10 female ducks. The test group was dosed by drenching *per os* from a syringe. A total dose of 40,000 mg/kg dicyclopentadiene, delivered 5 cc at a time over a two and one-half hour period. The ducks in the control group were dosed with water. All 40 ducks were observed for a period of 14 days for signs of intoxication and weight changes.

No mortality resulted from treatment with dicyclopentadiene. Therefore, the LD_{50} was determined to be greater than 40,000 mg/kg dicyclopentadiene. Slight intoxication was noted in 10% of the birds after 20,000 to 30,000 mg/kg had been administered. Recovery of these birds occurred within two hours after dosing. During the 14-day observation period, no deaths occurred and no further signs of intoxication were reported. There were no significant body weight changes or feed consumption differences at a 95% confidence interval. Necropsies of all birds showed no gross pathological changes attributable to dicyclopentadiene exposure [Aulerich et al., 1979].

• The single, oral LD₅₀ in the Bobwhite quail (*Colinus virginianus*) was determined using 220 birds (110 males and 110 females). The number of birds per dose group varied between 5 and 15. Birds were dosed by drenching *per os* using a 1 cc syringe until the desired dosage had been administered. Dose levels administered were 0, 200, 400, 600, 800, 900, 1,000, 1,100, 1,200, 1,400, and 1,600 mg/kg.

The LD_{50} oral was determined to be 1,010 mg/kg for the Bobwhite quail. Most deaths occurred within 48 to 96 hours after dosing. No mortality differences were noted between the sexes.

After 24 hours, signs of dicyclopentadiene-induced toxicity were noted at all dose levels. At this time, activity decreased and the birds became quiescent. Those that attempted to walk were unsteady and lacked coordination. During the 14 day post-treatment period, quail treated with dicyclopentadiene at levels higher than 400 mg/kg exhibited depressed feed consumption (p value not reported) during the first week. By the second week, feed consumption had improved at all levels.

Bird body weight was measured on day 0 and day 14. There were no significant weight changes and necropsies on all birds that died and those sacrificed at the end of the post-treatment observation period revealed no gross pathological changes [Aulerich et al., 1979].

- Rats were dosed subcutaneously with 1.0 ml/kg of dicyclopentadiene daily for 14 days. A second group of rats received a single dose of dicyclopentadiene (5.0 ml/kg) subcutaneously and both groups were sacrificed 96 hours after dosing. Leukocytosis was observed in both groups of rats. Gerade reported that rats dosed orally with dicyclopentadiene developed generalized congestion and hyperemia and focal hemorrhage in the kidney, intestine, stomach, bladder and lungs [Gerade, 1956].
- Four out of six rats (Carworth-Wistar) exposed for 4 hours to 2,000 ppm dicyclopentadiene by inhalation reportedly died [Smyth et al., 1954]. In a more recent study, one out of six male Carworth-Wistar rats exposed to this compound via inhalation for four hours died. However, inhalation exposure at a concentration of 1,000 ppm resulted in 100% mortality [Smyth et al., 1962].

Based on the oral LD_{50} value in rats, dicyclopentadiene is considered to be highly toxic by this route. This compound is classified as slightly to moderately toxic by the dermal route, based on the rabbit dermal LD_{50} value [Kinkead et al., 1971].

Numerous other acute animal studies have been conducted on dicyclopentadiene. Results of these studies are presented in Table 2. A summary of calculated 48-hour LC_{50} values for invertebrates and fish is presented in Table 3.

Route of Exposure	Species (Sex)/ Strain	<u># Animals</u>	Dose	<u>Reference</u>
Oral	Rat (NR)/NR	NR	LD ₅₀ =353 mg/kg	Kinkead, et al., 1971
Oral	Rat (male)/NR	NR	LD ₅₀ =520 mg/kg	Hart and Dacre, 1978
Oral	Rat (female)/ NR	NR	LD ₅₀ =378 mg/kg	Hart and Dacre, 1978
Oral	Rat (male)/CarworthWistar	5	LD ₅₀ =820 mg/kg	Smyth, et al., 1954
Oral	Rat (male)/Carworth Wistar	NR	LD ₅₀ ==410 mg/kg	Smyth, et al., 1962
Oral	Mouse (male)/NR	NR	LD ₅₀ = 190 mg/kg	Hart and Dacre, 1978
Oral	Mouse (female)/ NR	NR	LD ₅₀ = 250 mg/kg	Hart and Dacre, 1978
Inhalation	Rat (female)/6	NR	LC ₅₀ = 385.2 ppm/4 hr.	Kinkead, et al., 1971
Inhalation	Rat (male)/6	NR	LC ₅₀ = 359.4 ppm/4 hr.	Kinkead, et al., 1971
Inhalation	Mice (male)/NR	6	LC ₅₀ = 145.5 ppm/4 hr.	Kinkead, et al., 1971
Inhalation	Rabbit (male)/NR	4	LC ₅₀ = 771.0 ppm/4 hr.	Kinkead, et al., 1971
Inhalation	Guinea Pig (male)/NR	6	LC ₅₀ = 770.5 ppm/4 hr.	Kinkead, et al., 1971
Intraperitoneal	Rat (NR)/NR	NR	LD ₅₀ = 200 mg/kg	ГТП, 1988
Intraperitoneal	Mouse (NR)/NR	NR	LD ₅₀ = 200 mg/kg	ГТП, 1988
Skin	Rabbit (male)/New Zealand	5	10 mg/24H (open) Toxic effects: Severe skin irritation	Smyth, et al., 1954
Skin	Rabbit (male)/New Zealand	5	9300 µg/24H (open) Toxic effects: Severe skin irritation	Smyth, et al., 1962
Skin	Rabbit (NR)/NR	NR	LD ₅₀ = 5080 mg/kg Toxic effects: NR	Kinkead, et al., 1971
Skin	Rabbit (male)/New Zealand	4	LD ₅₀ = 6720 mg/kg	Smyth, et al., 1954
Skin	Rabbit (male)/New Zealand	4	LD ₅₀ = 4460 mg/kg	Smyth, et al, 1962
Еуе	Rabbit (male)/New Zealand	4	500 mg/24H Toxic effects: Mild eye irritation	[Smyth, et al., 1954 and Smyth, et al., 1962]

Table 2. Studies on Acute Exposure to Dicyclopentadiene in Animals

NR=not reported

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Table 3. Summary of Calculated LC_{50} Values for Invertebrates and Fish

Invertebrate Species	<u>48-Hour LC₅₀ (mg/l)</u>
Daphnia magna Gammarus fasciatus Asellus militaris Chironomus tentans	10.5 21.2 15.0 120.0
Fish Species	
Lepomis macrochirus Ictalurus punctatus Pimephales promelas Salmo gairdneri	23.8 15.7 31.1 15.9 [Bentley et al., 1976]

- C. Prechronic Studies
 - 1. Human Data

No data were found in the literature on the prechronic effects of dicyclopentadiene in humans.

- 2. Animal Data
- Feeding studies on dicyclopentadiene were conducted on male and female dogs for 14 days at dosage levels of 40, 125 and 375 ppm. In addition, male and female rats were studied for 90 days at dosage levels of 80, 250, and 750 ppm, and male and female mice were studied at dosage levels of 28, 91 and 273 ppm. In these experiments, no evidence of toxicity was found [Hart and Dacre, 1978]. No other information was reported.
- Two male and two female Alderly Park rats received ten, 6-hour inhalation exposures to dicyclopentadiene at concentrations of 250 ppm. One rat died after the second exposure. The survivors reportedly lost weight, had nose irritation, dyspnea, tremors, and were lethargic and hypersensitive. All blood tests were normal, and at necropsy no abnormalities were found. In addition, four male and four female rats that received fifteen 6-hour inhalation exposures at a dose level of 100 ppm per exposure exhibited no toxicological effects. At necropsy, all organs appeared normal [Gage, 1970].
- A preliminary inhalation study was conducted to determine the concentration levels for use in a subsequent 89-day inhalation study. The preliminary study was performed using four groups of six male and six female Harlan-Wistar rats. Each group was exposed to 0, 72, 146, and 332 ppm dicyclopentadiene and observed over a 10-day dosing period. Each group was exposed 7 hours per day, five days per week, over two weeks, for a total exposure time of 70 hours. Death occurred only for rats exposed at the 332 ppm dose level. The following breakdown of deaths occurring throughout the dosing period was reported: 2 males, 3 females on day 1; 1 female on day 2; 2 males, 2 females on day 3; and 2 males on day 4. Male rats in the 332 ppm group exhibited convulsions during and after the second exposure. All rats in the 332 ppm group exhibited lung hemorrhages and blood in the intestines, and females also exhibited hemorrhaging of the thymus. Rats exposed to the two lower concentrations did not exhibit adverse clinical signs during exposure periods, and no gross lesions were found at necropsy.

Groups of six male and six female albino mice inhaled concentrations of 0, 47, 72 and 146 ppm of dicyclopentadiene vapor on the same schedule described above. Mice receiving 146 ppm had convulsions and died during the first day of exposure. Five of the six mice of each sex exposed to 72 ppm died during the 10 days of exposure. The deaths were not preceded by convulsions, and no gross lesions were observed. The surviving mice had normal body weight gain. No deaths occurred in the

group of mice exposed to 47 ppm. In addition, weight gains were normal in this group, and no gross lesions were observed at necropsy.

One male beagle dog per concentration level inhaled 0, 20, 47, and 72 ppm dicyclopentadiene according to the above schedule. Exposure to 20 ppm resulted in diarrhea on the third day of exposure. The dog exposed to 47 ppm exhibited diarrhea and excessive salivation on the second day of exposure and lack of control of the hind quarters on the ninth day of exposure. The dog exposed to 72 ppm was inactive. At all dose levels, normal weight gain prevailed during the 10 days of exposure, and gross lesions observed at necropsy were not reportedly dose-related [Kinkead, et al., 1971].

• An 89-day inhalation study was conducted using four groups of 12 male and 12 female Harlan-Wister rats. Of the 96 animals studied, 72 were exposed to three different concentrations of dicyclopentadiene vapor (19.7, 35.2 and 73.8 ppm), and 24 were used as a negative control group. Each group was exposed seven hours per day, 5 days per week. Observed criteria for toxic stress in the rats included clinical signs, body weight changes which were statistically compared after exposure days 4, 13, 31, 55, 75 and 89, liver and kidney weight changes, and gross and microscopic pathology. Twenty tissue samples for microscopic examination were collected at necropsy from the thoracic and abdominal cavity of each animal.

The mean body weight gains in male and female rats exposed to 73.8 ppm were statistically significantly lower (p value not reported) than the control group after 4 days, but no further significant weight changes occurred for the remainder of the study. One female given 19.7 ppm had convulsions for 5 minutes after completing the exposure on day 45. Another female rat given 73.8 ppm experienced convulsions for about 5 minutes after exposure on day 19. No other signs attributable to the exposures were observed for the remainder of the study.

The mean kidney weight for male rats in all three exposure groups was significantly increased (0.001>p) when compared to the control, as was the mean kidney weight when expressed as percent of body weight (0.001>p). The mean liver weight gain was significantly (0.01>p>0.001) greater for male rats in the 73.8 and 19.7 ppm exposure groups and in the 35.2 ppm exposure group (0.05<p<0.01). The mean liver weight, expressed as percent of body weight, was significantly greater for male rats in the 73.8 ppm group (0.001>p) and the 19.7 ppm group (0.01>p>0.001). There were no significant weight gains in the liver and kidney for female rats at any exposure level.

Rats exposed to 73.8 ppm, and to a lesser degree to 35.2 ppm dicyclopentadiene, had kidney effects including round-cell accumulations, dilated tubules, casts, and tubular degeneration. The kidney lesions were more frequent, and of greater severity, in male rats than in female rats. Alterations in the livers of both male and female rats did not differ from those of the control. No dose-related pathologic changes were found in the lung, heart, spleen, adrenals, trachea, prostate, testis, colon, or mesentery of rats from any of the dose groups. The author concluded that the "no ill effect" level for dicyclopentadiene for 89 days appears to be below 19.7 ppm for rats [Kinkead, et al., 1971].

As part of the same study, an 89-day inhalation study of 12 male beagle dogs, divided into 4 groups of 3 dogs each, was conducted. The study groups were exposed to dose levels of 0, 8.9, 23.5 and 32.4 ppm. The dogs were exposed for 7 hours each day, 5 days each week. All twelve of the dogs survived the experiment. Body weight changes, clinical signs, hematocrit, total and differential white blood counts, blood urea nitrogen (BUN), serum-glutamic oxaloacetictransaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), serum acid phosphatase, serum alkaline phosphatase, and urine analysis were evaluated during the study. Hematologic and blood chemistry tests were performed 6 days prior to the study, and after 20, 37, 65, and 85 days. Urine analyses were performed 5 days prior to the study and after 21, 38, 68, and 87 days. At necropsy, body weight, liver and kidney weights, and gross pathology changes were determined. Twenty-eight tissue samples were obtained from the cranial, thoracic, and abdominal cavities of each dog for microscopic examination. The tissues included portions of the lung, liver, kidney, heart, spleen, adrenals, thyroid, parathyroid, esophagus, diaphragm, lymph node, gall bladder, maxillary gland, tongue, stomach, duodenum, pancreas, ileum, jejunum, colon, urinary bladder, prostate, testis, epididymis, brain, pituitary, skin, and eye.

The only toxic effects attributed to exposure to dicyclopentadiene were changes in blood chemistry test values. At 32.5 ppm, BUN and acid phosphatase values were slightly increased at the end of 20 days, and SGOT and acid phosphatase values increased for the 23.5 ppm exposure group after twenty days. Alkaline phosphatase increased after 86 days in the 32.5 ppm exposure group. No abnormal blood chemistry values were observed in dogs given 8.9 ppm. The authors report that "none of the isolated findings were of physiological significance."

Body weight and kidney and liver weights in the test groups did not differ from control values. In addition, no dose-related pathologic changes were found. Electrocardiograms were performed on all dogs at the conclusion of the experiment and all tracings were normal.

The authors concluded that the "no ill effect" concentration of dicyclopentadiene vapor to dogs for 89 days of exposure ranges between 8.9 ppm and 23.5 ppm [Kinkead, et al., 1971].

• The prechronic effects of dicyclopentadiene were determined in the juvenile pastel mink. Sixty animals were assigned to groups of 10 (5 males and 5 females). Dicyclopentadiene at concentrations of 0, 1, 10, 100, 1,000 and 10,000 ppm was administered in a mixture with mink feed. The experiment involved a 7-day pre-dosing acclimation period, followed by a 21-day dosing period, during which body weights were recorded at the beginning of dosing and on days 7, 14, and 21. Dosing

ceased after day 21, and the minks were observed for an additional 7 days. Mortality, signs of intoxication and behavioral changes were noted throughout both the dosing and recovery periods. Feed consumption was estimated on days 7, 14, and 21 of dosing, and on day 7 of recovery. At the conclusion of the study, blood samples were collected for hematocrit and differential leukocyte counts. Gross pathomorphological observations were made, and histopathological observations were conducted of the brain, heart, lungs, kidney, spleen, and liver.

All animals in the 10,000 ppm group appeared to be anorectic for the first 2 to 3 days of treatment. These animals became progressively emaciated, lethargic, and disoriented. Their stools were loose and had a tar-black color. Before death, the minks were immobilized with periodic, slight tonic convulsions.

The only deaths due to intake of dicyclopentadiene occurred in the 10,000 ppm dosed group. Four males and two females died before the end of the experiment. The mean lethal concentration (LC_{50}) value was estimated to be 6,800 ppm.

Mean body weights were significantly (p<0.05) reduced for the 10,000 ppm group by day 14 and decreased further (p<0.01) by day 21. During the 7-day observation period post-treatment, the mean weight gain increased, but was still significantly reduced (p<0.05) when compared to the control group.

The mean feed consumption for the 1,000 ppm and for the 10,000 ppm group was significantly lower (p<0.01 and p<0.05, respectively) than the control values. Feed consumption returned to levels slightly above the control values during the 7-day post-treatment period. The authors reported that the depression in feed consumption and the reduction in body weight observed in minks fed diet containing 10,000 ppm dicyclopentadiene could be attributed to starvation.

Hematocrit values were found to be significantly (p<0.01) lower for the 10,000 ppm group compared to the control group. The percentage of band-neutrophils was found to be significantly depressed (p<0.05) in the 1, 10, 100, and 1,000 ppm groups, but not for the 10,000 ppm group. The number of all other leukocytes was not significantly different compared to the controls for any of the dosed groups.

Necropsy revealed no consistent macroscopic pathological effects among the treatment groups. However, minks receiving the 10,000 ppm treatment lost body fat and died during the 21-day dosing period. Males receiving the 10,000 ppm treatment were found to have significant (p<0.01) decreases in heart, spleen and liver weights (p<0.05) when compared to the control animals. Females had no significant differences in organ weights at any dose level [Aulerich, et al., 1979].

• The prechronic effects of dicyclopentadiene have been studied in young adult male Mallard ducks. The number of ducks studied was not reported. The ducks received dicyclopentadiene for 32 days in corn oil mixed with

duck feed at dose levels of 0, 10, 100, 1,000, 5,000 and 10,000 ppm. During the dosing period, signs of intoxication and abnormal behavior were noted. Body weights of the birds were measured at the beginning and end of the dosing period, and the feed consumption was determined daily.

No mortality occurred during the 32-day period. Birds at the three highest dose levels experienced weight loss in amounts that were proportional to treatment level. Feed consumption was not affected by any level of dicyclopentadiene. Necropsies showed no gross pathological changes when compared to the control [Aulerich, et al., 1979].

• The prechronic effects of dicyclopentadiene have been studied in Bobwhite chicks (*Colinus virginianus*). Dicyclopentadiene dissolved in corn oil was administered in the diet at the following dose levels for 5 days: 0, 200, 4,000, 6,000, 8,000, 10,000, 12,000, 14,000, 16,000 and 18,000 ppm. Following the dietary administration of test feed for 5 days, the chicks were given untreated feed for the remaining three days of the study. The control diet consisted of 2 parts corn oil to 98 parts feed by weight. Body weights were recorded on days 0, 5, and 8 of the study. Feed was weighed on days 0 and 5 (treated feed) and on days 6 and 8 (untreated feed) to provide estimates of average feed consumption.

Dicyclopentadiene was found to have a minimal effect on feed consumption. Feed consumption in the chicks fed diets containing dicyclopentadiene increased in six of the treated groups, and decreased in three of the treated groups. The differences ranged from a 12.2 % decline for the quails that received the 10,000 ppm diet, to a 16.4% increase for the birds that received the 4,000 ppm diet, with a mean increase of 1.4 % above the control. During the 3-day post-treatment period, all groups with the exception of the 10,000 ppm group, had increased feed consumption compared to the control. The increases in feed consumption ranged from 3.0% at the 4,000 ppm level to 19.94% at the 8,000 ppm level, with a mean increase of 7.74% compared to the control.

Body weight gains were generally reduced in birds fed dicyclopentadiene. Birds fed diets containing 2,000-8,000 ppm had a mean weight gain of 2.86 g/b/d, a 0.1 g/b/d decrease compared to the control. Birds fed diet containing levels ranging from 10,000-18,000 ppm had a mean body weight gain of 2.38 g/b/d, a 0.58 g/b/d decrease compared to the control. During the post-treatment period, all groups with the exception of the 8,000 ppm level to 4.83 g/b/d in the 16,000 ppm group, representing a mean gain of 3.80 g/b/d (0.718 g /b/d greater than the control value).

The highest mortality occurred in the 2,000 ppm (20%) and 10,000 ppm (10%) groups. No mortality occurred in the other groups. Due to insufficient mortality, the LC_{50} value could not be determined. All birds that died during the study, as well as those that survived until study termination, were necropsied.

No gross or pathological changes between the treated and control groups were observed during necropsy [Aulerich, et al., 1979].

- D. Chronic/Carcinogenicity
 - 1. Human Data

No data were found on the chronic/carcinogenic effects of dicyclopentadiene on humans.

- 2. Animal Data
- Dicyclopentadiene was not found to be a sensitizer in the guinea pig. No other data were reported [Hart and Dacre, 1978].
- A study to determine the chronic effects of dicyclopentadiene in adult Mallard ducks and their progeny has been described. Results regarding the reproductive effects of this compound are described in Section V. E.2. Four groups of 21 ducks each, comprised of 3 sets of 2 male and 5 female ducks were studied. The ducks were dosed for 22 weeks with a corn-oil dicyclopentadiene solution mixed with duck feed. The food/chemical mixture was prepared at dose levels of 0, 32, 100, and 320 ppm dicyclopentadiene.

Body weights were taken at weeks 0, 2, 4, 6, 8 and 22. There was no significant difference in body weight change or feed consumption values in the dicyclopentadiene treated groups compared to the control groups.

All ducks survived the duration of the study and were sacrificed after 22 weeks. A gross examination of the liver, spleen, kidney, pancreas, proventriculus, gizzard, heart and brain was performed, and organ weights were determined. Histopathologic examination of the lungs, adrenals, duodenum, and sciatic nerve was also conducted. No gross or histopathologic differences between the treated and control groups were observed. In addition, no significant differences in organ weight at any treatment level were noted.

Hemoglobin concentration, packed red cell volume, and differential counts were determined for all birds at the termination of dosing. No significant differences were noted in any of the hematological parameters tested [Aulerich, et al., 1979].

• Adult Bobwhite quails (*Colinus virginianus*) were used to study longterm exposure to dicyclopentadiene during a single reproductive cycle (data regarding the reproductive toxicity portion of this study are described in Section V.E.2). One hundred and twenty quails were divided into four groups consisting of 15 male and 15 female birds each. Dicyclopentadiene was mixed with corn oil and added to quail feed at concentrations of 0, 400, 1,250, and 4,000 ppm, and administered for 20 weeks. The control diet consisted of 2 parts corn oil to 98 parts feed by weight. Feed consumption was measured biweekly for the duration of the experiment. Quail body weights were measured at 0, 2, 4, 6, and 8 weeks, and at the termination of the study. No significant change in feed consumption or body weight for either sex was observed.

No diet-related trends in mortality were noted. At the termination of the study, all surviving animals were sacrificed and gross examination of the liver, spleen, kidney, pancreas, proventriculus, gizzard, heart and brain was performed. Histopathologic examinations were conducted on samples from the lungs, adrenals, duodenum, and sciatic nerve. Liver weights of male quails fed 4,000 ppm dicyclopentadiene were found to be significantly less than liver weights of the male control quails (p>0.05). Organ weights of other treated quails were not significantly different from control values. Histopathologic examination revealed no treatment-related lesions.

In addition, determinations of differential counts, packed red-cell volume and hemoglobin concentration were completed on all birds that survived until study termination. There was no significant changes in hemoglobin and hematocrit values between study and control groups. However, hemoglobin and hematocrit values were significantly (p>0.05) greater for males than females in both groups. In addition, leukocyte analysis revealed that the number of eosinophils from quails fed 1,250 ppm was significantly greater (p>0.05) than in the control group.

The authors concluded that the parameters measured showed no significant chronic effects that could be attributed to dicyclopentadiene [Aulerich, et al., 1979].

• A chronic toxicity feeding study of 150 immature dark variety minks was conducted through one reproductive cycle (12 months). Data regarding the reproductive toxicity of dicyclopentadiene in mink are described in Section V.E.2. The mink were divided into five groups of 6 males and 24 females each. Dicyclopentadiene was mixed into mink feed in concentrations of 0, 100, 200, 400, and 800 ppm.

Ingestion of dicyclopentadiene in mink feed did not result in significant differences in mortality compared to the control group. A total of 133 mink survived the duration of the study. In addition, the body weights of treated animals did not show a consistent difference with respect to the controls.

Hematological parameters showed no consistent changes associated with chronic dicyclopentadiene administration. Hemocrit values and hemoglobin and mean corpuscular volume showed no significant differences in treated animals compared to controls.

No gross or histopathological treatment-related abnormalities were observed. In addition, no significant changes were observed in the weights of the liver, kidney, lungs, adrenals, heart, ovaries, and brain. Significant (p>0.05) increases in spleen weight were observed in the 400

ppm dietary group, and a reduction in the testes weight for the 800 ppm dietary group was also noted. The authors concluded that chronic ingestion of dicyclopentadiene in the diet had no effect on growth and survival of mink.

- E. Reproductive Effects and Teratogenicity
 - 1. Human Data

No information was found on the reproductive effects and teratogenicity of dicyclopentadiene in humans.

2. Animal Data

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• The reproductive effect of dicyclopentadiene on Mallard ducks has been studied. Eighty-four Mallard ducks were separated into four groups of 21 ducks each. Each group consisted of three subgroups of 5 female and 2 male ducks. Animals were treated for 22 weeks with dicyclopentadiene in duck feed at concentrations of 0, 32, 100 and 320 ppm. The reproductive effect of dicyclopentadiene was determined by assessing the number of eggs laid, egg shell thickness, and incubation parameters (percentage cracked, fertile, hatched, early dead, dead in shell, live in shell, pipped live, pipped dead).

No significant changes were found in egg production, egg shell thickness or in any of the incubation parameters compared to the control group. In addition, no maternal toxicity was observed in this study as described in section V.D.2 [Aulerich, et al., 1979].

• One hundred and fifty dark variety minks (5 groups comprised of 6 males and 24 females) were exposed to dietary concentrations of 0, 100, 200, 400 and 800 ppm dicyclopentadiene for 52 weeks prior to mating. Measures of reproductive toxicity included length of gestation, litter size, sex ratio, kit mortality, increase in kit biomass during lactation, and weight changes in lactating females.

Chronic exposure to dicyclopentadiene revealed no significant change for whelping lengths, gestation length, fecundity, kit weight at birth, or secondary weight rates. Also, no difference was noted in male fertility. However, a significant (p>0.05) depression in neonate weight gain was measured at four weeks for offspring from parents receiving the three highest treatment levels. There were no significant differences in kit mortality or in body weights of lactating females.

In addition, a significant reduction in testicular weight was observed in males fed 800 ppm dicyclopentadiene. However, no significant treatment - related ovarian weight differences were found. It was concluded that the chronic ingestion of dicyclopentadiene did not affect mink reproductive performance but significantly (p>0.05) affected offspring weight gain. No maternal toxicity was observed as described in section V.D.2 [Aulerich, et al., 1979].

• Adult Bobwhite quails (120 quails divided into 4 groups of 15 males and 15 females) were given feed mixed with a corn oil/dicyclopentadiene mixture at concentrations of 0, 400, 1,250 and 4,000 ppm dicyclopentadiene for 20 weeks. The control group received diet consisting of 2 parts corn oil to 98 parts feed by weight. The offspring resulting from regulated breeding were observed during two weeks posthatching. Measures of reproductive toxicity included egg production, egg shell thickness, progeny survival, and incubation parameters (percentage cracked, fertile, hatched, early dead, dead in shell, live in shell, pipped live, pipped dead).

Egg production was found to be reduced significantly (p>0.05) among hens fed 400 ppm compared to control hens. Egg production was not significantly different from controls in birds receiving higher dose levels. Incubation parameter data, egg shell thickness, and survival of the progeny were not significantly different from the control. In addition, gonad weight was not found to differ in the treated groups. It was concluded that dicyclopentadiene exerts minimal effects on the reproduction of Bobwhite quails at the levels tested. In addition, no maternal toxicity was observed as described in section V.D.2 [Aulerich, et al., 1979].

- F. Genetic Toxicology
 - 1. Prokaryotic Data

Dicyclopentadiene was not mutagenic in *Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1537 in the presence and absence of metabolic activation [Zeiger, et al., 1987].

2. Eukaryotic Data

No data were found on the genotoxic effects of dicyclopentadiene in eukaryotic systems.

- G. Other Toxicological Effects
 - 1. Immunotoxicity

No data were found on the immunotoxic effects of dicyclopentadiene in animals or humans.

2. Neurotoxicity

No data were found on the neurotoxic effects of dicyclopentadiene in animals or humans.

3. Biochemical Toxicology

Oral administration of dicyclopentadiene to rats at a concentration of 750 ppm for four days did not have an effect on hexobarbital-induced

sleeping time. Therefore, this compound is not considered to be a liver enzyme inducer [Hart and Dacre, 1978]. No other information was reported.

VI. STRUCTURE ACTIVITY RELATIONSHIPS

• An acute toxicity and carcinogenicity study was performed using the structurally related compound endo-dicyclopentadiene dioxide and a 70% exo-, 30% endo- mixture of dicyclopentadiene dioxide. Information regarding the toxicological methods was not reported for the acute toxicity study. However, the author reported the LD₅₀ for rats to be 0.21 gm/kg for endo-dicyclopentadiene dioxide and 0.31 gm/kg for the endo-dicyclopentadiene dioxide mixture. The lifetime tumorigenicity study involved painting the shaved back of thirty to forty C3H strain 90-day-old mice 3 days per week with endo-dicyclopentadiene dioxide. Observations were made of papillomas and carcinomas during each painting period. The mice were painted and observed until death. Neither chemical exhibited tumorigenicity over the lifespan (26-28 months) of the mice. Internal organs were not examined [Weil, et al., 1963].

VII. REFERENCES

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Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, <u>Toxic Hazards Research Unit</u>, <u>Annual Technical</u> <u>Report: 1976</u>, University of California, Dayton, Ohio, September 1976.

Aldrich Chemical Company, <u>Aldrich Catalog/Handbook of Fine Chemicals</u>. 1988, p. 515.

American Conference of Governmental Industrial Hygienists, <u>Documentation of</u> the <u>Threshold Limit Values and Biological Exposure Indices</u>. Fifth Edition. Cincinnati: ACGIH, 1986, p. 194.

American Conference of Governmental Industrial Hygienists, <u>Threshold Limit</u> <u>Values and Biological Exposure Indices for 1989-1990</u>, Cincinnati: ACGIH, 1989.

Aulerich, R.J., Coleman, T.H., Polin, D., Ringer, R.K., Howell, K.S., Jones, R.E. and Kavanagh, T.J., <u>Toxicology Study of Diisopropyl Methylphosphonate and</u> <u>Dicyclopentadiene in Mallard Ducks</u>, <u>Bobwhite Quail</u>, and <u>Mink</u>, Final Report. Supported by U.S. Army Medical Research and Development Command. Poultry Science Department, Michigan State University, East Lansing, Michigan, June 1979.

Bentley, R.E., Leblanc, G.A., Hollister, T.A., and Sleight, B.H. (EG&G, Bionomics, Wareham, Massachusetts), <u>Acute Toxicity of Diisopropylmethyl</u> <u>Phosphonate and Dicyclopentadiene to Aquatic Organisms</u>. Supported by U.S. Army Medical Research and Development Command, Washington, D.C., July 1976.

Bretherick, L., <u>Handbook of Reactive Chemical Hazards</u>, Third Edition. Boston: Butterworths, 1985, p. 772.

Bruner, R.H., "Pathologic Findings in Laboratory Animals Exposed to Hydrocarbon Fuels of Military Interest." <u>Advances in Modern Environmental</u> <u>Toxicology</u>, Vol. 7 (1984), pp. 133-140.

Budavari, S., ed., <u>The Merck Index, An Encyclopedia of Chemicals</u>, <u>Drugs, and</u> <u>Biologicals</u>, Eleventh Edition. Rahway, New Jersey : Merck, 1989, p. 2741.

Burrows, D.W., "Development of Guidelines for Contaminated Soil and Groundwater at U.S. Army Installations." Conference Proceedings of the International Conference on Environmental Pollution, Sponsored by the American Chemical Society, Washington, D.C., 1977, pp. 80-82.

Chemical Week Buyer's Guide 1990, <u>Chemical Week</u>, (October 1989), pp.9, 18, 19, 20, 21, 39.

Clayton, G.D. and Clayton, F.E., eds., <u>Patty's Industrial Hygiene and</u> <u>Toxicology</u>, Vol. 2B, Third Revised Edition. New York: Wiley-Interscience, 1981, pp. 3221-3243. Cysewski, S.J., Palmer, J.S., Crookshank, H. R. and Steel, E.G., "Toxicologic Evaluation of Diisopropyl Methylphosphonate and Dicyclopentadiene in Cattle." <u>Archives of Environmental Contamination and Toxicology</u>, Vol. 10 (1981), pp. 606-615.

12 6

Dreisbach, R.H., <u>Handbook of Poisoning: Prevention Diagnosis & Treatment</u>, Tenth Edition. Los Altos, California: Lange Medical Publications, 1980, pp. 181-189.

Eller, P.M., ed., National Institute for Occupational Safety and Health (NIOSH), <u>Manual of Analytical Methods</u>, Third Edition. DHEW (NIOSH) Publication No. 84-100. U.S. Department of Health, Education, and Welfare. Cincinnati, Ohio, 1984.

Gage, J.C., "The Subacute Inhalation Toxicity of 109 Industrial Chemicals." British Journal of Industrial Medicine, Vol. 27 (1970), pp. 1-18.

Gerarde, Horace W., "Noxious Gases and Vapors II: Hydrocarbons and Hydrocarbon Mixtures." <u>Drills Pharmacology in Medicine</u>, Fourth Edition, (1971), pp. 1206-1224.

Gerade, H. W., "Toxicological Studies on Hydrocarbons, II. A Comparative Study of the Effect of Benzene and Certain Mono-n-alkyl-benzenes on Hemopoiesis and Bone Marrow Metabolism in Rats." <u>AMA Archives of Industrial Health</u>, Vol. 13 (1956), pp. 468-474.

Grant, W.M., <u>Toxicology of the Eye</u>, Third Edition. Springfield: C.C. Thomas, 1986, p. 1030.

Hart, E.R. and Dacre, J.C., "Mammalian Toxicologic Studies on Dicyclopentadiene." <u>Proceedings of the International Congress on Toxicology as a Predictive Science</u>, New York: Academic Press, 1978, pp. 448-449.

The International Technical Information Institute, <u>Toxic and Hazardous</u> <u>Industrial Chemical Safety Manual for Handling and Disposal with Toxicity and</u> <u>Hazard Data</u>, Revised. Tokyo: The International Technical Information Institute, 1988, p. 171.

Ivie, G. W. and Oehler, D.D., "Fate of Dicyclopentadiene in a Lactating Cow." <u>Bulletin of Environmental Contamination and Toxicology</u>, Vol. 24 (1980), pp. 662-670.

Kavaler, A.R., <u>Chemical Marketing Reporter</u>, July, 1980. New York: Schnell Publishing Company, Inc., 1980, p. 9.

Kinkead, E.R., Pozzani, U.C., Geary, D.L., and Carpenter, C.P., "The Mammalian Toxicity of Dicyclopentadiene." <u>Toxicology and Applied</u> <u>Pharmacology</u>, Vol. 20 (1971), pp. 552-561.

Kirk-Othmer, <u>Concise Encyclopedia of Chemical Technology</u>. New York: Wiley-Interscience, 1985, p. 340.

Kirk-Othmer, <u>Encyclopedia of Chemical Technology</u>. Third Edition, Vol. 7, Copper Alloys to Distillation. New York: Wiley-Interscience, 1979, pp. 417-429.

л: ъ

Kline, E.R., Mattson, V.R., Pickering, Q.H., Spehar, D.L., and Stephan, C.E., "Effects of Pollution on Freshwater Organisms." Journal of Water Pollution Control, Vol. 59, No. 6 (1987), pp. 539-572.

Lenga, R.E., <u>The Sigma Aldrich Library of Chemical Safety Data</u>, Edition II. Milwaukee, Wisconsin: Sigma-Aldrich Corp., 1988.

Mackison, F. W., Stricoff, R.S., and Partridge, L. J. Jr., eds., <u>Occupational</u> <u>Health Guidelines for Chemical Hazards</u>, DHHS (NIOSH) Publication No. 81-123. National Institute for Occupational Safety and Health. Cincinnati, Ohio, 1981.

National Cancer Institute (NCI), 1989a, Letter from Dr. T. Cameron, Chairman, Chemical Selection Working Group, National Cancer Institute, to Dr. D. Canter, NTP.

National Cancer Institute (NCI), 1989b, Summary of Data for Chemical Selection. Dicyclopentadiene. Prepared for National Cancer Institute by Technical Resources, Inc., Tracor Technical Resources under contract number N01-CP-41003.

National Fire Protection Association, <u>Fire Protection Guide on Hazardous</u> <u>Materials</u>, Ninth Edition. Quincy, Massachusetts: National Fire Protection Association, 1986, p. 325M-35.

National Institute for Occupational Safety and Health (NIOSH), <u>Health Hazard</u> <u>Evaluation Report HETA 81-176-968</u>, Rocky Mountain Arsenal, Basin <u>F.Commerce City</u>, <u>Colorado</u>. Springfield Virginia: National Technical Information Service, 1981.

National Institute for Occupational Safety and Health (NIOSH), <u>NIOSH Pocket</u> <u>Guide to Chemical Hazards</u>, DHEW (NIOSH) Publication No. 85-114. National Institute for Occupational Safety and Health. Washington, D. C., September 1985.

National Institute for Occupational Safety and Health (NIOSH), National Occupational Exposure Survey (NOES), data communicated by Joseph A. Seta, Acting Section Chief, Division of Surveillance, Hazard Evaluations and Field Studies. April 1990.

Occupational Safety and Health Administration. Air Contaminants, (29 CFR Part 1910). Federal Register, Vol. 54, No. 12, (January 12, 1989), pp. 2343-2490.

Office of the Federal Register, <u>Code of Federal Regulations</u>, Title 21, Food and Drugs, Subpart B, part 175.105, U.S. Government Printing Office, Washington, D.C., April 1, 1990.

Office of the Federal Register, <u>Code of Federal Regulations</u>, Title 21, Food and Drugs, Subpart B, part 177.2600 (c) 4 (iii), U.S. Government Printing Office, Washington, D.C., April 1, 1990.

" t p

<u>OPD Chemical Buyers Directory</u>, Seventy Sixth Edition. New York: Schnell Publishing Company, Inc. 1989, pp. 242, 691, 694, 696, 699, 702.

Plunkett, E.R., <u>Handbook of Industrial Toxicology</u>, Third Edition. New York: Chemical Publishing Co., Inc., 1987, pp. 168-169.

Proctor, N.H. and Hughes, J.P., <u>Chemical Hazards of the Workplace</u>. Lippincott Company, 1978, pp. 193-194.

Roytech Publications, <u>Suspect Chemicals Sourcebook</u>, California: Roytech Publications, 1989, pp. 3-25, 4-1.

Sax, N.I. and Lewis, R.J. Sr., <u>Dangerous Properties of Industrial Materials</u>, Volume II. Seventh Edition. New York: Van Nostrand Reinhold, 1989, p. 441.

Sax, N.I. and Lewis, R.J. Sr., <u>Hawley's Condensed Chemical Dictionary</u>, Eleventh Edition. New York: Van Nostrand Reinhold, 1987, pp. 383, 384.

Sax, N.I. and Lewis, R.J., Sr., <u>Rapid Guide to Hazardous Chemicals in the</u> <u>Workplace</u>. New York: Van Nostrand Reinhold Company, 1986, p. 59.

Sittig, M., <u>Handbook of Toxic and Hazardous Chemicals and Carcinogens</u>, Second Edition. Park Ridge, New Jersey: Noyes Publications, 1985, pp. 337-338.

Smyth, H.F., Carpenter, C. P., Weil, C.S., and Pozzani, U.C., "Range-Finding Toxicity Data, List V." <u>AMA Archives of Industrial Hygiene and Occupational</u> <u>Medicine</u>, Vol. 10 (1954), pp. 61-68.

Smyth, Henry F., Carpenter, C.P., Weil, C.S., Pozzani, U.C. and Striegel, J.A., "Range-Finding Toxicity Data: List VI." <u>American Industrial Hygiene</u> <u>Association Journal</u>, Vol. 23, No.2 (March-April 1962), pp.95-107.

Spanggord, R.J., Chou, T.W. and Mabey, W.R., <u>Studies of Environmental Fates</u> of <u>DIMP and DCPD</u>, Final Report. SRI International, Menlo Park, California, September 1979.

SRI International, <u>1989 Directory of Chemical Producers</u>, Western Europe, Menlo Park, California, pp. 367, 368, 558, 586, 1149.

SRI International, <u>1989 Directory of Chemical Producers</u>, United States of America, Menlo Park, California, pp. 40, 81, 82, 111, 112, 139, 351.

U.S. Army Medical Research and Development Command, <u>Problem Definition</u> <u>Studies on Potential Environmental Pollutants II. Physical, Chemical,</u> <u>Toxicological, and Biological Properties of 16 Substances</u>, Washington, D.C.: US Army, December 1975. U. S. Coast Guard, <u>Chemical Hazards Response Information System (CHRIS). A</u> <u>Condensed Guide to Chemical Hazards</u>, U. S. Coast Guard Publication Number CG-446-1. U.S. Coast Guard. Washington, D.C. 1985.

U. S. Department of Commerce, <u>U.S. Imports for Consumption and General</u> <u>Imports</u>, FT246/Annual 1988, TSUSA Commodity by Country of Origin, U.S.Department of Commerce, 1989.

U. S. Department of Commerce, <u>U.S. Imports for Consumption and General</u> <u>Imports</u>, FT246/Annual 1987, TSUSA Commodity by Country of Origin, U.S.Department of Commerce, 1988.

U. S. Department of Commerce, <u>U.S. Imports for Consumption and General</u> <u>Imports</u>, FT246/Annual 1986, TSUSA Commodity by Country of Origin, U.S. Department of Commerce, 1987.

U. S. Department of Commerce, <u>U.S. Imports for Consumption and General</u> <u>Imports</u>, FT246/Annual 1985, TSUSA Commodity by Country of Origin, 1986.

United States Environmental Protection Agency, Research and Development, "Health and Environmental Effects Document for Cyclopentadiene and Dicyclopentadiene," Environmental Criteria and Assessment Office, Office of Health and Human Assessment, U.S. Environmental Protection Agency, Final Draft, Cincinnati, OH, September 1987.

United States Evironmental Protection Agency, 1990a. Personal Communication from Mr. Jeff Davidson, OTS, U.S. Environmental Protection Agency to Dr. Victor Fung, NTP, April, 1990.

United States Environmental Protection Agency, 1990b. Production Statistics for chemicals in the non-confidential TSCA substances inventory, data communicated by Ed Gross, Information Protection Specialist, Public Information Section, Office of Pesticides and Toxic Substances, July, 1990.

United States Environmental Protection Agency, 1990c. U. S. Environmental Protection Agency, Computer Printout (TSCAPP): 1977 Production Statistics for Chemicals in the Nonconfidential Initial TSCA Chemical Substances Inventory. Washington, DC: Office of Pesticides and Toxic Substances.

United States International Trade Commission, <u>Synthetic Organic Chemicals</u>, United States Production and Sales. U.S. Government Printing Office. Washington, D.C., 1986-1989.

Van Breemen, R.B., Fenselau, C.C., Cotter, R.J., Curtis, A.J., and Connolly, G., "Derivatives of Dicyclopentadiene in Ground Water." <u>Biomedical and</u> <u>Environmental Mass Spectrometry</u>, Vol. 14 (1987), pp. 97-102.

Verschueren, K., <u>Handbook of Environmental Data on Organic Chemicals</u>, Second Edition. New York: Van Nostrand Reinhold, 1983, pp. 512-513. Weast, R.C., ed., <u>CRC Handbook of Chemistry and Physics</u>, Sixty Ninth Edition, Boca Raton, Florida: CRC Press, Inc., 1989, p. C-244.

Weil, C.S., Condra, N., Haun, C., and Striegel, J.A., "Experimental Carcinogenicity and Acute Toxicity of Representative Epoxides."<u>American Industrial Hygiene Association Journal</u>, Vol. 24 (1963), pp. 305-325.

Weisburger, E.K., Russfield, A.B., Homburger, F., Weisburger, J. H., Boger, E., Van Dongen, C.G. and Chu, K. C., "Testing of Twenty-One Environmental Aromatic Amines or Derivatives for Long-Term Toxicity or Carcinogenicity." Journal of Environmental Pathology & Toxicology, Vol. 2 (1978), pp. 325-356.

Zeiger, E., Anderson, B., Haworth, S., Lawlor, T., Mortelmans, K., and Speck, W., "Salmonella Mutagenicity Tests: III. Results From the Testing of 255 Chemicals." <u>Environmental Mutagenesis</u>, Vol. 9, Supplement 9 (1987), pp. 1-3, 5, 11-19, 21, 29, 52.

APPENDIX I. ON-LINE DATABASES SEARCHED

DATE OF SEARCH

TIME PERIOD

BRS: HZDB

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May, 1990

DIALOG:		
Agricola	May, 1990	1970-1990
Agris International	May, 1990	1974-1990
Aquatic Science Abstracts	May, 1990	1978-1990
Biosis Previews	May, 1990	1969-1990
Biotechnology Abstracts	May, 1990	1982-1990
CAB Abstracts	May, 1990	1972-1990
Cancerlit	May, 1990	1963-1990
Chemical Engineering Abstracts	May, 1990	1971-1990
Chem Bus Newsbase	May, 1990	1984-1990
Chemical Exposure	May, 1990	1974-1987
Compendex Plus	May, 1990	1970-1990
CRIS USDA	May, 1990	
Embase	May, 1990	1974-1990
Enviroline	May, 1990	1970-1990
Environmental Bibliography	May, 1990	1974-1990
Federal Register	May 1990	1977-1990
Foods Adlibra	May 1990	1974-1990
FSTA	May 1990	1969-1990
Life Sciences Collection	May 1990	1978-1990
Medline	May 1000	1966-1990
NTTO	May 1000	1064-1000
Occupational Safety and Health	May 1000	1073 1000
Decopational Safety and Health	May 1000	108/ 1000
Pascal DTC Normaletter	May, 1990	1007 1000
PTS Newsletter	May, 1990	1907-1990
PIS Prompt	May, 1990	19/2-1990
Pollution Abstracts	May, 1990	19/0-1990
Scisearch	May, 1990	19/4-1990
Trade and Industry ASAP	May, 1990	1983-1990
I rade and industry index	May, 1990	1981-1990
World Translations Index	May, 1990	1984-1990
MEAD:		
Nexis/Lexis-BNA ENV	May, 1990	
NLM:		
Chemid	May, 1990 ·	
Chemline	May, 1990	
HSDB	May, 1990	
RTECS	May, 1990	
Toxline 65	May, 1990	1965-1980
Toxline	May, 1990	1981-1990
Toxlit	May, 1990	1981-1990
Toxlit 65	May 1990	1965-1980
Tokat 05	101493, 1990	
STN:		
Beilstein	May. 1990	
CA	May 1990	1967-1990
Čhemlist	May, 1990	
Registry	May 1990	
1000001		

APPENDIX II. SAFETY INFORMATION

HANDLING AND STORAGE

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Dicyclopentadiene is stable under normal laboratory conditions.

EMERGENCY FIRST AID PROCEDURES

- **Eye:** First check the victim for contact lenses and remove if present. Flush victim's eyes with water or normal saline solution for 20 to 30 minutes while simultaneously calling a hospital or poison control center. Do not put any ointments, oils, or medication in the victim's eyes without specific instructions from a physician. IMMEDIATELY transport the victim, after flushing eyes, to a hospital, if symptoms (such as redness or irritation) develop.
- Skin: IMMEDIATELY flood affected skin with water while removing and isolating all contaminated clothing. Gently wash affected skin areas thoroughly with soap and water. If symptoms such as inflammation or irritation develop, IMMEDIATELY call a physician or go to a hospital for treatment.
- Inhalation: IMMEDIATELY leave the contaminated area and take deep breaths of fresh air. If symptoms (such as wheezing, coughing, shortness of breath, or burning in the mouth, throat, or chest) develop, call a physician and be prepared to transport the victim to a hospital.

Provide proper respiratory protection to rescuers entering an unknown atmosphere. Whenever possible, Self-Contained Breathing Apparatus (SCBA) should be used.

Ingestion: If the victim is conscious and not convulsing, give 1 or 2 glasses of water to dilute the chemical and IMMEDIATELY call a hospital or poison control center. Be prepared to transport the victim to a hospital if advised by a physician.

If the victim is convulsing or unconscious, do not give anything by mouth, ensure that the victim's airway is open and lay the victim on his/her side with the head lower than the body. DO NOT INDUCE VOMITING. IMMEDIATELY TRANSPORT THE VICTIM TO A HOSPITAL.

• **PROTECTIVE EQUIPMENT**

Eye: Safety glasses.

- Gloves: Two pairs of dissimilar protective gloves shall be worn when handling the neat chemical, otherwise one pair. When contact with this chemical has been known to occur, change gloves immediately.
- <u>Clothing</u>: Minimally, a disposable laboratory suit (e.g. Tyvek®) shall be worn, as specified in the most current NTP Statement of Work or NTP Health and Safety Minimum Requirements.

Respiratory

6 10 24

<u>Protection</u>: A NIOSH-approved chemical cartridge respirator with an organic vapor cartridge.

• EXTINGUISHANT

Dry chemical, carbon dioxide or halon extinguisher

MONITORING PROCEDURES

There is no NIOSH analytical method reputed in the NIOSH Manual of Analytical Methods for dicyclopentadiene. However, method number 2523 describes monitoring procedures for 1,3-cyclopentadiene. This method involves absorption on a solid sorbent tube followed by dissolution with ethyl acetate. Analysis is by gas chromatography [Eller, 1984].

• SPILLS AND LEAKAGE

Persons not wearing the appropriate protective equipment and clothing shall be restricted from areas of spills until cleanup has been completed. When exposure to unknown concentrations may occur, air-purifying respirators may not be used. Chemical cartridge respirators with organic vapor cartridges may not be used when airborne concentrations exceed 1000 ppm.

If dicyclopentadiene is spilled the following steps shall be taken:

- 1. Remove all sources of ignition.
- 2. If a liquid solution is spilled, use vermiculite, sodium bicarbonate, sand, or paper towels to contain and absorb the spill.
- 3. Clean the spill area with dilute alcohol (approximately 60-70%) followed by a strong soap and warm water washing.
- 4. Dispose of all absorbed material as hazardous waste.

DECONTAMINATION OF LABORATORY EQUIPMENT

TDMS Terminal:

nal: Whenever feasible, a protective covering (e.g., plastic wrap) shall be placed over the keyboard when in use.

<u>General Equipment</u>: Before removing general laboratory equipment (i.e. lab carts, portable hoods and balances) from animal dosing rooms and/or chemical preparation areas, a decontamination process shall be conducted in addition to routine housekeeping procedures.

• WASTE MANAGEMENT AND DISPOSAL PROCEDURES

- Waste Management: If an inhalation study is to be conducted, all exhaust air from the inhalation chamber must be cleaned with appropriate air cleaning devices unless the laboratory has informed local and state air pollution regulatory agencies of both the laboratory's operating practices and the potential hazards of the chemicals in use. Compliance with all federal, state and local air pollution laws and regulations is required. Specific design of any air cleaning system selected must reflect the specific conditions of the laboratory (eg., air flow rates and volumes, mixing of exhaust streams, size of inhalation chamber) and the dosing regimen. All cleaning system designs must be described by the laboratory and approved by the NTP Office of Laboratory Health and Safety.
- <u>Waste Disposal</u>: Securely package and label, in double bags, all waste material. All potentially contaminated material (i.e., carcasses, bedding, disposable cages, labware) shall be disposed of by incineration in a manner consistent with federal (EPA), state, and local regulations or disposed of in a licensed hazardous waste landfill.