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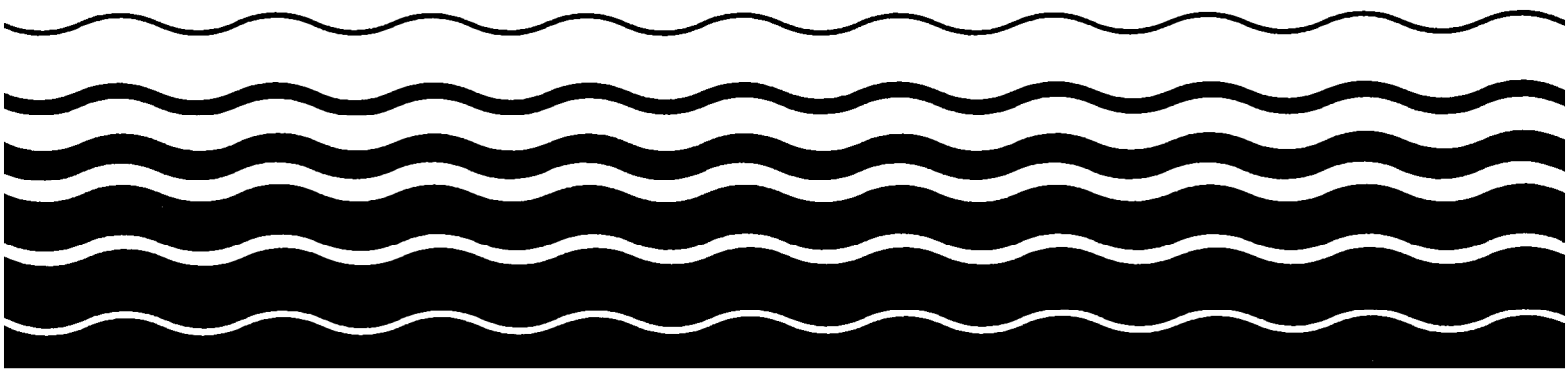
Ambient Water Quality Criteria for 2-chlorophenol



AMBIENT WATER QUALITY CRITERIA FOR

2-CHLOROPHENOL

Prepared By
U.S. ENVIRONMENTAL PROTECTION AGENCY

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FOREWORD

Section 304 (a)(1) of the Clean Water Act of 1977 (P.L. 95-217), requires the Administrator of the Environmental Protection Agency to publish criteria for water quality accurately reflecting the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare which may be expected from the presence of pollutants in any body of water, including ground water. Proposed water quality criteria for the 65 toxic pollutants listed under section 307 (a)(1) of the Clean Water Act were developed and a notice of their availability was published for public comment on March 15, 1979 (44 FR 15926), July 25, 1979 (44 FR 43660), and October 1, 1979 (44 FR 56628). This document is a revision of those proposed criteria based upon a consideration of comments received from other Federal Agencies, State agencies, special interest groups, and individual scientists. The criteria contained in this document replace any previously published EPA criteria for the 65 pollutants. This criterion document is also published in satisifaction of paragraph 11 of the Settlement Agreement in Natural Resources Defense Council, et. al. vs. Train, 8 ERC 2120 (D.D.C. 1976), modified, 12 ERC 1833 (D.D.C. 1979).

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304 (a)(1) and section 303 (c)(2). The term has a different program impact in each section. In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. The criteria presented in this publication are such scientific assessments. Such water quality criteria associated with specific stream uses when adopted as State water quality standards under section 303 become enforceable maximum acceptable levels of a pollutant in ambient waters. The water quality criteria adopted in the State water quality standards could have the same numerical limits as the criteria developed under section 304. However, in many situations States may want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. It is not until their adoption as part of the State water quality standards that the criteria become regulatory.

Guidelines to assist the States in the modification of criteria presented in this document, in the development of water quality standards, and in other water-related programs of this Agency, are being developed by EPA.

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2-CHLOROPHENOL

CRITERIA

Aquatic Life

The available data for 2-chlorophenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 4,380 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of 2-chlorophenol to sensitive freshwater aquatic life but flavor impairment occurs in one species of fish at concentrations as low as 2,000 µg/l.

No saltwater organisms have been tested with 2-chlorophenol and no statement can be made concerning acute or chronic toxicity.

Human Health

Sufficient data is not available for 2-chlorophenol to derive a level which would protect against the potential toxicity of this compound.

Using available organoleptic data, for controlling undesirable taste and odor qualities of ambient water, the estimated level is 0.1 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

INTRODUCTION

2-Chlorophenol is a commercially produced chemical used entirely as an intermediate in the production of other chemicals. It represents a basic chemical feedstock in the manufacture of higher chlorophenols for such uses as fungicides, slimicides, bactericides, antiseptics, disinfectants, and wood and glue preservatives. 2-Chlorophenol is also used to form intermediates in the production of phenolic resins, and has been utilized in a process for extracting sulfur and nitrogen compounds from coal.

2-Chlorophenol (ortho- or o-chlorophenol) is a substituted phenol having the empirical formula C_6H_5OCl. It has a molecular weight of 128.56, a density of 1.2573 at 25°C, and a vapor pressure of 1 mm Hg at 12.1°C (Sax, 1975; Stecher, 1968). 2-Chlorophenol melts at 8.7°C and exhibits a boiling point range of 175 to 176°C (Rodd, 1954; Judson and Kilpatrick, 1949).

The spatial configuration and resonance effect of 2-chlorophenol may suppress the activity of the halogen atom by hydrogen bonding, which partly accounts for the lower toxicity than the 3- and 4-chlorophenol isomers (Huang and Gloyna, 1968).

In aqueous solution, 2-chlorophenol is slightly soluble (1,000 mg/l) at 25°C and neutral pH (Henshaw, 1971; U.S. EPA, 1973). The log of the octanol/water partition coefficient for 2-chlorophenol is 2.16 (U.S. EPA, 1978). 2-Chlorophenol is weakly acidic, possesses a pKa of 8.48 in water at 25°C, and dissociates in alkaline solutions (Judson and Kilpatrick, 1949; Pearce and Simpkins, 1968). Its monovalent salts, in particular, are soluble in aqueous solutions, and the degree of solubility is pH-dependent.

Information concerning the presence and fate of 2-chlorophenol is incomplete or nonexistent. However, the generation of waste sources from the

commercial production of 2-chlorophenol, its chemically derived products, and the inadvertent synthesis of 2-chlorophenol due to chlorination of phenol in effluents and drinking water sources, may clearly indicate its importance in potential point source and non-point source water contamination.

The chlorination of phenol from dilute aqueous solutions (Aly, 1968; Barnhart and Campbell, 1972) and from sewage effluents (Jolley, 1973; Jolley, et al. 1975) has been demonstrated.

Microbial degradation of 2-chlorophenol under laboratory conditions has been reported. Studies on the metabolism of the herbicide, 2,4-dichlorophenoxyacetic acid (2,4-D), have demonstrated the dechlorination and aromatic ring degradation of 2-chlorophenol by an Arthrobacter species (Loos, et al. 1966). Nachtigall and Butler (1974) reported the complete oxidation of 2-chlorophenol by Pseudomonas sp. isolated from activated sludge.

REFERENCES

Aly, O.M. 1968. Separation of phenols in waters by thin-layer chromatography. Water Res. 2: 587.

Barnhart, E.L. and G.R. Campbell. 1972. The effect of chlorination on selected organic chemicals. U.S. Government Printing Office, Washington, D.C.

Henshaw, T.B. 1971. Adsorption/filtration plant cuts phenols from effluent. Chem. Eng. 78: 47.

Huang, J. and E.F. Gloyna. 1968. Effect of organic compounds on photosynthetic oxygenations. I. Chlorophyll destruction and suppression of photosynthetic oxygen production. Water Res. 2: 317.

Jolley, R.L. 1973. Chlorination effects on organic constituents in effluents from domestic sanitary sewage treatment plants. Ph.D. dissertation. University of Tennessee.

Jolley, R.L., et al. 1975. Chlorination of cooling water: A source of environmentally significant chlorine-containing organic compounds. Proc. 4th Natl. Symp. Radioecology. Corvallis, Oregon.

Judson, D.M. and M. Kilpatrick. 1949. The effects of substituents on the dissociation constants of substituted phenols. I. Experimental measurements in aqueous solutions. Jour. Am. Chem. Soc. 74: 3110.

Loos, M.A., et al. 1966. Formation of 2,4-dichlorophenol and 2,4-dichlorophenoxyacetate by Arthrobacter sp. Can. Jour. Microbiol. 13: 691.

Nachtigall, M.H. and R.G. Butler. 1974. Metabolism of phenols and chlorophenols by activated sludge microorganisms. Abstr. Annu. Meet. Am. Soc. Microbiol. 74: 184.

Pearce, P.J. and R.J.J. Simpkins. 1968. Acid strengths of some substituted picric acids. Can. Jour. Chem. 46: 241.

Rodd, E.H. 1954. Chemistry of Carbon Compounds. III-A. Aromatics. Elsevier Publishing Co., Amsterdam.

Sax, N.I. 1975. Dangerous Properties of Industrial Materials. 4th ed. Van Nostrand Reinhold Co., New York.

Stecher, P.G. (ed.) 1968. The Merck Index. 8th ed. Merck and Co., Rahway, New Jersey.

U.S. EPA. 1973. Preliminary environmental assessment of chlorinated naphthalenes, silicones, fluorocarbons, benzene polycarboxylates, and chlorophenols. Syracuse Univ. Res. Corp., Syracuse, New York. U.S. Environ. Prot. Agency.

U.S. EPA. 1978. In-depth studies on health and environmental impacts of selected water pollutants. EPA Contract No. 68-010-4646. U.S. Environ. Prot. Agency, Cincinnati, Ohio.

Aquatic Life Toxicology*

INTRODUCTION

Most of the toxicity data available for 2-chlorophenol have been acquired under static testing conditions without chemical measurements. Although this compound is quite soluble in water, one would expect some loss of the chemical through absorption by the animals and by the testing environment, which could result in a low estimate of toxicity. Only one chronic test has been conducted, and since no threshold level was attained, the data have limited value. Although 2-chlorophenol does not appear to be extremely toxic to freshwater aquatic life, it has been shown to impair the flavor of the edible portions of fish at very low concentrations.

No data are available on the effects of 2-chlorophenol on saltwater aquatic life.

EFFECTS

Acute Toxicity

Ten acute tests have been conducted on four fish and one invertebrate species (Table 1). Of these, only one was a flow-through test with measured concentrations. The LC_{50} values ranged from 2,580 µg/l for Daphnia magna (U.S. EPA, 1978) to 20,170 µg/l for the guppy (Pickering and Henderson, 1966). The species mean acute values (in µg/l) were 4,380 for Daphnia magna, 8,210 for bluegill, 12,370 for goldfish, 12,400 for the fathead minnow, and 20,170 for the guppy.

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*The reader is referred to the Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses in order to better understand the following discussion and recommendation. The following tables contain the appropriate data that were found in the literature, and at the bottom of each table are calculations for deriving various measures of toxicity as described in the Guidelines.

The 96-hour LC_{50} values for chlorinated phenols and bluegills are directly related to the degree of chlorination. These values decrease from 6,590 µg/l for 2-chlorophenol and 3,830 µg/l for 4-chlorophenol to 60 and 77 µg/l for pentachlorophenol.

No acute tests have been conducted with 2-chlorophenol and any saltwater species.

Chronic Toxicity

One chronic test was conducted with the fathead minnow (U.S. EPA, 1978), but no adverse effects were observed at the highest test concentration of 3,900 µg/l (Table 2). There are no data available on chronic effects on freshwater invertebrate species or on any saltwater species.

Species mean acute and chronic values are summarized in Table 3.

Plant Effects

Only one test was conducted with plants (Huang and Gloyna, 1967), and the effect level (500,000 µg/l) for a freshwater algal species indicates that plants may not be sensitive to 2-chlorophenol (Table 4).

Residues

A bioconcentration factor was found only for the bluegill (U.S. EPA, 1978). The test was conducted using ^{14}C-2-chlorophenol for 28 days at an exposure concentration of 9.2 µg/l, and the factor dermined was 214 (Table 5). The depuration rate was rapid with a half-life of less than one day.

Miscellaneous

As stated in the introduction, 2-chlorophenol was found to impair the flavor of fishes at lower concentrations than those at which it had a toxic effect (Henderson, et al. 1960; Shumway and Palensky, 1973) (Table 6). In the former study, bluegills were exposed for periods of one to four weeks to

2,000 µg/l of 2-chlorophenol and various concentrations of a number of organic nitriles. A taste panel of twelve members recorded their reaction to the cooked and coded fish samples. The only chemical that caused a definite panel reaction was 2-chlorophenol, which reaction ranged from mild to quite severe nausea. No attempt was made to establish a level of exposure which would not cause flavor impairment. The other experiment (Shumway and Palensky, 1973), was designed to provide this information. In this study, rainbow trout were exposed for 48 hours to a range of concentrations of 2-chlorophenol, and a panel of fifteen judges scored the flavor of the flesh on an increasing impairment scale of 0 to 6. The results were then plotted against exposure concentrations and graphically interpreted to arrive at an estimate of the highest concentration which would not impair the flavor of the flesh. For 2-chlorophenol, this concentration was estimated to be 60 µg/l in the exposure water.

The additional toxicity data (Table 6) do not appear to differ dramatically from the data already discussed.

Summary

The LC_{50} values for four freshwater fish and one invertebrate species and 2-chlorophenol range from 2,580 to 20,170 µg/l. The chronic data are of little value since no threshold level was reached. Flesh-tainting data indicate that the edible portions of fishes may become tainted at water concentrations as low as 2,000 µg/l. No data are available for any saltwater species and 2-chlorophenol.

CRITERIA

The available data for 2-chlorophenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 4,380 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of 2-chlorophenol to sensitive freshwater aquatic life but flavor impairment occurs in one species of fish at concentrations as low as 2,000 µg/l.

No saltwater organisms have been tested with 2-chlorophenol and no statement can be made concerning acute or chronic toxicity.

Table 1. Acute values for 2-chlorophenol

Species	Method*	LC50/EC50 (µg/l)	Species Mean Acute Value (µg/l)	Reference
		FRESHWATER SPECIES		
Cladoceran, *Daphnia magna*	S, U	7,430	-	Kopperman, et al. 1974
Cladoceran, *Daphnia magna*	S, U	2,580	4,380	U.S. EPA, 1978
Goldfish, *Carassius auratus*	S, U	12,370	12,370	Pickering & Henderson, 1966
Fathead minnow *Pimephales promelas*	S, U	11,630	-	Pickering & Henderson, 1966
Fathead minnow *Pimephales promelas*	S, U	14,480	-	Pickering & Henderson, 1966
Fathead minnow, *Pimephales promelas*	FT, M	12,400	12,400	Phipps, et al. Manuscript
Guppy *Poecilia reticulata*	S, U	20,170	20,170	Pickering & Henderson, 1966.
Bluegill, *Lepomis macrochirus*	S, U	6,590	-	U.S. EPA, 1978
Bluegill, *Lepomis macrochirus*	S, U	10,000	-	Pickering & Henderson, 1966
Bluegill (juvenile), *Lepomis macrochirus*	S, U	8,400	8,210	Henderson, et al. 1960

* S = static, FT = flow-through, U = unmeasured, M = measured

No Final Acute Value is calculable since the minimum data requirements are not met.

Table 2. Chronic values for 2-chlorophenol (U.S. EPA, 1978)

Species	Method*	Limits (µg/l)	Species Mean Chronic Value (µg/l)
FRESHWATER SPECIES			
Fathead minnow, *Pimephales promelas*	E-L	>3,900	-

* E-L = embryo-larval

No acute-chronic ratio is calculable.

Table 3. Species mean acute and chronic values for 2-chlorophenol

Number	Species	Species Mean Acute Value* (µg/l)	Species Mean Chronic Value (µg/l)	Acute-Chronic Ratio**
		FRESHWATER SPECIES		
5	Guppy, *Poecilia reticulata*	20,170	-	-
4	Fathead minnow, *Pimephales promelas*	12,400	-	-
3	Goldfish, *Carassius auratus*	12,370	-	-
2	Bluegill (juvenile) *Lepomis macrochirus*	8,210	-	-
1	Cladoceran, *Daphnia magna*	4,380	-	-

* Rank from high concentration to low concentration by species mean acute value.

**See the Guidelines for derivation of this ratio.

Table 4. Plant values for 2-chlorophenol (Huang & Gloyna, 1967)

Species	Effect	Result (µg/l)
	FRESHWATER SPECIES	
Alga, *Chlorella pyrenoidosa*	Reduction in chlorophyll in 72 hrs	500,000

Table 5. Residues for 2-chlorophenol (U.S. EPA, 1978)

Species	Tissue	Bioconcentration Factor	Duration (days)
	FRESHWATER SPECIES		
Bluegill, Lepomis macrochirus	Whole body	214	28

Table 6. Other data for 2-chlorophenol

Species	Duration	Effect	Result (µg/l)	Reference
		FRESHWATER SPECIES		
Rainbow trout, *Salmo gairdneri*	48 hrs	ETC*	60	Shumway & Palensky, 1973
Goldfish, *Carassius auratus*	8 hrs	42% mortality	31,100	Gersdorff & Smith, 1940
Goldfish, *Carassius auratus*	24 hrs	LC50	16,000	Kobayashi, et al. 1979
Fathead minnow, *Pimephales promelas*	192 hrs	LC50	6,340	Phipps, et al. Manuscript
Bluegill, *Lepomis macrochirus*	1 wk	Flavor impairment	2,000	Henderson, et al. 1960
Bluegill (juvenile), *Lepomis macrochirus*	48 hrs	LC50	8,100	Lammering & Burbank, 1960

*ETC = the highest estimated concentration of material that will not impair the flavor of flesh of exposed fish.

REFERENCES

Gersdorff, W.A. and L.E. Smith. 1940. Effect of introduction of the halogens into the phenol molecule on toxicity to goldfish. I. Monochlorophenols. Am. Jour. Pharmacol. 112: 197.

Henderson, C., et al. 1960. The effect of some organic cyanides (nitriles) on fish. Proc. 15th Ind. Waste Conf., Purdue Univ., Eng. Bull. Ed. 45: 120.

Huang, J. and E. Gloyna. 1967. Effects of toxic organics of photosynthetic reoxygenation. Environ. Health Engin. Res. Lab. PB 216-729.

Kobayashi, K., et al. 1979. Relation between toxicity and accumulation of various chlorophenols in goldfish. Bull. Japan Soc. Sci. Fish. 45: 173.

Kopperman, H.L., et al. 1974. Aqueous chloronation and ozonation studies. I. Structure-toxicity correlations of phenolic compounds to Daphnia magna. Chem. Biol. Inter. 9: 245.

Lammering, M.W. and N.C. Burbank. 1960. The toxicity of phenol, o-chlorophenol and o-nitrophenol to bluegill sunfish. Engin. Bull., Purdue Univ. Engin. Ext. Serv. 106: 541.

Phipps, G.L., et al. The acute toxicity of phenol and substituted phenols to the fathead minnow. (Manuscript)

Pickering, Q.H. and C. Henderson. 1966. Acute toxicity of some important petrochemicals to fish. Jour. Water Pollut. Control Fed. 38: 1419.

Shumway, D.L. and J.R. Palensky. 1973. Impairment of the flavor of fish by water pollutants. U.S. Environ. Prot. Agency, EPA-R3-73-010, U.S. Government Printing Office, Washington, D.C.

U.S. EPA. 1978. In-depth studies on health and environmental impacts of selected water pollutants. U.S. Environ. Prot. Agency, Contract No. 68-01-4646.

Mammalian Toxicology and Human Health Effects

INTRODUCTION

The potential for exposure of man to any synthetic chemical exists through any of several modes. These modes include: 1) exposure of industrial workers during synthesis, formulation, packaging, or transport; 2) exposure of users of the product at either a commercial or retail level; 3) contact with residues or metabolites of the product as a result of using commodities or environments containing the material; and 4) contact with the chemical as a metabolite of some other product.

To understand the route of entry of a chemical, one must first examine the sources and properties of the material. 2-Chlorophenol is a commercially produced chemical used as an intermediate in the production of other chemicals, and represents a basic chemical feedstock for the manufacture of higher chlorophenols.

Direct chlorination of phenol leads to the formation of both 2- and 4-chlorophenols. These isomers can be separated by fractional distillation, since the difference in their boiling points is greater than 40°C. Most of the commercially used 2-chlorophenol in the U.S. is recovered as a byproduct of the manufacture of 4-chlorophenol by direct chlorination of phenol.

The chlorination of phenol in aqueous solutions to form 2-chlorophenol and higher phenols has been demonstrated under conditions similar to those used for the disinfection of wastewater effluents and may represent a source of contamination (Aly, 1968; Barnhart and Campbell, 1972). Since chlorine and phenol do not normally occur in stoichiometric amounts, the concentrations of 2-chlorophenol actually produced in H_2O are likely to be lower than those found in experimental studies (Barnhart and Campbell, 1972).

Higher levels of chlorination become increasingly less favored. 2-Chlorophenol has been synthesized from phenol and chlorine at concentrations as low as 10 and 20 mg/l, respectively, within one hour (Barnhart and Campbell, 1972). Other studies have demonstrated the formation of 2-chlorophenol (1.7 µg/l) and numerous other chlorinated compounds during the chlorination of sewage effluents and power plant cooling waters (Jolley, 1973; Jolley, et al. 1975).

EXPOSURE

Ingestion from Water

2-Chlorophenol may exist in the aquatic environment in the dissolved form, associated with suspended matter and bottom sediments, and absorbed in biological tissues. Metal salts of this compound have greater water solubility, and if introduced or formed *in situ* would exist primarily in the dissolved form. Chlorophenols, being weak acids tend to ionize, depending upon the pH of the system. They are almost completely nonionized in aqueous solutions with a pH lower than 5, and become increasingly dissociated as the pH rises (Cserjesi, 1972).

No information could be found on the amounts of 2-chlorophenol present in finished water intended for human consumption.

In one study, industrial waste discharge was the principal point source of water pollution. During the manufacture of chlorophenols and 2,4-D, there is chemical waste generated as the result of incomplete reaction of the starting reactants, by-product formation, and incomplete recovery of desired products. Thus, the wastes contain a mixture of chlorophenols and other compounds. Waste arising from the manufacture of phenoxyalkanoic herbicides showed amounts of 2-chlorophenol ranging from a trace to 6 percent (Sidwell, 1971) (Tables 1 and 2) of the total phenols and chlorophenols.

TABLE 1

Chlorophenols in Industrial Plant Waste*

Date	25 January	3 March	21 April	28 May	27 August
Temp. °C	12	18	21	28.5	24
pH	7.5	7.6	7.4	7.4	7.0
Chlorophenols (mg/l)	68	118	125	112	74
Phenoxy Acids (mg/l)	167	183	241	235	199
Total Solids (mg/l)	6,960	40,100	76,320	104,860	11,000

*Source: Sidwell, 1971

TABLE 2

Relative Chlorophenol Content of Industrial Waste*

Date	25 January	3 March	21 April	28 May	27 August
Phenol Type	Percent of Total Phenols Present				
2-chloro	2.9	6.1	trace	trace	trace
phenol	3.4	6.2	1.7	24.8	trace
2,6-DCP	9.9	41.7	38.8	30.5	3.0
2,5-DCP	trace	6.2	1.7	trace	1.8
2,4-DCP	73.6	17.9	20.0	11.4	89.0
2,4,6-TCP	2.8	9.9	19.5	13.3	3.4
4-chloro	2.5	12.1	18.3	20.0	2.8
2,4,5-trichloro	4.7	trace	trace	trace	trace

*Source: Sidwell, 1971

Other possible point sources are chemical spills and the washing of containers or drums in which chlorophenols or the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) are stored.

Contamination of water with 2-chlorophenol may occur by (1) chlorination of phenol present in natural water and primary and secondary effluents of waste treatment plants (Burttschell, et al. 1959; Eisenhauer, 1964; Barnhart and Campbell, 1972), (2) direct addition of the chemicals or as contaminants or degradation products of 2,4-D used for aquatic weed control, and (3) wet and dry atmospheric fallout.

No direct data were found to show actual measured concentrations of 2-chlorophenol in water courses, impoundments, wells, or other human water supply sources.

Based on the relatively limited sources of water contamination by 2-chlorophenol, as well as the demonstrated decomposition in many aquatic situations, water should be a minor route of ingestion of 2-chlorophenol.

2-Chlorophenol may be removed from water by several mechanisms. One study (Ettinger and Ruchhoft, 1950) indicates that the dissipation of 2-chlorophenol is largely microbiological. Persistence appears to be short, but limnological factors, such as oxygen deficiency, may delay degradation (Aly and Faust, 1964). Microorganisms found in activated sludge and waste lagoons have been demonstrated to degrade 2-chlorophenol rather readily (Sidwell, 1971; Nachtigall and Butler, 1974).

Ettinger and Ruchhoft (1950) found that low concentrations (1 mg/l) of 2-chlorophenol added to a usual dilution of domestic sewage were not removed during periods of 20 to 30 days, presumably due to the absence of microorganisms capable of attacking the chemical. When a similar concentration was added to polluted river waters, the compound dissipated in 15 to 23 days.

Addition of a seed, consisting of water from a previous persistence experiment, increased significantly the removal of 2-chlorophenol. Apparently, the seed introduced some organisms already adapted to the chemical. This study also indicated that the removal of monochlorophenols requires the presence of an adapted microflora.

Ingols, et al. (1966) obtained data indicating the dechlorination of 2-chlorophenol and other monochlorophenols within three days of exposure to an activated sludge system (Table 3).

Primary treatment consists essentially of settling solids, after screening off large materials. Settling may not remove 2-chlorophenol from water, since it is adsorbed poorly on particulate or suspended matter.

Secondary treatment involves the removal of organic matter from waste water by biological processes. Since 2-chlorophenol and 2,4-dichlorophenol (2,4-DCP) are known to be easily biodegradable, secondary treatment should provide excellent removal of these chemicals.

Baird, et al. (1974), employing Warburg respiratory techniques, demonstrated that biodegradation of 2-chlorophenol at 1 mg/l in activated sludge was complete within three hours. Increasing the concentration to 100 mg/l considerably reduced the rate of respiration such that only 20 percent was degraded in six hours. This is probably due to microbial toxicity from 2-chlorophenol at this concentration. In a sludge not acclimated with high levels of 2-chlorophenol, certain amounts of the compound may be degraded initially, while oxidative intermediates that appear subsequently could be toxic to the microbial population. This indicates that 2-chlorophenol may persist longer, due to direct or indirect toxic effects, if waste containing high levels of the chemical is discharged into an unacclimated body of water.

TABLE 3

Degradation of Chlorophenols in Acclimated, Activated Sludge[a,b]

Compound	Amount of ring degradation of compound		Development of Chloride Ion	
	%	days	%	days
2-chlorophenol	100	3	100	4
3-chlorophenol	100	2	100	3
4-chlorophenol	100	3	100	3
2,4-DCP	100	5	100	5
2,5-DCP	52	4	16	4
2,4,6-TCP	100	3	75	3
NaPCP	0	4	0	4
Dichloroquinone	100	1	50	3
2,5-DCP benzoquinone	30	1	0	1

[a]Source: Modified from Ingols, et al. 1966
[b]Concentration of 100 mg/l

While a number of studies indicate rapid dissipation of 2-chlorophenol from waters by several mechanisms, human exposure cannot be fully evaluated unless studies are conducted measuring the 2-chlorophenol content in waters receiving wastes from point sources of chlorophenols or their precursors. Evidence of such studies was not found.

Ingestion from Food

Contamination of human foods with 2-chlorophenol could occur via soil, plants, animals, or aquatic sources. In all cases, any contamination is probably indirect and primarily a result of the use and subsequent metabolism of phenoxyalkanoic herbicides.

In 1971, U.S. farmers applied almost 16,000,000 kg of 2,4-D, representing 15 percent of all organic herbicide usage [U.S. Department of Agriculture (USDA), 1974].

Although 2-chlorophenol appears to be short-lived in soils, the data are inconclusive, and factors affecting its persistence need further study. However, microbial degradation is the apparent major route of dissipation for chlorophenols in soils. For 2,4-DCP, which is more likely to reach the soil system as a contaminant and degradation product of 2,4-D, its degradation under field conditions could be faster than degradation of the herbicide itself. The role of microorganisms in the degradation of 2,4-D has been conclusively demonstrated (Loos, 1975), and under favorable conditions 2,4-D disappears from soils in about 30 days (Kearney, et al. 1969). Warm, moist, well-aerated soils with ample organic matter content promote the proliferation of microorganisms known to metabolize 2,4-D. One of the chemicals in the metabolic pathway may be 2-chlorophenol. Limited information indicates the biodegradability of 2-chlorophenol (Walker, 1954; Baird, et al. 1974). Several genera of bacteria isolated from soil are capable of

metabolizing 2-chlorophenol. Pseudomonas sp., Nocardia sp., Mycobacterium coeliacum, and Bacillus sp. were demonstrated to oxidize 2-chlorophenol to 3-chlorocatechol (Spokes and Walker, 1974). The fate of the catechol intermediate was elucidated in a study by Evans, et al. (1971) of the metabolism of 2,4-D by Pseudomonas sp. Using 2,4-D as sole carbon source for Pseudomonas strains isolated from soil, the herbicide was metabolized to 2,4-DCP, 2-chlorophenol, 3,5-dichlorocatechol, and α-chloromuconate, which was further metabolized to release Cl^- and unidentified metabolites. The appearance in culture of 2-chlorophenol suggests the nonoxidative elimination of chlorine from 2,4-DCP or, possibly, 2,4-D itself. The accumulation of α-chloromuconate is probably a further manifestation of this phenomenon, since it is likely formed by enzymatic cleavage of 3-chlorocatechol, derived from either 2-chlorophenol or 3,5-dichlorocatechol.

It is probable that the sorption behavior of 2-chlorophenol is similar to 2,4-D. In natural soil systems, sorption may not be extensive, thereby favoring downward movement in soil with water.

The persistence of 2-chlorophenol in soils was studied by Walker (1954) using the percolation technique. Solutions of 2-chlorophenol (1.0 g/4 l tap water) were allowed to percolate through 100 g of a Rothamsted soil (light clay with a pH of 6.8), and the disappearance of the initial and subsequent doses was measured. Two-thirds of the initial dose disappeared in 10 days. Disappearance of subsequent doses occurred approximately twice as rapidly as that of the first dose, suggesting microbial participation. Further evidence of microbial decomposition was indicated by the more rapid disappearance of 2-chlorophenol in fresh than in sterilized soil within seven days of percolation.

Furthermore, the participation of soil microorganisms in the dissipation of 2-chlorophenol and other chlorophenols was reported by Alexander and Aleem (1961) using suspensions of two silt loam soils. Metabolism of the chemicals was evidenced by more rapid disappearance of incremental additions of the compounds than initial enrichments. Also, inhibition of degradation occurred on addition of sodium azide, a toxic agent. 2-Chlorophenol disappeared rapidly in suspensions of Dunkirk and Mardin silt loams; disappearance was faster for the latter soil.

No information was found on the uptake, absorption, and translocation of 2-chlorophenol by plants. The movement of 2-chlorophenol can only be inferred from the few available studies of 2,4-DCP in plants and from the potential for 2-chlorophenol to occur as a metabolic intermediate in the degradation of 2,4-D.

The metabolism of 2-chlorophenol in vascular plants is not well studied. The only available report demonstrated that 2-chlorophenol may be inactivated by glycoside formation in plant tissue. It has been demonstrated that when certain nonnaturally occurring chemicals are absorbed by various plants, glycoside formation takes place with the foreign chemical serving as the aglycon. Miller (1941) demonstrated that the metabolic fate of 2-chlorophenol in tomato plants included glycoside formation. 8-O-chlorophenyl-gentiobioside (a glycoside of 2-chlorophenol) was isolated from the roots of these tomato plants. No evidence for the formation of this glycoside in shoots was found. The fate of this metabolic product of 2-chlorophenol in plants is not known and warrants further investigation.

Domestic animals, including poultry, could ingest feeds containing pesticides or drink water contaminated directly with 2-chlorophenol and 2,4-DCP. Although some studies indicate the appearance and distribution of

2,4-DCP in tissues of animals fed with 2,4-D and Nemacide® [O-(2,4-dichlorophenol)-O,O-diethylphosphorothioate] (Clark, et al. 1975; Sherman, et al. 1972), in none of the studies was there evidence cited to indicate residues of 2-chlorophenol. Furthermore, Bjerke, et al. (1972) reported no contamination of milk and cream from cows given a 2,4-D (100 to 1,000 mg/kg) diet.

A bioconcentration factor (BCF) relates the concentration of a chemical in aquatic animals to the concentration in the water in which they live. The steady-state BCF for a lipid-soluble compound in the tissues of various aquatic animals seems to be proportional to the percent lipid in the tissue. Thus, the per capita ingestion of a lipid-soluble chemical can be estimated from the per capita consumption of fish and shellfish, the weighted average percent lipids of consumed fish and shellfish, and a steady-state BCF for the chemical.

Data from a recent survey on fish and shellfish consumption in the United States were analyzed by SRI International (U.S. EPA, 1980). These data were used to estimate that the per capita consumption of freshwater and estuarine fish and shellfish in the United States is 6.5 g/day (Stephan, 1980). In addition, these data were used with data on the fat content of the edible portion of the same species to estimate that the weighted average percent lipids for consumed freshwater and estuarine fish and shellfish is 3.0.

A measured steady-state bioconcentration factor of 214 was obtained for 2-chlorophenol, using bluegills containing about 1 percent lipids (U.S. EPA, 1978). An adjustment factor of 3.0/4.8 = 0.625 can be used to adjust the measured BCF from the 3.0 percent lipids of the bluegill to the 2.3 percent lipids that is the weighted average for consumed fish and shellfish. Thus,

the weighted average bioconcentration factor for 2-chlorophenol and the edible portion of all freshwater and estuarine aquatic organisms consumed by Americans is calculated to be 214 x 0.625 = 134.

Inhalation

The dispersal and distribution of 2-chlorophenol in air has apparently not been studied. One potential source of environmental pollution by 2-chlorophenol, however, is the manufacture of 2,4-D herbicides. Secondly, since 2-chlorophenol is volatile (1 mm Hg at 12°C), any 2-chlorophenol generated as a decomposition product of applied 2,4-D could be subject to general environmental dispersal. A third possibility for inhalation exposure could be the burning of containers, trash, or plant material contaminated with 2-chlorophenol. No data addressing the monitoring of air or workplace environments for 2-chlorophenol have been found. Therefore, the potential sources for human exposure through inhalation remain speculative.

Because of the volatility of 2-chlorophenol and the processes employed in its manufacture, the most probable source of inhalation exposure to 2-chlorophenol would occur in manufacturing plants producing 2-chlorophenol or possibly 2,4-D. The separation of 2-chlorophenol from 2,4-dichlorophenol involves fractional distillation which, if not done with regard to worker safety, could result in exposure by inhalation. The potential for airborne exposure to 2-chlorophenol in the general environment as a result of point source pollution has not been reported.

Although inhalation exposure to 2-chlorophenol associated with related products in general use (e.g., 2,4-D herbicide) does not seem likely, no data to verify atmospheric 2-chlorophenol presence or absence under such conditions have been found. Potential for such exposure seems quite low for several reasons. First, the principal general environmental source of

2-chlorophenol would be 2,4-D or its decomposition products. Since there is little evidence of 2-chlorophenol occurring as a permanent soil or plant metabolite of 2,4-D, the amount available to be volatilized would be either limited or absent. Secondly, any 2-chlorophenol which might be formed in soil or water is rapidly degraded by microorganisms (see Ingestion section), while 2-chlorophenol in plants is inactivated as a glycoside (Miller, 1941).

A third potential route of exposure, the burning of chlorophenol-containing products, has not been studied. Incineration of phenoxy herbicides should be accompanied by investigations of potential formation and/or dispersal of 2-chlorophenol, as well as other chlorophenols.

Direct studies of potential or actual exposure to 2-chlorophenol have not been found. However, after considering the nature of the production, uses, and persistence of 2-chlorophenol, inhalation exposure of the general population does not seem a significant threat, except for specific occupational settings in cases of large accidental spills. A recent case involving potential exposure of the general population to 2-chlorophenol is included here for reference purposes.

On January 11, 1979, a chemical spill occurred at Sturgeon, Missouri, as a result of a train derailment. Ortho-chlorophenol and phenol were major components of the spilled material. As a result, U.S. Environmental Protection Agency personnel were asked to supervise the clean-up of the spill.

Values of ortho-chlorophenol determined by the U.S. EPA (Fairless, 1979) at several dates after the spill are as follows:

Date of Collection 1979	2-Chlorophenol Concentration in Air (ppm)
January 11	0.013
January 11	0.004
January 11	0.190
January 29	<0.0005
January 29	<0.0005
January 29	<0.0005
March 6	<0.0003
March 6	<0.0003
March 6	<0.0003
March 6	0.0029

Analyses for 2-chlorophenol were made from the urine of several individuals working or residing in Sturgeon, Missouri, within several months after the spill. Results of those analyses conducted for the American Public Health Association (1979) are as follows:

1. Four adult males assisting in clean-up operations at the spill site had a mean 2-chlorophenol urine concentration of 1.98 ppm (range 1.4 - 2.6) on March 7, 1979. By April 11, 1979, when these same four individuals were again sampled, all had no detectable amount of 2-chlorophenol in their urine, (detection limit 0.25 ppm).

2. Nine persons residing in Sturgeon, Missouri within 40 to 200 feet of the spill site all had no detectable amount of 2-chlorophenol in their urine when sampled on April 11, 1979. These nine persons had no history of direct contact with 2-chlorophenol at the spill site and did not assist in clean-up operations. The only obvious source of exposure to 2-chlorophenol would have been via inhalation of chlorophenol from the atmosphere in Sturgeon.

   It should be noted that even though extremely low levels of 2-chlorophenol were measured by the U.S. EPA, a noticeable odor of chlorophenols could be detected for several months after the spill. Thus, organoleptic detection of chlorophenols is possible, even when measurable levels in air or urine cannot be found.

Dermal

2-Chlorophenol dermal absorption data have not been found. Since the compound is lipid soluble and likely to be poorly ionized at an environmental pH (Farquharson, et al. 1958), it could be readily absorbed through intact skin. Dermal absorption and resultant body burdon merit study.

As indicated for inhalation exposure, the only potentially significant dermal exposure to 2-chlorophenol would occur in the manufacture of handling of 2-chlorophenol or products which contain it. Ordinary and accepted methods of skin protection would be expected to prevent dermanl exposure to 2-chlorophenol. Dermal exposure to 2-chlorophenol from other sources (soil water, plant metabolites of 2,4-D) is considered to be insignificant for the same reasons as stated in the section on inhalation.

PHARMACOKINETICS

Absorption

Direct data on the absorption of 2-chlorophenol by man or experimental animals have not been found. Chlorophenol compounds are generally considered readily absorbed, as would be expected from their high lipid solubility and low degree of ionization at physiological pH (Doedens, 1963; Farquharson, et al. 1958). Although skin irritation and dermal absorption are reported as characteristic of monochlorophenols, direct quantitative data concerning the irritant potential of 2-chlorophenol have not been found. Toxicity studies to be discussed later indicate that 2-chlorophenol can be absorbed and can result in toxicosis; however, quantitative data for 2-chlorophenol absorption by various routes have not been found.

2-Chlorophenol may occur in mammals as a metabolite of other compounds. Exposure of rabbits to chlorobenzene has resulted in the formation of 2-chlorophenol (Lindsay-Smith, et al. 1972).

In addition, Selander, et al. (1975) reported the conversion of chlorobenzene to a mixture of monochlorophenols in perfused rat liver. Apparently, three different enzyme systems catalyze the conversion of chlorobenzene to 2-, 3-, and 4-chlorophenols.

Investigation of 2,4-D metabolism in mammals (Clark, et al. 1975) has not indicated 2-chlorophenol to be a metabolite of such exposure, while 2,4-DCP is considered the major metabolite.

Distribution

Direct information about the distribution and transportation of 2-chlorophenol is not available. However, at least two reports (Spencer and Williams, 1950; von Oettingen, 1949) on the rabbit and dog, respectively, indicate urinary excretion of 2-chlorophenol. Furthermore, since metabolites of 2-chlorophenols are identified as glucuronide and sulfate conjugates, it is possible that the liver might contain proportionally large amounts of 2-chlorophenol. Two reports concerning lesions induced by 2-chlorophenol (Patty, 1963; Bubnov, et al. 1969) indicate changes in liver and kidney, thus visually confirming the renal and hepatic distribution. No information concerning hepatic excretion or any indication of an enterohepatic cycle was found. While compounds of high lipophilia (which would include 2-chlorophenol) are often considered to accumulate in adipose tissue, no information to this effect was found for 2-chlorophenol. In fact, related compounds (2,4-dichlorophenol and pentachlorophenol) are considered to have relatively short half-lives (Clark, et al. 1975; Osweiler, et al. 1977). Whether this is true for 2-chlorophenol remains to be established. Since animals dosed with 2-chlorophenol display convulsive activity within several minutes of exposure (Farquharson, et al. 1958; Angel and Rogers, 1972), it can be assumed that the compound traverses the blood brain barrier and is distributed

in part in the central nervous system. The concentrations of 2-chlorophenol in brain and other organs or tissues during toxicosis remain to be determined.

Metabolism

The metabolism of 2-chlorophenol in man is not known. n experimental animals, von Oettingen (1949) cites work by Karpow (1893) showing that dogs excreted 87 percent of administered 2-chlorophenol as conjugates with sulfate and glucuronic acid. The rabbit also apparently conjugates 2-chlorophenol derived from chlorobenzene exposure (Lindsay-Smith, et al. 1972) by formation of sulfate and glucuronide conjugates. However, 2-chlorophenol was reported as only a minor metabolite of chlorobenzene in the rabbit (Lindsay-Smith, et al. 1972). Furthermore, only a small portion of the chlorophenols formed were monochlorophenols, and less than 6 percent of the free and metabolized chlorophenols was the 2-chlorophenol isomer.

Selander, et al. (1975) demonstrated that chlorobenzene is converted to o-, m-, and p-chlorophenols in perfused rat livers, as well as by noncellular systems including microsomes, post mitochondrial supernatant, and reconstituted soluble hemoprotein monooxygenase systems. Pretreatment with the inducing agents 3-methylcholanthrene and phenobarbital increased the formation of chlorophenols, while carbon monoxide and SKF 525A® (β-diethylaminoethyl diphenylpropylacetate) inhibited formation of o-, m-, and p-chlorophenols. The approximate in vivo ratios for formation of o-, m-, and p-chlorophenol were 1:2:4, respectively. Thus, formation of 2-chlorophenol via metabolism of chlorobenzene does not appear to be a significant or major route of exposure. While it is possible that 2-chlorophenol could form in man or animals as a result of exposure to phenoxyacetic acid herbicides, there are no data to support this conjecture. In fact, Clark, et al.

(1975), in studies of the metabolism of phenoxy herbicides, reported the major metabolite to be 2,4-DCP and did not mention detection of 2-chlorophenol.

Based on experimental work in two species (dogs and rabbits), it appears that mammalian metabolism of 2-chlorophenol follows the expected route for phenol metabolism (i.e., formation of conjugates of glucuronides and sulfates, with detection of these metabolites primarily in the urine).

Excretion

Studies of the excretion route or rate for 2-chlorophenol in man were not found. As mentioned before, von Oettingen (1949) reviewed the data of Karpow (1893), in which dogs given 2-chlorophenol excreted 87 percent of the compound in urine as sulfate and glucuronide conjugates. However, data were not developed from which the rate of excretion or half-life could be calculated. Lindsay-Smith, et al. (1972) identified phenolic metabolites in rabbit urine after administration of chlorobenzene. Of the free and conjugated forms of chlorophenols in rabbit urine, less than 6 percent was present as 2-chlorophenol.

No data have been found concerning measurement of tissue residues of 2-chlorophenol, either from direct administration or by formation as a metabolite of other compounds, nor have sufficient data accumulated to allow calculation of a half-life for 2-chlorophenol.

EFFECTS

Acute, Subacute, and Chronic Toxicity

The acute toxicity of 2-chlorophenol has been studied in a variety of organisms. The compound is considered to be an uncoupler of oxidative phosphorylation (Mitsuda, et al. 1963) and a convulsant poison (Farquharson, et al. 1958; Angel and Rogers, 1972). No reports of the subacute or chronic

toxicity of 2-chlorophenol have been found. This represents a serious data gap in the toxicologic evaluation of 2-chlorophenol.

Mammalian toxicity of 2-chlorophenol has not been well studied. There are no reports of human or domestic animal toxicoses from accidental or intentional exposure to 2-chlorophenol. Furthermore, there is no evidence linking 2-chlorophenol exposure in industrial workers to the chloracne, an effect often associated with higher chlorophenols (Huff and Wassom, 1974), nor is there evidence to suggest that the toxic dioxins are contaminants of, or are formed from, 2-chlorophenol.

Doedens (1963) briefly characterized the toxicity of 2-chlorophenol as being "likely" to be corrosive and irritating to the eyes and skin. However, specific data on the effects of 2-chlorophenol were not presented. The data from relatively few acute toxicological studies in laboratory animals are the only ones from which an evaluation of 2-chlorophenol can be made (Table 4). It may be seen by inspection of Table 4 that the subcutaneous minimum lethal dose (MLD) of 2-chlorophenol in the rabbit (950 mg/kg) is approximately 8 times that of the intravenous MLD, implying that the subcutaneous route retards bioavailability of 2-chlorophenol. At a physiological pH of 7.4, however, 2-chlorophenol is approximately only 5 percent ionized (Farquharson, et al. 1958); such a low degree of ionization would not account for this lessening of toxicity by the subcutaneous route.

The LD_{50} data in Table 4 indicate that 2-chlorophenol is more toxic by the oral than the subcutaneous route. At relatively acidic pH (e.g., stomach), the pKa of 2-chlorophenol (8.65) would allow for a highly unionized state, which is conducive to ready absorption from the stomach or the less acidic upper intestine. This effect could explain the greater oral toxicity of 2-chlorophenol.

TABLE 4

Lethal Doses of 2-Chlorophenol for Experimental Animals

Animal	Route of Administration	LD_{50} (mg/kg)	Source
Rat	Oral	670	Deichmann, 1943
Rat	Subcutaneous	950	Deichmann, 1943
Albino rat	Intraperitoneal	230[a]	Farquharson, et al. 1958
Rabbit	Subcutaneous	950	Christensen and Luginbyhl, 1975
Rabbit	Intravenous	120[a]	Kuroda, 1926, cited in von Oettingen, 1949
Mouse	Oral	670	Bubnov, et al. 1969
Guinea pig	Subcutaneous	800[a]	Christensen and Luginbyhl, 1975
Blue fox	Oral	440	Bubnov, et al. 1969
Unknown mammal	Oral	440	Christensen and Luginbyhl, 1975

[a]MLD (minimum lethal dose) values

Among the various species tested by the same route, there is a surprising similarity among acute toxicities. This would imply that initial absorption, metabolism, detoxification, and affected organs are quite similar among various species. It would be expected then that chronic toxicity would vary according to ability of a species to metabolize, inactivate, and excrete 2-chlorophenol on a long term basis. Unfortunately, studies of long term or chronic effects have not been reported.

Signs of 2-chlorophenol intoxication in rats are similar, whether the compound is administered subcutaneously, intraperitoneally, or orally. The toxicological picture includes restlessness and increased rate of respiration within a few miniutes following administration. Somewhat later, motor weakness develops, and tremors and convulsions induced by noise or touch occur. Eventually, dyspnea and the appearance of coma result and continue until death (Farquharson, et al. 1958). Following fatal poisoning, lesions in the rat include marked kidney injury, red blood cell casts in the tubules, fatty infiltration of the liver, and hemorrhages in the intestine (Patty, 1963). Bubnov, et al. (1969) report a similar pathological picture in the blue fox and the mouse. At lethal concentrations, 2-chlorophenol caused fatty degeneration of the liver, renal granular dystrophy, and necrosis of the stomach and intestinal mucosa. These signs are very similar to acute phenol toxicosis (Patty, 1963).

The convulsive action of 2-chlorophenol in mice was studied by Angel and Rogers (1972). Following intraperitoneal administration of 2-chlorophenol, a rapid onset of convulsions was noted. A simple exponential decay of the convulsive effect was noted, which the authors speculated could have been a result of removal from the central nervous system (CNS) by a simple chemical reaction. However, no information directly addressing this point is available.

Farquharson, et al. (1958) state that as phenol is progressively chlorinated, the molar toxicity shows a tendency to increase when pK value falls below 7. Furthermore, convulsions are the most characteristic effect of chlorophenols with pK values of 8.65 or higher. Thus, it may be that convulsions are in some way associated with undissociated molecules. No studies were found which attempted to evaluate the passage of chlorophenols with different pK values across the blood-brain barrier.

Synergism and/or Antagonism

Reports of studies directly assessing the synergism or antagonism of 2-chlorophenol by other compounds were not found. Since 2-chlorophenol is a weak uncoupler of oxidative phosphorylation (Mitsuda, et al. 1963), it may be expected that concomitant exposure to other uncouplers (e.g. pentachlorophenol, dinitrophenol) would enhance that effect. In addition, exposure to chlorinated hydrocarbon insecticides, with their characteristic convulsant activity, might also produce a magnified response.

Any agent causing liver damage sufficient to decrease the conjugation of 2-chlorophenol with glucuronide or sulfate could conceivably alter the excretion and/or toxicity of the parent compound. However, there are no specific studies to reflect such an effect, it is only speculative that the general tendency of conjugation to render a compound less toxic and more amenable to excretion would also operate in the case of 2-chlorophenol.

Teratogenicity and Mutagenicity

Pertinent data could not be located in the available literature concerning the teratogenicity and mutagenicity of 2-chlorophenol.

Carcinogenicity

The report of Boutwell and Bosch (1959) is the only one found dealing with the tumorigenicity of 2-chlorophenol. Repeated application of phenol

and some substituted phenols has been reported to promote skin tumors in mice after a single initiating dose of dimethylbenzanthracene (DMBA). Papillomas have developed in mice treated with phenol alone (not exposed to DMBA). In the studies of Boutwell and Bosch (1959), two trials included evaluation of 2-chlorophenol. In one of these, 25 µl of a 20 percent solution of 2-chlorophenol was applied twice weekly to female Sutter mice two to three months of age for 15 weeks. This application followed an initiating dose of 0.3 percent DMBA in benzene. Tumorigenic response was measured as follows:

(1) The percentage of surviving mice bearing one or more papillomas was ascertained.

(2) The total number of papillomas on all surviving mice was counted and divided by the number of survivors to give the average number of papillomas per mouse.

(3) The number of mice bearing malignant tumors was determined.

Results of the promoter trial with 2-chlorophenol are presented in Table 5. Related promoter experiments with phenol, as well as the benzene control, are included for comparative purposes. Based on the data, the authors concluded that the promoting activity of 2-chlorophenol is similar to that of phenol.

In a second experiment, Boutwell and Bosch (1959) administered in a similar manner 20 percent 2-chlorophenol in dioxane, but for 12 weeks and without an initiator. Results of this trial are also included in Table 5. In both trials, 2-chlorophenol was associated with a high incidence of papillomas. When DMBA was used as an initiator, 10 percent of the survivors developed carcinoma at the skin site of application; however when 2-chlorophenol alone was used, no carcinogenic response was observed.

Since the study was designed primarily to detect promoting activity, the effect of 2-chlorophenol as a primary carcinogen is not well defined.

TABLE 5

Appearance of Skin Tumors in Mice Treated Cutaneously with Phenols Following a Cutaneous Dose of 0.3% Dimethylbenzanthracene (DMBA) in Acetone [a]

Treatments[b]	Time Animals Examine (weeks)	No. of mice (survivors/total)	Survivors with Papillomas %	Average Papillomas per Survivor	Survivors with Epithelial Carcinomas %
Benzene control	12	12/12	0	0	0
10% phenol in benzene. No DMBA.	20	24/30	33	0.62	13
20% phenol in acetone.	12	21/24	58	-	5
20% phenol in benzene.	24	10/33	100	3.20	20
20% 2-chlorophenol in benzene.	15	31/35	61	1.48	10
20% 2-chlorophenol in dioxane. No DMBA.	12	28/30	46	0.64	0

[a]Source: Modified from Boutwell and Bosch, 1959
[b]All received DMBA except where stated

The study uses dermal applications of a phenolic compound at 20 percent concentration in organic solvents. The concentration is high enough that hair follicles and sebaceous glands are destroyed, and the papillomatous response observed may have developed in response to chemical and/or physical damage from application of an irritant compound. Even with this harsh treatment, no malignant neoplasia were observed, except when DMBA had been used as an initiator. The only neoplasia observed were at the site of the direct application. This study does not evaluate systemic carcinogenesis, and the route of administration is not appropriate to the prescribed models for carcinogenic risk assessment. The route of administration (dermal) has no established relationship to oral exposure.

Odor and taste thresholds for 2-chlorophenol in water have been reported by a number of investigators. Hoak (1957) reported the odor threshold of phenol and 19 phenolic compounds. In this study conducted at the Mellon Institute in Pittsburgh, Pennsylvania, a panel of two or four persons sniffed samples of pure phenolic compounds in odor-free water, which had been heated to 30 or 60°C. A flask of plain odor-free water was provided for comparison. The various samples were placed in random order before the test persons, and the flask with the lowest perceptible odor was noted by each individual sniffer. The lowest concentration detected was considered to be the threshold of the chemicals tested; chlorinated phenols were the compounds most easily detected. The odor thresholds reported for 2-chlorophenol were 0.33 µg/l at 30°C and 2.5 µg/l at 60°C (Hoak, 1957). Hoak speculated that odor should be expected to become more noticeable as temperature increases; however, in evaluating a series of chlorophenols and cresols, it was found that some compounds had higher odor thresholds at 30°C, while others were higher at 60°C.

Burttschell, et al (1959) made dilutions of 2-chlorophenol in carbon-filtered tap water and used a panel of from four to six persons to evaluate odor and taste. Tests were carried out at room temperature, which the investigator estimated to be 25°C. If a panel member's response was doubtful, the sample was considered negative. The geometric mean (2 µg/l for odor and µg/l for taste) of the panel responses was used as the organoleptic thresholds. Since the data presented did not indicate a range of responses, it is very possible that the odor threshold for some people in the Burttschell group was near the 0.33 µg/l value of Hoak.

Campbell, et al. (1958) studied the taste thresholds of six odor-producing chemicals. Solutions of the chemicals were prepared using redistilled water. Panels of 21 or 22 experienced judges participated in different organoleptic tests of the triangle type. Concentrations of chemicals chosen for the triangle tests were such that the odd sample would be identified by more than 35, but less than 100 percent of the judges. Samples were served in 25 ml portions, and the judges were asked only to identify odd sample. When 50 percent of the judges correctly separated the samples in a given triangle test, the concentration of 2-chlorophenol used in that test was considered to be the threshold level. Although a number of judges were able to detect the presence of 2-chlorophenol at a concentration of 2 µg/l, a threshold level of 6 µg/l was reported based on the experimental methodology used. It is interesting to note that, in this same study, a concentration of 1 µg 2-chlorophenol/l was determined to be the threshold for impairment of coffee brew, while eight of the tasters noted some impairment at 0.5 µg/l.

Dietz and Traud (1978) used a panel composed of 9 to 12 persons of both sexes and various age groups to test the organoleptic detection thresholds

for 126 phenolic compounds. To test for odor thresholds, 200 ml samples of the different test concentrations were placed in stoppered odor-free glass bottles, shaken for approximately five minutes, and sniffed at room temperature (20 to 22°C). For each test, water without the phenolic additive was used as a background sample. The odor tests took place in several individual rooms in which phenols and other substances with intense odors had not been used previously. Geometric mean values were used to determine threshold levels. To determine taste threshold concentrations of selected phenolic compounds, a panel of four test individuals tasted water samples containing various amounts of phenolic additives. As a point of comparison, water without phenolic additives was tasted first. Samples with increasing phenolic concentrations were then tested. Between samples, the mouth was rinsed with the comparison water and the test person ate several bites of dry white bread to "neutralize" the taste. Geometric mean detection level values for both tests provided threshold levels of 0.1 µg/l for taste and 10 µg/l for odor for 2-chlorophenol.

None of the four organoleptic studies described above, however, indicated whether the determined threshold levels made the water undesirable or unfit for consumption.

Studies on the impairment of fish flavor by 2-chlorophenol have also been reported. Henderson, et al. (1960) found that a concentration of 2,000 µg/l caused impaired flavor of bluegill sunfish after a 28-day static, renewal exposure. Only one concentration was tested, so no dose-related threshold was determined. Shumway and Palensky (1973) found 60 µg/l to be an estimated threshold concentration during a 48-hour flow-through exposure of rainbow trout. Schulze (1961) determined that 15 µg/l affected the flavor of carp after a 3-day flow-through exposure. Boetius (1954) studied the

flavor impairment of eels and oysters (species unspecified) in static systems, and found flavor impairment in brackish water at a concentration of 0.125 µg/l after 11 days for eels and four days for oysters. Methodology for determining flavor impairment was particularly lacking in the Boetius paper. Because of the subjectivity of flavor impairment, test methodology (especially in the selection of, and evaluation by, the test panel) is particularly important in the critical evaluation of a flavor impairment study.

CRITERION FORMULATION

Existing Guidelines and Standards

As can be determined from the available literature, no standards or guidelines exist for 2-chlorophenol.

Current Levels of Exposure

Overall, exposure of the general population to 2-chlorophenol would most likely occur in the form of consumption of phenol-containing chlorinated drinking water. This would limit exposure primarily to water supplies contaminated by a point source of 2-chlorophenol. Such sources should be relatively easy to identify and monitor, since analytical techniques for detection of 2-chlorophenol are available. Apparently, such monitoring is not being done.

Since 2-chlorophenol is not a universally reported metabolite of 2,4-D, exposure of the general population through use of 2,4-D is only speculative. If small amounts of 2-chlorophenol are formed and gain access to ground water or the soil, they are not expected to persist, in view of 2-chlorophenol's ready susceptibility to microbial attack.

Inhalation or dermal exposure have not been identified as significant routes of exposure for the general population. Since 2-chlorophenol is not used directly for any broad environmental application, it is logical to expect little exposure for the general population. However, due to lack of atmospheric monitoring data, any estimates of potential exposure are purely speculative. There have been no reported investigations of the persistence, movement, and fate of 2-chlorophenol in the atmosphere (U.S. EPA, 1979).

For industrial workers manufacturing or handling 2-chlorophenol, inhalation exposure should be considered a possible hazard, since the compound is volatile. Dermal exposure could also occur, since both phenol and cer-

tain chlorophenols are known to be dermally absorbed. However, specific absorption studies for 2-chlorophenol were not found (Doedens, 1963). According to a recent review by the U.S. Environmental Protection Agency, "No data on the routes or rates of entry of 2-chlorophenol in humans were found" (U.S. EPA, 1979).

Due to the lack of monitoring data or human body burden values, the extent of human exposure cannot be determined.

Special Groups at Risk

The only special group expected to be at risk of high exposure to 2-chlorophenol is industrial workers involved in the manufacture or handling of 2-chlorophenol. No data were found to relate exposure or body burden to conditions of contact with 2-chlorophenol.

Basis and Derivation of Criterion

Insufficient data exist to indicate that 2-chlorophenol is a carcinogenic agent. The only study performed (Boutwell and Bosch, 1959) was designed to detect the promoting activity of 2-chlorophenol with dimethylbenzanthracene-initiated tumors. (Under certain environmental conditions, 2-chlorophenol may produce a small amount of dibenzo-p-dioxins.) The recent National Cancer Institute (NCI, 1978) bioassay report of possible carcinogenicity of dibenzo-o-dioxin has concluded that it was not carcinogenic for Osborne-Mendel rats or B6C3F_1 mice. Due to the absence of sufficient toxicological data on which to base a criterion, the ambient water quality criterion for 2-chlorophenol is based on organoleptic data. As substantive and reliable human and other mammalian toxicity data become available, a criterion level based upon health effects may be postulated.

The data from Hoak (1957), Burttschell, et al. (1959), and Dietz and Traud (1978) all indicated that low microgram concentrations of 2-chlorophe-

nol in water are capable of producing a discernible odor. Burttschell, et al. (1959), Campbell, et al. (1958), and Dietz and Traud (1978) further observed a distinct flavor alteration of water at low microgram or sub-microgram levels of this chemical. The Burttschell, et al. (1959) and Dietz and Traud (1978) odor studies did not indicate a range of responses; however, because of the variability inherent in such procedures, it is certainly possible that the odor threshold for some evaluators (at least in the Burttschell, et al. group) would extend downward toward the 0.33 µg/l value of Hoak. Similarly, Burttschell, et al. (1959) did not indicate a range of concentrations in their taste test, and Campbell, et al. (1958) did not test concentrations of 2-chlorophenol below 2 µg/l; so it is also possible that some of the tasters in these tests could have at least been capable of detecting, if not actually detecting in the case of the Burttschell, et al. group, concentrations of 2-chlorophenol down near the 0.1 µg/l taste threshold determined by Dietz and Traud (1978). Thus, the data from these four studies are considered to be reasonably mutually supportive (i.e., Hoak's 0.33 µg/l for odor; Burttschell, et al. group's geometric mean values of 2 µg/l for odor and 4 µg/l for taste; Campbell, et al.'s derived 6 µg/l threshold for taste; and Dietz and Traud's geometric mean values of 10 µg/l for odor and 0.1 µg/l for taste).

The taste threshold determined by Dietz and Traud (1978) for the detection of 2-chlorophenol in water is used as the basis for the ambient water quality criterion. The Dietz and Traud study was chosen for a number of reasons. These authors present a recent study involving well-defined procedures and a number of documented controls. This study utilized "fresh" water from the base outlet of the Verse Dam (Germany) for all experiments. The water was described as clear and neutral with respect to both odor and

taste. These conditions are considered to more closely approximate the conditions of ambient water found in lakes, rivers, and streams than would those of the Hoak (1957), Burttschell, et al. (1959), or Campbell, et al. (1958) studies, which utilized carbon-filtered laboratory distilled or redistilled water. The 20 to 22°C temperature of the water in the Dietz and Traud odor and taste tests might also more closely approximate the temperature at which water is normally consumed than do the 30°C or 25°C temperatures used in the studies of Hoak (1957) and Burttschell, et al. (1959), respectively [Campbell, et al. (1958) did not indicate the temperature of the water used in their study]. However, it is recognized that the temperature of water consumed by humans is quite obviously variable, and no study will represent the temperature of water consumed by all Americans.

Therefore, based on the prevention of undesirable organoleptic characteristics, the criterion level for 2-chlorophenol in water is 0.1 µg/l. It should be emphasized that this criterion is based on aesthetics rather than health effects.

REFERENCES

Alexander, M. and M.I.H. Aleem. 1961. Effect of chemical structure on microbial decomposition of aromatic herbicides. Jour. Agric. Food Chem. 9: 44.

Aly, O.M. 1968. Separation of phenols in waters by thin layer chromatography. Water Res. 2: 587.

Aly, O.M. and S.D. Faust. 1964. Studies on the fate of 2,4-D and ester derivatives in natural surface waters. Jour. Agric. Food Chem. 12: 541.

American Public Health Association. 1979. Report received from Lois L. Gerchman, Poison Lab/Enbionics.

Angel, A. and K.J. Rogers. 1972. An analysis of the convulsant activity of substituted benzenes in the mouse. Toxicol. Appl. Pharmacol. 21: 214.

Baird, R.B., et al. 1974. The fate of phenolics in wastewater. Determination by direct-injection GLC and Warburg respirometry. Arch. Environ. Contam. Toxicol. 2: 165.

Barnhart, E.L. and G.R. Campbell. 1972. The effect of chlorination on selected organic chemicals. U.S. Government Printing Office, Washington, D.C.

Bjerke, E.L., et al. 1972. Residue study of phenoxy herbicides in milk and cream. Jour. Agric. Food Chem. 20: 963.

Boetius, J. 1954. Foul taste of fish and oysters caused by chlorophenol. Meddelelser Fra Danmarks Fisheri - O.G. Havurdersogelser. 4: 1.

Boutwell, R.K. and D.K. Bosch. 1959. The tumor-promoting action of phenol and related compounds for mouse skin. Cancer Res. 19: 413.

Bubnov, V.D., et al. 1969. Toxic properties of activated o-chlorophenol for white mice and blue foxes. Tr. Vses. Nauchno-Issled. Inst. Vet. Sanit. 33: 258. (Moscow)

Burttschell, R.H., et al. 1959. Chlorine derivatives of phenol causing taste and odor. Jour. Am. Water Works Assoc. 51: 205.

Campbell, C.L., et al. 1958. Effect of certain chemicals in water on the flavor of brewed coffee. Food Research. 23: 575.

Christensen, H.E. and T.T. Luginbyhl. 1975. Registry of toxic effects of chemical substances. U.S. Pub. Health Serv., Center for Dis. Control, Rockville, Maryland.

Clark, D.E., et al. 1975. Residues of chlorophenoxy acid herbicides and their phenolic metabolites in tissues of sheep and cattle. Jour. Agric. Food Chem. 23: 573.

Cserjesi, A.J. 1972. Detoxification of chlorinated phenols. Int. Biodeterior Bull. 8: 135. (Birmingham, England)

Deichmann, W.B. 1943. The toxicity of chlorophenols for rats. Fed. Proc. 2: 76.

Dietz, F. and J. Traud. 1978. Geruchs- und Geschmacks-Schwellen-Konzentrationen von Phenolkorpern Gas-Wasserfach. Wasser-Abwasser. 119: 318. (Ger.)

Doedens, J.D. 1963. Chlorophenols. In: Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley and Sons, Inc., New York. p. 325.

Eisenhauer, H.R. 1964. Oxidation of phenolic wastes. Jour. Water Pollut. Control Fed. 36: 1116.

Ettinger, M.B. and C.C. Ruchhoft. 1950. Persistence of monochlorophenols in polluted river water and sewage dilutions. U.S. Pub. Health Serv., Environ. Health Center, Cincinnati, Ohio.

Evans, W.C., et al. 1971. Bacterial metabolism of 2,4-dichlorophenoxyacetate. Biochem. Jour. 122: 543.

Fairless, B.J. 1979. Chief, Laboratory Branch, SVAN-LABO, U.S. Environ. Prot. Agency. Rep. EPA Form 1320-6(Rev. 3-76). March 30.

Farquharson, M.E., et al. 1958. The biological action of chlorophenols. Br. Jour. Pharmacol. 13: 20.

Henderson, C., et al. 1960. The effect of some organic cyanides (nitriles) on fish. Proc. 15th Ind. Waste Conf. Purdue Univ. Eng. Bull. Ed. 45: 120.

Hoak, R.D. 1957. The causes of tastes and odors in drinking water. Water Sewage Works. 104: 243.

Huff, J.E. and J.S. Wassom. 1974. Health hazards from chemical impurities: Chlorinated dibenzodioxins and chlorinated dibenzofurans. Int. Jour. Environ. Stud. 6: 13.

Ingols, R.S., et al. 1966. Biological activity of halophenols. Jour. Water Pollut. Control Fed. 38: 629.

Jolley, R.L. 1973. Chlorination effects on organic constitutents in effluents from domestic sanitary sewage treatment plants. Ph.D. dissertation. University of Tennessee.

Jolley, R.L., et al. 1975. Chlorination of cooling water: A source of environmentally significant chlorine-containing organic compounds. Proc. 4th Natl. Symp. Radioecology. Corvallis, Oregon.

Karpow, G. 1893. On the antiseptic action of three isomeric chlorophenols and of their salicylate esters and their fate in the metabolism. Arch. Sci. Biol. St. Petersburg. 2: 304.

Kearney, P.C., et al. 1969. Decontamination of pesticides in soils. Residue Rev. 29: 137.

Kuroda, T. 1926. Comparative studies on the action of o-, m-, and p-chlorophenol. Arch. Exp. Pathol. Pharmakol. 112: 60.

Lindsay-Smith, J.R. , et al. 1972. Mechanisms of mammalian hydroxylation: Some novel metabolites of chlorobenzene. Xenobiotica. 2: 215.

Loos, M.A. 1975. Phenoxyalkanoic Acids. In: P.C. Kearney and D.D. Kaufman (eds.), Herbicides. Marcell Dekker, Inc., New York. p. 1.

Miller, L.P. 1941. Induced formation of a β-gentiobioside in tomato roots. Contrib. Boyce Thompson Inst. 11: 387.

Mitsuda, H., et al. 1963. Effect of chlorophenol analogues on the oxidative phosphorylation in rat liver mitochondria. Agric. Biol. Chem. 27: 366.

Nachtigall, H. and R.G. Butler. 1974. Metabolism of phenols and chlorophenols by activated sludge microorganisms. Abstr. Annu. Meet. Am. Soc. Microbiol. 1974: 184.

National Cancer Institute. 1978. Bioassay of dibenzo-p-dioxin for possible carcinogenicity. DHEW Publ. No. (NIH) 78-1377.

Osweiler, G.D., et al. 1977. Toxicologic and residue aspects of pentachlorophenol. Proc. 10th Annu. Meet. Am. Assoc. Vet. Lab. Diagnosticians. Minneapolis, Minnesota.

Patty, F.A. 1963. Industrial Hygiene and Toxicology. II. Toxicology. Interscience Publishers, New York.

Schulze, E. 1961. Zur Geschmacklichen Beeinflussungen von Fischen durch Phenolhaltige Abnasser. Int. Rev. Gesamten Hydrobiol. Hydrogr. 46: 94.

Selander, H.G., et al. 1975. Metabolism of chlorobenzene with hepatic microsomes and soluble cytochrome P450 system. Arch. Biochem. Biophys. 168: 309.

Sherman, J., et al. 1972. Chronic toxicity and residues from feeding nemacide [O-(2,4-dichlorophenol)-O,O-diethylphosphorothioate] to laying hens. Jour. Agric. Food Chem. 23: 617.

Shumway, D.L. and J.R. Palensky. 1973. Impairment of the flavor of fish by water pollutants. EPA-R3-73-010. U.S. Environ. Prot. Agency. U.S. Government Printing Office, Washington, D.C.

Sidwell, A.E. 1971. Biological treatment of chlorophenolic wastes -- the demonstration of a facility for the biological treatment of a complex chlorophenolic waste. Water Pollut. Control Res. Ser. 12130 EKG.

Spencer, B. and R.T. Williams. 1950. Studies in detoxication. The metabolism of halogenobenzenes. A comparison of the glucuronic acid, etheral sulfate, and mercapturic acid conjugates of chloro-, bromo-, and iodo-benzenes and of the o-, m-, and p-chlorophenols. Biosynthesis of o-, m-, and p-chlorophenol glucuronides. Biochem. 47: 279.

Spokes, J.R. and N. Walker. 1974. Chlorophenol and chlorobenzoic acid co-metabolism by different genera of soil bacteria. Arch. Microbiol. 96: 125.

Stephan, C.E. 1980. Memorandum to J. Stara. U.S. EPA. July 3.

U.S. Department of Agriculture. 1974. Farmers' use of pesticides in 1971 -- quantities. Agric. Econ. Rep. No. 252. Econ. Res. Serv., Washington, D.C.

U.S. EPA. 1978. In-depth studies on health and environmental impacts of selected water pollutants. EPA Contract No. 68-010-4646. U.S. Environ. Prot. Agency, Washington, D.C.

U.S. EPA. 1979. Reviews of the environmental effects of pollutants: XI. Chlorophenols. June 1979. Health Effects Res. Lab., U.S. Environ. Prot. Agency, Cincinnati, Ohio.

U.S. EPA. 1980. Seafood consumption data analysis. Stanford Res. Inst. Inter., Menlo Park, California. Final Report, Task 11. Contract No. 68-01-3587.

von Oettingen, W.F. 1949. Phenol and its derivatives: The relation between their chemical constitution and their effect on the organism. Natl. Inst. Health Bull. 190: 193.

Walker, N. 1954. Preliminary observations on the deomposition of chlorophenols in soil. Plant Soil. 5: 194.