Water Quality

Ministry of Water, Land And Air Protection

Ambient Interim

Water Quality Guidelines

for

Phenols

Technical Report

Prepared pursuant to Section 2(e) of the
Environment Management Act, 1981

April 19, 2002

SUMMARY

This document is one in a series that establishes ambient water quality guidelines for British Columbia. The Canadian Council of Ministers of the Environment (CCME) has recently developed new guidelines of 4 ug/L for mono and dihydric phenols to protect freshwater aquatic life. The Ministry has published guidelines for chlorophenols, but needed to evaluate the CCME guidelines to decide which phenols were

Ministry of Environment | Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division | Mailing Address: PO Box 9362 Stn Prov Govt Victoria BC V8W 9M2 | Telephone: 250 387-9481 Facsimile: 250 356-1202 Website: www.gov.bc.ca/water

to be included as total phenols. Another factor that raised the priority of this review was that the Ministry is undertaking a Stage 2 Contaminated Sites Regulation amendment.

Suitable data documenting the effects of phenols for most water uses is lacking, therefore, we have only derived guidelines to protect aquatic life. Due to time and data constraints, and since the Ministry has guidelines for chlorinated phenols, this document only recommends working water quality guidelines for non-halogenated phenols to protect freshwater aquatic life. These working guidelines will need to be converted to more scientifically defensible guidelines when time and data permit.

At extremely low phenol values, there are two effects apparent in phenol-contaminated waters:

1. toxicity to aquatic life, and
2. the generation of an unpleasant taste in fish and shellfish.

The data on which these working guidelines for phenols are based are summarized in tables in the appendices to this report.

The working water quality guidelines are summarized in Table 1.

Table 1. Summary of Water Quality Guidelines for Phenol.

Non-halogenated phenol species	Guideline (micrograms/L)
4-hydroxyphenol (hydroquinone, quinol)	4.5 micrograms/L
3-hydroxyphenol (resorcinol)	12.5 micrograms/L
total of all other phenols*	50.0 micrograms/L

* ***Total of all other Phenols=Total Phenols - (all chlorinated phenols + hydroquinone + resorcinol).***

TABLES

PREFACE

THE MINISTRY OF WATER, LAND AND AIR PROTECTION develops ambient water quality guidelines for British Columbia. This work has two goals:

1. to provide guidelines for the evaluation of data on water, sediment and biota
2. to provide a basis for setting site-specific ambient water quality objectives.

The guidelines represent safe conditions or safe levels of a substance in water. The term ***guideline*** is defined as:

a maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent detrimental effects from occurring to a water use under given environmental conditions.

Water Quality guidelines are applied province-wide, but they are use-specific, and are being developed for these water uses:

- Raw drinking, public water supply and food processing
- Aquatic life and wildlife
- Agriculture (livestock watering and irrigation)
- Recreation and aesthetics
- Industrial (water supplies)

The guidelines are established following a thorough review of the recent scientific literature, guidelines set by other jurisdictions and environmental conditions in British Columbia. The scientific literature provides information on environmental fate, persistence and effects of toxicants on various life forms. This information is not always conclusive because it is often based on laboratory testing that, at best, only approximates field conditions. To compensate for this uncertainty, and applying the ***precautionary principle***, the guidelines have built-in safety factors that are conservative, while taking into account the natural background in the province. The guidelines are used to set ambient site-specific water quality objectives for specific waterbodies. In setting the objectives, considerations are given to present and future water uses, waste discharges, hydrology, limnology, oceanography and ambient water quality conditions at the site in question.

In most cases the objectives are the same as the guidelines. However, when natural background levels of substances exceed the guidelines, the site-specific objective could be less stringent than the guideline in order to take this high natural level into account. In rare instances ***for example if the resource is unusually valuable or of special provincial or ecological significance*** the safety factor could be increased enabling objectives to be more stringent than the guidelines. Another approach would be to develop site-specific objectives by conducting toxicity experiments in the field. However, because this approach is costly and time consuming, it is seldom used.

Neither the guidelines nor the objectives derived from them have any legal standing. However, objectives can be used to calculate waste discharge limits for contaminants. These limits are outlined in waste management permits, orders and approvals, all of which have legal standing. Objectives are not usually incorporated as conditions of a permit.

Water quality guidelines are subject to review and revision, as new information becomes available or as other circumstances dictate.

The guidelines apply to the ambient raw water source before it is diverted or treated for domestic use.
The Ministry of Health regulates the quality of water for domestic use after it is treated and delivered by a water purveyor.
Guidelines relating to public health at bathing beaches are the same as those used by the Ministry of Health which regulates the recreation and aesthetic use.

INTRODUCTION

PHENOLS

In chemical terminology, a phenol is a single aromatic ring organic compound with an -OH group. An alkyl, straight chain or ring, organic compound with an -OH group is an alcohol. A double aromatic ring organic compound with an -OH group is a naphthol.

Phenol, formerly called carbolic acid, is an aromatic organic compound, C_6H_5OH. It is weakly acidic and resembles an alcohol in structure. The colourless, needlelike crystals of purified phenol melt at 43°C (109°F) and boil at 182°C (360°F). Phenol is soluble in organic solvents and slightly soluble in water at room temperature, and completely soluble above 66°C (150.8°F). It is a constituent of coal tar.

Phenol was first used as a disinfectant in 1867 by the British surgeon Joseph Lister for sterilizing wounds, surgical dressings, and instruments. Dilute solutions are useful antiseptics, but strong solutions are corrosive and scarring to tissue. Less irritating and more efficient germicides have replaced phenol, but it is widely used in the manufacture of resins, plastics, insecticides, explosives, dyes, and detergents. It is also used as a raw material for the production of medicinal drugs such as aspirin.

The term phenol is also used for any of a group of related acidic compounds that are hydroxyl derivatives of aromatic hydrocarbons. These include such substances as cresol, catechol, quinol, xylenol, guaiacol and resorcinol. For consistency and clarity these are all named as substituted phenols in this document. See Appendix 1 for a partial list of some phenol compounds.

The latest CCME document combines all of the 1- and 2-hydric phenols together into one group for setting guidelines based on toxicity. We have followed the same procedure for establishing these working guidelines with the exception of setting separate guidelines for 4-hydroxyphenol (hydroquinone) and 3-hydroxyphenol (resorcinol). There are several reasons for this.

There can be large differences in the toxicity of the various distinct phenol compounds, particularly when the substituents are strong electron donors or sinks. This can lead to over-protection for some of these compounds because the guideline is established to accommodate the most toxic phenol.

There is a paucity of existing reliable data that can be used to set guidelines for individual compounds. The guidelines are set to account for the most toxic phenols. If circumstances warrant, it is recommended that dischargers carry out Water Effect Ratio trials with their specific effluent and their ambient water to determine an acceptable site-specific phenol concentration.

Toluene and the xylenes are not phenols in their un-substituted form. Toluene is 1-methyl benzene and the xylenes are: 1, 2-dimethyl benzene, 1, 3-dimethyl benzene or 1, 4-dimethyl benzene. However, if one of the other substitutions on the benzene ring is a hydroxy group, then they become a phenol, cresol or xylenol. Therefore, for example: 4-hydroxy toluene, 4-methyl phenol, 1-methyl-4-hydroxy benzene, and 1-hydroxy-4-methyl benzene are all the same compound, as are 3, 4-dimethyl phenol, 3, 4-dimethyl xylenol, 1-hydroxy-3, 4-dimethyl benzene and 2-methyl-4-hydroxy toluene.

One must be aware of all these alternate names when looking up data on phenol compounds. It is best to try to find one name in the Chemical Abstracts Service (CAS) registry that has a bewildering variety of alternate names listed. Using the substituted benzene or phenol nomenclature can reduce the ambiguity and confusion. In this document, we try to use only a few alternate names.

There are, in theory, an infinite number of phenols since up to 5 'R' groups (long-chain aliphatics) can be substituted and each of these can be very complex and substituted itself. In practice, there are far too many phenols to deal with individually but the toxic properties of many long-chain aliphatic substituted compounds will be quite similar. It is the toxicity of the phenols with simple substituents like methyl (-CH3), hydroxyl (-OH), amino (-NH2), nitro (-NO2), methoxy (-CH3O) and the halogens (-Cl, -Br, -I, -F) that are of most toxicological concern. Most phenols are used as bactericides, fungicides and herbicides; particularly the halogenated phenols, and especially the chlorinated halophenols.

The environmental half-lives of most phenols are short, rarely as long as a month. Some are photo-degraded, especially in air. The microbial half-life is short, typically measured in days under aerobic conditions. Once a discharge ceases, environmental levels will drop rapidly due to bacterial breakdown. The half-life of phenols in fish is less than one day and phenols do not accumulate. Hence the existence of high levels in fish tissues indicates chronic or current exposure.

Microorganisms will alter their metabolic processes to utilize phenols. If they have not previously been exposed there will be an initial adaptation period until a large microbial population has been established. Any subsequent additions of phenols will be quickly degraded.

RECOMMENDED GUIDELINES

The following guidelines are based on readily available existing information which is summarized in tables in Appendix 2. The Canadian Council of Ministers of the Environment (CCME) has set guidelines for all mono- and di-hydric phenols.

FRESHWATER AQUATIC LIFE

Aquatic Life is the only water use for which guidelines are being set in this document. They are working guidelines subject to revision when more complete data become available. The maximum concentration of 4-hydroxyphenol (quinol, hydroquinone, 1,4-benzenediol) should not exceed 4.5 micrograms/L. The maximum concentration of 3-hydroxyphenol (resorcinol, 1,3-benzenediol) should not exceed 12.5 micrograms/L, and the maximum concentration of the total of all other non-halogenated phenols should not exceed 50 micrograms/L.

RATIONALE

The lowest LC_{50} data found for many phenols is presented in Table 2. The lowest effect for 4-hydroxyphenol (hydroquinone) was for *Daphnia magna*, at 0.09 mg/L. For 3-hydroxyphenol (resorcinol), the lowest effect level measured was at 0.25 mg/L, also for*Daphnia magna*. These were divided by a safety factor of 20:1 in order to estimate a safe minimal, or no effect, level for other freshwater species.

The next most toxic form of phenol was reported for fathead minnows, *Pimphales promelas* using 4-phenylazophenol at 1.17 mg/L. We have assumed that the sum of all other phenols present (non-chlorinated) should not exceed this level since there are many phenol compounds with similar toxicity (see Table 2).Therefore, for all other phenols, we divided this level by a factor of 20 to estimate the safe level.

APPLICATION OF GUIDELINES

Chlorophenols, hydroquinone and resorcinol should be measured separately and compared to their respective proposed guideline values. A measurement of total phenols minus the sum of total chlorophenols, hydroquinone, and resorcinol allows one to determine if the guideline for total phenols is met.

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Appendix 1. List of Phenols in commercial use.

This is a selected list of some of the phenols that are in commercial use and may be found in waste streams. There are many more phenols, some found only in natural products and not in commercial use. All will have their own distinct acute and chronic guideline levels.

Phenol (CAS #108-95-2)

The basic, simplest, parent compound is phenol, C_6H_6O. It is also called monohydroxy benzene, hydroxy benzene, benzenol, phenylic acid, phenyl hydroxide, benzophenol, phenyl hydrate, phenylic alcohol, monophenol, phenic acid, oxybenzene, hydroxy benzene or carbolic acid. Phenol can have a wide variety and number of substituents on the other five locations of the benzene ring.

Cresols

Cresols, C_6H_8O, are methyl phenols and have one methyl group in the ortho, meta or para (second, third or fourth, respectively) position on the parent phenol. The unsubstituted parent compounds are also called ortho: 1-hydroxy-2-methyl benzene, 2-methyl phenol, 2-hydroxy toluene, 1-methyl-2-hydroxy benzene; meta: 1-hydroxy-3-methyl benzene, 3-methyl phenol, 3-hydroxy toluene, 1-methyl-3-hydroxy benzene: para: 1-hydroxy-4-methyl benzene, 4-methyl phenol, 4-hydroxy toluene and 1-methyl-4-hydroxy benzene.

The CAS numbers of the parent compounds are: o-cresol (CAS #95-48-7), m-cresol (CAS #108-39-4) and p-cresol (CAS #106-44-5).

Guaiacol (CAS #90-05-1)

Guaiacols, $C_7H_8O_2$, have an ortho or 2-substituted methoxy on the parent phenol. They are o-methoxy hydroxybenzenes and the parent unsubstituted compound is also called 1-hydroxy-2-methoxy benzene, 2-methoxy phenol and guaiacol. These are natural wood digestion products and often have other substitutions on the other four sites.

Resorcinol (CAS #108-46-3)

Resorcinols, $C_6H_6O_2$, have a second meta or 3-substituted hydroxy on the parent phenol. They are m-dihydroxy benzenes and the parent unsubstituted compound is also called 1, 3-dihydroxy benzene, 3-hydroxy phenol, 1, 3-benzenediol and Resorcinol.

Catechol (CAS #120-80-9)

Catechols, $C_6H_6O_2$, have a second ortho or 2-substituted hydroxy on the parent phenol. They are o-dihydroxy benzenes and also called 1, 2-dihydroxy benzene, 2-hydroxy phenol, 1, 2-benzenediol, pyrocatechol and catechol.

Xylenols

Xylenols, $C_8H_{10}O$, are dimethyl phenols. They have two methyl groups and at least one hydroxy group. The methyls may be 1, 2-, 1, 3- or 1, 4- (ortho, meta and para respectively, relative to each other) and the hydroxyl can then be on any of the other four sites. This allows for 6 different possible isomers. Choosing one of the isomers at random, some of the names are 1-hydroxy-3, 4-dimethyl benzene, 1, 2-dimethyl-4-hydroxy benzene, 3, 4-dimethyl phenol, 3, 4-xylenol, 4-hydroxy-o xylene and 2-methyl-4-hydroxy-toluene.

The CAS numbers of the six parent compounds are: 2, 3-xylenol (CAS# 526-75-0), 2, 4-xylenol.(CAS# 105-67-9), 2, 5-xylenol (CAS #95-87-4), 2, 6-xylenol (CAS# 576-26-1), 3, 4-xylenol (CAS #95-65-8) and 3, 5-xylenol (CAS# 108-68-9).

Quinol or Hydroquinone (CAS #123-31-9)

Quinols or hydroquinones, $C_6H_6O_2$, have a second para or 4-substituted hydroxy on the parent phenol. They are p-dihydroxy benzenes and the parent unsubstituted compound is also called 1, 4-dihydroxy benzene, 4-hydroxy phenol, 1, 4-benzenediol, hydroquinone and quinol.

Naphthols

When there are two joined aromatic rings with a hydroxy group on at least one of them, the compound is called a naphthol and now there are seven more sites for substitution and the nomenclature gets a little more complex. However, we are only concerned with phenols in this document.

The CCME aquatic life guideline for mono-hydric phenols and di-hydric phenols, as a group, is 4 micrograms/L in fresh water; no guideline was set in marine water. Toxicity varies widely by organism, dissolved oxygen and temperature. The sequence of decreasing toxicities is generally phenol, p-cresol, o-cresol, m-cresol and catechol. A preliminary search of the internet did not turn up much aquatic toxicity data, primarily MSDS, Material Safety Data Sheet, and OSHA, Occupational Safety and Health, lab-rat data. Some reported acute and chronic toxicity values are listed in the tables in Appendix 2.

Phenol, o-cresol, m-cresol, p-cresol, 2, 3-xylenol, 2, 4-xylenol, 2, 5-xylenol, 2, 6-xylenol, 3, 4-xylenol, 3, 5 xylenol and all the derivatives of catechol, resorcinol and quinol have low vapour pressures, under one kPa and high water solubilities, in the grams per litre range. Oxidation and microbial degradation are the main fates of phenols in the environment. Sorption is low as are log Kow values; generally under 2.0, reaching only 2.5 as a maximum.

Some simple substituted phenols

phenols

- 2-nitrophenol CAS #88-75-5, o-nitrophenol

- 4-nitrophenol CAS #100-02-7, p-nitrophenol
- 3-nitrophenol CAS #554-84-7, m-nitrophenol
- dinitrophenols (mixture) CAS #25550-58-7
- nitrophenols (all isomers) CAS #25154-55-6
- 4-nitrophenol sodium salt CAS #824-78-2
- 4-methoxyphenol CAS #150-76-5
- 2, 4-dinitrophenol CAS #51-28-5
- 2, 5-dinitrophenol CAS #329-71-5
- 2, 6-dinitrophenol CAS #573-56-8
- 2-methoxy-5-nitrophenol CAS #67233-85-6
- 2-nitrophenol sodium salt CAS #824-39-5
- 4-amino-2-nitrophenol CAS #119-34-6
- 4-carboxyphenol CAS #99-96-7
- 2, 4-dimethylphenol CAS #105-67-9
- 2, 6-dimethylphenol CAS #576-26-1
- 2, 6-dinitro-4-methylphenol CAS #609-93-8
- dinitrobutylphenol CAS #88-85-7
- 2,6-dibromo-4-nitrophenol CAS #99-28-5
- p-methylaminophenol CAS #150-75-4
- 2, 4, 6-trinitrophenol CAS #88-89-1
- 3-phenylphenol CAS #580-51-8
- 2-phenylphenol CAS #90-43-7

cresols

- 4, 6-dinitro-o-cresol CAS #534-52-1, 2-methyl-4, 6-dinitro phenol
- p-chloro-m-cresol CAS #59-50-7, 4-chloro-3-methyl phenol, 4-chloro-m-cresol, 4-chloro-3-cresol
- 4-chloro-o-cresol CAS #1570-64-5, 4-choloro-2-cresol, 4-chloro-2-methyl phenol, p-chloro-o-cresol
- 4, 6-diamino-o-cresol CAS #15872-73-8, 4, 6-diamino-2-cresol
- 2, 6-dinitro-p-cresol CAS #609-93-8, 2, 6-dinitro-4-cresol
- 2-nitro-4-cresol CAS #119-33-5, 2-nitro-p-cresol, o-nitro-p-cresol, o-nitro-4-cresol
- hexahydro cresol CAS #25639-42-3
- 4-methyl-m-cresol CAS #95-87-4, 4-methyl-3-cresol
- 2-methyl-p-cresol CAS #104-93-8, 2-methyl-4-cresol

guaiacols

- tetrachloro guaiacol CAS #2539-17-5

catechols

- 4, 5-dichloro catechol CAS #3428-24-8
- tetra bromo catechol CAS #488-47-1
- tetra chloro catechol CAS #1198-55-6

xylenols

- 4-chloro-m-xylenol CAS #88-04-0, 4-chloro-3, 5-xylenol, p-chloro-m-xylenol, p-chloro-3, 5-xylenol
- 4-amino-3, 5-xylenol CAS #3096-70-6

Some complex R group substituted phenols

Phenol

- 2-cyclohexyl-4, 6-dinitro-phenol CAS #131-89-5
  Dinex-111
- 2-(1-methylethoxy)-phenol CAS #114-26-1
  Methylcarbamate
  Baygon
  Propoxur
- 2, 4-di-(m-xylenol) dimethyl phenol CAS #105-67-9
- 3, 5-dimethyl-4-(methylthio)-phenol CAS #2032-65-7
  methylcarbamate
  methyl-carbamic acid
  4-(methylthio)-3, 5-xylyl ester
  Mesurol
  Methiocarb
  Mercaptodimethur
- sodium o-phenylphenol CAS #132-27-4
  2-hydroxybiphenyl sodium salt
  Dowicide A, [1,1'-biphenyl]-2-ol sodium salt
- 4, 4'-(1-methylethylidene) bis-phenol CAS #80-05-7
  4, 4'-isopropylidene diphenol
  Bisphenol A
- 4, 4'-(1, 2-diethyl-1, 2-ethenediyl) bis, (E)-phenol CAS #56-53-1
  diethylstilbestrol
  stilbestrol
  DES
  alpha, alpha'-diethylstilbenediol
- 2-(1-methylpropyl)-4, 6-dinitro-phenol CAS #88-85-7
  Dinoseb
  2-sec-butyl-4, 6-dinitrophenol
  DNBP
- 2-(1, 3-dioxolan-2-yl)-phenol CAS #6988-21-2
  Methylcarbamate
  Elocron
  Famid
  Dioxacarb
  2-(1, 3-Dioxolan-2-yl)phenyl methylcarbamate
- 2, 4-diaminophenol di-hydrochloride CAS #137-09-7
- 3-(1-methylethyl)phenol methylcarbamate CAS #64-00-6
- 4, 4'-isopropylidenebis 2, 6-dichlorophenol CAS #79-95-8
- 4-(1, 1-dimethylpropyl)phenol sodium salt CAS #31366-95-7

- 4-chloro-2-(phenylmethyl)phenol potassium salt CAS #35471-49-9
- 4-chloro-2-(pheylmethyl)phenol sodium salt CAS #3184-65-4
- 4-nitro-3-(trifluoromethyl)phenol CAS #88-30-2
- heptenylated phenol CAS #72624-02-3
- isobutylated methylstyrenated phenol CAS #68457-74-9
- methyl phenol patassium salt CAS #12002-51-6
- thiobis (tetrapropylene) phenol (9ci) CAS #68815-67-8
- benziocarb phenol CAS #28987-17-9
- 2-benzyl-4, 6-dichlorophenol EDF #335
- 2, 4-bis (1,1-dimethylpropyl)phenol CAS #120-95-6
- 2, 4-bis (1-methyl-1-phenylethyl)-6-((2-nitrophenyl) azo) phenol CAS #70693-50-4
- 2, 4-bis (dimethylaminomethyl)phenol CAS #5424-54-4
- 2, 6-ditert-butylphenol CAS #128-39-2
- 2, 4-diamino-6-methylphenol hydrochloride CAS #65879-44-9
- 3-(diethylamino)phenol CAS #91-68-9
- 4-(3, 4-dihydro-2, 2, 4-trimethyl-2H-1-benzopyran-4-yl) phenol CAS #472-41-3
- 2, 4-dimethyl-3-(chloromethyl)-6-tertbutylphenol CAS #23500-79-0
- 2, 6-dimethyl-4-heptylphenol CAS #25154-52-3
- 2-(1, 1-dimethyl)-5-methyphenol CAS #88-60-8
- 2-(1, 1-dimethylethyl)phenol CAS #88-18-6
- 2, 4-dinitro-6-cyclohexylphenol CAS #131-89-5
- dinonylphenol CAS #1323-65-5
- dodecylphenol CAS #27193-86-8
- 4-dodecylphenol CAS #104-43-8
- 2-formylphenol CAS #90-02-8
- 2-(2H-benzotriazol-2-yl)-4, 6-bis(1-methyl-1-phenylethyl) phenol CAS #70321-86-7
- 2-(2H-benzotriazol-2-yl)-4, 6-ditertpentylphenol CAS #25973-55-1
- 4, 4'-isopropylidene-bis(2-tertbutylphenol CAS #79-96-9
- 4, 4'-isopropylidenediphenol CAS #80-0507
- 4, 4'-isopropylidinebisphenol disodium salt CAS #2444-90-8
- magnesium thiobis(tetrapropenylphenolate CAS #68974-78-7
- 2-methoxy-4-formylphenol CAS #121-33-5
- 4-(methoxycarbonyl)phenol CAS #99-76-3
- (1-methyl-1-phenylethyl)phenol CAS #27576-86-9
- 4-(methylanino)phenolsulphate CAS #55-55-0
- 2, 2'-methyenebis (4-methyl-6-nonylphenol) CAS #7786-17-6
- (1-methylethyl)phenol CAS #25168-06-3
- 3-methyloxyphenol CAS #150-19-6
- n-stearoyl-p-aminophenol CAS #103-99-1
- 6-((2-nitrophenyl)azo)-2, 4-ditertpentylphenol CAS #52184-19-7
- 4-nonylphenol CAS #104-40-5
- o-sec-butylphenol CAS #89072-5
- ortho-benzyl-p-chlorophenol CAS #120-32-1
- p-hexylphenol CAS #2446-69-7
- p-tertamylphenol CAS #80-46-6
- p-amylphenol potassium salt CAS #53404-18-5
- 2, 2', 6, 6'-tetra-tertbuty-4, 4'-methylenediphenol CAS #118-82-1

- 2, 2', 6, 6'-tetrabromo-4, 4'-isopropylidenephenol CAS #79-94-7
- 4-(1, 1, 3, 3-tetramethylbutyl)phenol CAS #140-66-9
- (1, 1, 3, 3-tetramethylbutyl)phenol CAS #27193-28-8
- 2, 2'-thiobis (4, 6-dichloro)phenol CAS #97-18-7
- 2, 4, 6-tri(dimethylaminomethyl)phenol CAS #90-72-2
- 2, 4, 6-tri (tertbutyl)phenol CAS #732-26-3
- zinc phenolsulphonate CAS #127-82-2

Cresols

- 2-((o-nitrophenyl) azo)-p-cresol CAS #1435-71-8
- 2, 6-di-tertbutyl-p-cresol CAS #128-37-0
  2, 6-di-tertbutyl-4-cresol
- 4-chloro-alpha-phenyl-o-cresol CAS #120-32-1
- 3-amino-p-cresol methyl ether CAS #120-71-8
  m-amino-p-cresol methyl ether
- 2-(2H-benzotriazol-2yl)-p-cresol CAS #2440-22-4
- 3, 3', 3", 5, 5', 5"-hexa-tert-butyl-alpha, alpha', alpha"-(mesitylen-E2, 4, 6, -triyl) tri-p-cresol CAS #1709-70-2
- 6-isopropyl-m-cresol CAS #89-83-8
  6-isopropyl-3-cresol
- 6-tert-butyl-m-cresol CAS #88-60-8
  6-tert-butyl-3-cresol
- 4, 4'-thiobis (6-tert-buty-m-cresol CAS #96-69-5
  4, 4'-thiobis (6-tert-buty-3-cresol
- 4-(dimethylamino)-m-cresol methylcarbamate ester CAS #2032-59-9
  4-(dimethylamino)-3-cresol methylcarbamate ester
- 4-(methylthio)-m-cresol o, o-dimethyl phosphorothioate ester CAS #55-38-9
  4-(methylthio)-3-cresol o, o-dimethyl phosphorothioate ester
- 4-nitro-m-cresol o, o-dimethyl phosphorothioate ester CAS #55-38-9
  4-nitro-3-cresol o, o-dimethyl phosphorothioate ester
- 2, 2'-methylenebis (6-(1, 1-dimethylethyl)-p-cresol) CAS #119-47-1
  2, 2'-methylenebis (6-tert-butyl-p-cresol)
- 2, 2'-methylenebis (6-nonyl-p-cresol) CAS #7786-47-1
- o, o'-di-tert-butyl-p-cresol CAS #128-37-0
- o-cresol glycidyl ether CAS #2210-79-9
- p-cresol glycidyl ether CAS #26447-14-3
- 6, 6'-thiobis (4-chloro-o-cresol CAS #4418-66-0
- 2-((o-nitrophenyl) azo)-p-cresol CAS #1435-71-8
- o-tert-buty-p-cresol CAS #2409-55-4
  2-tert-buty-p-cresol
- alpha, alpha', alpha"-(2, 4, 6-trimethyl-s-phenyl) tris-2, 6-di-tert-butyl-p-cresol CAS #1709-70-2

Guaiacol

- Allyl guaiacol CAS #97-53-0

Resorcinol

- Resorcinol methyl ether CAS #150-19-6
- 4-benzoyl resorcinal CAS #131-56-6
  4-benzo resorcinol
- cresol-resorcinol di-isocyanate CAS #584-84-9
- 1, 3-bis (2, 3-epoxy) propyl resorcinol CAS #101-90-6
  resorcinol di-glycidyl ether
  resorcinol bis (2, 3-epoxy propyl) ether

Catechol

- p-tert-butyl catechol CAS #98-29-3
  4-tert-butyl catechol
- 4-allyl catechol-2-methyl ether CAS #97-53-0
- allyl catechol methylene ether CAS #94-59-7
  4-allyl pyrocatecol formaldehyde acetyl
- 4-propenyl catechol methylene ether CAS #120-58-1

Xylenols

- 4-(dimethylamino)-3, 5-xylenol methyl carbamate ester CAS #315-18-4
- 6-tert-butyl-3-(chloromethyl)-2, 4-xylenol CAS #23500-79-0
- 4-(methylthio)-3, 5-xylenol methyl carbamate CAS #2032-65-7

Appendix 2. Aquire data-base phenol toxicity values.

The lowest AQUIRE data base values for the various phenol groups range from 0.044 to 25.9 mg/L, three orders of magnitude. Using a standard acute to chronic ratio of 20 leads to guideline values from 2.2 to 1300 micrograms/L or 0.0022 to 1.30 mg/L. The CCME 1999 Guideline to protect aquatic life from mono and dihydric phenols is 4 micrograms/L. Setting the guideline to protect the most sensitive species from the most toxic phenol leads to gross overprotection for some species and some phenols. This AQUIRE data is for the un-substituted parent phenols of each group. The toxic values will change as hydroxy, nitro, amino, methyl, methoxy and other 'R' groups are substituted, at various places and in various numbers and combinations, onto the parent phenol of each group.

Table 2. The Lowest Reliable Freshwater Toxicity Data for Various Phenols in mg/L.

Table 2.1 (Sorted by the LC_{50} Value)

Phenol	Species	References	LC_{50}
4-hydroxyphenol (hydroquinone)	*Daphnia*	Bringmann *et al*, 1977	0.09
3-hydroxyphenol (resorcinol)	*Daphnia*	Ewell *et al*, 1986	0.25
4-phenylazophenol	fathead minnow	Geiger *et al*, 1984-1988	1.17
4-methylphenol (4-cresol)	*Daphnia*	Parkhurst *et al*, 1979	1.4
2,4-dinitro-6-methylphenol	fathead minnow	Geiger *et al*, 1984-1988	1.54
3-methylphenol (3-cresol)	*Daphnia*	Bringmann *et al*, 1977	1.6
4-tert-pentylphenol	fathead minnow	Geiger *et al*, 1984-1988	2.59
2,5-dinitrophenol	fathead minnow	Geiger *et al*, 1984-1988	3.36
4-hydroxyphenol (catechol)	fathead minnow	DeGraeve *et al*, 1980	3.5
2,5-dimethylphenol	*Daphnia*	Devilliers *et al*, 1985	3.5-10
phenol	*Daphnia*	Bringmann *et al*, 1977	3.9
2,4-dinitrophenol	*Daphnia*	LeBlanc, 1980	4.1
4-phenoxyphenol	fathead minnow	Geiger *et al*, 1984-1988	4.95

2-methylphenol (2-cresol)	*Daphnia*	Parkhurst *et al*, 1979	5.0
4-tert-butylphenol	fathead minnow	Geiger *et al*, 1984-1988	5.15
2-phenylphenol	fathead minnow	Geiger *et al*, 1984-1988	6.15
2,3-dimethylphenol	*Daphnia*	Devilliers *et al*, 1985	10-35
3,5-dimethylphenol	*Daphnia*	Devilliers *et al*, 1985	10-35
4-ethylphenol	fathead minnow	Geiger *et al*, 1984-1988	10.4
4-propylphenol	fathead minnow	Geiger *et al*, 1984-1988	11.0
2-allylphenol	fathead minnow	Geiger *et al*, 1984-1988	15.0
2,4-dimethylphenol	fathead minnow	Geiger *et al*, 1984-1988	16.6
4-nitrophenol	*Daphnia*	Bringmann *et al*, 1977	18
3-methyl-4-nitrophenol	*Daphnia*	Bringmann *et al*, 1977	18
3-nitrophenol	*Daphnia*	Bringmann *et al*, 1977	27
2-nitro-5-methylphenol	*Daphnia*	Bringmann *et al*, 1977	31
2-nitro-4-aminophenol	fathead minnow	Geiger *et al*, 1984-1988	36.2
2-nitrophenol	*Daphnia*	Bringmann *et al*,	63

		1977	
2-nitro-4-methylphenol	*Daphnia*	Bringmann *et al*, 1977	63
3-methoxyphenol	fathead minnow	Geiger *et al*, 1984-1988	74
2,4,6-trinitrophenol	*Daphnia*	LeBlanc, 1980	85
4-methoxyphenol	fathead minnow	Geiger *et al*, 1984-1988	110

Catechols, resorcinols, quinols, guaicols, cresols and xylenols have been named as substituted phenols.
2,3,4 are used instead of o,m,p.
Daphnia is Daphnia magna
fathead minnow is Pimphales promelas.

Table 2.2 (Sorted by the Phenol Compound)

Phenol	Species	Assay	References	LC_{50}
2-allylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	15.0
2-hydroxyphenol (catechol)	fathead	m, 96	DeGraeve *et al*, 1980	3.5
2-methylphenol (2-cresol)	*Daphnia*	n, 48	Parkhurst *et al*, 1979	5.0
2-nitrophenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	63
2-nitro-4-aminophenol	fathead	m, 96	Geiger *et al*, 1984-1988	36.2

2-nitro-4-methylphenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	63
2-nitro-5-methylphenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	31
2-phenylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	6.15
2,3-dimethylphenol	*Daphnia*	.....	Devilliers *et al*, 1985	10-35
2,4-dimethylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	16.6
2,4-dinitrophenol	*Daphnia*	n, 48	LeBlanc, 1980	4.1
2,4-dinitro-6-methylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	1.54
2,4,6-trinitrophenol	*Daphnia*	n, 48	LeBlanc, 1980	85
2,5-dimethylphenol	*Daphnia*	.....	Devilliers *et al*, 1985	3.5-10
2,5-dinitrophenol	fathead	m, 96	Geiger *et al*, 1984-1988	3.36
3-hydroxyphenol (resorcinol)	*Daphnia*	n, 96	Ewell *et al*, 1986	0.25
3-methoxyphenol	fathead	m, 96	Geiger *et al*, 1984-1988	74
3-methylphenol (3-cresol)	*Daphnia*	m, 24	Bringmann *et al*, 1977	1.6
3-methyl-4-nitrophenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	18
3-nitrophenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	27

3,5-dimethylphenol	*Daphnia*	.....	Devilliers *et al*, 1985	10-35
4-ethylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	10.4
4-methoxyphenol	fathead	m, 96	Geiger *et al*, 1984-1988	110
4-methylphenol (4-cresol)	*Daphnia*	n, 48	Parkhurst *et al*, 1979	1.4
4-nitrophenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	18
4-phenoxyphenol	fathead	m, 96	Geiger *et al*, 1984-1988	4.95
4-phenylazophenol	fathead	m, 96	Geiger *et al*, 1984-1988	1.17
4-propylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	11.0
4-tert-butylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	5.15
4-tert-pentylphenol	fathead	m, 96	Geiger *et al*, 1984-1988	2.59
phenol	*Daphnia*	n, 24	Bringmann *et al*, 1977	3.9

Catechols, resorcinols, quinols, guaicols, cresols and xylenols have been named as substituted phenols.
2,3,4 are used instead of o,m,p.
Daphnia is Daphnia magna
fathead is Pimphales promelas.
n = nominal, m = measured.
24, 48, 96 are the duration of the assay in hours.

Table 3. Aquire Database Unverified Records of Phenol Acute Toxicity, LC_{50}, in mg/L.

Table 3.1 (Phenol and the Xylenols)

phenol	xylenols					
	2,3-	2,4-	2,5-	2,6-	3,4-	3,5-
1.5	10.0	2.1	10.0	0.5	13.7	10.0
2.0	35.0	3.1	35.0	2.2	14.0	14.5
5.0	....	3.4	35.0	11.2	15.0	22.0
6.0	....	5.4	....	11.2	....	34.0
6.25	....	6.3	....	11.2	....	35.0
6.5	....	7.8	....	15.3	....	....
6.5	....	8.3	....	16.5	....	....
10.0	....	13.0	....	21.0	....	....
10.0	....	14.0	....	....	....	....
13.8	....	15.4	....	....	....	....
16.0	....	17.0	....	....	....	....
16.0	....	18.0	....	....	....	....
16.0	....	18.1	....	....	....	....

There are high values (over 100) for plants, mostly Lemna minor which floats on the surface and for some surficial insects. All values over 100 have been edited from the table. For phenol, where there were over 1000 AQUIRE records, and for o-cresol, only values under 19 mg/L are shown to keep the table to a reasonable length.

Table 3.2 (Cresols, Catechol, Resorcinol, Quinol and Guaicol)

catechol	resorcinol	quinol	guaicol	cresols		
				ortho-	meta-	para-
3.5	0.25	0.044	25.0	5.0	8.9	7.5
8.9	0.9	0.07	26.0	8.4	8.9	7.9
9.2	40.0	0.09	....	8.5	15.9	11.08
44.0	42.2	0.097	....	8.6	18.8	14.0
57.1	42.2	0.1	....	9.8	55.9	16.5
....	49.5	0.162	....	10.0	....	19.0
....	53.4	0.17	....	10.0	....	19.0
....	56.0	0.24	....	10.2	....	21.0
....	56.5	0.24	....	10.8	....	21.1
....	60.0	0.638	....	11.2	....	22.0
....	72.6	0.83	....	11.8	....	22.7
....	78.0	1.0	....	12.55.	....	26.0.
....	88.6	30.7	....	13.0	....	26.0

....	88.6	....	....	13.42	....	28.6
....	....	....	....	13.5	....	30.0
....	....	....	....	14.0	....	80.0
....	....	....	....	14.2	....	....
....	....	....	....	15.1	....	....
....	....	....	....	15.5	....	....
....	....	....	....	15.8	....	....
....	....	....	....	16.0	....	....
....	....	....	....	17.4	....	....
....	....	....	....	18.0	....	....
....	....	....	....	18.2	....	....
....	....	....	....	18.85	....	....

There are high values (over 100) for plants, mostly Lemna minor which floats on the surface and for some surficial insects. All values over 100 have been edited from the table. For phenol, where there were over 1000 AQUIRE records, and for o-cresol, only values under 19 mg/L are shown to keep the table to a reasonable length.

Table 4. Nominal LC_{50} in mg/L for 24 Hour Old *Artemia salina.*

phenol species	12 hours exposure	24 hours exposure
0-nitrophenol	11 (9.4-12.8)	6.5 (5.2-8.0)
p-nitrophenol	27 (23.5-30.9)	22.1 (18.6-26.4)
2,4-dinitrophenol	24 (20.0-28.9)	3.4 (1.6-7.0)
2,6-dinitrophenol	15.3 (13.2-17.6)	11.2 (10.3-12.1)
diaminophenol	20.2 (16.1-25.3)	14.7 (11.4-19.1)
diamidophenol	15.8 (13.2-38.2)	10.4 (8.6-12.5)

Barahona, M. V. and S. Sanchez-Fortun. 1996. Comparative Sensitivity of Three Age Classes of Artemia salina to Several Phenolic Compounds. Bull. Environm. Contam. Toxicol. 56: 271-278. Static, multiple reps, controls, DMSO co-solvent, temperature control, light control, nominal concentrations, no replacement.

Table 5. Nominal 24 Hour LC_{50} in mg/L for *Artemia salina.*

phenol species	24 hours old	48 hours old	168 hours old
0-nitrophenol	6.5 (5.2-8.0)	2.1 (1.3-3.3)	0.9 (0.3-2.3)
p-nitrophenol	22.1 (18.6-26.4)	2.4 (1.9-2.9)	0.6 (0.5-0.8)
2,4-dinitrophenol	3.4 (1.6-7.0)	0.2 (0.2-0.3)	0.1 (0.1-0.2)
2,6-dinitrophenol	11.2 (10.3-12.1)	2.2 (0.9-5.2)	0.5 (0.4-0.6)

diaminophenol	14.7 (11.4-19.1)	2.2 (1.0-4.8)	0.7 (0.5-1.0)
diamidophenol	10.4 (8.6-12.5)	0.7 (0.2-2.0)	0.5 (0.2-1.6)

Barahona, M. V. and S. Sanchez-Fortun. 1996. Comparative Sensitivity of Three Age Classes of Artemia salina to Several Phenolic Compounds. Bull. Environm. Contam. Toxicol. 56: 271-278. Static, multiple reps, controls, DMSO co-solvent, temperature control, light control, nominal concentrations, no replacement.

Table 6. Nominal LC_{50} in mg/L for 24 Hours Old *Daphnia magna* in Hardness 173 mg/L Water.

phenol species	24 hour	48 hour	NOEL
phenol	29 (20-39)	12 (7.3-20.0)	2.2
4-nitrophenol	24 (22-26)	22 (20-24)	13
2,4-dinitrophenol	4.5 (4.1-5.0)	4.1 (3.7-4.5)	3.1
2,4,6-trinitrophenol	greater than 220	85 (67-100)	less than 28
2,4-dimethylphenol	8.3 (5.9-11.0)	2.1 (1.8-2.5)	1.0
2,4-dinitro-6-methylphenol	4.3 (3.9-5.0)	3.1 (2.7-3.7)	1.5

LeBlanc, G. E. 1980. Acute Toxicity of Priority Pollutants to Water Flea (Daphnia magna). Bull. Environm. Contam. Toxicol. 24: 684-691. Static,

multiple reps, ph control, co-solvents, temperature control, light control, nominal concentrations, no replacement. co-solvent control, hardness control, evaporation control, dissolved oxygen control.

Table 7. Aquatic Organisms: LC_{50} or LC_{25} to Phenol in mg/L.

Species	[conc]	Time	References
Oncorhynchus mykiss-25	0.01	27 days	Birge *et al*, 1979, 1980
Rana pipiens-25	0.0128	9 days	Birge *et al*, 1979, 1980
Rana pipiens-50	0.04	9 days	Birge *et al*, 1979, 1980
amphibians-50	0.04-11.23	120-216 days	Birge *et al*, 1980
Oncorhynchus mykiss-50	0.07	27 days	Birge *et al*, 1979, 1980
fish (flow through)-50	0.07-2.67	6.5-58 days	Birge *et al*, 1979 DeGraeve *et al*, 1980 Millemann *et al*, 1984
marine invertebrates-50	172	24 hours	Smith *et al*, 1994
caddisflies and mayflies-50	2.0	48 hours	Kamshilov *et al*, 1978
Eristalis (flowerfly)-50	2000	48 hours	Kamshilov *et al*, 1978
marine invertebrates-50	32	96 hours	Key, 1981

Oncorhynchus mykiss-50	5.02	96 hours	McLeay, 1976
marine fish-50	5.6-30.6	96 hours	Kondaiah *et al*, 1994
Carassius auratus-50	85	2.5 hours	Kishino *et al*, 1995

From: Environment Canada. Priority Substances List Assessment Report. Phenol. February 2000.

Table 8. Fathead Minnow (*Pimphales promelas*) 96 Hour Phenol Bioassays in mg/L.

phenol species	96 hour LC_{50}	96 hour EC_{50}
2,4-dimethylphenol	16.6 (16.1-17.1)	.....
2,4-dinitrophenol	11.0 (8.78-13.7) 11.0 (9.69-12.6) 19.4 (18.5-20.4) 10.6 (9.57-11.8) 6.58 (5.86-7.39) 10.5 (9.32-11.7) 10.6 (9.53-11.9	11.0 (8.78-13.7) 11.0 (9.69-12.6) 10.6 (9.57-11.8) 6.58 (5.86-7.39) 10.5 (9.32-11.7) 10.6 (9.53-11.9
2,5-dinitrophenol	3.36 (2.99-3.78)	3.36 (2.99-3.78)
2-allylphenol	15.0 (13.7-16.3)	.....
2-nitrophenol	160 (141-182)	138 (122-155)
2-phenylphenol	6.15 (5.85-6.47)	.....
3-acetamidophenol	1130 (1070-1190)	1130 (1070-1190)

3-methoxyphenol	74.0 (70.3-77.8)	.....
4,6-dinitro-o-cresol 2-methyl-4,6-dinitrophenol	1.95 (1.81-2.09) 1.54 (1.40-1.70)	..... 1.54 (1.40-1.70)
4-acetamidophenol	814	814
4-amino-2-nitrophenol	36.2 (31.5-41.6)	.....
4-ethoxyphenol	10.4	10.4
4-methoxyphenol	110 (99.7-121)	94.9
4-methylphenol	16.5 (15.9-17.0)	16.5 (15.9-17.0)
4-nitrophenol	58.6 (56.2-61.1) 41.0 (37.7-44.6) 37.3 (34.4-40.5)	.....
4-propylphenol	11.0 (10.2-11.7)	8.62 (8.09-9.19)
nonylphenol	0.14	.....
phenol	28.8 (23.0-36.0) 32.4 (28.4-37.0) 49.7 (42.6-57.6)	.....
p-phenoxyphenol	4.95 (4.55-5.38)	4.95 (4.55-5.38)
p-phenylazophenol	1.17 (1.13-1.21)	.....
p-tert-butylphenol	5.15 (4.71-5.63)	.....
p-tert-pentylphenol	2.59	.....

- *Geiger, D. L. et al. 1988. Acute Toxicities of Organic Chemicals to Fathead Minnows (Pimphales promelas). Volume 4. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior.*
- *Geiger, D. L. et al. 1986. Acute Toxicities of Organic Chemicals to Fathead Minnows*

(Pimphales promelas). Volume 3. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior.

- *Geiger, D. L. et al. 1985. Acute Toxicities of Organic Chemicals to Fathead Minnows (Pimphales promelas). Volume 2. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior.*
- *Brooke, L. T. et al. 1984. Acute Toxicities of Organic Chemicals to Fathead Minnows (Pimphales promelas). Volume 1. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior.*
- *Measured toxicant values at 0, 24, 48, 72 and 96 hours. Controlled and measured temperature, pH, hardness, dissolved oxygen and alkalinity. No halogenated phenols are included in the table.*

Table 9. Aquatic Organisms: EC_X and other Non-Lethal Effects of Phenol in mg/L.

Species	[conc]	Time	References
Daphnia magna-NOEL	0.16	16 days	Deneer *et al*, 1988
Daphnia magna-EC_{10}	0.46	16 days	Deneer *et al*, 1988
Lemna perpusilla-EC_{50}	3.0	12-14 days	Blackman *et al*, 1955
Scenedesmus quadricauda-EC_{90}	7.53	24 days	Bringman *et al*, 1980
marine algae-LOEL	7.87	11 days	Thursby *et al*, 1985
marine algae-LOEL	49.8	5 days	Cowgill *et al*, 1989
Scenedesmus subspicatus-EC_{90}	1211	24 hours	Tisler *et al*, 1995
Lemna minor-EC_{50}	1500	48 hours	Rowe *et al*, 1982

Carassius auratus-50	85	2.5 hours	Kishino *et al*, 1995

From: Environment Canada. Priority Substances List Assessment Report. Phenol. February 2000.

There is a vast amount of data on the effects of phenol on aquatic organisms in tables 23 to 28 of the CCME supporting document on phenol. A few selected values have been collected in tables 10, 11 and 12 below. See the original document for the full data set and the full reference citations. The 'M' protocols were measured values; the 'N' values were nominal.

Table 10. Environment Canada Data for Phenol, Acute LC_{50} Freshwater Data in mg/L.

Aquatic organisms	test protocols	[mg/L]	References
Pimphales promelas	S, N, 48-h	8.3	Phipps *et al*, 1981
Pimphales promelas	F, M, 192-h	23	Phipps *et al*, 1981
Pimphales promelas	F, M, 96-h	24	Ruesink *et al*, 1975
Oncorhynchus mykiss	S, N, R, 96-h	5	McLeay, 1976
Oncorhynchus mykiss	S, N, R, 48-h	5.4	Brown *et al*, 1967
Oncorhynchus mykiss	F, M, 48-h	7.5	Mitrovic *et al*, 1976

Oncorhynchus mykiss	**S, N, R, 48-h**	**8**	**Brown *et al*, 1967**
Oncorhynchus mykiss	**S, N, R, 24-h**	**8.2**	**McLeay *et al*, 1976**
Oreochromis mossambicus	**S, N, 72-h**	**3**	**Nikonenko, 1986**
Notopterus notopterus	**S, N, 96-h**	**6.7**	**Gupta *et al*, 1983**
Rana pipiens	**F, M, 9-d**	**0.04**	**Birge *et al*, 1980**
Rana pipiens	**F, M, 5-d**	**0.05**	**Birge *et al*, 1980**
Rana catesbiana	**F, M, 5-d**	**0.6**	**Birge *et al*, 1980**
Rana catesbiana	**F, M, 9-d**	**0.23**	**Birge *et al*, 1980**
Daphnia magna	**S, N, 96-h**	**4.0**	**Ewelle *et al*, 1986**
Daphnia magna	**S, N, 264-h**	**4.0**	**Cowgill *et al*, 1991**
Daphnia magna	**S, M, 48-h**	**4.0**	**Lewis, 1983**
Ceriodaphnia dubia	**F, M, R, 48-h**	**3.1**	**Oris, 1991**
Ceriodaphnia dubia	**F, M, R, 48-h**	**4.3**	**Cowgill *et al*, 1991**
Daphnia pulex	**S, M, 48-h**	**18**	**Aleksyev *et al*, 1976**
Daphnia longsip	**S, M, 48-h**	**14**	**Aleksyev *et al*, 1987**
Ichthybotus hudsoni	**S, 96-h**	**2.5**	**Hickey *et al*, 1995**

Breton, Roger. 1998. Supporting Document for the Environmental Assessment of the Priority Substance Phenol. Canadian Environmental Protection Act, Environment Canada, Government of Canada. S-static, F-flow through, N-nominal, M-measured, R-static with renewal (some static tests with renewal have different results depending on the renewal frequency).

Table 11. Environment Canada Data for Phenol, Chronic Freshwater Data in mg/L.

Aquatic organisms	test protocols	[mg/L]	References
Pimphales promelas	F, M, 32-d MATC	1.83	Holcombe *et al*, 1982
Pimphales promelas	F, M, 30-d, LOEC	2.5	Degraeve *et al*, 1980
Oncorhynchus mykiss	F, M, 27-d, LC_{50}	0.07	Birge *et al*, 1979
Oncorhynchus mykiss	F, M, 27-d, LC_{25}	0.01	Birge *et al*, 1979
Lepomis macrochirus	F, M, 6.5-d, LC_{50}	1.69	Birge *et al*, 1979
Carassius auratus	F, M, 8-d, LC_{50}	0.34	Birge *et al*, 1979
Notopterus notopterus	S, N, 30-d MATC	0.3	Gupta, 1990
Daphnia magna	S, N, EC_{50}	7	Cowgill *et al*, 1991
Sphaerium novaezelandiae	S, 96-h EC_{50}	11.9	Hickey *et al*, 1995
Chaetocorophium	S, 96-h EC_{50}	8.1	Hickey *et al*,

lucasi			1995
Selenastrum capricornutum	S, N, EC_{32}	20	Reynolds *et al*, 1975
Photobacterium phosphoreumi	S, EC_{50}	12.5	Thomulka *et al*, 1993

Breton, Roger. 1998. Supporting Document for the Environmental Assessment of the Priority Substance Phenol. Canadian Environmental Protection Act, Environment Canada, Government of Canada. S-static, F-flow through, N-nominal, M-measured, R-static with renewal (some static tests with renewal have different results depending on the renewal frequency).

Table 12. Environment Canada Data for Phenol, Acute LC_{50} Marine Data in mg/L.

Marine organisms	test protocols	[mg/L]	References
Platichyhys flesus	S, M, 96-h	20.94	Smith *et al*, 1994
Solea solea	S, M, 96-h,	14.23	Smith *et al*, 1994
Chela atpar	F, N, 96-h,	12.1	Kondaiah *et al*, 1994
Ambassis gymnocephalus	F, N, 96-h,	5.6	Kondaiah *et al*, 1994
Puntius sofore	F, N, 96-h,	13.7	Kondaiah *et al*, 1994
Oryzias melanostigma	F, N, 96-h,	9.3	Kondaiah *et al*,

			1994
Aplocheilus panchax	F, N, 96-h,	9.4	Kondaiah *et al*, 1994
Panopeus herbstii	S, N, R, 96-h, LC_{25}	16	Key, 1981
Acartia clausi	S, N, 24-h, LC_{50}	3.8	Buttino, 1994

Breton, Roger. 1998. Supporting Document for the Environmental Assessment of the Priority Substance Phenol. Canadian Environmental Protection Act, Environment Canada, Government of Canada. S-static, F-flow through, N-nominal, M-measured, R-static with renewal (some static tests with renewal have different results depending on the renewal frequency).

Table 13. Shrimp (*Crangon septemspinosa*) and Clam (*Mya arenaria*) Toxicity in mg/L.

phenolic	LT_{50}	time in hours
phenol	7.5	21
3-methyl-4-nitrophenol	6.8	96
3,5-dimethylphenol	14.5	96
2,6-dimethylphenol	16.5	96
3,4-dimethylphenol	13.7	96
o-cresol	14.2	59
o-nitrophenol	32.9	96

p-nitrophenol	26.4	96
5-methyl-2-nitrophenol	4.4	44
hydroquinone	0.83	84
4-tert-butylphenol	1.9	96
4,6-dinitro-2-sec-butylphenol	5.1	96

McLeese, D. W. et al. 1979. Structure-Lethality Relationships for Phenol, Anilines and other Aromatic Compounds in Shrimp and Clams. Chemosphere (2): 53-57. Measured data, static with replacement.

Table 14. Phenol and Resorcinol 96 Hour LC_{50} Data.

Test Species	Phenol in mg/L	Resorcinol in mg/L
Asellus intermedius pillbug	25	greater than 100
Daphnia magna waterflea	4	0.25
Dugesia tigrina flatworm	32	greater than 100
Gammarus fasciatus sideswimmer	21	greater than 100
Helisoma trivolvis snail	greater then 100	greater than 100

Lumbriculus variegatus segmented worm	greater than 100	greater than 100
Pimphales promelas fathead minnow	32	40

Ewell, W. S. et al. 1986. Simultaneous Evaluation of the Acute Effects of Chemicals on Seven Aquatic Species. Environmental Toxicology and Chemistry (5): 831-840. Nominal chemistry, carbon filtered Lake Ontario water, static assay.

Table 15. Aquatic Organisms: 96 Hour LC_{50} Phenol Data in mg/L.

Test Fish and Amphibian Species	[phenol] mg/L
Oncorhynchus mykiss (rainbow trout)	0.15 (0.12-0.19)
Rana pipiens (leopard frog)	0.04 (0.03-0.05)
Rana temporarias (European common frog)	0.27 (0.17-0.39)
Ambystoma gracile (northwestern salamander)	0.38 (0.25-0.52)
Xenopus laevis (African clawed frog)	7.68 (5.73-10.52)
Rana palustris (pickerel frog)	9.87 (5.73-19.95)

Black, J. A. et al. 1982. The Aquatic Toxicity of Organic Compounds to Embryo-Larval

Stages of Fish and Amphibians. Research Report. University of Kentucky. Water Resources Research Institute, Lexington, Kentucky.

Table 16. Amphibians: 96 Hour LC_{50} Phenol Data in mg/L.

Amphibian Species	[phenol] mg/L	references
Rana pipiens	0.04 (0.03-0.05)	Black *et al*, 1982
Rana temporaria	0.27 (0.17-0.39)	Black *et al*, 1982
Rana palustris	9.87 (5.73-19.95)	Black *et al*, 1982
Xenopus laevis	7.68 (5.73-10.52)	Black *et al*, 1982
Bufo fowleri	2.45 (1.26-5.61)	Black *et al*, 1982
Ambystoma gracile	0.38 (0.25-0.52)	Black *et al*, 1982
Rana pipiens	0.05	Birge *et al*, 1980
Rana catesbiana	0.6	Birge *et al*, 1980

Table 17. Rainbow Trout (*Oncorhynchus mykiss*): 96 Hour LC_{50} Phenol Data in mg/L.

Phenol concentration	Reference
0.15 (0.12-0.19)	Black *et al*, 1982

0.07	Birge *et al*, 1979
0.01	Birge *et al*, 1979
5.0	McLeay, 1976
5.4	Brown *et al*, 1967
7.5	Mitrovic *et al*, 1968
8.0	Brown *et al*, 1967
8.2	McLeay, 1976
9.7	Hodson *et al*, 1984
11.6	Hodson *et al*, 1984
8.9	DeGraeve *et al*, 1980

Table 18. Fathead Minnow (*Pimphales promelas*): 96 Hour LC_{50} Phenol Data in mg/L.

Phenol concentration	Reference
~32	Black *et al*, 1982
32	Ewell, W. S. *et al*, 1986
8.3	Phipps *et al*, 1981
23	Phipps *et al*, 1981
24	Ruesink *et al*, 1975
28.8 (23.0-36.0)	Geiger, D. L. *et al*, 1984-88

32.4 (28.4-37.0)	Geiger, D. L. *et al*, 1984-88
49.7 (42.6-57.6)	Geiger, D. L. *et al*, 1984-88

Table 19. Rainbow and Fathead Minnow 96 Hour LC_{50} and Daphnia 48 Hour LC_{50} Phenol Data in mg/L.

Phenolic	rainbow	fathead	daphnia
phenol	8.9	67.5, 24.9	greater than 109
catechol	8.95	3.5	....
resorcinol	greater than 100	100	greater than 100
p-cresol	7.9	28.6	22.7
o-cresol	8.4	18.2	greater than 94
m-cresole	8.9	55.9	greater than 99.5
hydroquinone	0.097	0.044	0.162
p-benzoquinone	0.125	0.045	....

daphnia-Daphnia pullicaria
fathead-Pimphales promelas
rainbow-Oncorhynchus mykiss
DeGraeve, G. M. et al. 1980. Acute and Embryo-Larval Toxicity of Phenolic

Compounds. Arch. Environ. Contam. Toxicol. 9: 557-568.

Table 20. 24 Hour Phenolics Bioassays with *Daphnia magna* in mg/L.

Phenolic	LC_0	LC_{50}	LC_{100}
hydroquinone	0.04	0.09	0.31
m-cresol	1.6	8.9	25
phenol	3.9	31	125
4,6-dinitro-o-cresol	4.4	6.6	9.6
o-cresol	6.3	19	50
2,4-dinitrophenol	10	19	39
4-nitro-m-cresol	18	33	50
p-nitrophenol	18	35	50
m-nitrophenol	27	39	77
6-nitro-m-cresol	31	43	53
2-nitro-p-cresol	63	130	250
o-nitrophenol	63	210	500
2,4,6-dinitrophenol	88	145	250

Von Gottfried Bringmann et al. 1977. Befunde der Schadwirkung

Wassergefahrdender Stoffe gegen Daphnia magna. Z.f.Wasser-und-Abwasser-Forschung. 10 Jahrgang. Nr. 5/77.

Table 21. 48 Hour Phenolics Bioassays with *Daphnia magna* in mg/L.

Phenolic	[mg/L]
phenol	30.1
o-cresol	5.0
p-cresol	1.4
m-cresol	18.8

Parkhurst, B. R. et al. 1979. An Evaluation of the Acute Toxicity to Aquatic Biota of a Coal Conversion Effluent and its Major Components. Bull. Environm. Contam. Toxicol. 23: 349-356.

Table 22. 48 Hour Resorcinol Bioassay with *Daphnia pulex* in mg/L.

Phenolic	[mg/L]
Resorcinol	0.9

Trabalka, J. R. et al. Investigation of the Effects of Halogenated Organic Compounds Produced in Cooling Systems and Process Effluents on Aquatic Organisms.

Table 23. Hydroquinone and Phenol Bioassays in mg/L.

Species	Test Type	Phenol	Hydroquinone
Daphnia magna	24 hr EC_{50}	19.6 (15.7-25.6)	0.25 (0.14-0.16)
Daphnia magna	48 hr EC_{50}	5.55 (4.86-6.33)	0.13 (0.12-0.16)
Streptocephalus rubricaudatus	24 hr LC_{50}	36.3 (33.8-39.0)	0.07 (0.05-0.08)
Streptocephalus texanus	24 hr LC_{50}	21.9 (13.8-26.3)	0.10 (0.09-0.10)
Artemia salina	24 hr LC_{50}	28.2 (25.6-31.0)	30.7 (24.6-38.5)
Brachionius calyciflorus	24 hr LC_{50}	111.5 (94.9-131.3)	0.24 (0.18-0.33)
Photobacterium phosphoreum	5 min EC_{50}	24.4 (18.4-32.7)	0.28 (0.25-0.53)
Photobacterium phosphoreum	15 min EC_{50}	28.2 (20.1-39.0)	0.31 (0.19-0.53)
Photobacterium phosphoreum	30 min EC_{50}	27.0 (18.3-38.6)	0.24 (0.18-0.33)

Crisinel, A. et al. 1994. Cyst-based Ecotoxicological Tests Using Anostracans: Comparison of Two Species of Streptocephalus. Envir. Toxic. Water Quality. 9: 317-326.

Table 24. 48 Hour o-cresol Bioassays with *Daphnia* in mg/L.

Daphnia	Laboratory 1: Trial 1		Laboratory 2: Trial 1		Laboratory 2: Trial 2	
species	rep. 1	rep. 2	rep. 1	rep. 2	rep. 1	rep. 2
magna	9.8	8.6	23.8	23.1	15.1	14.0
pulex	10.8	8.5	.....	.....	.....	.....
cucullata	.....	.....	17.4	15.5	.....	.....

Canton, J. H. et al. 1978. Reproducibility of Short-Term and Reproductive Toxicity Experiments with Daphnia magna and Comparison of the Sensitivity of Daphnia magna with Daphnia pulex and Daphnia cucullata in Short-Term Experiments. Hydrobiologia 59(2): 135-140.

Table 25. 24 Hour Phenolics LC_{50} Bioassays with *Daphnia magna* and *Brachydanio rerio* in mg/L.

Phenolic	*Brachydanio rerio* (LC_{50})	*Daphnia magna* (LC_{50})

phenol	35-100	10-35
4-nitrophenol	10-35	10-35
3-nitrophenol	10-35	10-35
2,3-dimethylphenol	10-35	10-35
2,5-dimethylphenol	10-35	3.5-10
3,5-dimethylphenol	35-100	10-35
2,4-dinitro-6-methylphenol	1.0-3.5	3.5-10
hydroquinone	less than 1.0	less than 1.0

Devilliers et al. 1985. Intérêt de la relation dose-effet-temps en écotoxicologie pour la détermination des différentes classes chimiques de toxiques. Communication présentée au Congrès de l'AGHTM à Nancy, lors de la journée de la Commission d'Hydrologie Appliquée le 5 juin 1985.