



Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health

**PHENOL
1997**

This fact sheet provides Canadian soil quality guidelines for phenol for the protection of environmental and human health (Table 1). Supporting scientific documents are also available (Environment Canada 1996; Health Canada 1996).

Background Information

Phenol (C_6H_6O ; CAS 108-95-2) is a white to light pink crystalline solid, but is usually sold and used as a liquid (ATSDR 1989; Budavari 1989). It is an aromatic hydroxy compound belonging to the nonchlorinated monohydric phenol group. Synonyms for phenol include carbolic acid, hydroxy benzene, oxybenzene, phenic acid, phenyl hydroxide, phenylic acid, and phenyl hydrate. Phenol has a log K_{ow} of 1.46, a vapour pressure of 0.027 kPa (at

20°C), and a water solubility of 87 000 $mg \cdot L^{-1}$ (at 25°C). Phenol is primarily a human-made chemical, but also occurs naturally in decomposing organic material, animal wastes, and coal tar (ATSDR 1989).

Phenol is used in the production or manufacture of explosives, coke, fertilizers, illuminating gas, paints and paint removers, rubber, asbestos goods, wood preservatives, synthetic resins, textiles, drugs, pharmaceutical preparations, perfumes, Bakelite, and other plastics (Deichmann and Keplinger 1981). It is also used to make caprolactam for the production of nylon 6 and other synthetic fibres, and bisphenol A for the production of epoxy and other resins (ATSDR 1989). Phenol is used as a general disinfectant, an anaesthetic, and an antiseptic. It is present in a number of pharmaceuticals such as ointments, ear and nose drops, cold sore lotions,

Table 1. Soil quality guidelines for phenol ($mg \cdot kg^{-1}$).

Guideline	Land use			
	Agricultural	Residential/ parkland	Commercial	Industrial
Guideline	3.8^a	3.8^a	3.8^a	3.8^a
SQG _{HH}	3.8	3.8	3.8	3.8
Limiting pathway for SQG _{HH}	Groundwater check (drinking water)	Groundwater check (drinking water)	Groundwater check (drinking water)	Groundwater check (drinking water)
Provisional SQG _{HH}	NC ^b	NC ^b	NC ^b	NC ^b
Limiting pathway for provisional SQG _{HH}	ND	ND	ND	ND
SQG _E	20	20	128	128
Limiting pathway for SQG _E	Soil contact	Soil contact	Soil contact	Soil contact
Provisional SQG _E	NC ^c	NC ^c	NC ^c	NC ^c
Limiting pathway for provisional SQG _E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	0.1	1	10	10

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.

^aData are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated de novo guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

^bBecause data are sufficient and adequate to calculate an SQG_{HH} for this land use, a provisional SQG_{HH} is not calculated.

^cBecause data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_E is not calculated.

The guidelines in this fact sheet are for general guidance only. Site-specific conditions should be considered in the application of these values. The values may be applied differently in various jurisdictions. The reader should consult the appropriate jurisdiction before application of the values.

mouthwashes, gargles, toothache drops, analgesic rubs, throat lozenges, and antiseptic lotions (A. Karaokcu 1994, Health Canada, Ottawa, pers. com.). Approximately 93% of phenol produced in Canada is used in the production of phenolic resins, which are used as binding material in insulation materials, chipboard, and paints, and in casting sand foundries (Stanford Research Institute 1993; WHO 1994).

In Ontario, the 98th percentile of phenol concentrations in rural and urban parkland soils, not impacted by local point sources of pollution were 14 and 27 $\mu\text{g}\cdot\text{kg}^{-1}$, respectively (OMEE 1993). Phenol has been detected at contaminated sites at levels ranging from background to 26 900 $\mu\text{g}\cdot\text{kg}^{-1}$ (Marchand 1992; Pakdel et al. 1992). Marchand (1992) reported concentrations of nonchlorinated phenols ranging from 400 to 26 900 $\mu\text{g}\cdot\text{kg}^{-1}$ at a contaminated site near a petroleum refinery in Montreal.

Total phenolic concentrations in surface water across Canada are reported to be generally below 2 $\mu\text{g}\cdot\text{kg}^{-1}$, whereas groundwater concentrations range from 0.5 (detection limit) to 10 000 $\mu\text{g}\cdot\text{kg}^{-1}$ (CCREM 1987). Concentrations below 100 $\mu\text{g}\cdot\text{kg}^{-1}$ were reported in groundwater and piezometer well samples in Prince Edward Island (CCREM 1987). Sithole and Williams (1986) detected phenol in 3 of 120 raw water samples, with concentrations ranging from 0.12 to 0.357 $\mu\text{g}\cdot\text{kg}^{-1}$, in a Canadian national survey of drinking water samples.

Concentrations of phenol in the order of 1000 $\mu\text{g}\cdot\text{L}^{-1}$ have been reported downstream from pulp and paper and chemical industries in northern Ontario (Health and Welfare Canada 1980; CCREM 1987). Munro et al. (1985) reported concentrations of phenol ranging from 0.001 to 10 $\text{mg}\cdot\text{L}^{-1}$ in the waters of the St. Clair River.

Phenol levels ranging from <0.1 (detection limit) to 33.3 $\mu\text{g}\cdot\text{kg}^{-1}$ in sediment samples from various rivers in Quebec have been reported by Laliberté (1990). Phenol has also been detected in the sediments of the Ottawa river basin at concentrations of up to 0.2 $\text{mg}\cdot\text{kg}^{-1}$ (Paul and Laliberté 1987).

Environmental Fate and Behaviour in Soil

Phenol has a moderate vapour pressure of 0.027 kPa at 20°C and a Henry's law constant of 3.97×10^{-7} $\text{atm}\cdot\text{m}^3\cdot\text{mol}^{-1}$. Therefore, volatilization is expected to be rapid from surface soils (WHO 1994). In the atmosphere, phenol exists predominantly in the vapour phase (Eisenreich et al. 1981). The estimated half-life in air generally varies from 4 to 5 h (WHO 1994), but values ranging from 2.28 h to 22.8 h have been reported in the literature (Howard et al. 1991).

In soil, phenol is readily adsorbed by clays such as montmorillonite, kaolinite, and illite, with the rate of adsorption being influenced by sorptive capacity (Hemphill and Swanson 1963; Zhang and Sparks 1993). Adsorption reduces the rate of phenol biodegradation in soils, although sorption to clay surfaces is reversible (Saltzman and Yariv 1975; Knezovich et al. 1988). Relative to other mono-substituted benzene derivatives, phenol has a low K_{oc} and K_{ow} , hence, sorption to organic matter is expected to be low. In acidic soil, low adsorption and high mobility have been reported for phenol (Scott et al. 1982; Howard 1989).

In solution, phenol reacts as a weak acid. Based on its high pKa (9.99), phenol is not expected to dissociate in the environment at pH <9. Howard (1989) suggests that phenol may exist in a partially dissociated state in water and in moist soils.

Since phenol is soluble in water and moderately volatile, it is very mobile in soils (Howard 1989) and can readily leach through soils and contaminate groundwater.

Phenol absorbs light in the range of 290 to 330 nm and therefore may be subject to photodegradation (WHO 1994). Exposing phenol to radiation of 290 nm wavelength has been reported to result in a 32.5% reduction in the concentration of the parent compound (Freitag et al. 1985). An atmospheric photolysis half-life ranging from 46 to 173 h has been reported in the literature (Howard et al. 1991). Products of the atmospheric photochemical transformation of phenol include dihydroxybenzenes, nitrophenols, and numerous ring cleavage products (WHO 1994).

Phenol tends to biodegrade rapidly in the environment (i.e., within 2–5 d) (Baker and Mayfield 1980; Howard 1989). Both aerobic and anaerobic soil microorganisms are capable of utilizing phenol as a growth substrate, although decomposition under aerobic conditions is more rapid than under anaerobic conditions (Scott et al. 1982; Howard 1989). The complete mineralization of phenol to form carbon dioxide (under aerobic conditions) or carbon dioxide plus methane (anaerobic conditions) will occur under appropriate environmental conditions (Fedorak and Hrukey 1986; Dobbins et al. 1987; Tschuch and Fuchs 1987; Aquino et al. 1988; WHO 1994). Intermediate products of the biotransformation process include benzoate, catechol, *cis-cis*-muconate, β -keto adipate, succinate, and acetate (Paris et al. 1982; Krug et al. 1985; Knoll and Winter 1987). Bacteria of the genera *Pseudomonas* (e.g., *Pseudomonas putida*) are believed to play a major role in the degradation of phenol in soils and sediments (Bayly and Wigmore 1973; Haider et al. 1974; Knezovich et al. 1988). Other genera, such as *Achromobacter*, *Azotobacter*, *Arthrobacter*, *Bacillus*,

Brevibacterium, *Clostridium*, *Flavobacterium*, *Micrococcus*, and *Sarcina* have also been shown to actively degrade phenol (Haider et al. 1974; Visser et al. 1977).

Bioaccumulation

Relative to other substituted benzene derivatives, phenol has a low octanol–water partition coefficient ($\log K_{ow} = 1.46$) (WHO 1994). Therefore, phenol is not expected to bioaccumulate significantly (Verschuere 1983; Windholtz et al. 1983; Howard 1989; WHO 1994). Based on $\log K_{ow}$ data for phenol, a BCF of 7.6 has been calculated (Lyman et al. 1982).

Behaviour and Effects in Biota

Microbial Processes

Very few data are available on the toxicity of phenol to microbial processes such as nitrification, ammonification, and respiration. Several studies have shown that phenol inhibits nitrification significantly, especially at concentrations above 500 mg·kg⁻¹ (Tomlinson et al. 1966; Stafford 1974; Beccari et al. 1980; Neufeld et al. 1980; Benmoussa et al. 1986).

Terrestrial Plants

Phenols occur naturally in plants and soils. Since phenol and phenolics are relatively water soluble, they are present in the soil solution and are easily taken up by plants via root absorption and stored in different parts of the plant (Kuiters and Denneman 1987). Shafer and Schonherr (1985) reported that phenol was absorbed and stored in cuticle membranes of tomato (*Lycopersicon*) and green pepper (*Capsicum*) fruits and in rubber plant leaves. Absorption of C¹⁴-labeled phenol by roots in soybeans (*Glycine max.* L.) was reported by McFarlane et al. (1987). The absorbed phenol was stored in roots and not translocated to shoots, an observation that the authors attributed to in vivo metabolism of phenol to less mobile compounds.

Plant phenols play a role in resistance to insect damage (Leszczynski et al. 1985) and as defence agents against herbivores (Harborne 1985; Rhodes 1985; Haslam 1988).

Environment Canada (1995) reported that no effect on radish (*Raphanus sativa*) seedling emergence was observed in an artificial soil treated with 79 mg phenol·kg⁻¹ soil. At 125, 158, and 170 mg phenol·kg⁻¹ soil, radish seedling emergence was reduced by 25%, 41%, and

50%, respectively. A similar test on lettuce (*Lactuca sativa*) seedling emergence showed no effect at 40 mg phenol·kg⁻¹ soil, but at 79, 83, and 131 mg·kg⁻¹ seedling emergence was reduced by 23%, 25%, and 50%, respectively.

Terrestrial Invertebrates

No effect on earthworm (*Eisenia foetida*) mortality was observed at 160 mg phenol·kg⁻¹ soil, but at 210, 270, and 320 mg·kg⁻¹, the earthworms' mortality was 25%, 50%, and 74%, respectively (Environment Canada 1995). Neuhauser et al. (1985) reported an LC₅₀ for *E. foetida* of 401 mg phenol·kg⁻¹ soil.

Livestock and Wildlife

Phenol is readily absorbed (both orally and dermally) by animals (Clarke and Clarke 1975). The extent of dermal absorption depends primarily on the area of the skin exposed. Liao and Oehme (1980) reported that phenol absorption was influenced to a greater extent by the surface area of skin exposed than by the concentration of the applied solution. Phenol vapours are also absorbed into the pulmonary circulation (Deichmann and Keplinger 1981). After absorption, most of the phenol is oxidized and conjugated with sulphuric, glucuronic, and other acids.

Phenol poisoning in animals is usually associated with respiratory failure causing death. It may also cause damage to the lungs, liver, kidneys, heart, and genitourinary tract (Deichmann and Keplinger 1981).

Kao and Bridges (1979) reported that, following oral administration of phenol (25 mg·kg⁻¹ bw) in sheep and pigs, a high proportion of the dose is rapidly excreted through urine (in 3 h, 85% in sheep and 84% in pigs was recovered). Less than 0.5% was excreted in feces, suggesting that a considerable amount of phenol was absorbed. Phenyl phosphate was also reported as urinary metabolite of phenol in sheep.

LD₅₀ concentrations for rabbits exposed to phenol dermally range from 850 to 1400 mg·kg⁻¹ bw (Flickinger 1976; Vernot et al. 1977).

Schafer et al. (1983) reported an LD₅₀ of >113 mg·kg⁻¹ bw for the redwinged blackbird (*Agelaius phoeniceus*) following oral exposure to phenol.

Phenol toxicity was reported in pigs when phenyle (2.9% phenol) was used to disinfect the pig pen (Reid et al.

1982). The observed toxicological effects included skin ulcerations and nervous symptoms.

Human and Experimental Animal Health Effects

From the limited data available at the present time, it appears that most Canadians are mainly exposed to phenol by consuming food (78–89% of the total daily intake) and to a lesser extent by inhalation of phenol-contaminated air (up to about 22% of the total daily intake for teenagers). Both drinking water and soil ingestion were insignificant pathways of exposure, contributing to <0.1% of the overall daily exposure for all age classes. Exposure to phenol-containing products and nonprescription drugs could constitute the largest consumer exposure, but no Canadian use pattern of the latter products could be identified, and thus it was not possible to assess exposure via such products, especially by the dermal route (Health Canada 1996).

Phenol is readily and extensively absorbed after inhalation and oral and dermal exposure. Following absorption, phenol is rapidly distributed to all tissues, metabolized, and excreted in urine as free phenol and conjugated forms within approximately 24 h (Deichmann 1944; Piotrowski 1971; Capel et al. 1972; Liao and Oehme 1981; Edwards et al 1986).

Acute phenol poisonings in humans may result in death, regardless of the route of exposure (Bruce et al. 1987). Lethality has been associated with oral doses of 1.5 g phenol (range 1–60 g) in adults and 0.1–0.2 g phenol in children (Health and Welfare Canada 1980). Collapse, respiratory edema and failure, and damage to the kidneys, liver, pancreas, and spleen have been reported after acute exposure in humans. Symptoms of chronic and subchronic exposure to phenol include mouth sores, weight loss, vertigo, salivation, diarrhea, and dark urine (Merliss 1972).

Although some limited evidence in experimental animals suggests that phenol is a tumour promoter, phenol is “unclassifiable with respect to carcinogenicity in humans” (Group VI) because of the inadequate evidence of carcinogenicity in humans and experimental animals (Health Canada 1996).

WHO (1994) identified two critical studies for the derivation of a TDI via oral exposure. A multiple-dose, rat teratogenicity study by Jones-Price et al. (1983) provided a NOAEL of 60 mg·kg⁻¹ bw per day, based on dose-related signs of fetal toxicity such as decreased average fetal body weight. A NOAEL of 12 mg·kg⁻¹ bw per day,

based on kidney effects, was reported by Schlicht et al. (1992) in a limited 14-d study on female Fisher-344 rats. Using an uncertainty factor of 200 (10 for intraspecies variation, 10 for interspecies variation, and 2 for the limited database on the toxicity of phenol in animal studies), WHO (1994) recommended a range of 60–200 µg·kg⁻¹ bw per day as an upper limit of the TDI. The lowest TDI of the range recommended by WHO (1994), 60 µg·kg⁻¹ bw per day, is adopted provisionally by the Bureau of Chemical Hazards of Health Canada for the derivation of health-based soil quality guidelines for phenol at contaminated sites in Canada (Health Canada 1996).

Guideline Derivation

Canadian soil quality guidelines are derived for different land uses following the process outlined in CCME (1996a) using different receptors and exposure scenarios for each land use (Table 1). Detailed derivations for phenol soil quality guidelines are provided in Environment Canada (1996) and Health Canada (1996).

Soil Quality Guidelines for Environmental Health

Environmental soil quality guidelines (SQG_{ES}) are based on soil contact using data from toxicity studies on plants and invertebrates. In the case of agricultural land use, soil and food ingestion toxicity data for mammalian and avian species are included. To provide a broader scope of protection, a nutrient and energy cycling check is calculated. For industrial land uses, an off-site migration check is also calculated (Table 2).

For all land uses, the preliminary soil contact value (also called threshold effects concentration [TEC] or effects concentration low [ECL], depending on the land use) is compared to the nutrient and energy cycling check. If the nutrient and energy cycling check is lower, the geometric mean of the preliminary soil contact value and the nutrient and energy cycling check is calculated as the soil quality guideline for soil contact. If the nutrient and energy cycling check is greater than the preliminary soil contact value, the preliminary soil contact value becomes the soil quality guideline for soil contact.

For agricultural land use, the lower of the soil quality guideline for soil contact and the soil and food ingestion guideline is recommended as the SQG_E.

For residential/parkland and commercial land uses, the soil quality guideline for soil contact is recommended as the SQG_E.

Table 2. Soil quality guidelines and check values for phenol ($\text{mg}\cdot\text{kg}^{-1}$).

Guideline	Land use			
	Agricultural	Residential/ parkland	Commercial	Industrial
	3.8 ^a	3.8 ^a	3.8 ^a	3.8 ^a
Human health guidelines/check values				
SQG _{HH}	3.8 ^b	3.8 ^b	3.8 ^b	3.8 ^b
Soil ingestion guideline	1 900	1 900	7 000	150 000
Inhalation of indoor air check	500	500	1 800	2 100
Off-site migration check	—	—	—	28 000
Groundwater check (drinking water)	3.8	3.8	3.8	3.8
Produce, meat, and milk check	NC ^c	NC ^c	—	—
Provisional SQG _{HH}	NC ^d	NC ^d	NC ^d	NC ^d
Limiting pathway for provisional SQG _{HH}	ND	ND	ND	ND
Environmental health guidelines/check values				
SQG _E	20 ^e	20 ^e	128 ^e	128 ^e
Soil contact guideline	20	20	128	128
Soil and food ingestion guideline	NC ^f	—	—	—
Nutrient and energy cycling check	NC ^f	NC ^f	NC ^f	NC ^f
Off-site migration check	—	—	—	286
Groundwater check (aquatic life)	0.007 ^g	0.007 ^g	0.007 ^g	0.007 ^g
Provisional SQG _E	NC ^h	NC ^h	NC ^h	NC ^h
Limiting pathway for provisional SQG _E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	0.1	1	10	10

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health. The dash indicates guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

^aData are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated de novo guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

^bThe SQG_{HH} is the lowest of the human health guidelines and check values. For phenol, the SQG_{HH} is based on the groundwater check (drinking water).

^cNot calculated for phenol. Concerns about phenol should be addressed on a site-specific basis.

^dBecause data are sufficient and adequate to calculate an SQG_{HH} for this land use, a provisional SQG_{HH} is not calculated.

^eThe SQG_E is based on the soil contact guideline.

^fData are insufficient/inadequate to calculate this guideline/check.

^gThis check value has not been applied in the determination of the soil quality guideline. The applicability of the groundwater check (aquatic life) values should be determined on a site-specific basis.

^hBecause data are sufficient and adequate to calculate a SQG_E guideline for this land use, a provisional SQG_E is not calculated.

For industrial land use, the lower of the soil quality guideline for soil contact and the off-site migration check is recommended as the SQG_E .

In the case of phenol, there are insufficient data to derive the nutrient and energy cycling check and the soil and food ingestion guideline. The soil contact guidelines are recommended as the SQG_E for all land uses (Table 2).

The environmental groundwater check has been used to derive a phenol soil concentration intended to be protective of freshwater aquatic life associated with groundwater recharge to surface water. This groundwater check value is not applied in the determination of the environmental soil quality guidelines, but should be applied on a site-specific basis (Table 2).

Soil Quality Guidelines for Human Health

Human health soil quality guidelines (SQG_{HH}) for threshold contaminants are calculated from the TDI for the most sensitive receptor designated for a land use. For phenol, a provisional TDI has been adopted.

The phenol soil ingestion guideline has been approved by the Standards and Rulings Committee of the Bureau of Chemical Hazards of Health Canada as a preliminary soil quality guideline. The CCME, however, recommends the application of various check mechanisms, when relevant, in order to provide a broader scope of protection. For phenol, the lowest of the soil ingestion guideline, inhalation of indoor air check, off-site migration check, and groundwater (drinking water) check is recommended as the SQG_{HH} (Table 2).

The SQG_{HH} is therefore based on the groundwater for drinking water check for all land uses (Table 1).

Soil Quality Guidelines for Phenol

The soil quality guidelines for phenol are the lower of the SQG_{HH} and SQG_E for each land use. For all land uses, the soil quality guideline is the soil concentration calculated for the SQG_{HH} , which is based on the groundwater (drinking water) check (Table 1).

Because there are sufficient data to derive both an SQG_{HH} and an SQG_E for each land use, the soil quality guideline represents a fully integrated de novo guideline for each land use, derived according to the soil protocol (CCME 1996a). The interim soil quality criteria (CCME 1991) for phenol are superseded by the soil quality guidelines.

CCME (1996b) provides guidance on potential modifications to the final recommended soil quality guideline when setting site-specific objectives.

References

- Aquino, M.D., S. Korol, P. Santini, and J. Moreton. 1988. Biodegradation of phenolic compounds: I. Improved degradation of phenol and benzoate by indigenous strains of *Acinobacter* and *Pseudomonas*. *Rev. Latinoam. Microbiol.* 30(3):283–288. (Cited in WHO 1994.)
- ATSDR (Agency for Toxic Substances and Disease Registry). 1989. Toxicological profile for phenol. U.S. Department of Health and Human Services, U.S. Public Health Service, Atlanta, GA.
- Baker, M.D., and C.I. Mayfield. 1980. Microbial and nonbiological decomposition of chlorophenols and phenol in soil. *Water Air Soil Pollut.* 13:411–424.
- Bayly, R.C., and G.J. Wigmore. 1973. Metabolism of phenol and cresols by mutants of *Pseudomonas putida*. *J. Bacteriol.* 113:1112–1120.
- Beccari, M., R. Passino, R. Ramador, and V. Tandoi. 1980. Inhibitory effects on nitrification by typical compounds in coke plant wastewater. *Environ. Technol. Lett.* 1:245–252. (Cited in Benmoussa et al. 1986.)
- Benmoussa, H., G. Martin, F. Tonnard, Y. Richard, and O.A. Leprince. 1986. Étude de l'inhibition de la nitrification par les composés organiques. *Water Res.* 20:1465–1470.
- Bruce, R.M., J. Santodonato, and M.W. Neal. 1987. Summary review of the health effects associated with phenol. *Toxicol. Ind. Health* 3:535–568.
- Budavari, S. (ed.). 1989. *The Merck index: An encyclopedia of chemicals, drugs, and biologicals*. 11th ed. Merck and Co., Inc., Rahway, NJ.
- Capel, I.D., M.R. French, P. Milburn, R.L. Smith, and R.T. Williams. 1972. Fate of ^{14}C -phenol in various species. *Xenobiotica* 2:25–34.
- CCME (Canadian Council of Ministers of the Environment). 1991. Interim Canadian environmental quality criteria for contaminated sites. CCME, Winnipeg.
- . 1996a. A protocol for the derivation of environmental and human health soil quality guidelines. CCME, Winnipeg. [A summary of the protocol appears in Canadian environmental quality guidelines, Chapter 7, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]
- . 1996b. Guidance manual for developing site-specific soil quality remediation objectives for contaminated sites in Canada. CCME, Winnipeg. [Reprinted in Canadian environmental quality guidelines, Chapter 7, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]
- CCREM. (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines.
- Clarke, G.E.C., and M.L. Clarke. 1975. *Veterinary toxicology*. Bailliere Tindall, London. (Cited in Eales et al. 1981).
- Deichmann, W.B. 1944. Phenol studies; V, The distribution, detoxification, and excretion of phenol in the mammalian body. *Arch. Biochem.* 3:345–355.
- Deichmann, W.B., and M.L. Keplinger. 1981. Phenols and phenolic compounds. In: *Patty's industrial hygiene and toxicology*, G.D. Clayton and F.E. Clayton, eds. John Wiley and Sons, New York.
- Dobbins, D.C., J.R. Thornton-Manning, D.D. Jones, and T.W. Federle. 1987. Mineralization potential for phenol in subsurface soils. *J. Environ. Qual.* 16:54–58.

- Eales, F.A., J. Small, J.S. Oliver, and C. Quigley (eds.). 1981. Phenol poisoning in a newborn lamb. *Vet. Rec.* 108:421.
- Edwards, V.T., B.C. Jones, and D.H. Hutson. 1986. A comparison of the metabolic fate of phenol, phenyl glucoside and phenyl 6-O-malonyl-glucoside in the rat. *Xenobiotica* 16:801–807.
- Eisenreich, S.J., B.B. Looney, and J.D. Thornton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. *Environ. Sci. Technol.* 15:30–38.
- Environment Canada. 1995. Toxicity testing of National Contaminated Sites Remediation Program priority substances for the development of soil quality criteria for contaminated sites. Environmental Conservation Service, Evaluation and Interpretation Branch, Guidelines Division, Ottawa. Unpub.
- . 1996. Canadian soil quality guidelines for phenol: Environmental. Supporting document—Final draft. December 1996. Science Policy and Environmental Quality Branch, Guidelines Division, Ottawa.
- Fedorak, P.M., and S.E. Hrudey. 1986. Nutrient requirements for the methanogenic degradation of phenol and p-cresol in anaerobic draw and feed cultures. *Water Res.* 20:929–934.
- Flickinger, C.W. 1976. The benzenediols: Catechol, resorcinol and hydroquinone — A review of the industrial toxicology and current exposure limits. *Am. Ind. Hyg. Assoc. J.* 37:596–606. (Cited in WHO 1994.)
- Freitag, D., L. Ballhorn, H. Gayer, and F. Korte. 1985. Environmental hazard profile of organic chemicals. *Chemosphere* 14:1589–1616.
- Haider, K., G. Jagnow, R. Kohnen, and S.U. Lim. 1974. Degradation of chlorinated benzenes, phenols, and cyclohexane derivatives by benzene and phenol utilizing soil bacteria under aerobic conditions. *Arch. Microbiol.* 96:183–200.
- Harborne, J.B. 1985. Phenolics and plant defense. *Annu. Proc. Phytochem. Soc. Eur.* 25:393–408.
- Haslam, E. 1988. Plant polyphenols (syn. vegetable tannins) and chemical defense: A reappraisal. *J. Chem. Ecol.* 14:1789–1805.
- Health Canada. 1996. Canadian soil quality guidelines for phenol: Human health. Final report. Environmental Health Directorate, Air and Waste Section, Ottawa.
- Health and Welfare Canada. 1980. Phenols. In: Guidelines for Canadian drinking water quality 1978. Supporting documentation. Supply and Services Canada, Ottawa.
- Hemphill L., and W.S. Swanson. 1963. [No title.] *Eng. Ext. Ser.* (Purdue Univ.), No. 115, 204–217. (Cited in Yost and Anderson 1984.)
- Howard, P.H. 1989. Handbook of environmental fate and exposure data for organic chemicals, Vol. 1. Lewis Publishers, Chelsea, MI.
- Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. Handbook of environmental degradation rates. Lewis Publishers, Chelsea, MI.
- Jones-Price, C., T.A. Ledoux, J.R. Reel, P.W. Fisher, L. Langhoff-Paschke, and M.C. Marr. 1983. Teratologic evaluation of phenol in CD rats. PB85-104461/XAB. Research Triangle Institute, Research Triangle Park, NC.
- Kao, J., and J.W. Bridges. 1979. Metabolism of [¹⁴C]phenol by sheep, pig and rat. *Xenobiotica* 9:141–147.
- Knezovich, J.P., J.M. Hirabayashi, D.J. Bishop, and F.L. Harrison. 1988. The influence of different soil types on the fate of phenol and its biodegradation products. *Chemosphere* 17:2199–2206.
- Knoll, G., and J. Winter. 1987. Anaerobic degradation of phenol in sewage sludge: Benzoate formation from phenol and carbon dioxide in the presence of hydrogen. *Appl. Microbiol. Biotechnol.* 25:384–391.
- Krug, M., H. Ziegler, and G. Strabe. 1985. Degradation of phenolic compounds by the yeast *Candida tropicalis* HP-15: 1, Physiology and growth and substrate utilization. *J. Basic Microbiol.* 25:103–110.
- Kuiters, A.T., and C.A.G. Denneman. 1987. Water-soluble phenolic substances in soils under several coniferous and deciduous tree species. *Soil Biol. Biochem.* 19:765–769.
- Laliberté, D. 1990. Teneurs en métaux, BPC, pesticides organochlorés, HAP et composés phenoliques des sédiments et des poissons des rivières du Québec. QE 90-3. Réseau de surveillance des substances toxiques dans le milieu aquatique, Direction générale de l'assainissement des eaux.
- Leszczynski, B., J. Warchol, and N. Seweryn. 1985. The influence of phenolic compounds on the preference of winter wheat cultivars by cereal aphids. *Insect Sci. Appl.* 6:157–158.
- Liao, J.T.F., and W. Oehme. 1980. Literature reviews of phenolic compounds: I. Phenol. *Vet. Human Toxicol.* 22:160–164.
- Liao, T.F., and F.W. Oehme. 1981. Tissue distribution and plasma protein binding of [¹⁴C]phenol in rats. *Toxicol. Appl. Pharmacol.* 57:220–225.
- Lyman, W.J., W.F. Ruhl, and D.H. Rosenblatt. 1982. Handbook of chemical property estimation methods. McGraw-Hill, New York. (Cited in Howard 1989.)
- Marchand, N. 1992. Former Texaco Montreal Refinery Site Remediation. Paper presented at the Application of risk assessment to site remediation CPPI Workshop, Winnipeg, November 1992.
- McFarlane, J.C., T. Pflieger, and J. Fletcher. 1987. Transpiration effect on the uptake and distribution of bromacil, nitrobenzene and phenol in soybean plants. *J. Environ. Qual.* 16:372–376.
- Merliss, R.R. 1972. Phenol marasmus. *J. Occup. Med.* 14:55–56.
- Munro, J.R., M.G. Foster, T. Pawson, A. Stelzig, T. Tseng, and L. King. 1985. St. Clair River point source survey 1979–1980. Ontario Ministry of the Environment and Environment Canada, Toronto and Ottawa.
- Neufeld, R.D., A. Hill, and D. Adekoya. 1980. Phenol and free-ammonia inhibition to *Nitrosomonas* activity. *Water Res.* 14:1695–1703.
- Neuhauser, E.F., R.C. Loehr, M.R. Malecki, D.L. Milligan, and P.R. urkin. 1985. The toxicity of selected organic chemicals to the earthworm *Eisenia foetida*. *J. Environ. Qual.* 1:383–388.
- OMEE (Ontario Ministry of Environment and Energy). 1993. Ontario typical range of chemical parameters in soil, vegetation, moss bags and snow. Version 1.0a. PIBS 2792. Standards Development Branch, Phytotoxicology Section, Toronto.
- Pakdel, H., G. Couture, C. Roy, A. Masson, J. Locat, P. Gélinas, and S. Lesage. 1992. Developing methods for the analysis of toxic chemicals in soil and groundwater: The case of Ville-Mercier, Québec, Canada. In: Groundwater contamination and analysis of hazardous waste sites, S. Lesage and R.E. Jackson, eds. Marcel Dekker, Inc., New York.
- Paris, D.F., N.L. Wolfe, and W.C. Steen. 1982. Structure-activity relationships in microbial transformations of phenols. *Appl. Environ. Microbiol.* 44:153–158.
- Paul, M., and D. Laliberté. 1987. Teneurs en BPC, pesticides organochlorés, composés phenoliques et HAP des poissons et des sédiments du bassin versant de la rivière des Outaouais en 1985. QE 86-10. Réseau de surveillance des substances toxiques dans le milieu aquatique, Direction générale de l'assainissement des eaux.
- Piotrowski, J.K. 1971. Evaluation of exposure to phenol: absorption of phenol vapour in the lungs and through the skin and excretion of phenol in urine. *Brit. J. Ind. Med.* 28:172–178.
- Reid, G.G., P.J. Ketterer, H. Mawhinney, and P. Glover. 1982. Exposure to phenol and endrin as a cause of skin ulcerations and nervous signs in pigs. *Aust. Vet. J.* 59:160.
- Rhodes, M.J.C. 1985. The physiological significance of plant phenolic compounds. *Annu. Proc. Phytochem. Soc. Euro.* 25:99–117.
- Saltzman, S., and S. Yariv. 1975. Infrared study of the sorption of phenol and p-nitrophenol by montmorillonite. *Soil Sci. Soc. Am. Proc.* 39:474–479.

- Schafer, E.W., Jr., W.A. Bowles, Jr., and J. Hurlbut. 1983. The acute oral toxicity, repellency, and hazard potential of 998 chemicals to one or more species of wild and domestic birds. *Arch. Environ. Contam. Toxicol.* 12:355–382.
- Schlicht, M.P., V.C. Moser, B.M. Sumrell, E. Berman, and R.C. MacPhail. 1992. Systemic and neurotoxic effects of acute and repeated phenol administration (Abstract No. 1047). *Toxicologist* 12 (1):274. (Cited in WHO 1994.)
- Scott, H.D., D.C. Wolf, and T.L. Lavy. 1982. Apparent absorption and microbial degradation of phenol by soil. *J. Environ. Qual.* 11:107–112.
- Shafer, W.E., and J. Schonherr. 1985. Accumulation and transport of phenol, 2-nitrophenol and 4-nitrophenol in plant cuticles. *Ecotoxicol. Environ. Saf.* 10:239–252.
- Sithole, H.D., and D.T. Williams. 1986. Halogenated phenols in water at forty Canadian potable water treatment facilities. *J. Assoc. Off. Anal. Chem.* 69:807–810.
- Stafford, D.A. 1974. The effect of phenols and heterocyclic bases on nitrification in activated sludges. *J. Appl. Bacteriol.* 37:75–82.
- Stanford Research Institute. 1993. Phenol. In: CEH marketing research report, chemical economics handbook, L. Fujise, W. Cox. and M. Tashiro, eds. 686.500 A - 686.5001W. Stanford Research Institute International, Menlo Park, CA.
- Tomlinson, F., A. Boon, and C. Trotman. 1966. Inhibition of nitrification in the activated sludge process of sewage disposal. *J. Appl. Bacteriol.* 29:266–291.
- Tscheck, A., and G. Fuchs. 1987. Anaerobic degradation of phenol by pure cultures of nearly isolated denitrifying pseudomonas. *Arch. Microbiol.* 148:213-217.
- Vernot, E.H., J.D. MacEwen, C.C. Haun, and E.R. Kinkead. 1977. Acute toxicity and skin corrosion data for some organic and inorganic compounds and aqueous solutions. *Toxicol. Appl. Pharmacol.* 42:417–423.
- Verschuere, K. 1983. Handbook of environmental data on organic chemicals. 2d ed. Van Nostrand Reinhold Co., New York.
- Visser, S.A., G. Lamontagne, V. Zoulalian, and A. Tessier. 1977. Bacteria active in the degradation of phenols in polluted waters of the St. Lawrence River. *Arch. Environ. Contam. Toxicol.* 6:455–469.
- WHO (World Health Organization). 1994. Phenol. Environmental Health Criteria 161. Geneva.
- Windholz, M., S. Budavari, R.F. Blumetti, and E.S. Otterbein (eds.). 1983. The Merck index: An encyclopedia of chemicals, drugs and biologicals, 10th ed. Merck and Co. Inc., Rahway, NJ.
- Yost, E.C., and M.A. Anderson. 1984. Absence of phenol adsorption on goethite. *Environ. Sci. Technol.* 18:101–106.
- Zhang, P.C., and D.L. Sparks. 1993. Kinetics of phenol and aniline adsorption and desorption on an organic-clay. *Soil Sci. Soc. Am. J.* 57:340–345.

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Canadian Council of Ministers of the Environment. 1999 Canadian soil quality guidelines for the protection of environmental and human health: Phenol (1997). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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