EPA
United States Environmental Protection Agency
National Health Environmental Effects Research Laboratory
Corvallis, OR 97333
EPA/600/R-96/124
August 1996
C. 1

Amphibian Toxicity Data For Water Quality Criteria Chemicals

EPA/600/R-96/124
August 1996

AMPHIBIAN TOXICITY DATA FOR WATER QUALITY CRITERIA CHEMICALS

by

Gerald S. Schuytema
Alan V. Nebeker
U.S. Environmental Protection Agency
National Health and Environmental Effects Research Laboratory
Western Ecology Division
Corvallis, OR 97333

Project Officer:

Mary E. Kentula
U.S. Environmental Protection Agency
National Health and Environmental Effects Research Laboratory
Western Ecology Division
Corvallis, OR 97333

U.S. Environmental Protection Agency
Office of Research and Development
National Health and Environmental Effects Research Laboratory
Western Ecology Division
Corvallis, OR 97333

Disclaimer

This document has been subjected to U.S. Environmental Protection Agency peer and administrative review, and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This report should be cited as:

Schuytema, G.S. and A.V. Nebeker. 1996. Amphibian toxicity data for water quality criteria chemicals. EPA/600/R-96/124. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon.

CONTENTS

TABLES

ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Barbara Hagler, Stephanie Bianchi, and Kristina Dunn for literature searching and library assistance, and Patty Adkins for the demanding job of typing the tables. Helpful reviews were provided by Lawrence Blus, Michael Cairns, Stephen Dominguez and Christian Grue.

EXECUTIVE SUMMARY

The Clean Water Act of 1987 requires the U.S. Environmental Protection Agency to develop and publish water quality criteria; there are now more than 100 criteria documents published or in preparation. There is increasing recognition that amphibian data should be included in the derivation of water quality criteria. While water quality criteria protective of fishes may also protect amphibians, exceptions may occur in wetlands or ephemeral water bodies where there may be a high degree of exposure of amphibians to chemicals. The small amount of amphibian data presently in the water quality criteria documents is based on aquatic stages; there are no specific criteria for terrestrial life stages. The purpose of this report is to consolidate amphibian toxicity data into forms useful for others to derive or support ambient water quality criteria, and it covers only those chemicals in the existing or proposed U.S. EPA water quality criteria documents.

The structure of the tables in this report generally follows the format in existing water quality criteria documents wherein separate tables are given for acute data, chronic data, residue data and "other" data. Data on amphibian species non-resident in North America have been included in the "other data" tables to provide additional background information on amphibian response to toxic chemicals.

Only about one-fourth of the water quality criteria chemicals or chemical groups covered in this report have associated amphibian data in their criteria documents. New data were located for about half of the documents that originally contained no amphibian information. Additional information in this report has the potential to serve as supplemental data in about one-third of the documents which presently contain no amphibian data. Amphibian data in the tables were abstracted from 163 references. Another 101 references were reviewed but data were not included in the tables because of unsuitability for criteria development.

Fifty-eight species of amphibians were associated with over 135 chemicals, chemical subgroups, compounds and formulations. *Rana pipiens* and *Xenopus laevis* were linked with over 40 chemicals while 12 species of amphibians were associated with only a single chemical.

A scarcity of chronic toxicity data for amphibians makes it difficult to generalize about the protection afforded these animals by current water quality criteria. While the criteria for some animals (e.g. cadmium, dieldrin) appear protective of amphibians, the relationships between other criteria (e.g. naphthalene, nitrosamines, thallium) and existing toxicity data suggest that some amphibians may be at risk. Only a careful evaluation of all pertinent data and collection of new information will permit definitive conclusions about the safety of existing criteria.

INTRODUCTION

Water Quality Criteria Background

Section 304(a) of the Clean Water Act of 1987 requires the U.S. Environmental Protection Agency to develop and publish water quality criteria reflecting the latest scientific knowledge on identifiable health and welfare effects which may be expected from pollution in any body of water. In 1980, 65 ambient water quality criteria documents were published with new criteria appearing periodically thereafter (USEPA 1986a). There are presently over 100 criteria documents published or in preparation.

Guidelines for the derivation of these criteria are very complex and have been described in detail by Stephan *et al.* (1985). Basically, criteria are derived using a variety of aquatic organisms in toxicity tests. A final acute value is derived from acceptable acute test results. The guidelines require tests with at least one species of freshwater animal from at least eight different families. These families must be from the following animal groups: Salmonidae; a second family in the class Osteichthyes (e.g. bluegill); a third family in the phylum Chordata (may be an amphibian); a planktonic crustacean (e.g. cladoceran, copepod); a benthic crustacean (e.g. amphipod, isopod); an insect (e.g. mayfly, stonefly); a family or a phylum other than Arthropoda or Chordata (e.g. Annelida, mollusca); and a family in any insect order or any phylum not already represented.

Acute-chronic ratios are derived from acute and chronic toxicity tests on three or more species which include one fish, one invertebrate, and one acutely sensitive species. An acceptable test with a freshwater alga or vascular plant, and at least one acceptable bioconcentration factor (quotient of chemical in one or more tissues divided by concentration of chemical in water in which animal has been living) should also be available. A final chronic value may then be derived. Criteria are then generated from these tests. A criterion maximum concentration (equal to one-half the final acute value) is derived using the final acute value. A criterion continuous concentration is derived from the final chronic value, final plant value, and final residue value (lowest residue value obtained by dividing maximum permissible tissue concentration by bioconcentration factor), unless other data have shown that a lower value should be used. The value with the lowest concentration determines the criterion continuous concentration. Confidence in a criterion increases with the amount of available data.

Water Quality Criteria and Amphibians

Water quality criteria protective of fish may also protect amphibians, since in most cases fish are generally considered to be more sensitive to pollutants (Hall and Swineford 1980, Mayer and Ellersieck 1986). Exceptions may occur in wetlands and ephemeral bodies of water where the use of a chemical would suggest a high degree of exposure to amphibians, especially where natural or constructed wetlands are used for waste treatment. In addition, it is conceivable that stresses to amphibians, such as habitat fragmentation and ultraviolet radiation, which are often implicated in population declines, could be potentiated, or potentiate, chemical stresses.

Amphibians can be important indicators of environmental contamination, because they are present in both aquatic and terrestrial environments. There is increasing recognition that they are important factors in the environment and should be used in the derivation of water quality criteria (Williams *et al.* 1989).

Historically much emphasis has been placed on developing water quality criteria protective of aquatic species with the assumption that more semi-aquatic wildlife would also be protected (Williams *et al.* 1989). Mammals, birds and amphibians/reptiles are three wildlife subgroups identified by Williams *et al.* (1989) for which predictive/extrapolative models should be developed to generate criteria. The few acute amphibian data that have been considered in deriving criteria have historically focused on strictly aquatic stages such as embryos, larvae or tadpoles (USEPA 1980c, 1980e, 1980m, 1980s, 1986e, 1986f, 1993).

Objective

The purpose of this document is to locate and consolidate amphibian toxicity data into a form useful in deriving or supporting ambient water quality criteria.

LITERATURE SOURCES

Toxicity literature dealing with the effects of chemicals on amphibians was obtained primarily from the following sources: 1) on-going surveys of current journal indexes published weekly by the Institute for Scientific Information, Inc., Philadelphia, PA; 2) a recent comprehensive review of amphibian toxicity literature (Power *et al.* 1989); 3) data from ambient water quality criteria documents (Table 1); 4) the U.S. Environmental Protection Agency's aquatic toxicity information retrieval data base (AQUIRE) which covers data from 1970 to the present (Computer Sciences Corp. 1993); 5) information from amphibian data files maintained at the Western Ecology Division, National Health and Environmental Effects Research Laboratory, Corvallis, OR.

DATA FORMAT

Table Structure

The distribution of available data on water quality criteria chemicals and amphibians is presented in Tables 1-3. The structure of the data tables in this report (Tables 5 - 67) generally follows the format of the tables in existing water quality criteria documents (e.g. USEPA 1980c) wherein separate tables are given for acute, chronic, residue and "other" data. Only two chemicals were found where applicable chronic data were available: aldrin/dieldrin (Table 6B) and cadmium (Table 15B); applicable residue data were found only for aldrin/dieldrin (Table 6C).

Table Content

The data tables include information on the amphibian species name, life stage or age, chemical name, test compound or formulation, test duration, test method (whether static, flow-through, renewal, measured or unmeasured exposure concentrations), test results and literature citations. Amphibian data in water quality criteria documents are based only on North American resident species (see Stephan *et al.* 1985), with the exception of tributyltin (USEPA 1988d). Species such as *Xenopus laevis* which have reproducing wild populations in North America are included in this definition. This practice has been followed in the present report for acute, chronic and residue tables. Data for non-resident species have been included, however, in the "other data" tables as supplemental background information to the chemicals of concern. Acute data tables include the 96-hr LC50 (median lethal concentration). Chronic data tables include chronic levels (NOAEL - no observed adverse effects level and LOAEL - lowest observed adverse effect level) and the chronic value (geometric mean of the NOAEL and LOAEL). Residue tables include exposure concentrations, percent lipid, tissue type and BCF (bioconcentration factor). The "other data" tables include reported effects and chemical concentration; they include data not applicable for the acute and chronic data tables but potentially useful in characterizing the chemical's toxicity (e.g. exposure times generally other than 96 hours, physiological and developmental effects, percent mortality).

Hardness and pH are included for metals; pH is included for pentachlorophenol. In some cases where pH or hardness data were not provided, the type of dilution water (e.g. Holtfreter's Solution) is included. Exposure concentrations are generally given in micrograms per liter (µg/L). Concentrations of metals are expressed as the metal, not the compound. Concentrations of formulated products are given as the active ingredient if possible.

DATA DISTRIBUTION

Eighty-two of the 95 chemicals or chemical groups reviewed in this report are described in water quality criteria documents (Table 1). Each document covers a single chemical or chemical group and their related compounds or sub-divisions (e.g. cadmium: cadmium chloride, cadmium nitrate; chlorophenoxy herbicides: 2,4-D amine, 2,4, 5 -T amine). Criteria documents for 13 chemicals are in development and have not yet been published. Twelve chemicals also have updated versions of the documents. Only 29 of the documents (covering 23 chemicals or chemical groups) contained amphibian data. No amphibian data were located for 30 chemicals in either the water quality criteria documents or in other references. Amphibian resident species acute toxicity data were located in the published literature for 16 documents where there are presently no amphibian data and for nine documents already containing some data. New "other data" for resident species were located for 33 documents which contained no amphibian data and for 17 documents that contained some amphibian data. Non-resident species data were located for 25 documents which contained no amphibian data, and for 17 documents with existing data; this data was included to provide additional insight into the effects of chemicals on amphibians (Table 2).

The association of individual amphibian species and chemicals is summarized in Table 3. Fifty-eight species (names as reported by authors) were associated with over 135 chemicals (chemicals, compounds, subgroups, and formulations). *Rana pipiens* and *Xenopus laevis* were linked with 40 or more different chemicals. Some resident North American species (*Acris crepitans blanchardi, Acris gryllus, Bufo canorus, Bufo debilis debilis, Bufo punctatus, Hyla gratiosa, Hyla squirrela, Hyla versicolor, Notophthalmus viridescens, Rana grylio, Rana hecksheri, Triturus viridescens*) were found in conjunction with only a single chemical. The effects of mercury have been reported on over 25 resident or nonresident species (Tables 45A, 45B). In contrast, the effects of some chemicals have been reported on only one resident or non-resident species (acrolein, Table 5; antimony, Table 9; chlorinated phenols, Table 23; diazinon, Table 31; dichloropropanes and dichloropropenes, Table 32; dichlorvos, Table 33; DEHP, Table 34; mirex, Table 48; naphthalene, Tables 49A and 49B; nitrobenzene, Table 51; propoxur, Table 59. The paucity of amphibian data used in deriving water quality criteria is illustrated by the presence of only three water quality criteria documents which contain amphibian data in their acute data tables: aniline (Table 8A); pentachlorophenol (Table 54A); and toxaphene (Table 64A).

Documents which contained amphibian data in their "other" tables (data that can't presently be used for deriving criteria values) were aluminum (Table 7B), aniline (Table 8B),antimony III (Table 9), arsenic (Table 10), cadmium (Table 15C), chromium (Table 27), copper (Table 28B), endosulfan (Table 35), lead (Table 42), mercury (Table 45B), nickel (Table 50B), pentachlorophenol (Table 54B), selenium (Table 60B),silver (Table 61), thallium (Table 62), toxaphene (Table 64B), tributyltin (Table 65), and zinc (Table 67B). The dioxin document (USEPA 1984) contained an amphibian reference (see Appendix A) but was not included in this tabulation because exposure was by injection.

Data quality for the tables was evaluated according to the following standards. Unnamed species were generally not included unless the reference had already been cited in a water quality criteria document (e.g. Dilling and Healey 1926). References were also not included when toxic effects were determined using isolated tissues in vitro (e.g. skin, muscle), exposure concentrations were not clearly stated, test results were only presented in graphical form, body burdens or residues were presented without exposure concentrations, only spiked sediment and not water column concentrations were presented, test animals were exposed through injection, feeding or inhalation, exposure concentrations were only approximate, insufficient detail was presented about test conditions, the number of affected animals was not stated, exposure concentrations were not constant, and when the dose to effect relationship was unclear. A total of 101 references, (thirty eight percent of the total reviewed) associated with 36 of the chemicals, were reviewed but were not included in Tables 5 to 67 (Appendix. A). While not suitable for criteria development, they might provide additional insight into various aspects of the effects of toxic chemicals on amphibians.

CHEMICAL, CRITERIA AND SPECIES RELATIONSHIPS

Ambient water quality criteria for chemicals for which amphibian data has been located, either in existing water quality criteria documents or in other literature, are listed in Table 4. The criteria listed for acrolein, beryllium, carbon tetrachloride, chlorinated benzenes, chloroform, DDE, TDE, dichloropropanes, dichloropropenes, halomethanes, naphthalene, nitrosamines, phenol, phthalate esters, thallium, toluene and trichloroethylene are the lowest observed adverse effect levels (LOAEL) because insufficient data did not permit development of actual criteria. Actual acute criteria values listed are either a concentration not to be exceeded at any time, or a one-hour average concentration not to be exceeded more than once every three years on the average. Actual chronic criteria values listed are either a 24-hour average or a four-day average concentration not to be exceeded more than once every three years on the average.

The water quality criteria documents for chlorinated ethanes (USEPA 1980j) and chlorinated phenols (USEPA 1980k) present only a range of acute and chronic toxicity values for various species instead of specific criteria, indicating a need for more data. Limited toxicity data bases for polynuclear aromatic hydrocarbons (USEPA 1980bb) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (USEPA 1984) do not permit statements about acute or chronic criteria in the documents. The criterion given for boron (USEPA 1986a) is for long-term irrigation or sensitive crops. The criteria given for chlorophenoxy herbicides (USEPA 1986a) and manganese (USEPA 1986a) are for domestic water supplies.

It is difficult to generalize about the protectiveness of water quality criteria for amphibian species. For example, the criteria for cadmium and dieldrin (Table 4) would appear to be protective of amphibians. The cadmium acute and chronic criteria (3.9 and 1.1 µg/L) are well below the range of acute (468-850 µg/L) and chronic (24-210 µg/L) toxicity values reported in the literature (Tables 15A and 15B). The acute and chronic criteria for dieldrin (2.5 and 0.0019 µg/L) are likewise well below the range of acute (30-150 µg/L) and chronic (1.2-16.3 µg/L) toxicity literature values (Tables 6A and 6B). The chronic values in these two cases are the geometric mean of LOAEL and NOAEL values. The acute criteria values for many of the chemicals listed in Table 4 are lower than reported literature toxicity values for amphibians. However, since chronic toxicity values were not found in the literature for these chemicals, generalized conclusions about the protectiveness of criteria for these chemicals for amphibians maybe unwarranted.

In some cases, existing criteria may not be protective of amphibians. The single 96-hour LC50 value of 7 µg/L for acrolein (Table 5) is well below both the acute and chronic criteria values (68 and 21 µg/L), suggesting that some amphibians may be at risk. Acute criteria values for naphthalene, nitrosamines and thallium are greater than reported acute toxicity values for various amphibian species (Tables 49A, 52A, 62), also possibly suggesting these criteria may not protect amphibians. No chronic criteria are reported for these chemicals, however, making evaluation difficult.

The range of reported amphibian acute LC50 values may span the acute criterion value as in the case of aluminum where the criterion of 750 µg/L falls between reported LC50s of 400-1,600 µg/L for various species (Table 7A). Similarly, seven to eight-day LC50s (30-2130 µg/L) for resident species exposed to chromium span the acute criteria value of 1,700 µg/L (Table 27).

Many of the chronic criteria values in water quality documents are based on *Daphnia* life cycle tests. The results from these tests may not be equivalent to results obtained from amphibian life cycle tests which may ultimately be needed to derive meaningful protective criteria for amphibians.

RECOMMENDATIONS

The tabulated data in this report provides valuable information on the toxicity of water quality criteria chemicals to amphibians. It should be viewed as a guideline to the literature. Researchers should examine the original papers for full understanding of the data.

LITERATURE CITED

Abbasi, S.A., and R. Soni. 1984. Teratogenic effects of chromium (VI) in environment as evidenced by the impact on larvae of amphibian *Rana tigrina*: Implications in the environmental management of chromium. Intern. J. Environ. Studies 23: 131-137.

Albers, P.H. and R.M. Prouty. 1987. Survival of spotted salamander eggs in temporary ponds of coastal Maryland. Environ. Pollut. 46: 45-61.

Anguiano, O.L., C.M. Montagna, M. Chifflet de Llamas, L. Gauna and A.M. Pechen de D'Angelo. 1994. Comparative toxicity of parathion in early embryos and larvae of the toad *Bufo arenarum* Hensel. Bull. Environ. Contam. Toxicol. 52: 649-655.

Bantle, J.A., D.J. Fort and B.L. James. 1989. Identification of developmental toxicants using the frog embryo teratogenesis assay-*Xenopus* (FETAX). Hydrobiologia 188/189: 577-585.

Birge, W.J. 1978. Aquatic toxicology of trace elements of coal and fly ash. *In*: J.H. Thorpe and J.W. Gibbons (eds). Energy and Environmental Stress in Aquatic Systems. CONF-771114. Springfield, VA. pp 219-240.

Birge, W.J. and J.A. Black. 1977. A continuous flow system using fish and amphibian eggs for bioassay determinations on embryonic mortality and teratogenesis. Final Technical Report. EPA 560/5-77-002. U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, DC. National Technical Information Service, Springfield, VA. PB 285 191.

Birge, W.J. and J.A. Black. 1979. Effects of copper on embryonic and juvenile stages of aquatic animals. *In*: J.O. Nriagu (ed). Copper in the Environment. Part II. Wiley, NY. pp 374-398.

Birge, W.J. and J.A. Black. 1980. Aquatic toxicology of nickel. *In*: J.O. Nriagu (ed). Nickel in the Environment. Wiley, New York, NY. pp 349-366.

Birge, W.J., J.A. Black and R.A. Kuehne. 1980. Effects of organic compounds on amphibian reproduction. Res. Rept. No. 121. Water Resources Research Institute, University of Kentucky, Lexington. National Technical Information Service, Springfield, VA. PB80-147523.

Birge, W.J., J.A. Black and A.G. Westerman. 1978a. Effects of polychlorinated biphenyl compounds and proposed PCB-replacement products on embryo-larval stages of fish and amphibians. Res. Rept. No. 118. Water Resources Research Institute, University of Kentucky, Lexington. National Technical Information Service, Springfield, VA. PB 290 711.

Birge, W.J., J.A. Black and A.G. Westerman. 1979a. Evaluation of aquatic pollutants using fish and amphibian eggs as bioassay organisms. *In*: S.W. Nielson, G. Migaki and D.G. Scarpelli (eds). Animals as Monitors of Environmental Pollutants. Nat. Acad. Sci. Washington. pp. 108-118.

Birge, W.J., J.A. Black, A.G. Westerman and J.E. Hudson. 1979b. The effects of mercury on reproduction of fish and amphibians. *In*: J.O. Nriagu (ed). The Biogeochemistry of Mercury in the Environment. Elsevier/North-Holland Biomedical Press. pp. 529-655.

Birge, W.J., J.A. Black, A.G. Westerman and B.A. Ramey. 1983. Fish and amphibian embryos - a model system for evaluating teratogenicity, Fund. Appl. Toxicol. 3: 237-242.

Birge, W.J., J.E. Hudson, J.A. Black and A.G. Westerman. 1978b. Embryo-larval bioassays on inorganic coal elements and *in situ* biomonitoring of coal-waste effluents. *In*: D.F. Samuel, J.R. Stauffer, C.H. Hocutt and W.T. Mason. (eds). Surface Mining and Fish/Wildlife Needs in the Eastern United States. U.S. Dept. Int. Fish Wildl. Serv., FWS 0BS-78/81. pp 97-104. National Technical Information Service, Springfield, VA. PB 298 353.

Birge, W.J. and J.J. Just. 1973. Sensitivity of vertebrate embryos to heavy metals as a criterion of water quality. Res. Rept. No. 61. Water Resources Research Institute, University of Kentucky, Lexington. National Technical Information Service, Springfield, VA. PB 226 850.

Birge, W.J. and J.J. Just. 1975. Sensitivity of vertebrate embryos to heavy metals as a criterion of water quality. Phase I. Res. Rept. No. 71. Water Resources Research Institute, University of Kentucky, Lexington.

Birge, J.J. Just, A. Westerman, J.A. Black and O.W. Roberts. 1975. Sensitivity of vertebrate embryos to heavy metals as a criterion of water quality. Phase II.Bioassay procedures using developmental stages as test organisms. Res. Rept. No. 84. Water Resources Research Institute, University of Kentucky, Lexington.

Black, J.A. and W.J. Birge. 1980. An avoidance response bioassay for aquatic pollutants. Res. Rept. No. 123. Water Resources Research Institute, University of Kentucky, Lexington. National Technical Information Service, Springfield, VA. PB80-180490.

Black, J.A., W.J. Birge, W.E. McDonnell, A.G. Westerman, B.A. Ramey and D.M. Bruser. 1982. The aquatic toxicity of organic compounds to embryo-larval stages of fish and amphibians. Res. Rept. No. 133. Water Resources Research Institute, University of Kentucky, Lexington. National Technical Information Service, Springfield, VA. PB82-224601.

Bradford, D.F., C. Swanson and M.S. Gordon. 1992. Effects of low pH and aluminum on two declining species of amphibians in the Sierra Nevada, California. J. Herpetol. 26: 369-377.

Brooks, J.A. 1981. Otolith abnormalities in *Limnodynastes tasmaniensis* tadpoles after embryonic exposure to the pesticide dieldrin. Environ. Pollut. (Series A) 25: 19-25.

Browne, C.L. and J.N. Dumont. 1979. Toxicity of selenium to developing *Xenopus laevis* embryos. J. Toxicol. Environ. Health 5: 699-709.

Browne, C. and J.N. Dumont. 1980. Cytotoxic effects of sodium selenite on tadpoles (*Xenopus laevis*). Arch. Environ. Contam. Toxicol. 9: 181-191.

Canton, J.H. and W. Sloof. 1982. Toxicity and accumulation studies of cadmium (Cd^{2+}) with freshwater organisms of different trophic levels. Ecotoxicol. and Environ. Safety 6: 113-128.

Chang, L.W., L.L.M. Mak and A.H. Martin. 1976. Dose-dependent effects of methylmercury on limb regeneration of newts (*Triturus virdescens*). Environ. Res. 11: 305-309.

Chang, L.W., K.R. Reuhl and A.W. Dudley, Jr. 1974. Effects of methylmercury chloride on *Rana pipiens* tadpoles. Environ. Res. 8: 82-91.

Clark, K.L. and R.J. Hall. 1985. Effects of elevated hydrogen ion and aluminum concentrations on the survival of amphibian embryos and larvae. Can. J. Zool. 63: 116-123.

Clark, K.L. and B.D. LaZerte. 1985. A laboratory study of the effects of aluminum and pH on amphibian eggs and tadpoles. Can. J. Fish. Aquat. Sci. 42: 1544-1551.

Clark, K.L. and B.D. LaZerte. 1987. Intraspecific variation in hydrogen ion and aluminum toxicity in *Bufo americanus* and *Ambystoma maculatum*. Can. J. Fish. Aquat. Sci. 44: 1622-1628.

Collins, H.L., J.R. Davis and G.P. Markin. 1973. Residues of mirex in channel catfish and other aquatic organisms. Bull. Environ. Contam. Toxicol. 10: 73-77.

Computer Sciences Corporation. 1993. AQUIRE. Aquatic toxicity information retrieval database. U.S. Environmental Protection Agency, Environmental Research Laboratory, Duluth, MN

Cooke, A.S. 1970. The effect of pp'-DDT on tadpoles of the common frog (*Rana temporaria*). Environ. Pollut. 1: 57-71.

Cooke, A.S. 1972. The effects of DDT, dieldrin and 2,4-D on amphibian spawn and tadpoles. Environ. Pollut. 3: 51-68.

Cooke, A.S. 1973. Response of *Rana temporaria* tadpoles to chronic doses of pp'-DDT. Copeia 1973: 647-652.

Cooke, A.S. 1979. The influence of rearing density on the subsequent response to DDT dosing for tadpoles of the frog *Rana temporaria*. Bull. Environ. Contam. Toxicol. 21: 837-841.

Costa, H.H. 1965. Responses of freshwater animals to sodium cyanide solutions. III. Tadpoles of *Rana temporaria*. Ceylon J. Sci. (Biol. Sci.) 5: 97-104.

Cummins, C.P. 1986. Effects of aluminum and low pH on growth and development in *Rana temporaria* tadpoles. Oecologia (Berlin) 69: 248-252.

Cummins, C.P. 1988. Effect of calcium on survival times of *Rana temporaria* L. embryos at low pH. Func. Ecol. 2: 297-302.

Dale, J., B. Freedman, and J. Kerekes. 1985. Experimental studies of the effects of acidity and associated water chemistry on amphibians. Proc. NS Inst. Sci. 35: 35-54.

Davis, K.R., T.W. Schultz and J.N. Dumont. 1981. Toxic and teratogenic effects of selected aromatic amines on embryos of the amphibian *Xenopus laevis*. Arch. Environ. Contam. Toxicol. 10: 371-391.

Dawson, D.A., E.F. Stebler, S.L. Burks and J.A. Bantle. 1988. Evaluation of the developmental toxicity of metal-contaminated sediments using short-term fathead minnow and frog embryo-larval assays. Environ. Toxicol. Chem. 7: 27-34.

de Llamas, M.C., A.C. de Castro and A.M. Pechen de D'Angelo. 1985. Cholinesterase activities in developing amphibian embryos following exposure to the insecticides dieldrin and malathion. Arch. Environ. Contam. Toxicol. 14: 161-166.

De Young, D.J., J.A. Bantle and D.J. Fort. 1991. Assessment of the developmental toxicity of ascorbic acid, sodium selenate, coumarin, serotonin and 13-cis-retonoic acid using FETAX. Drug Chem. Toxicol. 14: 127-141.

de Zwart, D. and W. Sloof. 1987. Toxicity of mixtures of heavy metals and petrochemicals to *Xenopus laevis*. Bull. Environ. Contam. Toxicol. 38: 345-351.

Dial, N.A. 1976. Methylmercury: Teratogenic and lethal effects in frog embryos. eratology 13: 327-334.

Dilling, W.J. and C.W. Healey. 1926. Influence of lead and the metallic ions of copper, zinc, thorium, beryllium and thallium on the germination of frogs' spawn and the growth of tadpoles. Ann. Appl. Biol. 13: 177-188.

Dumont, J.N., T.W. Schultz and R.D. Jones. 1979. Toxicity and teratogenicity of aromatic amines to *Xenopus laevis*. Bull. Environ. Contam. Toxicol. 22: 159-166.

Dumpert, K. 1987. Embryotoxic effects of environmental chemicals: Tests with the South African clawed toad (*Xenopus laevis*). Ecotoxicol. and Environ. Safety 13: 324-338.

Dumpert, K. and E. Zietz. 1984. Plantanna (*Xenopus laevis*) as a test organism for determining the embryotoxic effects of environmental chemicals. Ecotoxicol. Environ. Safety 8: 55-74.

Edmisten, G.E. and J.A. Bantle. 1982. Use of *Xenopus laevis* larvae in 96-hr, flow-through toxicity tests with naphthalene. Bull. Environ. Contam. Toxicol. 29:392-399.

Fernandez, M., L. Gauthier and A. Jaylet. 1989. Use of newt larvae for *in vivo* genotoxicity testing of water: Results on 19 compounds evaluated by micronucleus test. Mutagenesis 4: 17-26.

Fernandez, M. and J. L'Haridon. 1994. Effects of light on the cytotoxicity and genotoxicity of benzo(a)pyrene and an oil refinery effluent in the newt. Environ. Molec. Mutagen. 24: 124-136.

Ferrari, L., A. Salibian and C.V. Muino. 1993. Selective protection of temperature against cadmium acute toxicity to *Bufo arenarum* tadpoles. Bull. Environ. Contam. Toxicol. 50: 212-218.

Fleming W.J., H. de Chacin, O.H. Pattee and T.G. Lamont. 1982. Parathion accumulation in cricket frogs and its effect on American kestrels. J. Toxicol. Environ. Health 10: 921-927.

Flickinger, E.L., K.A. King, W.F. Stout amd M.M. Mohn. 1980. Wildlife hazards from furadan 3G applications to rice in Texas. J. Wildl. Manag. 44: 190-197.

Fort, D.J.. B.L. James and J.A. Black. 1989. Evaluation of the developmental toxicity of five compounds with the frog embryo teratogenesis assay: *Xenopus* (FETAX) and a metabolic activation system. J. Appl. Toxicol. 9: 377-388.

Fort, D.J., J.R. Rayburn, D.J. DeYoung and J.A. Bantle. 1991. Assessing the efficacy of an arochlor 1254-induced exogenous metabolic activation system for FETAX. Drug Chem. Toxicol. 14: 143-160.

Fort, D.J., E.L. Stover, J.R. Rayburn, M. Hall and J.A. Bantle. 1993. Evaluation of the developmental toxicity of trichloroethylene and detoxification metabolites using *Xenopus.* Teratog. Carcinog. Mutagen. 13: 35-45.

Francis, P.C., W.J. Birge and J.A. Black. 1984. Effects of cadmium-enriched sediment on fish and amphibian embryo-larval stages. Ecotoxicol. and Environ. Safety 8: 378-387.

Freda, J., V. Cavdek and D.G. McDonald. 1990. Role of organic complexation in the toxicity of aluminum to *Rana pipiens* embryos and *Bufo americanus* tadpoles. Can. J. Fish. Aquat. Sci. 47: 217-224.

Freda, J. and D.G. McDonald. 1990. Effects of aluminum on the leopard frog, *Rana pipiens*: Life stage comparisons and aluminum uptake. Can. J. Fish. Aquat. Sci. 47: 210-216.

Freda, J. and D.G. McDonald. 1993. Toxicity of amphibian breeding ponds in the Sudbury region. Can. J. Fish. Aquat. Sci. 50: 1497-1503.

Gauna, L., A. Caballero de Castro, M. Chifflet de Llamas and A.M. Pechen de D'Angelo. 1991. Effects of dieldrin treatment on physiological and biochemical aspects of the toad embryonic development. Bull. Environ. Contam. Toxicol. 46: 633-640.

Ghate, H.V. and L. Mulherkar. 1980. Effect of mercuric chloride on embryonic development of the frog *Microhyla ornata*. Ind. J. Exp. Biol. 18: 1094-1096.

Goodnight, C.J. 1942. Toxicity of sodium pentachlorophenate and pentachlorophenol to fish. Indust. Eng. Chem. 34: 868-872.

Gopal, K., R.N. Khanna, M. Anand, and S.D. Gupta. 1981. The acute toxicity of endosulfan to freshwater organisms. Toxicol. Lett. 7: 453-456.

Hah, J.C. 1978. Effects of the heavy metal pollution on the primordial germ cells of developing amphibia. Korean J. Zool. 21: 43-58.

Hall, R.J. 1990. Accumulation, metabolism and toxicity of parathion in tadpoles. Bull.Environ. Toxicol. Chem. 44: 629-635.

Hall, R.J. and E. Kolbe. 1980. Bioconcentration of organophosphorus pesticides to hazardous levels by amphibians. J. Toxicol. Environ. Health. 6: 853-860.

Hall, R.J. and D. Swineford. 1979. Uptake of methoxychlor from food and water by the American toad (*Bufo americanus*). Bull. Environ. Contam. Toxicol. 23: 335-337.

Hall, R.J. and D. Swineford. 1980. Toxic effects of endrin and toxaphene on the southern leopard frog *Rana sphenocephala*. Environ. Pollut. (Ser. A.) 23: 53-65.

Hall, R.J. and D.M. Swineford. 1981. Acute toxicities of toxaphene and endrin to larvae of seven species of amphibians. Toxicol. Lett. 8: 331-336.

Hashimoto Y. and Y. Nishiuchi. 1981. Establishment of bioassay methods for the evaluation of acute toxicity of pesticides to aquatic organisms. J. Pestic. Sci. 6: 257-264 (JPN).

Herkovits, J. and C.S. Perez-Coll. 1991. Antagonism and synergism between lead and zinc in amphibian larvae. Environ. Pollut. 69: 217-221.

Herkovits, J. and C.S. Perez-Coll. 1993. Stage development susceptibility of *Bufo arenarum* embryos to cadmium. Bull. Environ. Contam. Toxicol. 50: 608-611.

Holcombe, G.W., G.L. Phipps, A.H. Sulaiman and A.D. Hoffman. 1987. Simultaneous multiple species testing: Acute toxicity of 13 chemicals to 12 diverse freshwater amphibian, fish and invertebrate families. Arch. Environ. Contam. Toxicol. 16: 697-710.

Hopfer, S.M., M.C. Plowman, K.R. Sweeney, J.A. Bantle and F.W. Sunderman, Jr. 1991. Teratogenicity of Ni^{2+} in *Xenopus laevis*, assayed by the FETAX procedure. Biol. Trace Elem. Res. 29: 203-216.

Horne, M.T. and W.A, Dunson. 1994. Exclusion of the Jeffersonianum salamander, Ambystoma jeffersonianum, from some potential breeding ponds in Pennsylvania: Effects of pH, temperature and metals on embryonic development. Arch. Environ. Toxicol. 27: 323-330.

Johnson, C.R. 1976. Herbicide toxicities in some Australian anurans and the effect of subacute dosages on temperature tolerance. Zool. J. Linn. Soc. 59: 79-83.

Johnson, C.R. 1980. The effects of five organophosphorus insecticides on thermal stress in tadpoles of the Pacific tree frog, *Hyla regilla*. Zool. J. Linn. Soc. 69: 143-147.

Joseph, K.V. and K.J. Rao. 1991. Protein degradation and related enzyme profiles on a sublethal toxicity of aldrin in the tissues of *Rana hexadactyla*. Ecotoxicol. and Environ. Safety 22: 32-35.

Juarez A. and J.A. Guzman. 1984. Chronic effect of five organochlorine insecticides on larvae of *Bufo arenarum* (H.). Communicaciones Biologicas 2: 411-415.

Juarez, A. and J.A. Guzman. 1986. Beta-glucronidase activity and thyroid hormones of by DDT. Comunicaciones Biologicas 4: 251-257.

Kagan, J., P.A. Kagan and H.E. Buhse, Jr. 1984. Light-dependent toxicity of a-terthienyl and anthracene toward late embryonic stages of *Rana pipiens*. J. Chem. Ecol. 10: 1115-1121.

Kagan, J., E.D. Kagan, I.A. Kagan, P.A. Kagan and S. Quigley. 1985. The phototoxicity of non-carcinogenic polycyclic aromatic hydrocarbons in aquatic organisms. Chemosphere 14: 1829-1834.

Kanamadi, R.D. and S.K. Saidapur. 1992. Effect of chronic exposure to the mercurial fungicide Emisan on spermatogenesis in *Rana cyanophlyctis*. J. Herpetol. 4: 508-510.

Kaplan, H.M. and S.S. Glaczenski. 1965. Hematological effects of organophosphate insecticides in the frog (*Rana pipiens*). Life Sci. 4: 1213-1219.

Kaplan, H.M. and J.G. Overpeck. 1964. Toxicity of halogenated hydrocarbon insecticides for the frog, *Rana pipiens*. Herpetologica 20: 163-169.

Kaplan, H.M. and L. Yoh. 1961. Toxicity of copper for frogs. Herpetologica 17: 131-135.

Kaplan, H.M., T.J. Arnholt, and J.E. Payne. 1967. Toxicity of lead nitrate solutions for frogs (*Rana pipiens*). Lab. Animal Care. 17: 240-246.

Keshaven, R. and P.B. Deshmukh. 1984. Vitamin A concentrations in liver and serum of the frog, *Rana tigrina*, treated with DDT and sevin. Indian J. Comp. Anim. Physiol. 2: 32-36.

Khangarot, B.S. and P.K. Ray. 1987. Sensitivity of toad tadpoles, *Bufo melanostictus* (Schneider), to heavy metals. Bull. Environ. Contam. Toxicol. 38: 523-527.

Khangarot, B.S., A. Sehgal and M.K. Bhasin. 1985a. "Man and Biosphere" - Studies on the Sikkim Himalayas. Part 4: Effects of chelating agent EDTA on the acute toxicity of copper and zinc on tadpoles of the frog *Rana hexadactyla*. Acta Hydrochim. Hydrobiol. 13: 121-125.

Khangarot, B.S., A. Sehgal and M.K. Bhasin. 1985b. "Man and Biosphere" - Studies on the Sikkim Himalayas. Part 5: Acute toxicity of selected heavy metals on the tadpoles of *Rana hexadactyla*. Acta Hydrochim. Hydrobiol. 13: 259-263.

Khangarot, B.S., A. Sehgal and M.K. Bhasin. 1985c. "Man and Biosphere" - Studies on the Sikkim Himalayas. Part 6: Toxicity of selected pesticides to the frog tadpole *Rana hexadactyla* (Lesson). Acta. Hydrochim. Hydrobiol. 13: 391-394.

Khudoley, V.V. 1977a. The induction of tumors in *Rana temporaria* with nitrosamines.Neoplasma 24: 249-252.

Khudoley, V.V. 1977b. Tumor induction by carcinogenic agents in anuran amphibian *Rana temporaria*. Arch. Geschwulstforsch. 47: 385-395.

Klaasen, H.E. and A.M. Kadoum. 1979. Distribution and retention of atrazine and carbofuran in farm pond ecosystems. Arch. Environ. Contam. Toxicol. 8: 345-353.

Lande, S.P. and S.L. Guttman. 1973. The effects of copper sulfate on the growth and mortality of *Rana pipiens* tadpoles. Herpetologica 29: 22-27.

Larsson, P. and A. Thuren. 1987. Di-2-ethylhexylphthalate inhibits the hatching of frog eggs and is bioaccumulated by tadpoles. Environ. Toxicol. Chem. 6:417-422.

Laughlin, R. and O. Linden. 1982. Sublethal responses of the tadpoles of the European frog *Rana temporaria* to two tributyltin compounds. Bull. Environ. Contam. Toxicol. 28: 494-499.

Licht, L.E. 1976. Time course of uptake, elimination and tissue levels of [^{14}C]DDT in wood-frog tadpoles. Can J. Zool. 54: 355-360.

Licht, L.E. 1985. Uptake of ^{14C} DDT by wood frog embryos after short term exposure.Comp. Biochem. Physiol. 81C: 117-119.

Linder, G., J. Wyant, R. Meganck, and B. Williams. 1991. Evaluating amphibian respons in wetlands impacted by mining activities in the western United States. *In*: Fift Biennial Symposium in the Management of Impacted Wildlife. Thorne Ecological Instit., Boulder, CO. pp 17-25.

Manson, J.M. and E.J. O'Flaherty. 1978. Effects of cadmium on salamander survival and limb regeneration. Environ. Res. 16: 62-69.

Marchal-Segault, D. 1976. Toxicity of some insecticides on *Bufo bufo* tadpoles. Bull. Ecol. 7: 411-416.

Marchal-Segault, D. and F. Ramade. 1981. The effects of lindane, an insecticide, on hatching and post embryonic development of *Xenopus laevis* (Daudin) anuran amphibian. Environ. Res. 24: 250-258.

Marian, M.P., V. Arul and T.J. Pandian. 1983. Acute and chronic effects of carbaryl on survival, growth, and metamorphosis in the bullfrog (*Rana tigrina*). Arch. Environ. Contam. Toxicol. 12: 271-275.

Marty, J., P. Lesca, A. Jaylet, C. Ardourel and J.L. Riviere. 1989. *In vivo* and *in vitro* metabolism of benzo(*a*)pyrene by the larva of the newt, *Pleurodeles watl.* Comp. Biochem. Physiol. 93C: 213-219.

Mayer, F.L., Jr., and M.R. Ellersieck. 1986. Manual of acute toxicity; Interpretation and data base for 410 chemicals and 66 species of freshwater animals. U.S.Fish Wildl. Serv., Resour. Publ. 160. Washington, D.C.

Miller, J.C. and R. Landesman. 1978. Reduction of heavy metal toxicity to *Xenopus* embryos by magnesium ions. Bull. Environ. Toxicol. 20: 93-95.

Mohanty-Hejmadi, P. and S.K. Dutta. 1981. Effects of some pesticides on the development of the Indian bull frog *Rana tigrina*. Environ. Pollut. (Ser. A) 24: 145-161.

Mudgall, C.F. and H.S. Patil. 1987. Toxic effects of dimethoate and methyl parathion on glycogen reserves of male and female *Rana cyanophlyctis*. J. Environ. Biol. 8: 237-244.

Muino, C.V., L. Ferrari and A. Salibian. 1990. Protective action of ions against cadmium toxicity to young *Bufo arenarum* tadpoles. Bull. Environ. Contam. Toxicol. 45: 313-319.

Mulla, M.S.. 1962. Frog and toad control with insecticides! Pest Control 30: 20, 64.

Mulla, M.S. 1963. Toxicity of organochlorine insecticides to the mosquito fish *Gambusia affinis* and the bullfrog *Rana catesbeiana*. Mosquito News 23: 299-303.

Mulla, M.S., L.W. Isaak and H. Axelrod. 1963. Field studies on the effects of insecticides on some aquatic wildlife species. J. Econ. Entolmol. 56: 184-188.

Nebeker, A.V., G.S. Schuytema and S.L. Ott. 1994. Effects of cadmium on limb regeneration in the northwestern salamander *Ambystoma gracile*. Arch. Environ. Contam. Toxicol. 27: 318-322.

Nebeker, A.V., G.S. Schuytema and S.L. Ott. 1995. Effects of cadmium on growth and bioaccumulation in the northwestern salamander *Ambystoma gracile*. Arch. Environ. Contam. Toxicol. 29: 492-499.

Nishiuchi, Y. and K. Yoshida. 1974. Effects of pesticides on tadpoles. Part 3. Noyaku Kensasho Hokuku 14: 66-68 (JPN) Pestab: 1714 (1975).

Osborn, D., A.S. Cooke and S. Freestone. 1981. Histology of a teratogenic effect of DDT on *Rana temporaria* tadpoles. Environ. Pollut. (Ser. A) 25: 305-319.

Padhye, A.D. and H.V. Ghate. 1992. Sodium chloride and potassium chloride tolerance of different stages of the frog, *Microhyla ornata*. Herpetol. J. 2: 18-23.

Paulose, P.V. 1988. Comparative study of inorganic and organic mercury poisoning on selected freshwater organisms. J. Environ. Biol. 9: 203-206.

Pawar, K.R., H.V. Ghate and M. Katdare. 1983. Effect of malathion on embryonic development of the frog *Microhyla ornata* (Dumeril and Bibrom). Bull. Environ. Contam. Toxicol. 31: 170-176.

Pawar, K.R. and M. Katdare. 1984. Toxic and teratogenic effects of fenitrothion, BHC and carbofuran on embryonic development of the frog *Microhyla ornata*. Toxicol. Lett. 22: 7-13.

Perez-Coll, C.S. and J. Herkovits. 1990. Stage development susceptibility to lead in *Bufo arenarum* embryos. Environ. Pollut. 63: 239-245.

Perez-Coll, C.S., J. Herkovits and A. Salibian. 1988. Embryotoxicity of lead on *Bufo arenarum*. Bull. Environ. Contam. Toxicol. 41: 247-252.

Porter, K.R. and D.E. Hakanson. 1976. Toxicity of mine drainage to embryonic and larval boreal toads (Bufonidae: *Bufo boreas*). Copeia 1976: 327-331.

Power,T., K.L. Clark, A. Harfenist and D.B. Peakall. 1989. A review and evaluation o. amphibian toxicological literature. Technical Report No. 61. Canadian Wilo Service, Environment Canada, Ottawa.

Punzo, F. 1993a. Effect of mercuric chloride on fertilization and larval development in the river frog, *Rana heckscheri* (Wright) (Anura: Ranidae). Bull. Environ. Contam. Toxicol. 51: 575-581.

Punzo, F. 1993b. Ovarian effects of a sublethal concentration of mercuric chloride in the river frog, *Rana heckscheri* (Anura: Ranidae). Bull. Environ. Contam. Toxicol. 50: 385-391.

Rao, R.I. and M.N. Madhyastha. 1987. Toxicities of some heavy metals to the tadpoles of frog, *Microhyla ornata* (Dumeril and Bibron). Toxicol Lett. 36: 205-208.

Romspert, A.P. 1976. Osmoregulation of the African clawed frog, *Xenopus laevis*, in hypersaline media. Comp. Biochem. Physiol. 54A: 207-210.

Rosenbaum, E.A., A. Caballero de Castro, L. Gauna and A.M. Pechen de D'Angelo. 1988. Early biochemical changes produced by malathion on toad embryos. Arch. Environ. Contam. Toxicol. 17: 831-835.

Rzehak, K., A. Maryanska-Nadachowska and M. Jordan. 1977. The effect of Karbotox 75, a carbaryl insecticide, upon the development of tadpoles of *Rana temporaria* and *Xenopus laevis*. Folia. Biol. (Krakow) 25: 391-399.

Sanders, H.O. 1970. Pesticide toxicities to tadpoles of the western chorus frog *Pseudracris triseriata* and Fowler's toad *Bufo woodhousii fowleri*. Copeia 1970: 246-251.

Scadding, S.R. 1990. Effects of tributyltin oxide on the skeletal structures of developing and regenerating limbs of the axolotl larvae, *Ambystoma mexicanum*. Bull. Environ. Contam. Toxicol. 45: 574-581.

Schuytema, G.S., A.V. Nebeker and W.L. Griffis. 1994. Toxicity of Guthion and Guthion 2S to *Xenopus laevis* embryos. Arch. Environ. Contam. Toxicol. 27: 250-255.

Schuytema, G.S., A.V. Nebeker and W.L. Griffis. 1995. Comparative toxicity of Guthion and Guthion 2S to *Xenopus laevis* and *Pseudracris regilla*. Bull. Environ. Contam. Toxicol. 54: 382-388

Schuytema, G.S., A.V. Nebeker, W.L. Griffis and K.N. Wilson. 1991. Teratogenesis, toxicity and bioconcentration in frogs exposed to dieldrin. Arch. Environ. Contam. Toxicol. 21: 332-350.

Slonim, A.R. and E.E. Ray. 1975. Acute toxicity of beryllium sulfate to salamander larvae (*Ambystoma* spp). Bull. Environ. Contam. Toxicol. 13: 307-312.

Sloof, W. and R. Baerselman. 1980. Comparison of the usefulness of the Mexican axolotl (*Ambystoma mexicanum*) and the clawed toad (*Xenopus laevis*) in toxicological bioassays. Bull. Environ. Contam. Toxicol. 24: 439-443.

Sloof, W. and J.H. Canton. 1983. Comparison of the susceptibility of 11 freshwater species to 8 chemical compounds. II. (Semi)Chronic toxicity tests. Aquat. Toxicol. 4: 271-282.

Sloof, W., J.H. Canton and J.L.M. Hermens. 1983. Comparison of the susceptibility of 22 freshwater species to 15 chemical compounds. I. (Sub)Acute toxicity tests. Aquat. Toxicol. 4: 113-128.

Snawder, J.E. and J.E. Chambers. 1989. Toxic and developmental effects of organophosphorus insecticides in embryos of the South African clawed frog. J. Environ. Sci. Health B24: 205-218.

Sobotka, J.M. and R.G. Rahwan. 1995. Teratogenesis induced by short and long-term exposure of *Xenopus laevis* progeny to lead. J. Toxicol. Environ. Health 44: 469-484.

Sreenivasen, A. and G.K. Swaminathan. 1967. Toxicity of six organophosphorus insecticides to fish. Curr. Sci. 36: 397-398.

Steele, C.W., S. Strickler-Shaw and D.H. Taylor. 1989. Behavior of tadpoles of the bullfrog, *Rana catesbeiana*, in response to sublethal lead exposure. Aquat. Toxicol. 14: 331-344.

Steele, C.W., S. Strickler-Shaw and D.H. Taylor. 1991. Failure of *Bufo americanus* tadpoles to avoid lead-enriched water. J. Herpetol. 25: 241-243.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. National Technical Information Service, Springfield, VA. PB85-227049.

Strickler-Shaw, S. and D.H. Taylor. 1990. Sublethal exposure to lead inhibits acquisition and retention of discriminate avoidance learning in green frog (*Rana clamitans*) tadpoles. Environ. Toxicol. and Chem. 9: 47-52.

Strickler-Shaw, S. and D.H. Taylor. 1991. Lead inhibits acquisition and retention learr. in bullfrog tadpoles. Neurotoxicol. and Teratol. 13: 167-173.

Taylor, D.H. 1990. Responses of green frog (*Rana clamitans*) tadpoles to lead-pollutea water. Environ. Toxicol. Chem. 9: 87-93.

Thurston, R.V., T.A. Gilfoil, E.L. Meyn, R.K. Zajdel, T.I. Aoki and G.D. Veith. 1985. Comparative toxicity of ten organic chemicals to ten common aquatic species. Water Res. 19: 1145-1155.

Tyler-Jones, R. , R.C. Beattie and R.J. Aston. 1989. The effects of acid water and aluminum on the embryonic development of the common frog, *Rana temporaria*. J. Zool. Soc. Lond. 219: 355-372.

U.S. Environmental Protection Agency. 1976. Quality criteria for water. Washington, DC.

U.S. Environmental Protection Agency. 1980a. Ambient water quality criteria for acrolein. EPA 440/5-80-016. Office of Water Regulation and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980b. Ambient water quality criteria for benzene. EPA 440/5-80-018. Office of Water Regulation and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980c. Ambient water quality criteria for aldrin/dieldrin. EPA 440/5-80-019. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980d. Ambient water quality criteria for arsenic. EPA 440/5-80-021. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980e. Ambient water quality criteria for beryllium. EPA 440/5-80-024. Office of Water Regulations and Standards,Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980f. Ambient water quality criteria for cadmium. EPA 440/5-80-025. Office of Water Regulations and Standards. Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980g. Ambient water quality criteria for carbon tetrachloride. EPA 440/5-80-026. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980h. Ambient water quality criteria for chlordane. EPA 440/5-80-027. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980i. Ambient water quality criteria for chlorinated benzenes. EPA 440/5-80-028. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980j. Ambient water quality criteria for chlorinated ethanes. EPA 440/5-80-029. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980k. Ambient water quality criteria for chlorinated phenols. EPA 440/5-80-032. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980l. Ambient water quality criteria for chloroform. EPA 440/5-80-033. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980m. Ambient water quality criteria for DDT. EPA 440/5-80-038. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980n. Ambient water quality criteria for dichloropropane and dichloropropene. EPA 440/5-80-043. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980o. Ambient water quality criteria for endosulfan. EPA 440/5-80-046. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980p. Ambient water quality criteria for endrin. EPA 440/5-80-047. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980q. Ambient water quality criteria for halomethanes. EPA 440/5-80-051. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980r. Ambient water quality criteria for heptachlor. EPA 440/5-80-052. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980s. Ambient water quality criteria hexachlorocyclohexane. EPA 440/5-80-054. Office of Water Regulations ai Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980t. Ambient water quality criteria for lead. EPA 440/5-80-057. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980u. Ambient water quality criteria for mercury. EPA 440/5-80-058. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980v. Ambient water quality criteria for naphthalene. EPA 440/5-80-059. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980w. Ambient water quality criteria for nickel. EPA 440/5-80-060. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980x. Ambient water quality criteria for nitrosamines. EPA 440/5-80-064. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980y. Ambient water quality criteria for phenol. EPA 440/5-80-066. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980z. Ambient water quality criteria for phthalate esters. EPA 440/5-80-067. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980aa. Ambient water quality criteria for polychlorinated biphenyls. EPA 440/5-80-068. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980bb. Ambient water quality criteria for polynuclear aromatic hydrocarbons. EPA 440/5-80-069. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980cc. Ambient water quality criteria for silver. EPA 440/5-80-071. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980dd. Ambient water quality criteria for thallium. EPA 440/5-80-074. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980ee. Ambient water quality criteria for toluene. EPA 440/5-80-075. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980ff. Ambient water quality criteria for toxaphene. EPA 440/4-80-076. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1980gg. Ambient water quality criteria for trichloroethylene. EPA 440/5-80-077. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1984. Ambient water quality criteria for 2,3,7,8-tetrachlorodibenzo-p-dioxin. EPA 440/5-84-007. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1985a. Ambient water quality criteria for arsenic - 1984. EPA 440/5-84-033. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1985b. Ambient water quality criteria for cadmium - 1984. EPA 440/5-84-032. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1985c. Ambient water quality criteria for chromium - 1984. EPA 440/5-84-029. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1985d. Ambient water quality criteria for copper. EPA 440/5-84-031. Office of Water Regulations and Standards, Criteria and Standards Division, Washington DC.

U.S. Environmental Protection Agency. 1985e Ambient water quality criteria for cyanide-1984. EPA 440/5-84-028. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC

U.S. Environmental Protection Agency. 1985f. Ambient water quality criteria for lead -1984. EPA 440/5-84-027. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1985g. Ambient water quality criteria for mercury EPA 440/5-84-026. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1986a. Quality criteria for water 1986. EPA 440/5-86-001. Office of Water Regulations and Standards, Washington, DC.

U.S. Environmental Protection Agency. 1986b. Ambient water quality criteria for nickel. EPA 440/5-86-004. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1986c. Ambient water quality criteria for chloropyrifos 1986 EPA 440/5-86-005. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1986d. Ambient water quality criteria for parathion -1986. EPA 440/5-86-007. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1986e. Ambient water quality criteria for pentachlorophenol - 1986. EPA 440/5-86-009. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1986f. Ambient water quality criteria for toxaphene - 1986. EPA 440/5-86-006. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1987a. Ambient water quality criteria for zinc - 1987. EPA 440/5-87-003. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC

U.S. Environmental Protection Agency. 1987b. Ambient water quality criteria for selenium - 1987. EPA 440/5-87-006. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1987c. Ambient water quality criteria for di-2-ethylhexyl phthalate. EPA 440/5-87-013.Draft. Office of Research and Development, Environmental Research Laboratories; Duluth, MN, Narragansett, RI.

U.S. Environmental Protection Agency. 1988a. Ambient water quality criteria for chloride - 1988. EPA 440/5-88-001. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC

U.S. Environmental Protection Agency. 1988b. Ambient water quality criteria for aluminum - 1988. EPA 440/5-88-008. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1988c. Ambient aquatic life water quality criteria for antimony III. EPA 440/5-88-093. Office of Research and Development, Office of Science and Technology, Health and Ecological Criteria Division, Washington, DC.

U.S. Environmental Protection Agency. 1988d. Ambient water quality criteria for tributyltin. EPA 440/5-88 Draft. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. Environmental Protection Agency. 1993. Ambient aquatic life water quality criteria for aniline. EPA 440/5-93 Draft. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

van Wijngaarden, P. Leeuwangh, W.G.H. Lucassen, K. Romijn, R. Ronday, R. van der Velde and W. Willigenburg. 1993. Acute toxicity of chlorpyrifos to fish, a newt and aquatic invertebrates. Bull. Environ. Contam. Toxicol. 51: 716-723.

Vardia, H.K., P. Sambasira Rao and V.S. Durve. 1984. Sensitivity of toads to 2,4-D and endosulfan pesticides. Arch. Hydrobiol. 100: 395-400.

Venturino, A. L.E. Gauna, R.M. Bergoc and A.M. Pechen de D'Angelo. 1992. Effect of exogenously applied polyamines on malathion toxicity in the toad *Bufo arenarum* Hensel. Arch. Environ. Contam. Toxicol. 22: 135-139.

Weis, J. 1975. The effect of DDT on tail regeneration in *Rana pipiens* and *R. catesbeiana* tadpoles. Copeia 1975: 765-767.

Williams, B., S. Marcy and S. Gerould. 1989. Water quality to protect wildlife resources. EPA 600/3-89-067. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

Wohlgemuth, E. 1977. Toxicity of endrin to some species of aquatic vertebrates. Acta. Sc. Nat. Brno 11: 1-38.

Woodall, C., N. Maclean and F. Crossley. 1988. Responses of trout fry (*Salmo gairdneri*) and *Xenopus laevis* tadpoles to cadmium and zinc. Comp. Biochem. Physiol. 89C: 93-99.

Yasmeen, N. and Nayeemunnisa. 1985. Effects of methyl parathion on the rate of oxygen consumption of tadpoles of frog, *Rana cyanophlyctis*. Current Sci. 54: 649-651.

Zaffaroni, N,P., T. Zavanella, M.L. Ferrari and E. Arias. 1986. Toxicity of 2-methyl-4-chlorophenoxyacetic acid to the adult crested newt. Environ. Res. 41: 201-206.

Zavanella, T., N.P. Zaffaroni and E. Arias. 1988. Evaluation of the carcinogenic risk of the phenoxyherbicide MCPA to an urodele amphibian. Ecotoxicol. and Environ. Safety 16: 114-122.

Zettergren, L.D., B.W. Boldt, D.H. Petering, M.S. Goodrich, D.N. Weber and J.G.Zettergren. 1991. Effects of prolonged low level cadmium exposure on the tadpole immune system. Toxicol. Lett. 55: 11-19.

Table 1. Water quality criteria (WQC) chemicals and associated amphibian literature.

Chemical	EPA WQC document [a] publication number	Amphibian data [b] found in: WQC documents	Other publications
Acenaphthene	EPA 440/5-80-015	—	—
	EPA 440/5-80-016	—	X
Acrylonitrile	EPA 440/5-80-017	—	—
Aldrin/Dieldrin	EPA 440/5-80-019	USEPA 1980c	X
Aluminum	EPA 440/5-88-008	USEPA 1988b	X
Ammonia	EPA 440/5-85-001	—	—
Aniline	EPA 440/5-93 Draft	USEPA 1993	X
Antimony	EPA 440/5-80-020	—	—
Antimony(III)	EPA 440/5-88-093	USEPA 1988c	—
Arsenic	EPA 440/5-80-021 EPA 440/5-84-033	USEPA 1980d USEPA 1985a	X X
Atrazine	—	—	X
Benzene	EPA 440/5-80-018	—	X
Benzidine	EPA 440/5-80-023	—	—
Beryllium	EPA 440/5-80-024	USEPA 1980e	X
Boron	EPA 440/5-86-001[c]	—	X
Cadmium	EPA 440/5-80-025 EPA 440/5-84-032	USEPA 1980f USEPA 1985b	X X
Carbaryl	—	—	X
Carbofuran	—	—	X
Carbon tetrachloride	EPA 440/5-80-026	—	X
Chlordane	EPA 440/5-80-027	—	X
Chloride	EPA 440/5-88-001	—	X
Chlorinated benzenes	EPA 440/5-80-028	—	X
Chlorinated ethanes	EPA 440/5-80-029	—	X
Chlorinated naphthalenes	EPA 440/5-80-031	—	—

Table 1. (continued)

Chemical	EPA WQC document [a] publication number	Amphibian data [b] found in:	
		WQC documents	Other publications
Chlorinated phenols	EPA 440/5-80-032	—	X
Chlorine	EPA 440/5-84-030	—	—
Chloroalkyl ethers	EPA 440/5-80-030	—	—
Chloroform	EPA 440/5-80-033	—	X
2-Chlorophenol	EPA 440/5-80-034	—	—
Chlorophenoxy herbicides	EPA 440/5-86-001[c]	—	X
Chlorpyrifos	EPA 440/5-86-005	—	X
Chromium	EPA 440/5-80-035	—	X
	EPA 440/5-84-029	USEPA 1985c	X
Copper	EPA 440/5-80-036	—	X
	EPA 440/5-84-031	USEPA 1985d	X
Cyanide	EPA 440/5-80-037	—	X
	EPA 440/5-84-028	—	X
DDT	EPA 440/5-80-038	USEPA 1980m	X
Demeton	—	—	—
Dichlorobenzenes	EPA 440/5-80-039	—	—
Diazinon	—	—	X
Dichlorobenzidine	EPA 440/5-80-040	—	—
Dichloroethylenes	EPA 440/5-80-041	—	—
2, 4-Dichlorophenol	EPA 440/5-80-042	—	—
Dichloropropanes/ Dichloropropenes	EPA 440/5-80-043	—	X
Dichlorvos	—	—	X
Di-2-ethylhexyl phthalate (DEHP)	EPA 440/5-87-013	—	X
2, 4 -Dimethylphenol	EPA 440/5-80-044	—	—

Table 1. (continued)

Chemical	EPA WQC document [a] publication Number	Amphibian data [b] found in: WQC documents	Other publications
Dinitrotoluene	EPA 440/5-80-045	—	—
Diphenylhydrazine	EPA 440/5-80-062	—	—
Endosulfan	EPA 440/5-80-046	USEPA 1980o	X
Endrin	EPA 440/5-80-047	—	X
Ethylbenzene	EPA 440/5-80-048	—	—
Fluoranthene	EPA 440/5-80-049	—	—
Guthion	—	—	X
Haloethers	EPA 440/5-80-050	—	—
Halomethanes	EPA 440/5-80-051	—	X
Heptachlor	EPA 440/5-80-052	—	X
Hexachlorobutadiene	EPA 440/5-80-053	—	—
Hexachlorocyclohexane	EPA 440/5-80-054	USEPA 1980s	X
Hexachlorocyclopenta - diene	EPA 440/5-80-055	—	—
Iron	EPA 440/5-86-001[c]	—	X
Isophorone	EPA 440/5-80-056	—	—
Lead	EPA 440/5-80-057 EPA 440/5-84-027	USEPA 1980t USEPA 1985f	X X
Malathion	EPA 440/5-86-001[c]	—	X
Manganese	EPA 440/5-86-001[c]	—	X
Mercury	EPA 440/5-80-058 EPA 440/5-84-026	USEPA 1980u USEPA 1985g	X X
Methoxychlor	EPA 440/5-86-001[c]	—	X
Methyl parathion	—	—	X
Mirex	EPA 440/5-86-001[c]	—	X
Naphthalene	EPA 440/5-80-059	—	X

Table 1. (continued)

Chemical	EPA WQC document [a] publication Number	Amphibian data [b] found in: WQC documents	Other publications
Nickel	EPA 440/5-80-060 EPA 440/5-86-004	USEPA 1980w USEPA 1986b	X X
Nitrobenzene	EPA 440/5-80-061	—	—
Nitrophenols	EPA 440/5-80-063	—	X
Nitrosamines	EPA 440/5-80-064	—	X
Nonylphenol	—	—	—
Parathion	EPA 440/5-86-007	—	X
Pentachlorophenol	EPA 440/5-80-065 EPA 440/5-86-009	— USEPA 1986e	X X
Phenanthrene	—	—	—
Phenol	EPA 440/5-80-066	—	X
Phthalate esters	EPA 440/5-80-067	—	X
Polychlorinated biphenyls (PCBs)	EPA 440/5-80-068	—	X
Polynuclear aromatic hydrocarbons	EPA 440/5-80-069	—	X
Propoxur	—	—	X
Selenium	EPA 440/5-80-070 EPA 440/5-87-006	— USEPA 1987b	X X
Silver	EPA 440/5-80-071	USEPA 1980cc	X
Sulfides, Hydrogen sulfide	EPA 440/5-86-001[c]	—	—
1,2,4-TCB	—	—	—
2, 4, 5-TCP	—	—	—
Tetrachloroethylene	EPA 440/5-80-073	—	—
2, 3, 7, 8 - Tetra-chlorodibenzo-p-dioxin	EPA 440/5-84-007	USEPA 1984	X
Thallium	EPA 440/5-80-074	USEPA 1980dd	X

Table 1. (continued)

Chemical	EPA WQC document [a] publication Number	Amphibian data [b] found in: WQC documents	Other publications
Toluene	EPA 440/5-80-075	—	X
Toxaphene	EPA 440/5-80-076	USEPA 1980ff	X
	EPA 440/5-86-006	USEPA 1986f	X
Tributyltin	EPA 440/5-88 Draft	USEPA 1988d	X
Trichloroethylene	EPA 440/5-80-077	—	X
Vinyl chloride	EPA 440/5-80-078	—	—
Zinc	EPA 440/5-80-079	—	X
	EPA 440/5-87-003	USEPA 1987a	X

[a] Criteria for chemicals without a listed number are in development and have not yet been published.
[b] Citations in the "WQC" column indicate the presence of amphibian data in existing water quality criteria documents (mostly in the "other data" tables and not useful for deriving water quality criteria). Additional amphibian data located in other publications are indicated by Xs in the "other" column. Tables 5 to 67 include the data from both sources. Chemicals with no entries indicate an absence of applicable data.
[c] Criteria for chemicals with EPA number EPA 440/5-86-001 are collectively listed in Quality Criteria for Water 1986 (USEPA 1986a) and originally appeared in Quality Criteria for Water 1976 (USEPA 1976). These two publications contain little background toxicity data.

Table 2. Distribution of additional acute and "other" amphibian data beyond that found in water quality criteria (WQC) documents.[a]

	Additional data located for WQC documents with some amphibian data			Additional data located for WQC documents without any amphibian data		
Chemical	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"
Acrolein	—	—	—	X	—	—
Aldrin/Dieldrin	X	X	X	—	—	—
Aluminum	X	X	X	—	—	—
Aniline	—	—	X	—	—	—
Arsenic	—	X	X	—	—	—
Atrazine	—	—	—	—	X	—
Benzene	—	—	—	—	X	X
Boron	—	—	—	—	X	—
Cadmium	X	X	X	—	—	—
Carbaryl	—	—	—	—	X	X
Carbofuran	—	—	—	—	X	X
Carbon tetrachloride	—	—	—	—	X	X
Chlordane	—	—	—	—	X	X
Chloride	—	—	—	—	X	X
Chlorinated benzenes	—	—	—	—	X	—
Chlorinated ethanes	—	—	—	X	X	—
Chlorinated phenols	—	—	—	X	—	—

Table 2. (continued)

Chemical	Additional data located for WQC documents with some amphibian data			Additional data located for WQC documents without any amphibian data		
	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"
Chloroform	—	—	—	—	X	X
Chlorophenoxy herbicides	—	—	—	X	X	X
Chlorpyrifos	—	—	—	—	X	X
Chromium	—	X	X	—	—	—
Copper	X	X	X	—	—	—
Cyanide	—	—	—	—	—	X
DDT	—	X	X	—	—	—
Diazinon	—	—	—	—	—	X
Dichloropropanes/Dichloropropenes	—	—	—	—	X	—
Dichlorvos	—	—	—	—	—	X
Di - 2 - ethylhexyl phthalate (DEHP)	—	—	—	—	—	X
Endosulfan	—	—	X	—	—	—
Endrin	—	—	—	X	X	X
Guthion	—	—	—	X	X	—
Halomethanes	—	—	—	—	X	—
Heptachlor	—	—	—	X	X	X
Hexachlorocyclohexane	X	X	X	—	—	—

Table 2. (continued)

Chemical	Additional data located for WQC documents with some amphibian data: Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"	Additional data located for WQC documents without any amphibian data: Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"
Iron	—	—	—	X	X	X
Lead	—	X	X	—	—	—
Malathion	—	—	—	X	X	X
Manganese	—	—	—	—	X	X
Mercury	X	X	X	—	—	—
Methoxychlor	—	—	—	X	X	—
Methyl parathion	—	—	—	X	X	X
Mirex	—	—	—	—	X	—
Naphthalene	—	—	—	—	X	—
Nickel	X	X	X	—	—	—
Nitrobenzene	—	—	—	—	X	—
Nitrosamines	—	—	—	X	—	X
Parathion	—	—	—	X	X	X
Pentachlorophenol	—	X	X	—	—	—
Phenol	—	—	—	X	X	X
Phthalate esters	—	—	—	—	X	—
Polychlorinated biphenyls (PCBs)	—	—	—	—	X	—
Polynuclear aromatic hydrocarbons	—	—	—	X	X	X

Table 2. (continued)

Chemical	Additional data located for WQC documents with some amphibian data			Additional data located for WQC documents without any amphibian data		
	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"	Resident[b] acute	Resident[c] "other"	Non-resident[d] "other"
Propoxur	—	—	—	—	—	X
Selenium	—	X	—	—	—	—
Silver	—	X	X	—	—	—
Thallium	—	X	—	—	—	—
Toluene	—	—	—	—	X	—
Toxaphene	X	X	—	—	—	—
Tributyltin	—	—	X	—	—	—
Trichloroethylene	—	—	—	X	X	X
Zinc	X	X	X	—	—	—

[a] Additional chronic data was located only for aldrin/dieldrin and cadmium.
[b] Acute data pertaining to resident species.
[c] Resident species data suitable for "other data" tables.
[d] Non-resident species data suitable for "other data" tables included to provide additional insight into the effects of chemicals on amphibians.

Table 3. Summary of amphibian species and associated chemicals[a].

Species	Chemical	Table number	Reference
Acris crepitans	Carbofuran (Furadan 3G)	17	Flickinger *et al.*1980
	Endrin	36B	Hall and Swineford 1981
	Parathion	53B	Fleming *et al.* 1982
	Toxaphene	64B	Hall and Swineford 1981
Acris crepitans blanchardi	Mercuric chloride	45B	Birge *et al.* 1979b
Acris gryllus	Mirex (bait)	48	Collins *et al.* 1973
Adelotus brevis	2,4-D amine	25B	Johnson 1976
	2,4,5-T amine	25B	Johnson 1976
	Sodium arsenite	10	Johnson 1976
Ambystoma gracile	Benzene	12	Black *et al.* 1982
	Cadmium chloride	15A, 15B	Nebeker *et al.* 1994, 1995
	Carbon tetrachloride	18	Black *et al* 1982
	Chlorobenzene	21	Black *et al.* 1982
	Chloroform	24	Black *et al.* 1982
	1,2-Dichloroethane	22B	Black *et al.* 1982
	Phenol	55B	Black *et al.* 1982
	Toluene	63	Black *et al.* 1982
Ambystoma jeffersonianum	Aluminum chloride	7B	Horne and Dunson 1994
	Copper chloride	28A	Horne and Dunson 1994
	Lead chloride	42	Horne and Dunson 1994
	Zinc chloride	67B	Horne and Dunson 1994
Ambystoma maculatum	Aluminum	7B	Dale *et al.* 1985, Albers and Prouty 1987
	Aluminum chloride	7B	Clark and LaZerte 1987
	Beryllium sulfate	13	Slonim and Ray 1975
	Endrin	36B	Hall and Swineford 1981
	Toxaphene	64B	Hall and Swineford 1981

Table 3. (Continued)

Species	Chemical	Table number	Reference
Ambystoma mexicanum	Aniline	8B	Sloof and Baerselman 1980, Sloof *et al.* 1983
	Benzene	12	Sloof and Baerselman 1980, Sloof *et al.* 1983
	Cadmium nitrate	15C	Sloof and Baerselman 1980, Sloof *et al.* 1983
	Mercuric chloride	45B	Sloof and Baerselman 1980, Sloof *et al.* 1983
	Pentachlorophenol	54B	Sloof and Baerselman 1980, Sloof *et al.* 1983
	Tributyltin oxide	65	Scadding 1990
	Trichloroethylene	66B	Sloof and Baerselman 1980, Sloof *et al.* 1983
Ambystoma opacum	Aluminum chloride	7B	Birge *et al.* 1978b
	Beryllium sulfate	13	Slonim and Ray 1975
	Cadmium chloride	15C	Birge *et al.* 1978b
	Chromium trioxide	27	Birge *et al.* 1978b
	Copper sulfate	28B	Birge *et al.* 1978b, Birge and Black 1979
	Endrin	36B	Hall and Swineford 1981
	Lead chloride	42	Birge *et al.* 1978b
	Mercuric chloride	45B	Birge *et al.* 1978b, 1979b
	Nickel chloride	50B	Birge *et al.* 1978b
	Silver nitrate	61	Birge *et al.* 1978b
	Toxaphene	64B	Hall and Swineford 1981
	Zinc chloride	67B	Birge *et al.* 1978b
Bufo americanus	Aluminum	7B	Clark and LaZerte 1985
	Aluminum chloride	7A	Freda *et al.* 1990, Freda and McDonald 1993
	Aluminum (inorganic monomeric)	7B	Clark and Hall 1985
	Aroclor 1016	57	Birge *et al.* 1978a

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Aroclor 1242	57	Birge *et al.* 1978a
	Aroclor 1254	57	Birge *et al.* 1978a
	Atrazine	11	Birge *et al.* 1980, Birge *et al.* 1983
	Copper sulfate	28B	Birge and Black 1980
	Endrin	36B	Hall and Swineford 1981
	Lead nitrate	42	Steele *et al.* 1991
	Methoxychlor	46B	Hall and Swineford 1979
	Phenol	55B	Birge *et al.* 1980
	Toxaphene	64B	Hall and Swineford 1981
Bufo arenarum	Aldrin	6D	Juarez and Guzman 1984
	Cadmium	15C	Herkovits and Perez-Coll 1993
	Cadmium chloride	15C	Munio *et al.* 1990, Ferrari *et al.* 1993
	Chlordane	19	Juarez and Guzman 1984
	DDT	30B	Juarez and Guzman 1984, 1986
	Dieldrin	6D	de Llamas *et al.* 1985, Gauna *et al.* 1991
	Heptachlor	39B	Juarez and Guzman 1984b
	Lead	42	Perex-Coll and Herkovits 1990, 1991
	Lead nitrate	42	Perez-Coll *et al.* 1988
	Malathion	43B	de Llamas *et al.* 1985, Rosenbaum *et al.* 1988, Venturino *et al.* 1992
	Parathion	53B	Anguiano *et al.* 1994
	Zinc	67B	Herkovits and Perez-Coll 1991
Bufo boreas	Copper sulfate	28B	Porter and Hakanson 1976
	Ferrous sulfate	41B	Porter and Hakanson 1976

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Guthion (formulation)	37B	Mulla *et al.* 1963
	Methyl parathion (formulation)	47B	Mulla 1962, Mulla *et al.* 1963
	Parathion (formulation)	53B	Mulla *et al.* 1963
	Zinc sulfate	67B	Porter and Hakanson 1976
Bufo bufo	DDT	30B	Cooke 1972, Marchal-Segault 1976
	Dieldrin	6D	Cooke 1972
Bufo bufo japonicus	Carbaryl (formulation)	16	Hashimoto and Nishiuchi 1981
	DDT (formulation)	30B	Hashimoto and Nishiuchi 1981
	Diazinon	31	Hashimoto and Nishiuchi 1981
	Endosulfan (formulation)	35	Hashimoto and Nishiuchi 1981
	Endrin (formulation)	36B	Hashimoto and Nishiuchi 1981
	Parathion	53B	Hashimoto and Nishiuchi 1981
	Pentachlorophenol (formulation)	54B	Hashimoto and Nishiuchi 1981
	Pentachlorophenol-copper	54B	Nishiuchi and Yoshida 1974
	Pentachlorophenol-sodium (formulation)	54B	Nishiuchi and Yoshida 1974
	Phenyl mercury acetate (formulation)	45B	Hashimoto and Nishiuchi 1981
	Propoxur	59	Hashimoto and Nishiuchi 1981
Bufo canorus	Aluminum (inorganic monomeric)	7B	Bradford *et al.* 1992
Bufo debilis debilis	Mercuric chloride	45B	Birge *et al.* 1979b
Bufo fowleri	Aroclor 1016	57	Birge *et al.* 1978a
	Aroclor 1242	57	Birge *et al.* 1978a
	Aroclor 1254	57	Birge *et al.* 1978a
	Boric acid	14	Birge and Black 1977
	Carbon tetrachloride	18	Birge *et al.* 1980, Black *et al.* 1982

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Chloroform	24	Birge *et al.* 1980, Black *et al.* 1982
	Copper sulfate	28B	Birge and Black 1979
	Diisononylphthalate	56	Birge *et al.* 1978a
	Dioctylphthalate	56	Birge *et al.* 1978a
	Mercuric chloride	45B	Birge and Black 1977, Birge *et al.* 1979b, Birge *et al* 1983
	Methylene chloride	38	Birge *et al.* 1980
	Nickel chloride	50B	Birge and Black 1980
	Phenol	55B	Birge *et al.* 1980
Bufo marinus	2,4-D amine	25B	Johnson 1976
	2,4,5-T amine	25B	Johnson 1976
	Sodium arsenite	10	Johnson 1976
Bufo melanostictus	Cadmium sulfate	15C	Khangarot and Ray 1987
	Copper sulfate	28B	Khangarot and Ray 1987
	2,4-D	25B	Vardia *et al.* 1984
	Endosulfan	35	Vardia *et al.* 1984
	Mercuric chloride	45B	Khangarot and Ray 1987, Palouse 1988
	Nickel sulfate	50B	Khangarot and Ray 1987
	Potassium dichromate	27	Khangarot and Ray 1987
	Silver nitrate	61	Khangarot and Ray 1987
	Zinc sulfate	67B	Khangarot and Ray 1987
Bufo punctatus	Mercuric chloride	45B	Birge and Black 1977, Birge *et al.* 1979b, Birge *et al.* 1983
Bufo woodhousii fowleri	Aldrin	6A	Sanders 1970, Mayer and Ellersieck 1986
	Benzene hexachloride	40A	Sanders 1970, Mayer and Ellersieck 1986

Table 3. (Continued)

Species	Chemical	Table number	Reference
	2,4-D butoxyethanol ester	25A	Mayer and Ellersieck 1986
	DDT	30A, 30B	Sanders 1970, Mayer and Ellersieck 1986
	Dieldrin	6A	Sanders 1970, Mayer and Ellersieck 1986
	Endrin	36A	Sanders 1970, Mayer and Ellersieck 1986
	Guthion	37A	Sanders 1970, Mayer and Ellersieck 1986
	Heptachlor	39A	Sanders 1970, Mayer and Ellersieck 1986
	Lindane	40A	Sanders 1970, Mayer and Ellersieck 1986
	Malathion	43A	Sanders 1970, Mayer and Ellersieck 1986
	Methoxychlor	46B	Sanders 1970, Mayer and Ellersieck 1986
	Parathion	53A	Mayer and Ellersieck 1986
	Silvex 2-(2,4,5-T)	25B	Sanders 1970
	Silvex (propylene glycol butyl ether ester)	25B	Mayer and Ellersieck 1986
	TDE	30A	Sanders 1970, Mayer and Ellersieck 1986
	Toxaphene	64A	Sanders 1970, Mayer and Ellersieck 1986
Gastrophryne carolinensis	Aluminum chloride	7B	Birge 1978, Birge *et al.* 1979a
	Antimony trichloride	9	Birge 1978, Birge *et al.* 1979a
	Cadmium chloride	15C	Birge 1978, Birge *et al.* 1979a
	Chromium trioxide	27	Birge 1978, Birge *et al.* 1979a
	Copper sulfate	28B	Birge 1978, Birge and Black 1979, Birge *et al.* 1979

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Lead chloride	42	Birge 1978, Birge *et al.* 1979a
	Manganese chloride	44	Birge 1978, Birge *et al.* 1979
	Mercuric chloride	45B	Birge and Black 1977, Birge 1978,Birge *et al.* 1979b, Birge *et al.* 1979a, 1983
	Nickel chloride	50B	Birge 1978b, Birge *et al.* 1979a, Birge and Black 1980
	Silver nitrate	61	Birge 1978, Birge *et al.* 1979a
	Sodium arsenite	10	Birge 1978, Birge *et al.* 1979a
	Sodium selenate	60B	Birge *et al.* 1978, Birge *et al.* 1979b
	Thallium trichloride	62	Birge 1978, Birge *et al.* 1979a
	Zinc chloride	67B	Birge 1978, Birge *et al.* 1979a
Hyla chrysocelis	Copper sulfate	28B	Birge and Black 1979
	Mercuric chloride	45B	Birge *et al.* 1979b, Birge *et al.* 1983
Hyla chrysocephala	Mercuric chloride	45B	Birge and Black 1977
Hyla crucifer	Chloroform	24	Birge *et al.* 1980
	Mercuric chloride	45B	Birge *et al.* 1979b
Hyla gratiosa	Mercuric chloride	45B	Birge *et al.* 1979b
Hyla regilla	Chlorpyrifos	26	Johnson 1980
	Malathion	43B	Johnson 1980
	Methyl parathion	47B	Johnson 1980
Hyla squirella	Mercuric chloride	45B	Birge and Black 1977, Birge *et al.* 1979b
Hyla versicolor	Mercuric chloride	45B	Birge *et al.* 1979b
Limnodynastes peroni	2,4-D amine	25B	Johnson 1976
	2,4,5-T amine	25B	Johnson 1976
	Sodium arsenite	10	Johnson 1976

Table 3. (Continued)

Species	Chemical	Table number	Reference
Limnodynastes tasmaniensis	Dieldrin	6D	Brookes 1981
Microhyla ornata	Benzene hexachloride	40B	Pawar and Katdare 1984
	Cadmium chloride	15C	Rao and Madhyastha 1987
	Carbofuran	17	Pawar and Katdare 1984
	Copper sulfate	28B	Rao and Madhyastha 1987
	Malathion	43B	Pawar *et al.* 1983
	Manganese sulfate	44	Rao and Madhyastha 1987
	Mercuric chloride	45B	Ghate and Mulherkar 1980, Rao and Madhyastha 1987
	Potassium chloride	20	Padhye and Ghate 1992
	Sodium chloride	20	Padhye and Ghate 1992
	Zinc sulfate	67B	Rao and Madhyastha 1987
Notophthalmus viridescens	Cadmium acetate	15C	Manson and O'Flaherty 1978
Pleurodeles waltl	Aroclor 1254	57	Fernandez *et al.* 1989
	Benzo[a]pyrene	58B	Fernandez *et al.* 1989, Marty *et al.* 1989, Fernandez and L'Haridon 1994
Pseudacris regilla	Guthion	37A, 37B	Schuytema *et al.* 1995
	Guthion 2S	37A, 37B	Schuytema *et al.* 1995
Pseudacris triseriata	2,4-D amine salt (Weeder 64)	25A	Sanders 1970
	DDT	30A	Sanders 1970
	Dieldrin	6A	Sanders 1970, Mayer and Ellersieck 1986
	Endrin	36A	Sanders 1970, Mayer and Ellersieck 1986
	Guthion	37A	Mayer and Ellersieck 1986
	Lindane	40A	Sanders 1970, Mayer and Ellersieck 1986

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Malathion	43A	Sanders 1970, Mayer and Ellersieck 1986
	Methoxychlor	46A	Sanders 1970, Mayer and Ellersieck 1986
	Methyl parathion	47A	Mayer and Ellersieck 1986
	Parathion	53A	Sanders 1970, Mayer and Ellersieck 1986
	Silvex (butyl ether ester)	25A	Sanders 1970
	TDE	30A	Sanders 1970
	Toxaphene	64A	Sanders 1970, Mayer and Ellersieck 1986
Rana arvalis	Di-2-ethylhexyl phthalate (DEHP)	34	Larsson and Thuren 1987
Rana breviceps	Mercuric chloride	45B	Paulose 1988
	Methyl mercury chloride	45B	Paulose 1988
Rana catesbeiana	Aldrin (formulation)	6D	Mulla 1963
	Atrazine	11	Klaassen and Kadoum 1979, Birge *et al.* 1980, Birge *et al.* 1983
	Cadmium chloride	15C	Zettergren *et al.* 1991
	Carbon tetrachloride	18	Birge *et al.* 1980
	Chlordane (formulation)	19	Mulla 1963
	DDT	30B	Weis 1975
	DDT (formulation)	30B	Mulla 1963
	Dieldrin	6A, 6D	Schuytema *et al.* 1991
	Dieldrin (formulation)	6D	Mulla 1963
	Endrin	36A, 36B	Hall and Swineford 1981, Thurston *et al.* 1985
	Endrin (formulation)	36B	Mulla 1963
	Heptachlor (formulation)	39B	Mulla 1963
	Hexachloroethane	22A	Thurston *et al.* 1985

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Lead nitrate	42	Steele *et al.* 1989, Strickler-Shaw and Taylor 1991
	Lindane (EC 1.65)	40B	Mulla 1963
	Malathion (formulation)	43B	Hall and Kolbe 1980
	Mercuric chloride	45B	Birge and Just 1973, 1975
	Methylene chloride	38	Birge *et al.* 1980
	Parathion	53B	Hall and Kolbe 1980, Hall 1990
	Pentachlorophenol	54A	Thurston *et al.* 1985
	Phenol	55B	Birge *et al.* 1980
	Sodium arsenite	10	Birge and Just 1973
	Toxaphene	64B	Hall and Swineford 1981
	Toxaphene (formulation)	64B	Mulla 1963
Rana clamitans	Lead nitrate	42	Taylor 1990, Strickler-Shaw and Taylor 1990
	Parathion	53B	Hall and Kolbe 1980, Hall 1990
Rana cyanophlyctis	Methoxyethyl mercuric chloride (formulation)	45B	Kanamadi and Saidapur 1992
	Methyl parathion (formulation)	47B	Yasmeen and Nayeemunisa 1985, Mudgall and Patil 1987
Rana grylio	Mercuric chloride	45B	Birge and Black 1977, Birge *et al.* 1979b, Birge *et al.* 1983
Rana heckscheri	Mercuric chloride	45A, 45B	Birge and Black 1977, Birge *et al.* 1979b, Punzo 1993a, 1993b
Rana hexadactyla	Aldrin	6D	Joseph and Rao 1991
	Arsenic trioxide	10	Khangarot *et al.* 1985b
	Carbaryl (Kelex)	16	Khangarot *et al.* 1985c
	Carbofuran (Furadan)	17	Khangarot *et al.* 1985c
	Copper sulfate	28B	Khangarot *et al.* 1985a, 1985b
	Ferrous sulfate	41B	Khangarot *et al.* 1985b

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Lead nitrate	42	Khangarot *et al.* 1985b
	Lindane	40B	Khangarot *et al.* 1985c
	Malathion (formulation)	43B	Khangarot *et al.* 1985c
	Mercuric chloride	45B	Khangarot *et al.* 1985b
	Pentachlorophenol-sodium	54B	Khangarot *et al.* 1985c
	Potassium chromate	27	Khangarot *et al.* 1985b
	Potassium dichromate	27	Khangarot *et al.* 1985b
	Silver nitrate	61	Khangarot *et al.* 1985b
	Zinc sulfate	67B	Khangarot *et al.* 1985a, 1985b
Rana muscosa	Aluminum (inorganic monomeric)	7B	Bradford *et al.* 1992
Rana nigromaculata	Cadmium chloride	15C	Hah 1978
	Lead nitrate	42	Hah 1978
	Mercuric chloride	45B	Hah 1978
Rana palustris	Atrazine	11	Birge *et al.* 1980
	Carbon tetrachloride	18	Birge *et al.* 1980, Black *et al.* 1982
	Chloroform	24	Birge *et al.* 1980, Black *et al.* 1982
	Phenol	55B	Birge *et al.* 1980
	Methylene chloride	38	Birge *et al.* 1980
Rana pipiens	Aldrin	6D	Kaplan and Overpeck 1964
	Aluminum chloride	7A, 7B	Freda and McDonald 1990, Freda *et al.* 1990
	Anthracene	58B	Kagan *et al.* 1984
	Aroclor 1016	57	Birge *et al.* 1978a
	Aroclor 1242	57	Birge *et al.* 1978a
	Aroclor 1254	57	Birge *et al.* 1978a
	Atrazine	11	Birge *et al.* 1980

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Benzene	12	Black *et al.* 1982
	Benzene hexachloride	40B	Kaplan and Overpeck 1964
	Borax	14	Birge and Black 1977
	Boric acid	14	Birge and Black 1977
	Cadmium chloride	15C	Birge and Just 1973, Birge *et al.* 1975, Francis *et al.* 1984, Zettergren *et al.* 1991
	Carbon tetrachloride	18	Black *et al.* 1980
	Chlordane	19	Kaplan and Overpeck 1964
	Chlorobenzene	21	Black *et al.* 1982
	Chloroform	24	Birge *et al.* 1980, Black *et al.* 1982
	DDT	30B	Weis 1975
	1,2-Dichlorobenzene	21	Black *et al.* 1982
	1,2-Dichloroethane	22B	Black *et al.* 1982
	Dieldrin	6A 6B, 6C, 6D	Kaplan and Overpeck 1964, Schuytema *et al.* 1991
	Diisononylphthalate	56	Birge *et al.* 1978a
	Dioctylphthalate	56	Birge *et al.* 1978a
	Endosulfan (Thiodan I)	35	Mulla 1963
	Endosulfan (Thiodan II)	35	Mulla 1963
	Endrin	36B	Kaplan and Overpeck 1964
	Fluoranthene	58B	Kagan *et al.* 1985
	Lead nitrate	42	Kaplan *et al.* 1967
	Malathion	43B	Kaplan and Glaczenski 1965
	Mercuric chloride	45B	Birge and Just 1973, 1975, Birge and Black 1977, Birge *et al.* 1979b, Birge *et al.* 1983,
	Methoxychlor	46B	Kaplan and Overpeck 1964
	Methyl mercury chloride	45B	Chang *et al.* 1974, Dial 1976

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Nitrobenzene	51	Black *et al.* 1982
	Parathion	53B	Kaplan and Glaczinski 1965
	Pentachlorophenol-sodium	54B	Goodnight 1942
	Phenol	55B	Birge *et al.* 1980
	Pyrene	58B	Kagan *et al.* 1985
	Sodium arsenite	10	Birge and Just 1973
	Toluene	63	Black *et al.* 1982
	Toxaphene	64B	Kaplan and Overpeck 1964
	Zinc	67B	Kaplan and Glaczenski 1965
Rana sphenocephala	Endrin	36B	Hall and Swineford 1980
	Toxaphene	64B	Hall and Swineford 1980, 1981
Rana sylvatica	Aluminum chloride	7A, 7B	Clark and La Zerte 1985, Freda and McDonald 1993
	Aluminum (inorganic monomeric)	7B	Clark and Hall 1985
	DDT	30B	Licht 1985, 1976
	Endrin	36B	Hall and Swineford 1981
	Toxaphene	64B	Hall and Swineford 1981
Rana temporaria	Aluminum	7B	Tyler-Jones *et al.* 1989
	Aluminum chloride	7B	Cummins 1986
	Calcium chloride	20	Cummins 1988
	Carbaryl (Karbatox 75)	16	Rzehak *et al.* 1977
	Carbon tetrachloride	18	Black *et al.* 1980
	Chloroform	24	Black *et al.* 1982
	Cyanide	29	Costa 1965
	2,4-D	25B	Cooke 1972
	DDT	30B	Cooke 1970, 1972, 1973, 1979; Osborn *et al.* 1981

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Dieldrin	6D	Cooke 1972
	Endrin	36B	Wohlgemuth 1977
	N-nitrosodimethylamine	52B	Khudoley 1977a, 1977b
	Phenol	55B	Black *et al.* 1982
	Tributyltin fluoride	65	Laughlin and Linden 1982
	Tributyltin oxide	65	Laughlin and Linden 1982
Rana tigrina	Carbaryl	16	Marian *et al.* 1983
	DDT	30B	Keshaven and Deshmukh 1984
	Endosulfan	35	Gopal *et al.* 1981
	Malthion (formulation)	43B	Mohanty-Hejmadi and Dutta 1981
	Potassium dichromate	27	Abbasi and Soni 1984
Scaphiopus hammondi	Guthion (formulation)	37B	Mulla *et al.* 1963
	Methyl parathion (formulation)	47B	Mulla 1962, Mulla *et al.* 1963
	Parathion (formulation)	53B	Mulla *et al.* 1963
Triturus cristatus carnifex	MCPA	25B	Zaffaroni *et al.* 1986, Zavanella *et al.* 1988
Triturus viridescens	Methyl mercury chloride	45B	Chang *et al.* 1976
Triturus vulgaris	Chlorpyrifos	26	van Wijngaarden *et al.* 1993
	DDT	30B	Cooke 1972
Xenopus laevis	Acrolein	5	Holcombe *et al.* 1987
	Aluminum	7A, 7B	Dale *et al.* 1985, Linder *et al.* 1991
	Aniline	8A, 8B	Dumont *et al.* 1979, Sloof and Baerselman 1980, Davis *et al.* 1981, Sloof *et al.* 1983, Dumpert 1987

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Benzene	12	Sloof and Baerselman 1980, Sloof *et al.* 1983, de Zwart and Sloof 1987
	Benzo[a]pyrene	58A	Fort *et al.* 1989
	Cadmium	15A, 15C	Miller and Landesman 1978, Linder *et al.* 1991
	Cadmium chloride	15C	Canton and Sloof 1982, Woodall *et al.* 1988
	Cadmium nitrate	15C	Sloof and Baerselman 1980, Sloof *et al.* 1983, de Zwart and Sloof 1987
	Carbaryl (Karbatox 75)	16	Rzehak *et al.* 1987
	Carbon tetrachloride	18	Black *et al.* 1980
	Chloroform	24	Black *et al.* 1982
	Copper	28B	Linder *et al.* 1991
	Copper sulfate	28B	de Zwart and Sloof 1987
	1,3-Dichloropropane	32	de Zwart and Sloof 1987
	Dieldrin	6A, 6B, 6C, 6D	Schuytema *et al.* 1991
	Guthion	37A, 37B	Schuytema *et al.* 1994, 1995
	Guthion 2S	37A, 37B	Schuytema *et al.* 1994, 1995
	Iron	41A, 41B	Linder *et al.* 1991
	Lead	42	Miller and Landesman 1978
	Lead acetate	42	Sobotka and Rahwan 1995
	Lindane	40B	Marchal-Segault and Ramade 1981
	Malathion	43A, 43B	Snawder and Chambers 1989, 1990
	Manganese	44	Miller and Landesman 1978
	Mercury	45B	Miller and Landesman 1978

Table 3. (Continued)

Species	Chemical	Table number	Reference
	Mercuric chloride	45B	Birge *et al.* 1979b, Sloof and Baerselman 1980, Sloof *et al.* 1983, de Zwart and Sloof 1987
	Methyl mercury chloride	45B	Dumpert and Zietz 1984
	Naphthalene	49A, 49B	Edmisten and Bantle 1982
	Nickel	50A, 50B	Linder *et al.* 1991
	Nickel chloride	50A, 50B	Hopfer *et al.* 1991
	N-nitroso-dimethylamine	52A	Fort *et al.* 1991
	Parathion	53A	Snawder and Chambers 1984
	Pentachlorophenol	54B	Sloof and Baerselman 1980, Sloof *et al.* 1983, Sloof and Canton 1983
	Phenol	55A, 55B	Black *et al.* 1982, Holcombe *et al.* 1987, Dumpert 1987
	Potassium dichromate	27	Sloof and Canton 1983
	Selenium	60A, 60B	Linder *et al.* 1991
	Sodium chloride	20	Romspert 1976
	Sodium selenate	60A	DeYoung *et al.* 1991
	Sodium selenite	60B	Browne and Dumont 1979, 1980
	Trichloroethylene	66A, 66B	Sloof and Baerselman 1980, Sloof *et al.* 1983, Fort *et al.* 1991, 1993
	2,4,6-Trichlorophenol	23	Holcombe *et al.* 1987
	Zinc	67A, 67B	Linder *et al.* 1991
	Zinc sulfate	67A, 67B	Dawson *et al.* 1988, Woodall *et al.* 1988, Fort *et al* 1989, Bantle *et al.* 1989

Table 3. (Continued)

Species	Chemical	Table number	Reference
Unidentified	Dichlorvos	33	Streenivasen and Swaminathan 1967
	Thallium nitrate	62	Dilling and Healey 1926

[a] Species names are as reported by authors; no attempt was made to combine species where names have been changed (e.g. *Hyla regilla* = *Pseudacris regilla*.). The chemicals include all reported compounds and subgroups of the major chemicals and chemical groups listed in Tables 1 and 2.

Table 4. Published water quality criteria values for each chemical or chemical group[a].

Chemical	Concentrations in $\mu g/L$		Reference
	Acute criteria	Chronic criteria	
Acrolein	68[b]	21[b]	USEPA 1980a
Aldrin	3.0[c]	—	USEPA 1980c
Aluminum	750[d,e]	87[d]	USEPA 1988b
Aniline	28[e]	14[f]	USEPA 1993
Antimony (III)	88[e]	30[f]	USEPA 1988c
Arsenic	360[e]	190[f]	USEPA 1985a
Benzene	5,300[b]	—	USEPA 1980b
Beryllium	130[b]	5.3[b]	USEPA 1980e
Boron	[g]	[g]	USEPA 1986a
Cadmium	3.9[e,h]	1.1[f,h]	USEPA 1985b
Carbon tetrachloride	35,200[b]	—	USEPA 1980g
Chlordane	2.4[c]	0.0043[i]	USEPA 1980h
Chloride	860,000[e,j]	230,000[f,j]	USEPA 1988a
Chlorinated benzenes	250[b]	50[b]	USEPA 1980i
Chlorinated ethanes	[k]	[l]	USEPA 1980j
Chlorinated phenols	[m]	[n]	USEPA 1980k
Chloroform	28,900[b]	1,240[b]	USEPA 1980l
Chlorophenoxy herbicides	[o]	[o]	USEPA 1986a
Chlorpyrifos	0.083[e]	0.041[f]	USEPA 1986c
Chromium (III)	1,700[e,h]	210[f,h]	USEPA 1985c
Chromium (VI)	16[e]	11[f]	USEPA 1985c
Copper	18[e,h]	12[f,h]	USEPA 1985d
Cyanide	22[e]	5.2[f]	USEPA 1985e
DDT	1.1[c]	0.0010[i]	USEPA 1980m
DDE	1,050[b]	—	USEPA 1980m
TDE	0.06[b]	—	USEPA 1980m

Table 4. (Continued)

Chemical	Concentrations in $\mu g/L$		Reference
	Acute criteria	Chronic criteria	
Dichloropropanes	23,000[b]	5,700[b]	USEPA 1980n
Dichloropropenes	6,060[b]	244[b]	USEPA 1980n
Dieldrin	2.5[c]	0.0019[f]	USEPA 1980c
Di-2-ethylhexyl phthalate (DEHP)	400[e]	360[f]	USEPA 1987c
Endosulfan	0.22[c]	0.056[i]	USEPA 1980o
Endrin	0.18[c]	0.0023[i]	USEPA 1980p
Halomethanes	11,000[b]	—	USEPA 1980q
Heptachlor	0.52[c]	0.0038[i]	USEPA 1980r
Hexachlorocyclohexane (Lindane)	2.0[c]	0.080[i]	USEPA 1980s
Iron	—	1000[p]	USEPA 1986a
Lead	82[eh]	3.2[fh]	USEPA 1985f
Malathion	—	0.1[p]	USEPA 1986a
Manganese	[q]	[q]	USEPA 1986a
Mercury	2.4[e]	0.012[f]	USEPA 1985g
Methoxychlor	—	0.03[p]	USEPA 1986a
Mirex	—	0.001[p]	USEPA 1986a
Naphthalene	2,300[b]	620[b]	USEPA 1980v
Nickel	1,400[eh]	160[fh]	USEPA 1986b
Nitrosamines	5,850[b]	—	USEPA 1980x
Parathion	0.065[e]	0.013[f]	USEPA 1986d
Pentachlorophenol	20[eh]	13[fh]	USEPA 1986e
Phenol	10,200[b]	2,560[b]	USEPA 1980y
Phthalate esters	940[b]	3[b]	USEPA 1980z
Polychlorinated biphenyls (PCBS)	2[e]	0.014[i]	USEPA1980aa
Polynuclear aromatic hydrocarbons	[r]	[r]	USEPA 1980bb

Table 4. (Continued)

Chemical	Concentrations in $\mu g/L$		Reference
	Acute criteria	Chronic criteria	
Selenium	20[e]	5[f]	USEPA 1987b
Silver	4.1[eh]	0.12[fh]	USEPA 1980cc
2, 3, 7, 8-Tetrachloro-dibenzo-p-dioxin	[r]	[r]	USEPA 1984
Thallium	1,400[b]	40[b]	USEPA 1980dd
Toluene	17,500[b]	—	USEPA 1980ee
Toxaphene	0.73[e]	0.0002[f]	USEPA 1986f
Tributyltin	0.149[e]	0.0264[f]	USEPA 1988d
Trichloroethylene	45,000[b]	21,900[b]	USEPA 1980gg
Zinc	120[eh]	110[fh]	USEPA 1987a

[a] Criteria are listed only for chemicals where amphibian data was found in existing water quality criteria documents or in other literature.
[b] Criteria not developed because of insufficient data. Value given is lowest observed adverse effect level (LOAEL).
[c] Acute value is concentration not to be exceeded at any time.
[d] Freshwater organisms should not be affected unacceptably when pH is between 6.5 and 9.0.
[e] Acute value is one-hour average concentration not to be exceeded more than once every three years on the average.
[f] Chronic value is four-day average concentration not to be exceeded more than once every three years on the average.
[g] Criterion is 750 $\mu g/L$ for long-term irrigation on sensitive crops.
[h] Hardness dependent criterion-100 mg/L.
[i] Chronic value is concentration as a 24-hour average.
[j] Value for chloride associated with sodium.
[k] Toxicity increases with increasing chlorination. Acute toxicity for various species ranges from 980 $\mu g/L$ for hexachloroethane to 118,000 $\mu g/L$ for 1, 2-dichloroethane.
[l] Toxicity increases with increasing chlorination. Chronic toxicity for various species ranges from 540 $\mu g/L$ for hexachloroethane to 20,000 $\mu g/L$ for 1, 2-dichloroethane.
[m] Toxicity increases with increasing chlorination. Acute toxicity ranges from as low as 30 $\mu g/L$ for 4-chloro-3-methylphenol to greater than 500,000 $\mu g/L$ for other compounds.
[n] Toxicity increases with increasing chlorination. Chronic toxicity occurs as low as 970 $\mu g/L$ for 2, 4, 6-trichlorophenol.
[o] Human health criteria are 100 $\mu g/L$ for 2, 4-D and 10 $\mu g/L$ for 2, 4, 5-TP in domestic water supply.
[p] No time frame given.
[q] Criteria for domestic water supply is 50 $\mu g/L$.
[r] Limited data does not permit statement about acute or chronic criteria.

Table 5. Acrolein - acute data

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)[b]	Reference
Xenopus laevis	Tadpole	F, M	7	Holcombe *et al.* 1987

[a] F = flow-through, M = measured
[b] LC50 = median lethal concentration

Table 6A. Aldrin/Dieldrin - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	Aldrin	S, U	68	Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole	Aldrin	S, U	150	Sanders 1970[b]
Bufo woodhousii fowleri	Tadpole	Dieldrin	S, U	150	Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole	Dieldrin	S, U	150	Sanders 1970[b]
Pseudacris triseriata	Tadpole	Dieldrin	S, U	100	Mayer and Ellersieck 1986, Sanders 1970[b]
Rana catesbeiana	Tadpole	Dieldrin	F, M	30.3, 8.7	Schuytema *et al.* 1991
Rana pipiens	Tadpole	Dieldrin	F, M	71.3	Schuytema *et al.* 1991
Xenopus laevis	Embryo	Dieldrin	R, M	>179.2	Schuytema *et al.* 1991
Xenopus laevis	Tadpole	Dieldrin	F, M	49.5, 40.4	Schuytema *et al.* 1991
Xenopus laevis	Juvenile	Dieldrin	F, M	46.8	Schuytema *et al.* 1991

[a] F = flow-through, M = measured, R = static-renewal, S = static, U = unmeasured

[b] Reference also cited in Table 6 (other data) of the water quality criteria document for aldrin/dieldrin EPA 440/5-80-019 (USEPA 1980c)

Table 6B. Aldrin/Dieldrin - chronic data

Species	Stage/Age	Chemical	Method[a]	Duration	Chronic limits[b] (µg/L)		Chronic value[c] (µgL)	Reference
					NOAEL	LOAEL		
Rana pipiens	Tadpole	Dieldrin	F, M	28 d	1.9[d]	4.1[d]	2.4	Schuytema *et al.* 1991
Xenopus laevis	Embryo	Dieldrin	R, M	21 d	1.3[e] 10.3[d]	5.0[e] 25.8[d]	2.5 16.3	Schuytema *et al.* 1991
Xenopus laevis	Tadpole	Dieldrin	F, M	24 d	0.8[d]	1.8[d]	1.2	Schuytema *et al.* 1991

[a] F = flow-through, M = measured, R = static-renewal
[b] NOAEL = No observed adverse effect level, LOAEL = lowest observed adverse effect level
[c] Geometric mean of NOAEL and LOAEL
[d] Limits based on mortality
[e] Limits based on deformity

Table 6C. Aldrin/Dieldrin - residue data.

Species	Stage/Age	Chemical	Conc. (μg/L)	% lipid	Tissue	BCF[b]	Reference
Rana pipiens	Tadpole	Dieldrin	0.8	1.0	Whole body	440-690	Schuytema *et al.* 1991
			1.9			210	
			2.1			390	
			4.1			160	
			10.0			200	
Xenopus laevis	Tadpole	Dieldrin	0.9	0.8	Whole body	470	Schuytema *et al.* 1991
			1.8			420	
			3.8			380	
			9.7			310	
Xenopus laevis	Tadpole	Dieldrin	2.0	0.8	Whole body	400	Schuytema *et al.* 1991
			2.3			300	
			4.2			480	
			9.3			320	
			20.5			340	
			1.1[a]			1,640	
Xenopus laevis	Juvenile	Dieldrin	2.1	2.6	Whole body	2,140	Schuytema *et al.* 1991

[a] In DMF carrier, all others in acetone carrier
[b] BCF = bioconcentration factor (quotient of chemical in tissue divided by concentration of chemical in water)

Table 6D. Aldrin/Dieldrin - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (FgL)	Reference
Bufo arenarum	Embryo	Aldrin	R, U	≤ 42 d	0% mortality	1,000	Juarez and Guzman 1984
				15 d	100% mortality	5,000	
				10 d	100% mortality	15,000	
Rana catesbeiana	Tadpole	Aldrin (formulation)	U, isolated in pond	96 hr	30% mortality	0.112 kg/ha[b]	Mulla 1963
					100% mortality	0.560 kg/ha[b]	
Rana hexadactyla	Adult	Aldrin	S, U	4 wk	Decrease in protein	240	Joseph and Rao 1991
					brain-55.4%		
					muscle-51.2%		
					kidney-54%		
					intestine-52.1%		
Rana pipiens	Adult	Aldrin	R, U	30 d	40% mortality	300	Kaplan and Overpeck 1964
Bufo arenarum	Embryo	Dieldrin	R,U	20-25 d	25-30% accelerated metamorphosis	20	de Llamas *et al.* 1985
				20-25 d	100% mortality	200	
				4 hr	22.7% AChE inhibition at 11d	2,000	
				4 hr	28.7% ChE inhibition at 11d	2,000	
				11 d	26.7% AChE inhibition at 11d	2,000	
				11 d	25.5% ChE inhibition at 11d	2,000	
Bufo arenarum	Unfertilized oocyte	Dieldrin	R, U	1 hr	19.7% AChE inhibition at 11d	2,000	de Llamas *et al.* 1985
				4 hr	22.3% AChE inhibition at 11d	2,000	
Bufo arenarum	Fertilized oocyte	Dieldrin	R, U	4 hr	22.75 ACHE inhibition at 11d	2,000	de Llamas *et al.* 1985
				11 d	28.7% ACHE inhibition at 11d	2,000	
Bufo arenarum	Tadpole	Dieldrin	S, U	7-8 d	Behavioral effects	200	Gauna *et al.* 1991
				14 d	Beginning mortality	200	
				16 d	17% decrease in phospholipids	200	

Table 6D. Aldrin/Dieldrin (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)[a]	Reference
Bufo bufo	Tadpole	Dieldrin	S, U	48 hr	0% mortality, most with abnormal snouts	500	Cooke 1972
Limnodynastes tasmaniensis	Embryo	Dieldrin	S, U[c]	7 hr	0% cephalic abnormalities at 19 d 20% cephalic abnormalities at 20 d	10 100	Brookes 1981
Rana catesbeiana	Tadpole	Dieldrin (formulation)	U, isolated in pond	24 hr	100% mortality	0.112 kg/ha[b]	Mulla 1963
Rana catesbeiana	Embryo	Dieldrin	R, U	21 d	LC50	34.4	Schuytema *et al.* 1991
Rana pipiens	Tadpole	Dieldrin	F, M	28 d	LC50	8.3	Schuytema *et al.* 1991
Rana pipiens	Adult	Dieldrin	F, M	28 d	LC50	53.4	Schuytema *et al.* 1991
Rana pipiens	Adult	Dieldrin	R, U	30 d	LC50	100	Kaplan and Overpeck 1964
Rana temporaria	Tadpole	Dieldrin	S, M	48 hr	5% mortality 47% mortality, many with abnormal snouts	20 500	Cooke 1972
Xenopus laevis	Embryo	Dieldrin	R, M	7 d 14 d 21 d	LC50 LC50 LC50	167.9 27.9 14.9	Schuytema *et al.* 1991

Table 6D. Aldrin/Dieldrin (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μgL)[a]	Reference
Xenopus laevis	Tadpole	Dieldrin	R, M	10 d	LC50	2.9[c]	Schuytema *et al.* 1991
				14 d	LC50	10.9	
				24 d	LC50	5.5	
				28 d	LC50	<2.0	

[a] F = flow-through, M = measured, R = static renewal, S = static, U = unmeasured
[b] Active ingredient
[c] DMF carrier, others in acetone

Table 7A. Aluminum - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Bufo americanus	Embryo	Aluminum chloride	S, M	>997 >1,029 >1,038 805	4.8 4.6 4.4 4.2	— — — —	Freda and McDonald 1993
Bufo americanus	Tadpole	Aluminum chloride	S, M	627	4.5	6.1[c]	Freda *et al.* 1990
Rana pipiens	Embryo	Aluminum chloride	S, M	403 811	4.8 4.6	6.1[c] 6.1[c]	Freda and McDonald 1990
Rana pipiens	Embryo	Aluminum chloride	S, M	471	4.8	6.1[c]	Freda *et al.* 1990
Rana sylvatica	Embryo	Aluminum chloride	S, M	746 >1,118 >1,150 1,148	4.8 4.6 4.4 4.2	— — — —	Freda and McDonald 1993
Xenopus laevis	Embryo	Aluminum	R, U	1,600	5.5	—	Linder *et al.* 1991

[a] M = measured, R = renewal, S = static, U = unmeasured

[b] Values expressed as aluminum

[c] Hardness calculated from Ca and Mg concentrations

Table 7B. Aluminum - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma jeffersonianum	Embryo	Aluminum chloride	S, M	96 hr	Mortality ameliorated	>250	4.5	—	Horne and Dunson 1994
					No effect on development rate	2,000	4.5	—	
Ambystoma maculatum	Embryo	Aluminum	In pond, M	Time to emergence	Survival and Al conc. negatively correlated	80-1,380	3.68-5.18	3.6-14.4[c]	Albers and Prouty 1987
Ambystoma maculatum	Embryo	Aluminum chloride	S, U	Until hatched	22-66% hatch	0	4.3	7.1[c]	Clark and La Zerte 1987
					28-79% hatch	200	4.3	7.1[c]	
					24-64% mortality	0	4.3	7.1[c]	
					15-61% mortality	200	4.3	7.1[c]	
Ambystoma maculatum	Embryo	Aluminum	—	31 d	11% hatch	100	4	—	Dale *et al.* 1985[d]
					3% hatch	400	—	—	
					2% hatch	700	—	—	
					2% hatch	1,100	—	—	
Ambystoma opacum	Embryo	Aluminum chloride	S, M	8 d	LC50	2,280	7.2-7.8	93-105	Birge *et al.* 1978b[e]
Bufo americanus	Embryo	Aluminum (inorganic monomeric)	In acidified stream, M	96 hr	72% hatch	35	4.3	—	Clark and Hall 1985
				96 hr	11% hatch	46	4.3	—	
Bufo americanus	Embryo	Aluminum	S, U	8-11 d	100% hatch	20	5.75	7.8[c]	Clark and LaZerte 1985
					94% hatch	20	4.75	7.8[c]	
					61% hatch	20	4.14	7.8[c]	
					99% hatch	100	4.75	7.8[c]	
					55% hatch	100	4.14	7.8[c]	

Table 7B. Aluminum (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Bufo canorus	Embryo	Aluminum (inorganic monomeric)	S, U	7 d	Hatch time reduced	39	4.9	—	Bradford *et al.* 1992
					Hatch time reduced	70	5.3	—	
					Hatch time reduced	80	5.8	—	
Bufo canorus	Tadpole	Aluminum (inorganic monomeric)	S, U	7 d	Length reduced	39	4.9	—	Bradford *et al.* 1992
					Length reduced	70	5.3	—	
					Length reduced	80	5.8	—	
Gastrophryne carolinensis	Embryo	Aluminum chloride	R, M	7 d	LC50	50	7.4	195	Birge 1978[e], Birge *et al.* 1979a[e]
Rana muscosa	Embryo	Aluminum (inorganic monomeric)	S, U	7 d	Hatch time unaffected	39	4.9	—	Bradford *et al.* 1992
					Hatch time unaffected	70	5.3	—	
					Hatch time unaffected	80	5.8	—	
Rana pipiens	Embryo	Aluminum chloride	S, M	96 hr	75% mortality	0	4.2	6.1[c]	Freda *et al.* 1990
					60% mortality	125	4.2	6.1[c]	
					49% mortality	250	4.2	6.1[c]	
					54% mortality	450	4.2	6.1[c]	
Rana pipiens	Tadpole (pre-stage 25)	Aluminum chloride	S, M	96 hr	20% mortality	0	4.2	6.1[c]	Freda and McDonald 1990
					100% mortality	$\geq$250	4.4-4.6	6.1[c]	
					100% mortality	$\geq$250	4.8	6.1[c]	
Rana pipiens	Tadpole	Aluminum chloride	S, M	96 hr	6-13% mortality	1,000	4.2-4.6	6.1[c]	Freda and McDonald 1990
					40% mortality	1,000	4.8	6.1[c]	

Table 7B. Aluminum (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana sylvatica	Embryo	Aluminum (inorganic monomeric)	In acidified stream, M	96 hr	91% hatch	35	4.3	—	Clark and Hall 1985
					83% hatch	46	4.3	—	
Rana sylvatica	Embryo	Aluminum chloride	S, U	8-12 d	93% hatch	20	5.75	7.8[c]	Clark and La Zerte 1985
					87% hatch	20	4.75	7.8[c]	
					67% hatch	20	4.14	7.8[c]	
					94% hatch	100	4.75	7.8[c]	
					67% hatch	100	4.14	7.8[c]	
Rana temporaria	Embryo	Aluminum	F, M	Until gill circulation	47% deformity	400	4.5	203[c]	Tyler-Jones *et al.* 1989
					18.7% mortality	200	4.5	203[c]	
					20.8% mortality	200	6.0	203[c]	
Rana temporaria	Tadpole	Aluminum chloride	S, M	Until foreleg emergence	42% mortality	800	4.4	[f]	Cummins 1986
				Until metamor-phosis	50% mortality	1,600	4.4	[f]	

Table 7B. Aluminum (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Embryo	Aluminum	—	11 d	0% hatch	150	4.0	—	Dale *et al.* 1985[d]
					88% hatch	150	4.5	—	
					100% hatch	900	4.5	—	
					100% hatch	150	5.0	—	
					90% hatch	900	5.0	—	
					100% hatch	150	6.0	—	
					100% hatch	900	6.0	—	
					100% mortality	150	4.5	—	
					38% mortality	200	4.5	—	
					0% mortality	400	4.5	—	
					100% mortality	900	4.5	—	
					0% mortality	400	5.0	—	
					100% mortality	900	5.0	—	
					0% mortality	400	6.0	—	
					50% mortality	900	6.0	—	

[a] F = flow-through, M = measured, R = renewal S = static, U = unmeasured
[b] Values expressed as aluminum
[c] Hardness calculated from reported calcium and magnesium concentrations
[d] Reference not seen, cited in Power *et al.* 1989
[e] Reference also cited in Table 6 (other data) of the water quality criteria document for aluminum EPA 440/5-86-008 (USEPA 1988a)
[f] Artificial softwater

Table 8A. Aniline - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (µg/L)	Reference
Xenopus laevis	Embryo (mid-blastula)	S, M	550,000	Davis *et al.* 1981[b]
Xenopus laevis	Embryo (tailbud)	S, M	940,000	Davis *et al.* 1981[b]
Xenopus laevis	Tadpole	S, M	150,000	Davis *et al.* 1981[b]

[a] M = measured, S = static
[b] Reference also cited in Table 1 (acute data) of the draft water quality criteria document for aniline EPA 440/5-93 Draft (USEPA 1993)

Table 8B. Aniline - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma mexicanum	Larva	S, U	48 hr	LC50	440,000	Sloof and Baerselman 1980, Sloof *et al.* 1983
Xenopus laevis	Embryo	S, U	96 hr	28% mortality 11% deformity 4% mortality 6 % deformity	10,000 10,000 50,000 50,000	Dumont *et al.* 1979[b]
Xenopus laevis	Embryo (med. blastula)	S, M	120 hr 96 hr 120 hr	LC50 EC50 (teratogeny) EC50 (teratogeny)	500,000 91,000 370,000	Davis *et al.* 1981[b]
Xenopus laevis	Embryo (tailbud)	S, M	12 hr	LC50	95,000	Davis *et al.* 1981[b]
Xenopus laevis	Embryo	R, U	12 wk	delayed development	1,000	Dumpert 1987[b]
Xenopus laevis	Tadpole	R, U	12 d	100% mortality	90,000	Dumpert 1987[b]
Xenopus laevis	Tadpole	S, U	48 hr	LC50	560,000	Sloof and Baerselman 1980[b], Sloof *et al.* 1983[b]

[a] M = measured, R = renewal, S = static, U = unmeasured

[b] Reference also cited in Table 5 (other data) of the draft water quality criteria document for aniline EPA/440-5-93 Draft (USEPA 1993)

Table 9. Antimony (III) - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (Fg/L)	pH	Hardness (as mg/L CaCO3)	Reference
Gastrophryne carolinensis	Embryo	Antimony trichloride	R, M	7 d	LC50	300	7.4	195	Birge 1978[c], Birge *et al.* 1979a[c]

[a] M = measured, R= renewal
[b] Value expressed as antimony
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for antimony (III) EPA 440/5-88-093 (USEPA 1988c)

Table 10. Arsenic - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Adelotus brevis	Tadpole	Sodium arsenite	S, U	96 hr	LC50	55,400	—	51.2[c]	Johnson 1976
Ambystoma opacum	Embryo	Sodium arsenite	F, M	8 d	LC50	4,450	7.2-7.8	93-105	Birge *et al.* 1978b[d]
Bufo marinus	Tadpole	Sodium arsenite	S, U	96 hr	LC50	70,900	—	51.2[c]	Johnson 1976
Gastrophryne carolinensis	Embryo	Sodium arsenite	R, M	7 d	LC50	40	7.4	195	Birge 1978[d] Birge *et al.* 1979a[d]
Rana catesbeiana and Rana pipiens	Tadpole	Sodium arsenite	R, M	96 hr	19% mortality	10,000	[e]	[e]	Birge and Just 1973
					50% mortality	25,000	[e]	[e]	
				22 d	24% mortality	5,000	[e]	[e]	
					87% mortality	10,000	[e]	[e]	
Rana catesbeiana and Rana pipiens	Adult	Sodium arsenite	R, M	96 hr	0% mortality	25,000	[e]	[e]	Birge and Just 1973
					30%mortality	50,000	[e]	[e]	
				25 d	0% mortality	25,000	[e]	[e]	
					80% mortality	50,000	[e]	[e]	
Rana hexadactyla	Tadpole	Arsenic trioxide	S, U	96 hr	LC50	249	6.1	249	Khangarot *et al.* 1985b
Limnodynastes peroni	Tadpole	Sodium arsenite	S, U	96 hr	LC50	34,600	—	51.2[c]	Johnson 1976

[a] F= flow-through, M= measured, R= renewal, S= static, U= unmeasured
[b] Values expressed as arsenic
[c] Hardness calculated from calcium and magnesium concentrations
[d] Reference also cited in Table 6 (other data) of the water quality document for arsenic EPA 440/5-84-033 (USEPA 1985a)
[e] Modified Holtfreter's Solution

Table 11. Atrazine - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo americanus	Embryo	F, M	7 d	LC50	48,000	Birge *et al.* 1980, Birge *et al.* 1983
				2% deformity at hatch	5,560	
				3% deformity at hatch	10,800	
				6% deformity at hatch	24,800	
				17% deformity at hatch	48,200	
Rana catesbeiana	Embryo	F, M	8 d	LC50	410	Birge *et al.* 1980, Birge *et al.* 1983
				1% deformity at hatch	51	
				3% deformity at hatch	410	
				7% deformity at hatch	6,330	
				22% deformity at hatch	14,800	
				47% deformity at hatch	26,400	
				100% deformity at hatch	45,800	
Rana catesbeiana	Tadpole	Pond, M	2 d post-treatment	289 µg/Kg body burden	300	Klaassen and Kadoum 1979
			23 d post-treatment	278 µg/Kg body burden	300	
			51 d post-treatment	309 µg/Kg body burden	300	
			85 d post-treatment	235 µg/Kg body burden	300	
Rana palustris	Embryo	F, M	8 d	LC50	17,960	Birge *et al.* 1980
				2% deformity at hatch	1,040	
				5% deformity at hatch	20,800	
				18% deformity at hatch	33,900	
Rana pipiens	Embryo	F, M	9 d	LC50	7,680	Birge *et al.* 1980
				2% deformity at hatch	210	
				5% deformity at hatch	1,130	
				9% deformity at hatch	6,540	
				13% deformity at hatch	13,200	

Table 11. Atrazine (continued)

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana pipiens	Embryo	F, M	9 d	46% deformity at hatch	48,700	Birge *et al.* 1980

[a] F= flow-through, M = measured

Table 12. Benzene - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Ambystoma gracile	Embryo	F, M	9 d	LC50	5,210	Black *et al.* 1982
				9% deformity at hatch	5,430	
				27% deformityat hatch	36,700	
Ambystoma mexicanum	Larva	S, U	48 hr	LC50	370,000	Sloof and Baerselman 1980, Sloof *et al.* 1983
Rana pipiens	Embryo	F, M	9 d	LC50	3,660	Black *et al.* 1982
				0% deformity at hatch	2,990	
				16% deformity at hatch	5,070	
Xenopus laevis	Tadpole	S, U	48 hr	LC50	190,000	de Zwart and Sloof 1987, Sloof and Baerselman 1980, Sloof *et al.* 1983

[a] F= flow-through, M = measured, S = static, U = unmeasured

Table 13. Beryllium - acute data

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (µg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Ambystoma maculatum	Larva (small)	Beryllium sulfate	S, U	3,150 31,500	— —	20-25 400	Slonim and Ray 1975[c]
Ambystoma maculatum	Larva (medium)	Beryllium sulfate	S, U	8,020 18,200	— —	20-25 400	Slonim and Ray 1975[c]
Ambystoma maculatum	Larva (large)	Beryllium sulfate	S, U	8,320 18,200	— —	20-25 400	Slonim and Ray 1975[c]
Ambystoma opacum	Larva (medium)	Beryllium sulfate	S, U	3,150 31,500	— —	20-25 400	Slonim and Ray 1975[c]

[a] S = static, U = unmeasured
[b] Values expressed as beryllium
[c] Reference also cited in Table 5 (other data) of the water quality criteria document for beryllium EPA 440/5-80-024 (USEPA 1980a)

Table 14. Boron - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)[b]	pH	Hardness (as mg/L $CaCO_3$)	Reference
Bufo fowleri	Embryo	Boric acid	F, M	Until hatch	LC1 (threshold)	25,000	7.6	50	Birge and Black 1977
					LC1 (threshold)	5,000	7.6	200	
				4 d post hatch	LC1 (threshold)	25,000	7.6	50	
					LC1 (threshold)	5,000	7.6	200	
Rana pipiens	Embryo	Boric acid	F, M	Until hatch	LC1 (threshold)	26,000	7.7	50	Birge and Black 1977
					LC1 (threshold)	23,000	7.7	200	
				4 d post hatch	LC1 (threshold)	13,000	7.7	50	
					LC1 (threshold)	22,000	7.7	200	
Rana pipiens	Embryo	Borax	F, M	Until hatch	LC1 (threshold)	6,000	8.3	50	Birge and Black 1977
					LC1 (threshold)	3,000	8.4	200	
				4 d post hatch	LC1 (threshold)	5,000	8.3	50	
					LC1 (threshold)	3,000	8.4	200	

[a] F= flow-through, M= measured
[b] Values expressed as boron

Table 15A. Cadmium - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Ambystoma gracile	Larva	Cadmium Chloride	F, M	468.4	6.8	45	Nebeker *et al.* 1995
Xenopus laevis	Embryo	Cadmium	R, U	850	7.2-7.5	—	Linder *et al.* 1991

[a] F = flow-through, M = measured, R = renewal, U = unmeasured
[b] Values expressed as cadmium

Table 15B. Cadmium - chronic data.

Species	Stage/Age	Chemical	Method[a]	Duration	Chronic limits[b] (μg/L)		Chronic value[c] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
					NOAEL	LOAEL				
Ambystoma gracile	Larva	Cadmium chloride	F, M	10 d	12.8	44.6	24	6.8	45	Nebeker *et al.* 1994
				24 d	48.9	193.1	97	6.8	45	
Ambystoma gracile	Larva	Cadmium chloride	F, M	10 d	193.1	227.3	210	6.8	45	Nebeker *et al.* 1995
				24 d	48.9	193.1	97	6.8	45	

[a] F= flow-through, M = measured

[b] NOAEL = no observed adverse effect level, LOAEL = lowest observed adverse effect level. Limits based on limb regeneration (Nebeker *et al.* 1994) and growth (Nebeker *et al.* 1995). Values expressed as cadmium

[c] Geometric mean of NOAEL and LOAEL

Table 15C. Cadmium - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma mexicanum	Larva	Cadmium nitrate	S, U	48 hr	LC50	470	[c]	209[c]	Sloof and Baerselman 1980, Sloof *et al.* 1983
Ambystoma opacum	Embryo	Cadmium chloride	S, M	8 d	LC50	150	7.2-7.8	93-105	Birge *et al.* 1978b[de]
Bufo arenarum	Embryo	Cadmium	S, U	24 hr	100% arrested development	250	[f]	[f]	Herkovits and Perez-Coll 1993
Bufo arenarum	Tadpole (young)	Cadmium chloride	R, U	96 hr	LC50 20°C LC50 25°C	2,190 2,650	[g] [g]	[g] [g]	Ferrari *et al.* 1993
Bufo arenarum	Tadpole (prometa-morphic)	Cadmium chloride	R, U	96 hr	LC50 20°C LC50 25°C	3,060 6,770	[g] [g]	[g] [g]	Ferrari *et al.* 1993
Bufo arenarum	Tadpole	Cadmium chloride	R, U	96 hr	LC50	2,080	[g]	[g]	Munio *et al.* 1990
Bufo melanostictus	Tadpole	Cadmium sulfate	S, U	96 hr	LC50	8,180	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Cadmium chloride	R, M	7 d	LC50	40	7.4	195	Birge 1978[de], Birge *et al.* 1979a
Microhyla ornata	Tadpole (1 wk)	Cadmium chloride	S, U	96 hr	LC50	1,580	6.9	142-145	Rao and Madhyastha 1987
Microhyla ornata	Tadpole (4 wk)	Cadmium chloride	S, U	96 hr	LC50	1,810	6.9	142-145	Rao and Madhyastha 1987

Table 15C. Cadmium (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Notophthalmus viridescens	Larva	Cadmium acetate	R, M	25 d	30% mortality	2,000	—	—	Manson and O'Flaherty 1978
					17% mortality	2,500	—	—	
					33% mortality	3,000	—	—	
					40% mortality	3,500	—	—	
					46% mortality	4,000	—	—	
					60% mortality	4,500	—	—	
				51 d	35% mortality	2,250	—	—	
					45% mortality	4,500	—	—	
					80% mortality	6,750	—	—	
				55 d	Poor chondrification in 62% regenerated limbs	3,000	—	—	
Rana nigromaculata	Embryo	Cadmium chloride	S, U	24 hr	26.3 germ cells at 6.5 d	600	—	—	Hah 1978
					22.4 germ cells at 6.5 d	1,200	—	—	
					16.3 germ cells at 6.5 d	2,400	—	—	
					25.1 germ cells at 11 d	600	—	—	
					23.4 germ cells at 11 d	1,200	—	—	
					17.6 germ cells at 11 d	2,400	—	—	
					36.5 germ cells at 17d	600	—	—	
					38.3 germ cells at 17d	1,200	—	—	
					31.8 germ cells at 17d	2,400	—	—	
Rana catesbeiana and Rana pipiens	Tadpole	Cadmium chloride	S, U	96 hr	LC50	3,700	7.0	'	Zettergren *et al.* 1991
Rana pipiens	Embryo (cleavage stage)	Cadmium chloride	F, U	96 hr	32% mortality	100	[h]	[h]	Birge *et al.* 1975
					67% mortality	500	[h]	[h]	
					18% mortality	1,000	[h]	[h]	
					92% mortality	2,500	[h]	[h]	
					89% mortality	5,000	[h]	[h]	
				10 d	37% mortality	100	[h]	[h]	

Table 15C. Cadmium (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana pipiens	Embryo (cleavage stage)	Cadmium chloride	F, U	10 d	70% mortality	500	[h]	[h]	Birge *et al.* 1975
					20% mortality	1,000	[h]	[h]	
				15 d	47% mortality	100	[h]	[h]	
					70% mortality	500	[h]	[h]	
					59% mortality	1,000	[h]	[h]	
Rana pipiens	Embryo (neural tube stage)	Cadmuim chloride	F, U	96 hr	26% mortality	100	[h]	[h]	Birge *et al.* 1975
					49% mortality	500	[h]	[h]	
				10 d	30% mortality	100	[h]	[h]	
					59% mortality	500	[h]	[h]	
					30% mortality	100	[h]	[h]	
					63% mortality	500	[h]	[h]	
Rana pipiens	Embryo (tail bud stage)	Cadmium chloride	F, U	96 hr	10% mortality	500	[h]	[h]	Birge *et al* 1975
				10 d	30% mortality	500	[h]	[h]	
				15 d	50% mortality	500	[h]	[h]	
Rana pipiens	Embryo	Cadmium chloride	S, M	6-7 d	0% mortality	77	7.9-8.2	102	Francis *et al.* 1984
Rana pipiens	Tapole .	Cadmium chloride	R, M	96 hr	19% mortality	10,000	[h]	[h]	Birge and Just 1973
					95% mortality	25,000	[h]	[h]	
				10 d	54% mortality	10,000	[h]	[h]	
					95% mortality	25,000	[h]	[h]	
Rana pipiens	Tadpole	Cadmium chloride	S, U	42 d	Increased Bμ cell frequency	400-800	7.0	[i]	Zettergren *et al.* 1991
Xenopus laevis	Embryo	Cadmium	S, U	96 hr	NOEC	100-200	7.2-7.5	—	Linder *et al.* 1991
					LOEC	200-400	7.2-7.5	—	

Table 15C. Cadmium (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Embryo	Cadmium	S, U	6 d	9% mortality, 0 mg/L Mg	10	[f]	[f]	Miller and Landesman 1978
					13% mortality, 0 mg/L Mg	100	[f]	[f]	
					98% mortality, 0 mg/L Mg	1,000	[f]	[f]	
					2% mortality,2 mg/L Mg	10	[f]	[f]	
					7% mortality, 2 mg/L Mg	100	[f]	[f]	
					70% mortality,2 mg/L Mg	1,000	[f]	[f]	
					9% mortality, 20 mg/L Mg	10	[f]	[f]	
					9% mortality, 20 mg/L Mg	100	[f]	[f]	
					41% mortality, 20 mg/L Mg	1,000	[f]	[f]	
					7% mortality, 200 mg/L Mg	10	[f]	[f]	
					5% mortality, 200 mg/L Mg	100	[f]	[f]	
					6% mortality,200 mg/L Mg	1,000	[f]	[f]	
					Slight deformity, 200 mg/L Mg	1,000	[f]	[f]	
					Severe deformity, 0 mg/L Mg	1			
Xenopus laevis	Tadpole	Cadmium chloride	S, U	48 hr	LC50	3,200	—	170	Canton and Sloof 1982[d]
				100 d	LC50	1,500	—	—	
				100 d	EC50 (development)	650	—	—	
Xenopus laevis	Tadpole	Cadmium nitrate	S, U	48 hr	LC50	7,360	[c]	[c]	de Zwart and Sloof 1987
Xenopus laevis	Tadpole	Cadmium nitrate	S, U	48 hr	LC50	11,648	[c]	209[c]	Sloof and Baerselman 1980[d], Sloof *et al.* 1983[d]

Table 15C. Cadmium (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Tadpole	Cadmium chloride	S, M	90 hr	80% mortality	25,600	7.0	296[j]	Woodall *et al.* 1988
					100% mortality	40,960	7.0	296[j]	
					0% mortality (96 hr pre-treatment with 1,300 µg/L Cd)	25,600	7.0	296[j]	
					30% mortality (96 hr pre-treatment with 1,300 µg/L Cd)	40,960	7.0	296[j]	
					35% mortality (96 hr pre-treatment with 1,300 µg/L Cd)	51,200	7.0	296[j]	

[a] F= flow-through, M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as Cadmium
[c] Dutch Standard Water
[d] Reference also cited in Table 6 (other data) of the water quality criteria document for cadmium EPA 440/5-84-032 (USEPA 1985b)
[e] Reference also cited in Table 6 (other data) of the water quality criteria document for cadmium EPA 440/5-80-025 (USEPA 1980d)
[f] 10% Holtfreter's Solution
[g] Artifical pond water
[h] Modified Holtfreter's Solution
[i] Reported as 102-105 meq $CaCO_3$
[j] Reported as 296 µg/L

Table 16. Carbaryl - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo bufo japonicus	Tadpole	Carbaryl (formulated)	—	48 hr	LC50	7,200	Hashimoto and Nishiuchi 1981
Rana hexadactyla	Tadpole	Carbaryl (Kelex)	R, U	96 hr	LC50	55,340	Khangarot *et al.* 1985c
Rana temporaria	Tadpole	Carbaryl (Karbatox 75)	—	24 hr	100% mortality	500,000 - — 1,000,000	Rzehak *et al.* 1977[b]
					Deformity and increased mortality	100,000	
			—	10 d	Deformity and increased mortality	10,000	
Rana tigrina	Tadpole (0.02g)	Carbaryl	S, U	96 hr	LC50	6,200	Marian *et al.* 1983
Rana tigrina	Tadpole (1.2g)	Carbaryl	S, U	96 hr	LC50	11,700	Marian *et al.* 1983
Xenopus laevis	Tadpole	Carbaryl (Karbatox 75)	—	8 d	Deformity	1,000	Rzehak *et al.* 1977[b]
					20% mortality first week	1,000	
					80% mortality second week	1,000	

[a] R = renewal, S = static, U = unmeasured
[b] Reference not seen, cited in Power *et al.* 1989

Table 17. Carbofuran - other data.

Species	Stage/Age	Chemical	Method*	Duration	Effect	Conc. (Fg/L)	Reference
Acris crepitans	Adult	Carbofuran (Furadan 3G)	Rice field water, M	15 min	Abnormal behavior or paralysis	560 g/ha	Flickinger *et al.* 1980
Microhyla ornata	Embryo	Carbofuran	R, U	96 hr	LC50	44, 230	Pawar and Katdare 1984
					5.1% deformity	1,000	
					54.4% deformity	10,000	
					96.6% deformity	30,000	
					100% deformity	70,000	
Microhyla ornata	Tadpole	Carbofuran	R, U	96 hr	LC50	13,470	Pawar and Katdare 1984
Rana hexadactyla	Tadpole	Carbofuran (Furadan)	R, U	96 hr	LC50	11,270	Khangarot *et al.* 1985c

*M = measured, R = renewal, U = unmeasured

Table 18. Carbon tetrachloride - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma gracile	Embryo	F, M	9 d	LC50	1,980	Black *et al.* 1982
			5 d	3% deformity	10,600	
			5 d	10% deformity	24,200	
			5 d	21% deformity	41,800	
Bufo fowleri	Embryo	F, M	7 d	LC50	2,830	Birge *et al.* 1980, Black *et al.* 1982
			3 d	0% deformity	690	
			3 d	3% deformity	4,980	
			3 d	11% deformity	92,500	
Rana catesbeiana	Embryo	F, M	8 d	LC50	900	Birge *et al.* 1980
			4 d	1% deformity	60	
			4 d	8% deformity	1,180	
			4 d	17% deformity	7,810	
Rana palustris	Embryo	F, M	8 d	LC50	2,370	Birge *et al.* 1980, Black *et al.* 1982
			4 d	0% deformity	4,980	
			4 d	100% deformity	92,500	
Rana pipiens	Embryo	F, M	9 d	LC50	1,640	Black *et al.* 1980
			5 d	2% deformity	76	
			5 d	6% deformity	670	
			5 d	11% deformity	1,070	
			5 d	18% deformity	24,000	
			5 d	44% deformity	41,200	
Rana temporaria	Embryo	F, M	9 d	LC50	1,160	Black *et al.* 1980
			5 d	3% deformity	670	
			5 d	12% deformity	10,700	
			5 d	17% deformity	24,000	
			5 d	67% deformity	41,200	

Table 18. Carbon tetrachloride (continued)

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Xenopus laevis	Embryo	F, M	6 d	LC50	24,420	Black *et al.* 1980
			2 d	1% deformity	600	
			2 d	4% deformity	10,500	
			2 d	10% deformity	27,200	

[a] F= flow-through, M =measured

Table 19. Chlordane - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc ($\mu g/L$)	Reference
Bufo arenarum	Embryo	Chlordane	S, U	<42 d	0% mortality	1,000	Juarez and Guzman 1984
				20 d	100% mortality	5,000	
				14 d	100% mortality	15,000	
Rana catesbeiana	Tadpole	Chlordane (formulation)	U, isolated in pond	96 hr	30% mortality	0.56 kg/ha[b]	Mulla 1963
Rana pipiens	Adult	Chlordane	S, U	30 d	40% mortality	500	Kaplan and Overpeck 1964

[a] S = static, U = unmeasured
[b] Active ingredient

Table 20. Chloride - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	Reference
Microhyla ornata	Embryo	Potassium chloride	S, U	96 hr	LC50	673,000	Padhye and Ghate 1992
Microhyla ornata	Tadpole (8 d)	Potassium chloride	S, U	96 hr	LC50	758,000	Padhye and Ghate 1992
Microhyla ornata	Tadpole (hindlimb)	Potassium chloride	S, U	96 hr	LC50	1,208,000	Padhye and Ghate 1992
Microhyla ornata	Embryo	Sodium chloride	S, U	96 hr	LC50	1,646,000	Padhye and Ghate 1992
Microhyla ornata	Tadpole (8 d)	Sodium chloride	S, U	96 hr	LC50	3,051,000	Padhye and Ghate 1992
Microhyla ornata	Tadpole (hindlimb)	Sodium chloride	S, U	96 hr	LC50	4,206,000	Padhye and Ghate 1992
Rana temporaria	Embryo	Calcium chloride	S, U	88 hr	0% mortality	11,882[c]	Cummins 1988
Xenopus laevis	Adult	Sodium chloride	S, M	114 d[d]	LC50	8,869,000-9,926,000	Romspert 1976

[a] M = measured, S = static, U =unmeasured
[b] Value expressed as chloride
[c] Includes 7,080 μg/L from calcium chloride in addition to 4,350 μg/L from sodium chloride and 452 μg/L used in artificial soft dilution water
[d] Concentrations increased in 50 mM (1,772,000 μg)) increments of chloride from 50 to 250 mM/L (1,772,000 to 8,869,000 μg/L) in 90 days and then in 10 mM (354,000 μg) increments to 300 mM/L (10,634,000 μg/L) over 24 days

Table 21. Chlorinated benzenes - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Ambystoma gracile	Embryo	Chlorobenzene	F, M	9 d	LC50	1,150	Black *et al.* 1982
					7% deformity at hatch	630	
					27% deformity at hatch	18,400	
Rana pipiens	Embryo	Chlorobenzene	F, M	9 d	LC50	1,200	Black *et al.* 1982
					4% deformity at hatch	630	
					38% deformity at hatch	14,600	
Rana pipiens	Embryo	1, 2- Dichloro-benzene	F, M	9 d	LC50	5,560	Black *et al.* 1982
					2% deformity at hatch	120	
					6% deformity at hatch	150	
					5% deformity at hatch	1,640	
					6% deformity at hatch	7,430	
					10% deformity at hatch	12,300	

[a] F= flow-through, M = measured

Table 22A. Chlorinated ethanes - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Rana catesbeiana	Tadpole	Hexachloroethane	F, M	2,440 3,180	Thurston *et al.* 1985

[a] F= flow-through, M=measured

Table 22B. Chlorinated ethanes - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma gracile	Embryo	1,2-Dichloro-ethane	F, M	9 d	LC50	2,540	Black *et al.* 1982
					5% deformity at hatch	2,580	
					16% deformity at hatch	21,400	
Rana pipiens	Embryo	1,2-Dichloro-ethane	F, M	9 d	LC50	4,400	Black *et al.* 1982
					3% deformity at hatch	1,070	
					6% deformity at hatch	2,690	
					25% deformity at hatch	21,900	

[a] F= flow through, M = measured

Table 23. Chlorinated phenols - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Tadpole	2, 4, 6 - Trichlorophenol	F , M	1,200	Holcombe *et al.* 1987

[a]F= flow-through, M = measured

Table 24. Chloroform - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma gracile	Embryo	F, M	9 d	LC50	21,500	Black *et al.* 1982
				3% deformity at hatch	5,880	
				9% deformity at hatch	9,120	
				14% deformity at hatch	63,300	
Bufo fowleri	Embryo	F, M	7 d	LC50	35,140	Birge *et al.* 1980, Black *et al.* 1982
				3% deformity at hatch	6,040	
				5% deformity at hatch	40,000	
Hyla crucifer	Embryo	F, M	7 d	LC50	270	Birge *et al.* 1980
				2% deformity at hatch	8.7	
				4% deformity at hatch	73	
				10% deformity at hatch	690	
				0% deformity at hatch	7,340	
Rana palustris	Embryo	F, M	8 d	LC50	20,550	Birge *et al.* 1980, Black *et al.* 1982
				3% deformity at hatch	10,100	
				5% deformity at hatch	32,100	
Rana pipiens	Embryo	F, M	9 d	LC50	4,160	Birge *et al.* 1980, Black *et al.* 1982
				1% deformity at hatch	21	
				2% deformity at hatch	160	
				2% deformity at hatch	660	
				12% deformity at hatch	11,800	
				100% deformity at hatch	26,900	
Rana temporaria	Embryo	F, M	9 d	LC50	16,950	Black *et al.* 1982
				3% deformity at hatch	6,050	
				9% deformity at hatch	9,900	
				21% deformity at hatch	64,100	

Table 24. Chloroform (continued)

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Xenopus laevis	Embryo	F, M	6 d	LC50	68,000	Black *et al.* 1982
				3% deformity at hatch	1,020	
				2% deformity at hatch	6,150	
				3% deformity at hatch	8,400	
				15% deformity at hatch	67,800	

[a] F = flow-through, M = measured

Table 25A. Chlorophenoxy herbicides - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (µg/L)	Reference
Bufo woodhousii fowleri	Tadpole	2, 4 - D butoxyethanol ester	S, U	>10,000	Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	Weeder 64 (amine salt of 2, 4 - D)	S, U	100,000	Sanders 1970
Pseudacris triseriata	Tadpole	Silvex (butyl ether ester)	S, U	28,000	Sanders 1970

[a] S = static, U = unmeasured

Table 25B. Chlorophenoxy herbicides - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Adelotus brevis	Tadpole	2, 4 - D amine	S, U	96 hr	LC50	200,000	Johnson 1976
Adelotus brevis	Tadpole	2, 4 , 5 -T amine	S, U	96 hr	LC50	200,000	Johnson 1976
Bufo marinus	Tadpole	2, 4 - D amine	S, U	96 hr	LC50	288,000	Johnson 1976
Bufo marinus	Tadpole	2, 4 , 5 -T amine	S, U	96 hr	LC50	340,000	Johnson 1976
Bufo melanostictus	Tadpole	2, 4 - D	S, U	96 hr	LC50	8,050	Vardia *et al.* 1984
Bufo woodhousii fowleri	Tadpole	Silvex 2 -(2, 4, 5 -T)	S, U	48 hr	LC50	20,000	Sanders 1970
Bufo woodhousii fowleri	Tadpole	Silvex (propylene glycol butyl ether ester)	S, U	24 hr	LC50	19,000	Mayer and Ellersieck 1986
Limnodynastes peroni	Tadpole	2, 4 - D amine	S, U	96 hr	LC50	287,000	Johnson 1976
Limnodynastes peroni	Tadpole	2, 4, 5 - T amine	S, U	96 hr	LC50	169,000	Johnson 1976
Rana temporaria	Tadpole	2, 4 - D	S, U	48 hr	0% mortality	50,000	Cooke 1972
Triturus cristatus carnifex	Adult (male)	MCPA	S, U	17 hr 35 hr	LC50 LC50	3,200,000 1,600,000	Zaffaroni *et al.* 1986
Triturus cristatus carnifex	Adult (female)	MCPA	S, U	21 hr 45 hr	LC50 LC50	3,200,000 1,600,000	Zaffaroni *et al.* 1986
Triturus cristatus carnifex	Adult	MCPA	S, U	1 yr	No significant tumor incidence	400,000	Zavanella *et al.* 1988

[a] S = Static, U = unmeasured

Table 26. Chlorpyrifos - other data

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Hyla regilla	Tadpole	S, U	24 hr	Onset of thermal stress at 35.3 °C	25	Johnson 1980
			24 hr	Onset of thermal stress at 34.1°C	50	
Triturus vulgaris	Adult	S, M	96 hr	EC10 (locomotional behavior)	>96	van Wijngaarden *et al.* 1993

[a] S = Static, M = measured, U = unmeasured

Table 27. Chromium - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma opacum	Embryo	Chromium trioxide	S, M	8 d	LC50	2,130	7.2-7.8	93-105	Birge *et al.* 1978b[c]
Bufo melanostictus	Tadpole	Potassium dichromate	S, U	96 hr	LC50	49,290	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Chromium trioxide	R, M	7 d	LC50	30	7.4	195	Birge 1978[c], Birge *et al.* 1979a
Rana hexadactyla	Tadpole	Potassium chromate	R, U	96 hr	LC50	100,000	6.1	20	Khangarot *et al.* 1985b
		Potassium dichromate	R, U	96 hr	LC50	42,950	6.1	20	
Rana tigrina	Tadpole	Potassium dichromate	S, U	72 hr	100% mortality 60-100% deformity	2,000 2,000	6.1 6.1	4 4	Abbasi and Soni 1984
Xenopus laevis	Tadpole	Potassium dichromate	S, U	100 d	NOL(E)C (mortality)	1,000	—	—	Sloof and Canton 1983
					NOL(E)C (development)	3,200	—	—	
					NOL(E)C (growth	3,200	—	—	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as chromium
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for chromium EPA 440/5-84-029 (USEPA 1985c)

Table 28A. Copper - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma jeffersonianum	Embryo	Copper chloride	S, M	315	4.5	—	Home and Dunson 1994
Xenopus laevis	Embryo	Copper	R, U	110	7.5	—	Linder *et al.* 1991

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as copper

Table 28B. Copper - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma opacum	Embryo	Copper sulfate	S, M	8 d	LC50	770	7.2-7.8	93-105	Birge *et al.* 1978 b[c], Birge and Black 1979[c]
Bufo americanus	Tadpole	Copper sulfate	F, M	20 min.	avoidance	100	7.6	112	Black and Birge 1980
Bufo boreas	Tadpole	Copper sulfate	S, U	12 hr 61 d	100% mortality 100% metamorphosis	3,700 20	5-6 5-6	— —	Porter and Hakanson 1976
Bufo fowerli	Embryo	Copper sulfate	S, M	7 d	LC50	26,960	7.2-7.8	100	Birge and Black 1979[c]
Bufo melanostictus	Tadpole	Copper sulfate	S, U	96 hr	LC50	320	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Copper sulfate	R, M	7 d	LC50	40	7.4	195	Birge 1978[c], Birge and Black 1979[c], Birge *et al.* 1979a
Hyla chrysocelis	Embryo	Copper sulfate	S, M	7 d	LC50	40	7.2-7.8	100	Birge and Black 1979[c]
Microhyla ornata	Tadpole (1 wk)	Copper sulfate	S, U	96 hr	LC50	5,040	6.9	142-145	Rao and Madhyastha 1987
Microhyla ornata	Tadpole (4 wk)	Copper sulfate	S, U	96 hr	LC50	5,380	6.9	142-145	Rao and Madhyastha 1987
Rana hexadactyla	Tadpole	Copper sulfate	S, U	96 hr	LC50	39	8.1	20	Khangarot *et al.* 1985a, 1985b

Table 28B. Copper (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana pipiens	Embryo	Copper sulfate	S, M	8 d	LC50	50	7.2-7.8	100	Birge and Black 1979[c]
Rana pipiens	Tadpole	Copper sulfate	S, M	72 hr 96 hr	LC50 100% mortality	150 60	7.7 7.7	— —	Lande and Guttman 1973
Rana pipiens	Adult	Copper sulfate	S, U	72 hr	LC50	6,368	4.9-5.6	—	Kaplan and Yoh 1961
Xenopus laevis	Embryo	Copper	S, U	96 hr	NOEC LOEC	50 100	7.5 7.5	— —	Linder *et al.* 1991
Xenopus laevis	Tadpole	Copper sulfate	S, U	48 hr	LC50	677	[d]	[d]	de Zwart and Sloof 1987

[a] F = flow-through, M = measured, S = static, R = renewal, U = unmeasured
[b] Values expressed as copper
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for copper EPA 440/5-84-031(USEPA 1985d)
[d] Dutch Standard Water

Table 29. Cyanide - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Rana temporaria	Tadpole	Sodium cyanide	U[c]	25-30 min	time to avoidance at 12-14°C	260	–	—	Costa 1965
				60 min.	no avoidance at 0-2°C	1,300	—	—	
				4-5 min.	time to avoidance at 0-2° C	130,000	—	—	
				35-40 min.	time to avoidance at 26-28°C	260	—	—	
				4-5 min	time to avoidance at 13-14°C	2,600	3.2	—	
				1-2 min	time to avoidance at 13-14°C	2,600	5.1	—	
				6-7 min	time to avoidance at 13-14°C	2,600	8.8	—	
				1-2 min	time to avoidance at 13-14°C	2,600	10.2	—	

[a] U = unmeasured
[b] Values expressed as cyanide
[c] Citation for methodology given in reference

Table 30A. DDT - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole (1 wk)	DDT	S, U	750	Sanders 1970[b], Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole (4-5 wk)	DDT	S, U	1,000	Sanders 1970[b], Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole (6 wk)	DDT	S, U	100	Sanders 1970[b], Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole (7 wk)	DDT	S, U	30	Sanders 1970[b], Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole	TDE	S, U	140	Sanders 1970[b], Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	DDT	S, U	800	Sanders 1970[b]
Pseudacris triseriata	Tadpole	TDE	S, U	400	Sanders 1970[b]

[a] S = static, U = unmeasured
[b] Reference also cited in Table 6 (other data) of the water quality criteria document for DDT EPA 440/5-80-038 (USEPA 1980m)

Table 30B. DDT - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	Reference
Bufo arenarum	Embryo	DDT	S, U	42 d 16 d 12 d	0% mortality 100% mortality 100% mortality	1,000 5,000 15,000	Juarez and Guzman 1984
Bufo arenarum	Embryo	DDT	S, U	31 d	beta-glucronidase activity significantly higher than in controls	1,000	Juarez and Guzman 1986
Bufo bufo	Tadpole	DDT	—	72 hr	LC50	300-500	Marchal-Segault 1976
Bufo bufo	Tadpole (9-10mm)	DDT	S, U	48 hr	0% mortality, 15% mortality 2 d post-exposure	500	Cooke 1972
Bufo bufo	Tadpole (12-14mm)	DDT	S, U	48 hr	0% mortality, 5% mortality 5 d post-exposure 0% mortality, 90% mortality 5 d post-exposure	5 500	Cooke 1972
Bufo bufo	Tadpole (16-20mm)	DDT	S, U	48 hr	0% mortality, 5% mortality 5 d post-exposure 100% mortality	20 500	Cooke 1972
Bufo bufo	Tadpole (19-23mm)	DDT	S, U	48 hr	20 % mortality, 100% mortality 5-d post-exposure	500	Cooke 1972
Bufo bufo japonicus	Tadpole	DDT (formulation)	—	48 hr	LC50	31,000	Hashimoto and Nishiuchi 1981
Bufo woodhousii fowleri	Tadpole	DDT	S, U	24 hr	LC50	5,400	Mayer and Ellersieck 1986
Rana catesbeiana	Tadpole	DDT (formulation)	U, isolated in pond	96 hr 48 hr	0% mortality 80% mortality	0.112 kg/ha[b] 0.560 kg/ha[b]	Mulla 1963

Table 30B. DDT (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	Reference
Rana catesbeiana	Tadpole	DDT	S, R	7 d	30% mortality	5	Weis 1975
					30% mortality, significantly less regeneration than controls	25	
Rana pipiens	Tadpole	DDT	S, R	8 d	Significantly less regeneration than controls	5	Weis 1975
				12 d	30% mortality	5	
				5 d	Significantly less regeneration than controls	25	
				8 d	60% mortality	25	
Rana sylvatica	Embryo	DDT	S, M	24 hr	0.16 mg/kg residue in jellied embryos (stage 13-18)	25	Licht 1985
					0.82-1.57 mg/kg residue in jelly-free embryos (stage 20)	25	
Rana sylvatica	Tadpole	DDT	S, U	96 hr	16.51 mg/kg residue in liver at 15°C, 2.96 mg/kg at 21°C	1	Licht 1976
				7 d	9.43 mg/kg residue in liver at 15°C, 2.67 mg/kg at 21°C	1	
				96 hr	16.73 mg/kg residue in liver at 15°C, 6.20 mg/kg at 21°C	3	
				7 d	9.71 mg/kg residue in liver at 15°C, 5.27 mg/kg at 21°C	3	
				7 d	9.7-37.4 mg/kg residue in fat at 15°C	1	
				10 d	18.6-23.7 mg/kg residue in fat at 15°C	1	
				7 d	26.7-81.7 mg/kg residue in fat at 15°C	3	

Table 30B. DDT (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	Reference
Rana temporaria	Tadpole (12-14 mm)	DDT	S, U	48 hr	80 % mortality, 90% mortalty 1d post-exposure	500	Cooke 1972
Rana temporaria	Tadpole (15-20 mm)	DDT	S, U	48 hr	80 % mortality 100% mortality	50 500	Cooke 1972
Rana temporaria	Tadpole (24-34 mm)	DDT	S, U	48 hr	0% mortality, 29% mortality 5 d post-exposure 100% mortality	20 500	Cooke 1972
Rana temporaria	Tadpole (37-40 mm)	DDT	S, U	48 hr	94% mortality	500	Cooke 1972
Rana temporaria	Tadpole	DDT	S, M	1 hr	3,470 mg/kg whole body residue, 19% abnormal snouts 48 hr post-exposure	1,000	Cooke 1970
				1 hr	12,800 mg/kg whole body residue, 37% abnormal snouts 48 hr post-exposure	10,000	
Rana temporaria	Tadpole (300mg)	DDT	S, M	48 hr	2.5 mg/kg whole body residue, 0% abnormal snouts	100	Cooke 1979
Rana temporaria	Tadpole (700mg)	DDT	S, M	48 hr	7.5 mg/kg whole body residue, 29% abnormal snouts	100	Cooke 1979

Table 30B. DDT (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	Reference
Rana temporaria	Tadpole	DDT	S, M	28 d	0.82 mg/kg whole body residue on day 33, 0.57 mg/kg on day 39	0.1	Cooke 1973
			S, M	28 d	2 mg/kg whole body residue on day 15, 4.3 mg/kg on day 33, 3.3 mg/kg on day 39	1	
Rana temporaria	Tadpole	DDT	S, U	48 hr	29% with abnormal snouts at 96 hr	100	Osborn *et al.* 1981
Rana tigrina	Adult	DDT	S, U	96 hr	Decreased vitamin A stores in liver	1,000,000	Keshavan and Deshmukh 1984
Triturus vulgaris	Larva	DDT	S, U	48 hr	33% mortality	500	Cooke 1972

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Active ingredient

Table 31. Diazinon - other data.

Species	Stage/Age	Chemical	Method	Duration	Effect	Conc. (Fg/L)	Reference
Bufo bufo japonicus	Tadpole	Diazinon (formulation)	—	48 hr	LC50	14,000	Hashimoto and Nishiuchi 1981

Table 32. Dichloropropanes and Dichloropropenes - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Xenopus laevis	Tadpole	1, 3 - Dichloro-propane	S, U	48 hr	LC50	63,000	de Zwart and Sloof 1987

[a] S = static, U = unmeasured

Table 33. Dichlorvos - other data

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Unidentified	Tadpole	S, U	48 hr	LC50 100% mortality	10,000 18,000	Sreenivasen and Swaminathan 1967

[a] S = static, U = unmeasured

Table 34. Di - 2 - ethylhexyl phthalate (DEHP) - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana arvalis	Embryo	S, M	30 d	Approximate 50% hatch	150 µg/g[b]	Larsson and Thuren 1987

[a] M = measured, S = static
[b] Fresh weight in sediments

Table 35. Endosulfan - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo bufo japonicus	Tadpole	Endosulfan (formulation)	---	48 hr	LC50	9,000	Hashimoto and Nishiuchi 1981
Bufo melanostictus	Tadpole	Endosulfan	S, U	96 hr	LC50	123	Vardia *et al.* 1984
Rana pipiens	Tadpole	Endosulfan (Thiodan II)	U, isolated in pond	96 hr	10% mortality	0.112 kg/ha[b]	Mulla 1963[c]
						0.560 kg/ha[b]	
				24 hr	100% mortality		
Rana pipiens	Tadpole	Endosulfan (Thiodan I)	U, isolated in pond	24 hr	60% mortality	0.112 kg/ha[b]	Mulla 1963[c]
					100% mortality	0.560 kg/ha[b]	
Rana tigrina	Tadpole	Endosulfan	S, U	96 hr	LC50	1.8	Gopal *et al.* 1981

[a] S = static, U = unmeasured
[b] Active ingredient
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for endosulfan EPA 440/5-80-046 (USEPA 1980p)

Table 36A. Endrin - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	S, U	120	Sanders 1970, Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	S, U	180	Sanders 1970, Mayer and Ellersieck 1986
Rana catesbeiana	Tadpole	F, M	2.5	Thurston *et al.* 1985

[a] F = flow-through, M = measured, S = static, U = unmeasured

Table 36B. Endrin - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Acris crepitans	Tadpole	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	23 10	Hall and Swineford 1981
Ambystoma maculatum	Larva	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	48 56	Hall and Swineford 1981
Ambystoma opacum	Larva	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	18 18	Hall and Swineford 1981
Bufo americanus	Tadpole	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	8 10	Hall and Swineford 1981
Bufo bufo japonicus	Tadpole	Endrin (formulation)	—	48 hr	LC50	12,000	Hashimoto and Nishiuchi 1981
Rana catesbeiana	Tadpole	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	>40 2	Hall and Swineford 1981
Rana catesbeiana	Tadpole	Endrin (formulation)	U, isolated in pond	96 hr	90% mortality	0.112kg/ha[b]	Mulla 1963
Rana hexadactyla	Tadpole	Endrin (formulation)	S, U	96 hr	LC50	0.21	Khangarot *et al.* 1985c
Rana pipiens	Adult	Endrin	S,U	30 d	30% mortality	30	Kaplan and Overpeck 1964
Rana sphenocephala	Embryo	Endrin	F, M	96 hr	LC50 at 8 d	25	Hall and Swineford 1980
Rana sphenocephala	Tadpole	Endrin	F, M	24 hr 96 hr	EC50-behavior LC50 at 8 d	13 9	Hall and Swineford 1981

Table 36B. Endrin (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana sphenocephala	Tadpole	Endrin	F, M	96 hr	LC50 at 8 d	6	Hall and Swineford 1980
Rana sphenocephala	Sub-adult	Endrin	F, M	96 hr	LC50 at 8 d	5	Hall and Swineford 1980
					71.4 concentration factor at death	10	
					34.4 concentration factor at death	12	
					51.8 concentration factor at death	16	
					59.4 concentration factor at death	22	
					94.3 concentration factor at death	30	
Rana sylvatica	Tadpole	Endrin	F, M	24 hr	EC50 - behavior	<16	Hall and Swineford 1981
				96 hr	LC50 at 8 d	34	
Rana temporaria	Tadpole (2 d)	Endrin (formulation)	S, U	72 hr	LC50	425.3[b]	Wohlgemuth 1977
Rana temporaria	Tadpole (8 d)	Endrin (formulation)	S, U	72 hr	LC50	50.5[b]	Wohlgemuth 1977
Rana temporaria	Tadpole (16 d)	Endrin (formulation)	S, U	72 hr	LC50	287.5[b]	Wohlgemuth 1977
Rana temporaria	Tadpole (45 d)	Endrin (formulation)	S, U	72 hr	LC50	24.3[b]	Wohlgemuth 1977
Rana temporaria	Tadpole (86 d)	Endrin (formulation)	S, U	72 hr	LC50	17.2[b]	Wohlgemuth 1977
Rana temporaria	Tadpole (107 d)	Endrin (formulation)	S, U	72 hr	LC50	14.7[b]	Wohlgemuth 1977

[a] F = flow-through, M = measured, S = static, U = unmeasured
[b] Active ingredient

Table 37A. Guthion - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (µg/L)	Reference
Bufo woodhousii fowleri	Tadpole	Guthion	S, U	130	Sanders 1970
Bufo woodhousii fowleri	Tadpole	Guthion	S, U	109	Mayer and Ellersieck 1986
Pseudacris regilla	Tadpole	Guthion	R, M	4,140	Schuytema *et al.* 1995
Pseudacris regilla	Tadpole	Guthion 2S	R, M	840 [b] 460 [b]	Schuytema *et al.* 1995
Pseudacris triseriata	Tadpole	Guthion	S, U	3,200	Mayer and Ellersieck 1986
Xenopus laevis	Embryo	Guthion	R, M	1,660 [cd] 2,010 [cd] >890 [ce] 4,950 [ce] 4,910 [ce] 7,630 [ce] 6,100 [d] 6,280 [d] >890 [e] >7,620 [e] 11,810 [e] 10,630 [e]	Schuytema *et al.* 1994
Xenopus laevis	Embryo	Guthion 2S	R, M	>1,300 [bc] 1,600 [b]	Schuytema *et al.* 1994
Xenopus laevis	Tadpole	Guthion	R, M	2,940	Schuytema *et al.* 1995

Table 37A. Guthion (continued)

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Tadpole	Guthion 2S	R, M	590[b] 420[b]	Schuyterna *et al.* 1995

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Active ingredient
[c] EC50 - deformity (median effective concentration)
[d] In 10 ml test volume
[e] In 100 ml test volume

Table 37B. Guthion - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo boreas	Tadpole	Guthion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla *et al.* 1963
Pseudacris regilla	Tadpole	Guthion	R, M	8 d	LC50	2,770	Schuytema *et al.* 1995
					NOAEL (mortality)	1,780	
					LOAEL (mortality)	9,670	
Pseudacris regilla	Tadpole	Guthion 2S	R, M	96 hr	NOAEL (mortality)	360[b]	Schuytema *et al.* 1995
					NOAEL (mortality)	370[b]	
					LOAEL (mortality)	700[b]	
					LOAEL (mortality)	790[b]	
				8 d	LC50	760[b]	
					NOAEL (mortality)	370[b]	
					LOAEL (mortality)	790[b]	
Scaphiopus hammondi	Tadpole	Guthion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla *et al.* 1963
Xenopus laevis	Embryo	Guthion	R, M	96 hr	NOAEL (length)[c]	660	Schuytema *et al.* 1994
					LOAEL (length)[c]	2,200	
					NOAEL (deformity)[c]	510	
					LOAEL (deformity)[c]	1,310	
					NOAEL (mortality)[c]	3,140	
					LOAEL (mortality)[c]	7,160	
					NOAEL (length)[d]	1,130	
					LOAEL (length)[d]	3,110	
					NOAEL (deformity)[d]	3,110	
					LOAEL (deformity)[d]	7,310	
					NOAEL (mortality)[d]	7,160	
					LOAEL (mortality)[d]	14,060	

Table 37B. Guthion (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Xenopus laevis	Embryo	Guthion 2S	R, M	96 hr	NOAEL (length)	480[b]	Schuytema *et al.* 1994
					LOAEL (length)	1,300[b]	
					NOAEL (mortality)	1,300[b]	
					LOAEL (mortality)	3,800[b]	
Xenopus laevis	Tadpole	Guthion	R, M	96 hr	NOAEL (mortality)	340	Schuytema *et al.* 1995
					LOAEL (mortality)	1,720	
Xenopus laevis	Tadpole	Guthion 2S	R, M	96 hr	NOAEL (mortality)	250[b]	Schuytema *et al.* 1995
					LOAEL (mortality)	490[b]	

[a] M = measured, R = renewal
[b] Active ingredient
[c] In 10 ml test volume
[d] In 100 ml test volume

Table 38. Halomethanes - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo fowleri	Embryo	Methylene chloride	F, M	7 d	LC50	>32,000	Birge *et al.* 1980
					2% deformity at hatch	32,100	
Rana catesbeiana	Embryo	Methylene chloride	F, M	8 d	LC50	17,780	Birge *et al.* 1980
					1% deformity at hatch	660	
					6% deformity at hatch	6,730	
					20% deformity at hatch	46,800	
Rana palustris	Embryo	Methylene chloride	F, M	8 d	LC50	>32,000	Birge *et al.* 1980
					3% deformity at hatch	10,100	
					5% deformity at hatch	32,100	

[a] F = flow-through, M = measured

Table 39A. Heptachlor - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowerli	Tadpole	S, U	440	Sanders 1970
Bufo woodhousii fowerli	Tadpole	S, U	435	Mayer and Ellersieck 1986

[a] S = static, U = unmeasured

Table 39B. Heptachlor - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Bufo arenarum	Embryo	Heptachlor	S, U	≤ 42 d	0% mortality	1,000	Juarez and Guzman 1984b
				15 d	100% mortality	5,000	
				13 d	100% mortality	15,000	
Rana catesbeiana	Tadpole	Heptachlor (formulation)	U, isolated in pond	96 hr	80% mortality	0.560 kg/ha[b]	Mulla 1963

[a] S = static, U = unmeasured
[b] Active ingredient

Table 40A. Hexachlorocyclohexane - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	Benzene hexachloride	S, U	3,200	Sanders 1970
Bufo woodhousii fowleri	Tadpole	Benzene hexachloride	S, U	4,350	Mayer and Ellersieck 1986
Bufo woodhousii fowleri	Tadpole	Lindane	S, U	4,400	Sanders 1970[b]
Bufo woodhousii fowleri	Tadpole	Lindane	S, U	3,200	Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	Lindane	S, U	2,700	Sanders 1970[b]
Pseudacris triseriata	Tadpole	Lindane	S, U	2,650	Mayer and Ellersieck 1986

[a] S = static, U = unmeasured
[b] Reference also cited in Table 6 (other data) for the water quality criteria document for hexachlorocyclohexane EPA 440/5-80-054 (USEPA 1980s)

Table 40B. Hexachlorocyclohexane - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Microhyla ornata	Embryo	Benzene hexachloride	R, U	96 hr	LC50	23,370	Pawar and Katdare 1984
					12.5% deformity	10,000	
					100% deformity	20,000	
Microhyla ornata	Tadpole	Benzene hexachloride	R, U	96 hr	LC50	7,270	Pawar and Katdare 1984
Rana catesbeiana	Tadpole	Lindane (EC 1.65)	U, isolated in pond	96 hr	0% mortality	0.112 kg/ha[b]	Mulla 1963
					10% mortality	0.560 kg/ha[b]	
Rana hexadactyla	Tadpole	Lindane	—	96 hr	LC50	3,970	Khangarot *et al.* 1985c
Rana pipiens	Adult	Benzene hexachloride	S, U	30 d	15% mortality	17,000	Kaplan and Overpeck 1964
Xenopus laevis	Embryo	Lindane	S, U	time to hatch	52% hatch	0	Marchal-Segault and Ramade 1981
					52% hatch	500	
					51% hatch	1,000	
					31% hatch	2,000	
Xenopus laevis	Tadpole	Lindane	S, U	1 wk post-hatch	0% mortality	500	Marchal-Segault and Ramade 1981
				2 wk post-hatch	21% mortality	500	
				3 wk post-hatch	26% mortality	500	
				6 wk post-hatch	79% mortality	500	
				12 wk post-hatch	79% mortality	500	
				1 wk post-hatch	4% mortality	1,000	

Table 40B. Hexachlorocyclohexane (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Xenopus laevis	Tadpole	Lindane	S, U	2 wk post-hatch	37% mortality	1,000	Marchal-Segault and Ramade 1981
				3 wk post-hatch	71% mortality	1,000	
				6 wk post-hatch	100% mortality	1,000	
				1 wk post-hatch	6% mortality	2,000	
				2 wk post-hatch	75% mortality	2,000	
				3 wk post-hatch	89% mortality	2,000	
				6 wk post-hatch	100% mortality	2,000	

[a] R = renewal, S = static, U = unmeasured
[b] Active ingredient

Table 41A. Iron - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Xenopus laevis	Embryo	Iron	R, U	1,900	6.0	—	Linder *et al.* 1991
				1,800	6.0	—	

[a] R = renewal, U = unmeasured
[b] Values expressed as iron

Table 41B. Iron - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b]	pH	Hardness (as mg/L $CaCo_3$)	Reference
Bufo boreas	Tadpole	Ferrous sulfate	R, U	18 d	100% mortality	35,000	5-6	—	Porter and
				20 d	100% mortality	30,000	5-6	—	Hakanson
				39 d	100% meta-morphosis	20,000	5-6	—	1976
Rana hexadactyla	Tadpole	Ferrous sulfate	—	96 hr	LC50	17,620	6.1	20	Khangarot *et al.* 1985b
Xenopus laevis	Embryo	Iron	R, U	96 hr	NOEC	300	6.0	—	Linder *et al.*
					LOEC	600	6.0	—	1991

[a] R = renewal, U = unmeasured
[b] Values expressed as iron

Table 42. Lead - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma jeffersonianum	Embryo	Lead chloride	S, M	96 hr	None	2,000	4.5	-	Horne and Dunson 1994
Ambystoma opacum	Embryo	Lead chloride	S, M	8 d	LC50	1,460	7.2-7.8	93-105	Birge *et al.* 1978b[c]
Bufo americanus	Tadpole	Lead nitrate	S, U	144 hr	No avoidance	500-1,000	—	—	Steele *et al.* 1991
Bufo arenarum	Embryo	Lead nitrate	S, U	48 hr	LC50 80-100% deformity	470-900 1,000	[d] [d]	[d] [d]	Perez-Coll *et al.* 1988
Bufo arenarum	Embryo (stage 12)	Lead	S, U	20 hr	12% mortality, 70% deformity at 96 hr	1,000	[d]	[d]	Perez-Coll and Herkovits 1990
Bufo arenarum	Embryo (stage 18)	Lead	S, U	20 hr	55% mortality, 41% deformity at 96 hr	1,000	[d]	[d]	Perez-Coll and Herkovits 1990
Bufo arenarum	Embryo (stage 20)	Lead	S, U	20 hr	20% mortality, 38% deformity at 96 hr	1,000	[d]	[d]	Perez-Coll and Herkovits 1990
Bufo arenarum	Tadpole	Lead	S, U	120 hr	40% mortality 60% mortality	8,000 16,000	[d] [d]	[d] [d]	Herkovits and Perez-Coll 1991
Gastrophryne carolinensis	Embryo	Lead chloride	R, M	7 d	LC50	40	7.4	195	Birge 1978[c], Birge *et al.* 1979a
Rana catesbeiana	Tadpole	Lead nitrate	R, M	144 hr	Activity less variable in controls, no effects on avoidance or preference	1,000	7.2	340	Steele *et al.* 1989

Table 42. Lead (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc[b] (Fg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana catesbeiana	Tadpole	Lead nitrate	R, U	48 hr	Impaired learning response	500	7.2	340	Strickler-Shaw and Taylor 1991
				144 hr	Reduced learning response	500	7.2	340	
				24 hr	Impaired learning response	625-1,000	7.2	340	
				144 hr	Pronounced depression in response	625-1,000	7.2	340	
				120 hr	Decreased learning retention	625-1,000	7.2	340	
Rana clamitans	Tadpole	Lead nitrate	S, U	144 hr	Locomotor activity same as control	500	—	—	Taylor 1990
				144 hr	Increased variability in locomotor activity	750-1,000	—	—	
Rana clamitans	Tadpole	Lead nitrate	S, U	120 hr	Adverse effects on memory	750	7.2	340	Strickler-Shaw and Taylor 1990
				144 hr	Adverse effects in learning	750	7.2	340	
Rana hexadactyla	Tadpole	Lead nitrate	S, U	96 hr	LC50	33,280	6.1	20	Khangarot *et al.* 1985b

Table 42. Lead (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (Fg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana nigromaculata	Embryo	Lead nitrate	S, U	24 hr	23.6 primordial germ cells at 6.5 d	11,200	—	—	Hah 1978
					23.7 primordial germ cells at 11 d	11,200	—	—	
					37.4 primordial germ cells at 17 d	11,200	—	—	
					18.2 primordial germ cells at 6.5 d	21,700	—	—	
					18.5 primordial germ cells at 11 d	21,700	—	—	
					36.2 primordial germ cells at 17 d	21,700	—	—	
					17.3 primordial germ cells at 6.5 d	43,400	—	—	
					18.8 primordial germ cells at 11 d	43,400	—	—	
					33.8 primordial germ cells at 17 d	43,400	—	—	
Rana pipiens	Adult	Lead nitrate	R, U	30 d	LC50	105,000[de]	—	—	Kaplan *et al.* 1967[c]
Xenopus laevis	Embryo	Lead	S, U	6 d	Moderate deformation at 200 mg/L Mg	1,000	[d]	[d]	Miller and Landesman 1978
					Severe deformation at 0 mg/L Mg	1	[d]	[d]	
					1% mortality at 200 mg/L Mg	1,000	[d]	[d]	
					18% mortality at 0 mg/L Mg	1	[d]	[d]	

Table 42. Lead (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Embryo	Lead acetate	S, U	96 hr	13% with deformed tail	1,000	7.7	110	Sobotka and Rahwan 1995
					50% with deformed tail	3,000	7.7	110	
					38% with neural tube deficit	3,000	7.7	110	
				3 wk	27% with deformed tail	500	7.7	110	
					50% with defromed tail	1,000	7.7	110	
				96 hr	Whole body residue 1.2 μg/g	500	7.7	110	
					Whole body residue 2.8 μg/g	1,000	7.7	110	
					Whole body residue 13.0 μg/g	3,000	7.7	110	
				1 wk	Whole body residue 17.6 μg/g	500	7.7	110	
					Whole body residue 40.4 μg/g	1,000	7.7	110	
					Whole body residue 110.8 μg/g	3,000	7.7	110	
				2 wk	Whole body residue 28.4 μg/g	500	7.7	110	
					Whole body residue 47.2 μg/g	1,000	7.7	110	
					Whole body residue 104.8 μg/g	3,000	7.7	110	

Table 42. Lead (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Embryo	Lead acetate	S, U	3 wk	Whole body residue 3.2 μg/g	20	7.7	110	Sobotka and Rahwan 1995
					Whole body residue 2.6 μg/g	50	7.7	110	
					Whole body residue 7.1 μg/g	100	7.7	110	
					Whole body residue 100.5 μg/g	3,000	7.7	110	
				6 mo.	Whole body residue 2.2 μg/g	20	7.7	110	
					Whole body residue 2.4 μg/g	50	7.7	110	
					Whole body residue 9.0 μg/g	100	7.7	110	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as lead
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for lead EPA 440/5-84-027 (USEPA 1985f)
[d] 10% Holtfreter's solution
[e] Cited as 100 μg/L in water quality criteria document

Table 43A. Malathion - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	S, U	420	Sanders 1970, Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	S, U	200	Sanders 1970, Mayer and Ellersieck 1986
Xenopus laevis	Embryo	S, U	10,900 330[b] 790[c] 2,160[d]	Snawder and Chambers 1989

[a] S = static, U = unmeasured
[b] EC50 (abnormal pigmentation)
[c] EC50 (abnormal gut)
[d] EC50 (abnormal notochord)

Table 43B. Malathion - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo arenarum	Embryo	Malathion	S, U	5 d	67% mortality	44,000	Rosenbaum *et al.* 1988
Bufo arenarum	Embryo	Malathion	S, U	5 d	Development unaffected 100% mortality	470 47,300	de Llamas *et al.* 1985
Bufo arenarum	Tadpole	Malathion	S, U	144 hr	LC50	19,200	Venturino *et al.* 1992
Hyla regilla	Tadpole	Malathion	S, U	24 hr	Lowered thermal tolerance	25-500	Johnson 1980
Microhyla ornata	Embryo	Malathion	S, U	96 hr	23% deformity 100% deformity 100% deformity, 35% mortality 100% mortality	1,000 5,000 10,000 15,000	Pawar *et al.* 1983
Rana hexadactyla	Tadpole	Malathion (formulation)	S, U	96 hr	LC50	0.59	Khangarot *et al.* 1985c
Rana catesbeiana	Tadpole	Malathion (formulation)	F, U	96 hr	40% mortality	5,000	Hall and Kolbe 1980
Rana pipiens	Adult	Malathion	—	48 hr 15 d	LC50 83% mortality	150,000 175,000	Kaplan and Glaczenski 1965[b]
Rana tigrina	Embryo	Malathion (formulation)	R, U	24 hr 24 hr ≤52 d	100% mortality Threshold survival LC50	40,000 30,000 900-700[c]	Mohanty-Hejmadi and Dutta 1981
Rana tigrina	Tadpole (feeding stage)	Malathion (formulation)	R, U	7 d ≤49	100% mortality Threshold beyond feeding stage	40,000-5,000[c] 900	Mohanty-Hejmadi and Dutta 1981

Table 43B. Malathion (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana tigrina	Tadpole (limb bud stage)	Malathion (formulation)	R, U	>49	Threshold beyond limb bud stage	90,000	Mohanty-Hejmadi and Dutta 1981
				>49	Threshold metamorphosis	7,000	
Xenopus laevis	Embryo	Malathion	S, U	96 hr	18% deformity	1,000	Snawder and Chambers 1990
					100% deformity	5,000	

[a] F = flow-through, R = renewal, S = static, U = unmeasured
[b] Reference not seen, cited in Power *et al.* 1989
[c] Exposed to decreasing concentrations

Table 44. Manganese - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Gastrophryne carolinensis	Embryo	Manganese chloride	S, M	7 d	LC50	1,420	7.4	195	Birge 1978, Birge *et al.* 1979a
Microhyla ornata	Tadpole (1 wk)	Manganese sulfate	R, U	96 hr	LC50	14,840	6.9	142-145	Rao and Madhyastha 1987
	Tadpole (4 wk)	Manganese sulfate	R, U	96 hr	LC50	14,330	6.9	142-145	
Xenopus laevis	Embryo	Manganese	S, U	6 d	No deformation at 200 μg/L Mg	10,000	[c]	[c]	Miller and Landesman 1978
					Severe deformation at 0 μg/L Mg	1	[c]	[c]	
					6% mortality at 200 μg/L Mg	10,000	[c]	[c]	
					8% mortality at 0 μg/L Mg	1	[c]	[c]	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as manganese
[c] 10% Holtfreter's solution

Table 45A. Mercury - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Rana heckscheri	Tadpole	Mercuric chloride	S, M	502	7.2	351	Punzo 1993a
Rana heckscheri	Adult	Mercuric chloride	S, M	3,252	7.2	352	Punzo 1993b

[a] M = measured, S = static
[b] Value expressed as mercury

Table 45B. Mercury - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Acris crepitans blanchardi	Embryo	Mercuric chloride	R, M	7 d	LC50	10.4	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Ambystoma mexicanum	Larva	Mercuric chloride	S, M	48 hr	LC50	259	[d]	[d]	Sloof and Baerselman 1980[c]
Ambystoma mexicanum	Larva	Mercuric chloride	S, M	48 hr	LC50	296	—	—	Sloof *et al.* 1983
Ambystoma opacum	Embryo	Mercuric chloride	R, M	7 d	LC50	107.5	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Ambystoma opacum	Embryo	Mercuric chloride	S, M	8 d	LC50	110	7.2-7.8	93-105	Birge *et al.* 1978b
Bufo bufo japonicus	Tadpole	Phenyl mercury acetate (formulation)	—	48 hr	LC50	120	—	—	Hashimoto and Nishiuchi 1981
Bufo debilis debilis	Embryo	Mercuric chloride	R, M	7 d	LC50	40	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Bufo fowleri	Embryo	Mercuric chloride	R, M	7 d	LC50	65.9	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983
Bufo fowleri	Tadpole	Mercuric chloride	R, M	7-8 d	1% deformity	5	7.0-7.8	90-105	Birge *et al.* 1983
					2% deformity	10	7.0-7.8	90-105	
					7% deformity	25	7.0-7.8	90-105	
					16% deformity	50	7.0-7.8	90-105	
					16% deformity	75	7.0-7.8	90-105	
Bufo fowleri	Tadpole	Mercuric chloride	R, M	72 hr	LC50	25-50	7.9	200	Birge and Black 1977

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Bufo melanostictus	Tadpole	Mercuric chloride	S, U	96 hr	LC50	43.6	7.4	185	Khangarot and Ray 1987
Bufo melanostictus	Tadpole	Mercuric chloride	S, U	96 hr	LC50	185	7.4-7.6	220-240	Paulose 1988
Bufo melanostictus	Tadpole	Methyl mercury chloride	S, U	96 hr	LC50	56	7.4-7.6	220-240	Paulose 1988
Bufo punctatus	Embryo	Mercuric chloride	R, M	7 d	LC50	36.8	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983
Bufo punctatus	Embryo	Mercuric chloride	R, M	7 d	1% deformity	7	7.0-7.8	90-105	Birge *et al.* 1983
					8% deformity	10	7.0-7.8	90-105	
					11% deformity	25	7.0-7.8	90-105	
					60% deformity	50	7.0-7.8	90-105	
					82% deformity	75	7.0-7.8	90-105	
Bufo punctatus	Embryo	Mercuric chloride	R, M	72 hr	LC50	25-50	7.9	200	Birge and Black 1977
Gastrophryne carolinensis	Embryo	Mercuric chloride	R, M	7 d	LC50	1.3	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983
Gastrophryne carolinensis	Embryo	Mercuric chloride	R, M	7 d	LC50	1	7.4	195	Birge 1978, Birge *et al.* 1979a
Gastrophryne carolinensis	Embryo	Mercuric chloride	R, M	7 d	8% deformity	1	7.0-7.8	90-105	Birge *et al.* 1983
					12% deformity	2	7.0-7.8	90-105	
					17% deformity	5	7.0-7.8	90-105	
Gastrophryne carolinensis	Embryo	Mercuric chloride	R, M	72 hr	LC50	1	7.9	200	Birge and Black 1977

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Hyla chrysocelis	Embryo	Mercuric chloride	R, M	7 d	LC50	2.4	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983
Hyla chrysocelis	Embryo	Mercuric chloride	R, M	7 d	1% deformity	1	7.0-7.8	90-105	Birge *et al.* 1983
					5% deformity	2	7.0-7.8	90-105	
					14% deformity	5	7.0-7.8	90-105	
					23% deformity	7	7.0-7.8	90-105	
Hyla chrysocephala	Embryo	Mercuric chloride	R, M	72 hr	LC50	5	7.9	200	Birge and Black 1977
Hyla crucifer	Embryo	Mercuric chloride	R, M	7 d	LC50	2.8	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Hyla gratiosa	Embryo	Mercuric chloride	R, M	7 d	LC50	2.5	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Hyla squirella	Embryo	Mercuric chloride	R, M	7 d	LC50	2.4	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Hyla squirella	Embryo	Mercuric chloride	R, M	3 d	LC50	5	7.9	200	Birge and Black 1977
Hyla versicolor	Embryo	Mercuric chloride	R, M	7 d	LC50	2.6	7.0-7.8	90-105	Birge *et al.* 1979b[c]
Microhyla ornata	Embryo	Mercuric chloride	S, U	96 hr	LC50	126	—	54	Ghate and Mulherkar 1980
Microhyla ornata	Tadpole	Mercuric chloride	S, U	96 hr	LC50	88	—	54	Ghate and Mulherkar 1980

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Microhyla ornata	Tadpole (1 wk)	Mercuric chloride	S, U	96 hr	LC50	1,120	—	142-145	Rao and Madhyastha 1987
Microhyla ornata	Tadpole (4 wk)	Mercuric chloride	S, U	96 hr	LC50	1,430	—	142-145	Rao and Madhyastha 1987
Rana breviceps	Tadpole	Mercuric chloride	S, U	96 hr	LC50	207	7.4-7.6	220-240	Paulose 1988
Rana breviceps	Tadpole	Methyl mercury chloride	S, U	96 hr	LC50	60	7.4-7.6	220-240	Paulose 1988
Rana catesbeiana and R. pipiens	Tadpole	Mercuric chloride	S, M	5 d	LC50	1,000	•	•	Birge and Just 1973[f], 1975
Rana catesbeiana and R. pipiens	Adult	Mercuric chloride	S, M	96 hr	0% mortality 20% mortallity 80% mortality	5,000 7,500 10,000	• • •	• • •	Birge and Just 1973[f]
Rana cyanophlyctis	Adult	Methoxyethyl mercuric chloride (formulation)	R, U	96 hr 130 d	LC50 Spermatogenesis affected	1,650 330	— —	— —	Kanamadi and Saidapur 1992
Rana grylio	Embryo	Mercuric chloride	R, M	7 d	LC50	67.2	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana grylio	Embryo	Mercuric chloride	R, M	7 d	1% deformity	25	7.0-7.8	90-105	Birge *et al*.1983
					4% deformity	50	7.0-7.8	90-105	
					5% deformity	75	7.0-7.8	90-105	
Rana grylio	Embryo	Mercuric chloride	R, M	6 d	LC50	75	7.9	200	Birge and Black 1977
Rana heckscheri	Embryo	Mercuric chloride	R, M	7 d	LC50	59.9	7.0-7.8	90-105	Birge *et al*. 1979b[c]
Rana heckscheri	Embryo	Mercuric chloride	R, M	6 d	LC50	75	7.9	200	Birge and Black 1977
Rana heckscheri	Embryo	Mercuric chloride	S, U	96 hr	LC50	502	7.2	351	Punzo 1993a
				3 hr	90% fertilization success	370	7.2	351	
					69% fertilization success	739	7.2	351	
					27% fertilization success	1,848	7.2	351	
					0% fertilization success	3,695	7.2	351	
				2-3 wk	1.5-2.3% deformity	370	7.2	351	
					1.5-6.5% deformity	739	7.2	351	
					4.5-34.0% deformity	1,848	7.2	351	
Rana heckscheri	Adult	Mercuric chloride	S, M	96 hr	LC50	3,252	7.2	352	Punzo 1993b
				30-60 d	Significant decrease in ovarian mass	650	7.2	352	

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana hexadactyla	Tadpole	Mercuric chloride	S, U	96 hr	LC50	51	6.1	20	Khangarot *et al.* 1985b
Rana nigromaculata	Embryo	Mercuric chloride	S, U	24 hr	20.6 primordial germ cells at 6.5 d	150	[e]	[e]	Hah 1978
					21.2 primordial germ cells at 11 d	150	[e]	[e]	
					35.2 primordial germ cells at 17 d	150	[e]	[e]	
					18.2 primordial germ cells at 6.5 d	300	[e]	[e]	
					18.0 primordial germ cells at 11 d	300	[e]	[e]	
					28.1 primordial germ cells at 17 d	300	[e]	[e]	
					11.0 primordial germ cells at 6.5 d	590	[e]	[e]	
					12.3 primordial germ cells at 11 d	590	[e]	[e]	
					22 primordial germ cells at 17 d	590	[e]	[e]	
Rana pipiens	Embryo	Mercuric chloride	R, M	7 d	LC50	7.3	7.0-7.8	90-105	Birge *et al.* 1979b[c], Birge *et al.* 1983
Rana pipiens	Embryo	Mercuric chloride	R, M	7 d	4% deformity	1	7.0-7.8	90-105	Birge *et al.* 1983
					7% deformity	2	7.0-7.8	90-105	
					14% deformity	5	7.0-7.8	90-105	
					15% deformity	7	7.0-7.8	90-105	
					9% deformity	10	7.0-7.8	90-105	
					19% deformity	25	7.0-7.8	90-105	
					31% deformity	50	7.0-7.8	90-105	

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana pipiens	Embryo (cleavage)	Mercuric chloride	S, M	96 hr	6% mortality	0.1	•	•	Birge and Just 1973[f],1975
					7% mortality	1	•	•	
					100% mortality	10	•	•	
Rana pipiens	Embryo (blastula)	Mercuric chloride	S, M	96 hr	22% mortality	0.1	•	•	Birge and Just 1973[f],1975
					18% mortality	1	•	•	
					100% mortality	10	•	•	
Rana pipiens	Embryo (gastrula)	Mercuric chloride	S, M	96 hr	5% mortality	0.1	•	•	Birge and Just 1973[f],1975
					15% mortality	1	•	•	
					20% mortality	10	•	•	
					100% mortality	100	•	•	
Rana pipiens	Embryo (neurula)	Mercuric chloride	S, M	96 hr	4% mortality	0.4	•	•	Birge and Just 1973[f],1975
					12% mortality	1	•	•	
					7% mortality	10	•	•	
					100% mortality	100	•	•	
Rana pipiens	Embryo (tail bud)	Mercuric chloride	S, M	96 hr	5% mortality	0.1	•	•	Birge and Just 1973[f],1975
					7% mortality	1	•	•	
					20% mortality	10	•	•	
					80% mortality	100	•	•	
Rana pipiens	Embryo	Mercuric chloride	R, M	6 d	LC50	10	7.9	200	Birge and Black 1977
Rana pipiens	Embryo (blastula)	Methyl mercury chloride	S, U	5 d	LC50	12-16	[h]	[h]	Dial 1976[c,f]
					EC50 (deformity)	0-4	[h]	[h]	
Rana pipiens	Embryo (gastrula)	Methyl mercury chloride	S, U	5 d	LC50	8-12	[h]	[h]	Dial 1976[c,f]
					EC50 (deformity)	8-12	[h]	[h]	

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Rana pipiens	Embryo (neurula)	Methyl mercury chloride	S, U	5 d	LC50	12-16	[h]	[h]	Dial 1976[c,f]
					EC50 (deformity)	12	[h]	[h]	
Rana pipiens	Tadpole	Methyl mercury chloride	S, U	48 hr	100% mortality	50-100	—	—	Chang *et al.* 1974[c]
				3-4 mo	No metamorphosis	1-10			
Triturus viridescens	Adult	Methyl mercury chloride	R, U	≥2 d	Delayed regeneration	8			Chang *et al.* 1976[c,f]
				8 d	100% mortality	800[j]			
				17 d	100% mortality	240[j]			
Xenopus laevis	Embryo	Mercury	S, U	6 d	Moderate to severe deformity at 200 mg/L Mg	100	[k]	[k]	Miller and Landesman 1978
					Severe deformity at 0 mg/L Mg	1	[k]	[k]	
					21% mortality at 200 mg/L Mg	100	[k]	[k]	
					6% mortality at 0 mg/L Mg	1	[k]	[k]	
Xenopus laevis	Embryo	Methyl mercury chloride	R, M	≥10 d	18% deformity	0.3	—	[i]	Dumpert and Zietz 1984
					21% deformity	1.6	—	[i]	
					38% deformity	8	—	[i]	
					61% deformity	40	—	[i]	
					37% deformity	80	—	[i]	
					12% mortality	0.3	—	[i]	
					21% mortality	1.0	—	[i]	
					11% mortality	8	—	[i]	
					22% mortality	40	—	[i]	
					63% mortality	80	—		

Table 45B. Mercury (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Embryo	Mercuric chloride	R, M	7 d	54% mortality[m]	0.16	7.3	102	Birge *et al.* 1979b
					72% mortality[m]	0.34	7.3	102	
Xenopus laevis	Tadpole	Mercuric chloride	S, U	48 hr	LC50	74	[d]	[d]	de Zwart and Sloof 1987, Sloof *et al.* 1983[c], Sloof and Baerselman 1980[c]

[a] F = flow-through, M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as mercury (*Bufo bufo japonicus* entry expressed as formulation, *Rana cyanophlyctis* entry expressed as methoxyethyl mercuric chloride)
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for mercury EPA 440/5-84-026 (USEPA 1985g)
[d] Dutch Standard water
[e] Modified Holtfreter's Solution
[f] Reference also cited in Table 6 (other data) of the water quality criteria document for mercury EPA 440/5-80-058 (USEPA 1980l)
[g] Sternberg's Solution
[h] Holtfreter's Solution
[i] Cited as 8 μg/L in EPA/5-80-058 (USEPA 1980l) and as 1,000 μg/L in EPA/ 440/5-84-026 (USEPA 1985g)
[j] Cited as 24 μg/L in EPA 5-80-058 (USEPA 1980l) and as 1,000 μg/L in EPA/ 440/5-84-026 (USEPA 1985g)
[k] 10% Holtfreter's Solution
[l] German standard 16-19 dH
[m] Parents held in 0.2 μg/L mercury for 11 months

Table 46A. Methoxychlor - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Pseudacris triseriata	Tadpole	S, U	330	Sanders 1970
Pseudacris triseriata	Tadpole	S, U	333	Mayer and Ellersieck 1986

[a] S = static, U = unmeasured

Table 46B. Methoxychor - other data

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Bufo americanus	Adult	S, M	1 d	Whole body residue 145 μg/kg	69	Hall and Swineford 1979
			6 d	Whole body residue 244 μg/kg	69	
			36 d	Whole body residue 124 μg/kg	69	
Bufo woodhousii fowleri	Tadpole	S, U	48 hr	LC50	110	Sanders 1970
Bufo woodhousii fowleri	Tadpole	S, U	48 hr	LC50	100	Mayer and Ellersieck 1986
Rana pipiens	Adult	S, U	30 d	25% mortality	80	Kaplan and Overpeck 1964

[a] M = measured, S = static, U = unmeasured

Table 47A. Methyl parathion - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (µg/L)	Reference
Pseudacris triseriata	Tadpole	S, U	3,700	Mayer and Ellersieck 1986

[a] S = static, U = unmeasured

Table 47B. Methyl parathion - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo boreas	Tadpole	Methyl parathion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla 1962, Mulla *et al.* 1963
Hyla regilla	Tadpole	Methyl parathion	S, U	24 hr	Lowered thermal tolerance	25-100	Johnson 1980
Scaphiopus hammondi	Tadpole	Methyl parathion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla 1962, Mulla *et al.* 1963
Rana cyanophlyctis	Tadpole	Methyl parathion (formulation)	S, U	24 hr	Increased brain glucose, increased oxygen consumption	5,000	Yasmeen and Nayeemunisa 1985
Rana cyanophlyctis	Tadpole	Methyl parathion (formulation)	R, U	96 hr	LC50-male LC50-female	8,000 11,500	Mudgall and Patil 1987

[a] R = renewal, S = static, U = unmeasured
[b] Active ingredient

Table 48. Mirex - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Acris gryllus	Adult	Mirex (bait)	M, single dose to pond	5 d post-treatment	Whole body residue 30 µg/kg	4.2 g/ha[b]	Collins *et al.* 1973
				38 d post-treatment	Whole body residue 226 µg/kg	4.2 g/ha[b]	
				6 mo post-treatment	Whole body residue 288 µg/kg	4.2 g/ha[b]	
				12 mo post-treatment	Whole body residue 20 µg/kg	4.2 g/ha[b]	
				16 mo post-treatment	Whole body residue 50 µg/kg	4.2 g/ha[b]	

[a]M = measured
[b]Active ingredient

Table 49A. Naphthalene - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Tadpole	F, M	2,100	Edmisten and Bantle 1982

[a] F = flow-through, M = measured

Table 49B. Naphthalene - other data

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Xenopus laevis	Tadpole	F, M	6 hr	EC50 (pigment loss)	3,700	Edmisten and Bantle 1982
				EC50 (absence of swimming)	1,700, 2,300	

[a] F = flow-through, M = measured

Table 50A. Nickel - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Xenopus laevis	Embryo	Nickel	S,U	1,800	6.0	—	Linder *et al.* 1991
				1,700	6.0	—	
Xenopus laevis	Embryo	Nickel chloride	R, M	21,429	6.8	[c]	Hopfer *et al.* 1991
				146[d]	6.8	[c]	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as nickel
[c] FETAX solution
[d] EC50

Table 50B. Nickel - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma opacum	Embryo	Nickel chloride	S, M	8 d	LC50	420	7.2-7.8	93-105	Birge *et al.* 1978b[cd]
Bufo fowleri	Embryo	Nickel chloride	R, M	7 d	LC50	11,030	7.2-7.7	95-103	Birge and Black 1980[d]
Bufo melanostictus	Tadpole	Nickel sulfate	S, U	96 hr	LC50	25,320	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Nickel chloride	R, M	7 d	LC50	50	7.4	195	Birge 1978b[cd], Birge *et al.* 1979a[cd]
Gastrophryne carolinensis	Embryo	Nickel chloride	R, M	7 d	LC50	50	—	95-103	Birge and Black 1980[d]
Xenopus laevis	Embryo	Nickel chloride	R, M	24 hr	26% deformity 5-29 hr post-fertilization	1,761	6.8	[e]	Hopfer *et al.* 1991
					92% deformity 29-53 hr post-fertilization	1,761	6.8	[e]	
					100% deformity 53-75 hr post-fertilization	1,761	6.8	[e]	
					21% deformity 75-101 hr post-fertilization	1,761	6.8	[e]	
Xenopus laevis	Embryo	Nickel	S, U	96 hr	NOEC	<300	7.4	—	Linder *et al.* 1991
					LOEC	300	7.4	—	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as nickel
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for nickel EPA 440/5-80-060(USEPA 1980w)
[d] Reference also cited in Table 6 (other data) of the water quality criteria document for nickel EPA 440/5-86-004(USEPA 1986b)
[e] Fetax solution

Table 51. Nitrobenzene - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana pipiens	Embryo	F, M	9 d	LC50	640	Black *et al.* 1982
				2%deformity	100	
				0%deformity	410	
				4% deformity	1,270	

[a] F = flow-through, M = measured

Table 52A. Nitrosamines - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Embryo	N-nitroso-dimethylamine	S, U	3,500 3,200 2,300[b]	Fort *et al.* 1991

[a] S = static, U = unmeasured
[b] EC50

Table 52B. Nitrosamines - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana temporaria	Adult	N - nitroso-dimethylamine	R, U	63 d	First tumor induction, 43.6% tumor incidence	5,000	Khudoley 1977a, 1977b
				77 d	First tumor induction, 44.2% tumor incidence	50,000	
				144 d	50% tumor incidence	5,000	

[a] R = renewal, U = unmeasured

Table 53A. Parathion - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	S, U	>1,000	Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	S, U	1,000	Sanders 1970
Pseudacris triseriata	Tadpole	S, U	1,080	Mayer and Ellersieck 1986
Xenopus laevis	Embryo	S, U	14,700 330[b] 460[c] 5,420[d]	Snawder and Chambers 1984

[a] S = static, U = unmeasured
[b] EC50 (abnormal pigmentation)
[c] EC50 (abnormal gut)
[d] EC50 (abnormal notochord)

Table 53B. Parathion - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Acris crepitans	Adult	Parathion	S, M	96 hr	Whole body residue 80 µg/kg	1,000	Fleming *et al.* 1982
					Whole body residue 4,600 µg/kg	10,000	
Bufo arenarum	Embryo	Parathion	S, U	120 hr	LC50	20,200	Anguiano *et al.* 1994
Bufo arenarum	Tadpole	Parathion	S, U	120 hr	LC50	4,500	Anguiano *et al.* 1994
Bufo boreas	Tadpole	Parathion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla *et al.* 1963
Bufo bufo japonicus	Tadpole	Parathion	—	48 hr	LC50	7,200	Hashimoto and Nishiuchi 1981
Rana catesbeiana	Tadpole	Parathion	F, U	96 hr	95% mortality	5,000	Hall and Kolbe 1980
			F, M	96 hr	Magnified 64 times	4 -1,000	
Rana catesbeiana	Tadpole	Parathion	S, M	96 hr	Whole body residue 4,400 µg/kg at biomass loading of 12.75 g/L	1,000	Hall 1990
					Whole body residue 240 µg/kg at biomass loading of 25 g/L	1,000	
			F, M	96 hr	Whole body residue 740 µg/kg at biomass loading of 12.75 g/L and flow of 0.5 ml/min	1,000	

Table 53B. Parathion (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Rana catesbeiana	Tadpole	Parathion	F, M	96 hr	Whole body residue 740 μg/kg at biomass loading of 12.75 g/L and flow of 5 ml/min	1,000	Hall 1990
					Whole body residue 490 μg/kg at biomass loading of 25 g/L and flow at 0.5 ml/min	1,000	
					Whole body residue 730 μg/kg at biomass loading of 25 g/L and flow of 5 ml/min	1,000	
Rana clamitans	Tadpole	Parathion	S, M	24 hr	0% mortality at 10 animals/L	5,000	Hall 1990
					0% mortality at 20 animals/L	5,000	
Rana clamitans	Tadpole	Parathion	F, M	24 hr	15% mortality at 10 animals/L and flow of 0.5 ml/min	5,000	Hall 1990
					85% mortality at 10 animals/L and flow of 5 ml/min	5,000	
					0% mortality at 20 animals/L and flow of 0.5 ml/min	5,000	
					75% mortality at 20 animals/L and flow of 5 ml/min	5,000	
Rana pipiens	Adult	Parathion	—	48 hr	LC50	10,000	Kaplan and Glaczinski 1965[c]
				15 d	Increase in anemia and leucopenia with increasing concentration	5,000-25,000	

Table 53B. Parathion (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Scaphiopus hammondi	Tadpole	Parathion (formulation)	U, isolated in pond	24 hr	0% mortality	0.45 kg/ha[b]	Mulla *et al.* 1963

[a] F = flow-through, M = measured, S = static, U = unmeasured
[b] Active ingredient
[c] Reference not seen, cited in Power *et al.* 1989

Table 54A. Pentachlorophenol - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	pH	Reference
Rana catesbeiana	Tadpole	F, M	207	8	Thurston *et al.* 1985[b]

[a] F = flow-through, M = measured

[b] Reference also cited in Table 1 (acute data) of the water quality criteria document for pentachlorophenol EPA 440/5-86-009 (USEPA 1986e); value in document, 44.48 μg/L, had been adjusted to pH 6.5

Table 54B. Pentachlorophenol - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	pH	Reference
Ambystoma mexicanum	Larva	Pentachlorophenol	S, U	48 hr	LC50	300	[b]	Sloof and Baerselman 1980, Sloof *et al.* 1983
Bufo bufo japonicus	Tadpole	Pentachlorophenol (formulation)	—	48 hr	LC50	0.25	—	Hashimoto and Nishiuchi 1981
Bufo bufo japonicus	Tadpole	Pentachlorophenol-sodium (formulation)	—	96 hr	LC50	320	—	Nishiuchi and Yoshida 1974
Bufo bufo japonicus	Tadpole	Pentachlorophenol-copper	—	96 hr	LC50	350	—	Nishiuchi and Yoshida 1974
Rana hexadactyla	Tadpole	Pentachlorophenol-sodium	R, U	96 hr	LC50	18.4	6.2	Khangarot *et al.* 1985c
Rana pipiens	Tadpole	Pentachlorophenol-sodium	S, U	9.5 hr	100% mortality	800	7.8	Goodnight 1942[c]
Xenopus laevis	Tadpole	Pentachlorophenol	S, U	48 hr	LC50	260	[b]	Sloof and Baerselman 1980[c], Sloof *et al.* 1983[c]
Xenopus laevis	Tadpole	Pentachlorophenol	S, U	100 d	NOL(E)C for mortality, development and growth	32	[b]	Sloof and Canton 1983[c]

[a] R = renewal, S = static, U = unmeasured
[b] Dutch Standard Water
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for pentachlorophenol EPA 440/5-86-009 (USEPA 1986e)

Table 55A. Phenol - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (µg/L)	Reference
Xenopus laevis	Tadpole	F, M	>51,000	Holcombe *et al.* 1987

[a] F = flow-through, M = measured

Table 55B. Phenol - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma gracile	Embryo	F, M	9 d	LC50	380	Black *et al.* 1982
Bufo americanus	Embryo	F, M	7 d	LC50	>890	Birge *et al.* 1980
				0% deformity at hatch	22	
				2% deformity at hatch	36	
				1% deformity at hatch	63	
				2% deformity at hatch	220	
				9% deformity at hatch	890	
Bufo fowleri	Embryo	F, M	7 d	LC50	2,450	Birge *et al.* 1980
				0% deformity at hatch	62	
				1% deformity at hatch	530	
				5% deformity at hatch	10,200	
Rana catesbeiana	Embryo	F, M	7 d	LC50	230	Birge *et al.* 1980
				0% deformity at hatch	62	
				2% deformity at hatch	530	
				15% deformity at hatch	10,200	
Rana palustris	Embryo	F, M	8 d	LC50	9,870	Birge *et al.* 1980
				0% deformity at hatch	15	
				2% deformity at hatch	1,860	
				15% deformity at hatch	21,800	
Rana pipiens	Embryo	F, M	9 d	LC50	40	Birge *et al.* 1980
				5% deformity at hatch	4.7	
				2% deformity at hatch	7.3	
				9% deformity at hatch	74	

Table 55B. Phenol (continued)

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Rana temporaria	Embryo	F, M	9 d	LC50	270	Black *et al.* 1982
				2% deformity at hatch	120	
				6% deformity at hatch	720	
				56% deformity at hatch	1,450	
Xenopus laevis	Embryo	F, U	5 wk	No effect on body length	100-1,000	Dumpert 1987
				100% mortality	50,000	
Xenopus laevis	Embryo	F, M	6 d	LC50	7,680	Black *et al.* 1982
				1% deformity at hatch	1,450	
				8% deformity at hatch	14,000	
				16% deformity at hatch	26,400	

[a] F = flow-through, M = measured, U = unmeasured

Table 56. Phthalate esters - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo fowleri	Embryo	Dioctyl-phthalate	R, U	7-8 d	LC50	3,880	Birge *et al.* 1978a
Bufo fowleri	Embryo	Diisononyl-phthalate	R, U	7-8 d	LC50	2,950	Birge *et al.* 1978a
					1% deformity at hatch	1,000	
					5% deformity at hatch	100,000	
Rana pipiens	Embryo	Dioctyl-phthalate	R, U	7-8 d	LC50	4,440	Birge *et al.* 1978a
					1% deformity at hatch	1,000	
					5% deformity at hatch	10,000	
Rana pipiens	Embryo	Diisononyl-phthalate	R, U	7-8 d	LC50	3,360	Birge *et al.* 1978a
					1% deformity at hatch	100	
					4% deformity at hatch	10,000	

[a] R = renewal, U = unmeasured

Table 57. Polychlorinated biphenyls (PCBs) - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Bufo americanus	Embryo	Aroclor 1016	R, U	7-8 d	LC50	7.16	Birge *et al.* 1978a
					1% deformity at hatch	1	
					16% deformity at hatch	10	
					29% deformity at hatch	100	
					34% deformity at hatch	1,000	
Bufo americanus	Embryo	Aroclor 1242	R, U	7-8 d	LC50	2.71	Birge et al. 1978a
					1% deformity at hatch	0.1	
					6% deformity at hatch	1	
					10% deformity at hatch	10	
					32% deformity at hatch	100	
					47% deformity at hatch	1,000	
Bufo americanus	Embryo	Aroclor 1254	R, U	7-8 d	LC50	2.02	Birge et al. 1978a
					2% deformity at hatch	0.1	
					5% deformity at hatch	1	
					13% deformity at hatch	10	
					25% deformity at hatch	100	
					100% deformity at hatch	1,000	
Bufo fowleri	Embryo	Aroclor 1016	R, U	7-8 d	LC50	27.72	Birge et al. 1978a
					1% deformity at hatch	10	
					2% deformity at hatch	100	
					11% deformity at hatch	1,000	
Bufo fowleri	Embryo	Aroclor 1242	R, U	7-8 d	LC50	12.09	Birge *et al.* 1978a
					1% deformity at hatch	1	
					2% deformity at hatch	10	
					6% deformity at hatch	100	
					13% deformity at hatch	1,000	

Table 57. Polychlorinated biphenyls (PCBs) (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (μg/L)	Reference
Bufo fowleri	Embryo	Aroclor 1254	R, U	7-8 d	LC50	3.74	Birge *et al.* 1978a
					1% deformity at hatch	0.1	
					2% deformity at hatch	1	
					4% deformity at hatch	10	
					9% deformity at hatch	100	
Pleurodeles waltl	Larva	Aroclor 1254	R, U	12 d	No increase in micronucleated erythrocytes	50	Fernandez *et al.* 1989
Rana pipiens	Embryo	Aroclor 1016	R, U	7-8 d	LC50	6.19	Birge *et al.* 1978a
Rana pipiens	Embryo	Aroclor 1242	R, U	7-8 d	LC50	2.13	Birge *et al.* 1978a
					2% deformity at hatch	1	
					5% deformity at hatch	10	
					55% deformity at hatch	100	
Rana pipiens	Embryo	Aroclor 1254	R, U	7-8 d	LC50	1.03	Birge *et al.* 1978a
					2% deformity at hatch	1	
					18% deformity at hatch	10	

[a] R = renewal, U = unmeasured

Table 58A. Polynuclear aromatic hydrocarbons - acute data.

Species	Stage/Age	Chemical	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Embryo	Benzo[a]pyrene	S, U	>10,000 12,000[b] 10,000[b]	Fort *et al.* 1989

[a] S = static, U = unmeasured
[b] EC50

Table 58B. Polynuclear aromatic hydrocarbons - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Pleurodeles waltl	Embryo (jellied)	Benzo[a]-pyrene	S, M	120 hr	10% mortality	50	Fernandez and L' Haridon 1994
				48 hr	58% mortality with UVA exposure	12.5	
				48 hr	90% mortality with UVA exposure	25	
				48 hr	94% mortality with UVA exposure	50	
Pleurodeles waltl	Embryo (dejellied)	Benzo[a]-pyrene	S, M	312 hr	24% mortality	25	Fernandez and L' Haridon 1994
				18 hr	8% mortality with UVA exposure	12.5	
				36 hr	100% mortality with UVA exposure	12.5	
				18 hr	33% mortality with UVA exposure	25	
				54 hr	100% mortality with UVA exposure	25	
Pleurodeles waltl	Larva	Benzo[a]-pyrene	R, U	12 d	Increase in micronucleated erythrocytes	25	Fernandez *et al.* 1989
Pleurodeles waltl	Larva	Benzo[a]-pyrene	S, U	48 hr	Increase in micronucleated erythrocytes	200	Marty *et al.* 1989
Rana pipiens	Embryo	Anthracene	S, U	30 min	LC50 during sunlight exposure	65	Kagan *et al.* 1984
				5 hr	LC50 during sunlight exposure	25	
Rana pipiens	Tadpole	Anthracene	S, U	1 hr	LC50 during sunlight exposure	110	Kagan *et al.* 1985
Rana pipiens	Tadpole	Fluoranthene	S, U	1 hr	LC50 during sunlight exposure	90	Kagan *et al.* 1985

Table 58B. Polynuclear aromatic hydrocarbons (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana pipiens	Tadpole	Pyrene	S, U	1 hr	LC50 during sunlight exposure	140	Kagan *et al.* 1985

[a] M = measured, R = renewal, S = static, U = unmeasured

Table 59. Propoxur - other data.

Species	Stage/Age	Method	Duration	Effect	Conc. (Fg/L)	Reference
Bufo bufo japonicus	Tadpole	---	48 hr	LC50	35,000	Hashimoto and Nishiuchi 1981

Table 60A. Selenium - acute data

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (µg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Xenopus laevis	Embryo	Sodium selenate	S, U	7,106	[c]	[c]	DeYoung *et al.* 1991
				7,942	[c]	[c]	
				11,286	[c]	[c]	
				2,508[d]	[c]	[c]	
				2,926[d]	[c]	[c]	
				3,762[d]	[c]	[c]	
Xenopus laevis	Embryo	Selenium	S, U	1,500	6.5	—	Linder *et al.* 1991
				2,000	6.5	—	

[a] S = static, U = unmeasured
[b] Values expressed as selenium
[c] FETAX solution
[d] EC50

Table 60B. Selenium - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Gastrophryne carolinensis	Embryo	Sodium selenate	R, M	7d	LC50	90	7.4	195	Birge 1978[c], Birge *et al.* 1979b[c]
Xenopus laevis	Embryo	Sodium selenite	S, U	1-7 d	epidermal abnormalities, muscle cell degeneration	600-3,000	—	—	Browne and Dumont 1980
Xenopus laevis	Embryo	Sodium selenite	S, M	3 d	LC50	2,412	—	—	Browne and Dumont 1979
				5 d	LC50	786	—	—	
				7 d	LC50	456	—	—	
Xenopus laevis	Embryo	Selenium	S, U	96 hr	NOEC	800	6.5-7.0	—	Linder *et al.* 1991
					LOEC	1,600	—	—	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as selenium
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for selenium EPA 440/5-87-006 (USEPA 1987b)

Table 61. Silver - other data

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L CaCo$_3$)	Reference
Ambystoma opacum	Embryo	Silver nitrate	R, M	8 d	LC50	240	7.2-7.8	93-105	Birge *et al.* 1978b[c]
Bufo melanostictus	Tadpole	Silver nitrate	S, U	96 hr	LC50	4.1	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Silver nitrate	R, M	7 d	LC50	10	7.4	195	Birge 1978, Birge *et al.* 1979a
Rana hexadactyla	Tadpole	Silver nitrate	S, U	96 hr	LC50	25,700	6.1	20	Khangarot *et al.* 1985b

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as silver
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for silver EPA 440/5-80-071(USEPA 1980cc)

Table 62. Thallium - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L CaCO3)	Reference
Frog (unidentified)	Embryo	Thallium nitrate	R, U	—	100% mortality at emergence	409	—	—	Dilling and Healy 1926[c]
Gastrophryne carrolinensis	Embryo	Thallium trichloride	R, M	7 d	LC50	110	7.4	195	Birge 1978, Birge *et al.* 1979a

[a] M = measured, S = static, U = unmeasured
[b] Values expressed as thallium
[c] Reference also cited in Table 6 (other data) of the water quality criteria document for thallium EPA 440/5-80-074 (USEPA 1980dd)

Table 63. Toluene - other data.

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma gracile	Embryo	F, M	9 d	LC50	850	Black *et al.* 1982
				10% deformity at hatch	400	
				36% deformity at hatch	25,400	
				100% deformity at hatch	41,500	
Rana pipiens	Embryo	S, M	9 d	LC50	390	Black *et al.* 1982
				3% deformity at hatch	410	
				50% deformity at hatch	22,600	
				100% deformity at hatch	35,300	

[a]F = flow-through, M = measured, S = static

Table 64A. Toxaphene - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Bufo woodhousii fowleri	Tadpole	S, U	140	Sanders 1970[b]
Bufo woodhousii fowleri	Tadpole	S, U	150	Mayer and Ellersieck 1986
Pseudacris triseriata	Tadpole	S, U	500	Sanders 1970[b]
Pseudacris triseriata	Tadpole	S, U	390	Mayer and Ellersieck 1986

[a] S = static, U = unmeasured
[b] Reference also cited in Table 1 (acute data) of the water quality criteria document for toxaphene EPA 440/5-86-006 (USEPA 1986d)

Table 64B. Toxaphene - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Acris crepitans	Tadpole	Toxaphene	F, M	96 hr 24 hr	LC50 EC50 (behavior)	76 >1,000	Hall and Swineford 1981[b]
Ambystoma maculatum	Larva	Toxaphene	F, M	96 hr 24 hr	LC50 at 8 d EC50 (behavior)	34 227	Hall and Swineford 1981[b]
Ambystoma opacum	Larva	Toxaphene	F, M	96 hr 24 hr	LC50 at 8 d EC50 (behavior)	342 170	Hall and Swineford 1981[b]
Bufo americanus	Tadpole	Toxaphene	F, M	96 hr 24 hr	LC50 at 8 d EC50 (behavior)	34 38	Hall and Swineford 1981[b]
Rana catesbeiana	Tadpole	Toxaphene	F, M	96 hr 24 hr	LC50 at 8 d EC50 (behavior)	99 312	Hall and Swineford 1981[b]
Rana catesbeiana	Tadpole	Toxaphene (formulation)	U, isolated in pond	96 hr 24 hr	0% mortality 100% mortality	0.112kg/ha[c] 0.560kg/ha[c]	Mulla, 1963
Rana pipiens	Adult	Toxaphene	S, U	30 d	25% mortality	600	Kaplan and Overpeck 1964
Rana sphenocephala	Tadpole	Toxaphene	F, M	96 hr 24 hr	LC50 at 8 d 24 hr	130 193	Hall and Swineford 1981
Rana sphenocephala	Embryo	Toxaphene	F, M	96 hr	LC50 at 15 d LC50 at 20 d LC50 at 24 d	651 60 46	Hall and Swineford 1980[b]
Rana sphenocephala	Tadpole	Toxaphene	F, M	96 hr	LC50 at 8 d LC50 at 15 d LC50 at 30 d	168 65 32	Hall and Swineford 1980[b]

Table 64B. Toxaphene (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Rana sphenocephala	Subadult	Toxaphene	F, M	96 hr	LC50 at 8 d	378	Hall and Swineford 1980[b]
					37.9 concentration factor in killed animals	58	
					52.6 concentration factor in killed animals	78	
					28.7 concentration factor in killed animals	150	
					16.1 concentration factor in killed animals	280	
					36.8 concentration factor in killed animals	760	
Rana sylvatica	Tadpole	Toxaphene	F, M	96 hr	LC50 at 8 d	195	Hall and Swineford 1981
				24 hr	EC50 (behavior)	36	

[a] F = flow-through, M = measured, S = static, U = unmeasured
[b] Reference also cited in Table 6 (other data) of the water quality criteria document for toxaphene EPA 440/5-86-006 (USEPA 1986f)
[c] Active ingredient

Table 65. Tributyltin - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma mexicanum	Larva	Tributyltin oxide	S, U	1 d	100% mortality	48.6	Scadding 1990
				7 d	80% mortality	14.6	
				49 d	90% mortality	14.6	
				49 d	Most limbs with defects	4.86	
				49 d	Limbs with slightly increased defects	1.46	
				49 d	Normal limb development	0.49	
Rana temporaria	Embryo	Tributyltin fluoride	S, U	5 d	LC50	28.2	Laughlin and Linden 1982[c]
					Body water loss	28.2	
Rana temporaria	Embryo	Tributyltin oxide	S, U	5 d	40% mortality	29.2	Laughlin and Linden 1982[c]
					Body water loss	29.2	

[a] S = static, U = unmeasured
[b] Values expressed as tributyltin cation
[c] Reference also cited in Table 6 (other data) of the water quality cirteria document for tributyltin EPA 440/5-88-draft (USEPA 1988d)

Table 66A. Trichloroethylene - acute data.

Species	Stage/Age	Method[a]	96-hr LC50 (μg/L)	Reference
Xenopus laevis	Embryo	S, U	425,000 443,000 34,000[b] 37,000[b]	Fort *et al.* 1991, 1993

[a] S = static, U = unmeasured
[b] EC50

Table 66B. Trichloroethylene - other data

Species	Stage/Age	Method[a]	Duration	Effect	Conc. (µg/L)	Reference
Ambystoma mexicanum	Larva	S, U	48 hr	LC50	48,000	Sloof *et al.* 1983, Sloof and Baerselman 1980
Xenopus laevis	Tadpole	S, U	48 hr	LC50	45,000	Sloof *et al.* 1983, Sloof and Baerselman 1980

[a] S = static, U = unmeasured

Table 67A. Zinc - acute data

Species	Stage/Age	Chemical	Method[a]	96-hr[b] LC50 (μg/L)	pH	Hardness (as mg/L $CaCo_3$)	Reference
Xenopus laevis	Embryo	Zinc sulfate	S, M	34,500	7.0	100[c]	Dawson *et al.* 1988
				3,600[d]	7.0	100[c]	
Xenopus laevis	Embryo	Zinc sulfate	S, M	14,175	[e]	100[c]	Fort *et al.* 1989
				13,689	[e]	100[c]	
				899[d]	[e]	100[c]	
				1,276[d]	[e]	100[c]	
Xenopus laevis	Embryo	Zinc sulfate	S, U	1,944[d]	[e]	[e]	Bantle *et al.* 1989
Xenopus laevis	Embryo	Zinc	S, U	1,300	6.6	—	Linder *et al.* 1991

[a] S = static, M = measured, U = unmeasured
[b] Values expressed as zinc
[c] Normalized
[d] EC50
[e] FETAX solution

Table 67B. Zinc - other data.

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (μg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Ambystoma jeffersonianum	Embryo	Zinc chloride	S, M	96 hr	No toxic response or effect on development rate	2,000	4.5	—	Horne and Dunson 1994
Ambystoma opacum	Embryo	Zinc chloride	S, M	8 d	LC50	2,380	7.2-7.8	93-105	Birge *et al.* 1978b
Bufo arenarum	Tadpole	Zinc	S, U	120 hr	5% mortality 65% mortality	16,000 32,000	[c] [c]	[c] [c]	Herkovits and Perez-Coll 1991
Bufo boreas	Tadpole	Zinc sulfate	R, U	12 hr 61 d	100% mortality 100% metamorphosis	39,000 100	— 5-6	— —	Porter and Hakanson 1976
Bufo melanostictus	Tadpole	Zinc sulfate	S, U	96 hr	LC50	19,860	7.4	185	Khangarot and Ray 1987
Gastrophryne carolinensis	Embryo	Zinc chloride	R, M	7 d	LC50	10	7.4	195	Birge1978[d], Birge *et al.* 1979a[d]
Microhyla ornata	Tadpole (1 wk)	Zinc sulfate	S, U	96 hr	LC50	22,410	6.8-6.9	142-145	Rao and Madhyastha 1987
Microhyla ornata	Tadpole (4 wk)	Zinc sulfate	S, U	96 hr	LC50	23,080	6.8-6.9	142-145	Rao and Madhyastha 1987
Rana hexadactyla	Tadpole	Zinc sulfate	S, U	96 hr	LC50	2,100	6.1	20	Khangarot *et al.* 1985a, 1985b
Rana pipiens	Adult	Zinc	R	15 d	LC50	155,000	—	—	Kaplan and Glaczenski 1965[e]

Table 67B. Zinc (continued)

Species	Stage/Age	Chemical	Method[a]	Duration	Effect	Conc.[b] (µg/L)	pH	Hardness (as mg/L $CaCO_3$)	Reference
Xenopus laevis	Tadpole	Zinc sulfate	S, M	90 hr	80% mortality	2,300	7.0	296	Woodall *et al.* 1988
					45% mortality	3,400	7.0	296	
					50% mortality	4,500	7.0	296	
					15% mortality, pre-treated with 1,100 µg/L Zn for 96 hr	4,500	7.0	296	
Xenopus laevis	Embryo	Zinc	S, U	96 hr	NOEC	400	5.5-6.7	—	Linder *et al.* 1991
					LOEC	800	5.5-6.7	—	

[a] M = measured, R = renewal, S = static, U = unmeasured
[b] Values expressed as Zinc
[c] 10% Holtfreter's solution
[d] Reference also cited in Table 6 (other data) of the water quality criteria document for zinc EPA 440/5-87-003 (USEPA 1987a)
[e] Reference not seen, cited in Power *et al.* 1989

APPENDIX A

Amphibian References not used in Tables 5-67B

Chemical List:

Aldrin/Dieldrin

Akkermans *et al.* 1974, 1975a,1975b 1975c; Dowd *et al.* 1985, Fonovich de Schroeder and Pechen de D'Angelo 1991, Georgacakis *et al.* 1971, Kaiser and Dunham 1972-1973, Korschgen 1970, Nishiuchi 1980a, Punzo *et al.* 1979, Rane and Mathur 1978, Vinson *et al.* 1963, Webb *et al.* 1979

Aluminum

Canton and Sloof 1982, Marquis 1982, Olsson *et al.* 1987

Benzene

Garavini and Seren 1978, Lipnick 1989

Cadmium

Beyer *et al.* 1985, Birge *et al.* 1977, Dawson *et al.* 1985, Dmowski and Karolewski 1979, Fox and Sillman 1979, Gale *et al.* 1973, Hall and Mulhern 1984, Hillyard *et al.* 1979, Kanno *et al.* 1978, Kasinathan *et al.* 1987, Niethammer *et al.* 1985, Pramoda and Saidapur 1986, Suzuki and Akitomi 1983, Suzuki and Tanaka 1983, Suzuki *et al.* 1986

Carbaryl

Ardizzone *et al.* 1990, Sampath *et al.* 1995, Webb *et al.* 1979

Chlordane

Albright *et al.* 1980, Dowd *et al.* 1985, Nishiuchi 1980B, Webb *et al.* 1979

Chloride

Shpun *et al.* 1992

Chlorinated benzenes

Nishiuchi 1980b

Chlorophenoxy herbicides

Nishiuchi 1979, 1980b

Chlorpyrifos

Johnson and Prine 1976

Copper

Beck 1956, Beyer *et al.* 1985, Cicero 1990. Cooke 1973, Dawson *et al.* 1985, Gale *et al.* 1973, Goldfisher and Schiller 1970, Hall and Mulhern 1984, Jordan *et al.* 1977, Kanno *et al.* 1978, Miller and Mackay 1983, Pavel and Kucera 1986[a], Rico *et al.* 1987

Dichlorvos

Tomar and Pandey 1988

DDT

Cooke 1971, 1973; Dowd *et al.* 1985, Dimond *et al.* 1968, Ferguson andGilbert 1967, Finley and Pillmore 1963, Harri 1980, Harri *et al.* 1979, Herald 1949, Hunt and Bishoff 1960, Jabbar Kahn 1975, Kaiser and Dunham 1972-1973, Kirk 1988, Licht 1976, Logier 1949, Nishiuchi 1980a, Peaslee 1970,Punzo *et al.* 1979, Rajendra *et al.* 1980, Rico *et al.* 1987, Spiers 1949, Tarzwell 1950, van den Bercken and Akkermans 1971, Webb *et al.* 1979

Endosulfan

Nishiuchi 1980a

Endrin

Dowd *et al.* 1985, Rosato and Ferguson 1968, Webb *et al.* 1979, Wohlgemuth and Trnkova 1979

Heptachlor

Dowd *et al.* 1985, Kaiser and Dunham 1972-1973, Nishiuchi 1980a, Webb *et al.* 1979, Whitacre and Ware 1967

Hexachlorocyclohexane

Dowd *et al.* 1985, Jabbar Kahn 1975, Kaiser and Dunham 1972-1973, Publicover *et al.* 1979, Rico *et al.* 1987, Webb *et al.* 1979

Iron

Pavel and Kucera 1986[a]

Lead

Barrett 1947, Beyer *et al.* 1985, Birdsall *et al.* 1986, Dawson 1933, Dawson *et al.* 1985, Dmowski and Karolewski 1979, Fox and Sillman 1979, Gale *et al.* 1973, Hall and Mulhern 1984, Ireland 1977, Krishnamoorthy *et al.* 1987, Niethammer *et al.* 1985, Rico *et al.* 1987, Schroeder and Tipton 1968

Malathion

Baker 1985, Giles 1970, Kowsalya *et al.* 1987

Manganese

Gale *et al.* 1973, Pavel and Kucera 1986[a]

Mercury

Birge *et al.* 1977, Cox and Holm 1975, Dustman *et al.* 1972, Fox and Sillman 1979, Hall and Mulhern 1984, Rico *et al.* 1987, Terhivuo *et al.* 1984, Yorio and Bentley 1973

Methoxychlor

Webb *et al.* 1979

Methyl parathion

Johnson and Prine 1976, Woodham *et al.* 1977, Yasmeen and Nayeemunnisa 1986

Naphthalene

Blankenmeyer *et al.* 1990, Lipnick 1989

Nitrophenols

Görge *et al.* 1987, Statham *et al.* 1978, Zettergren *et al.* 1988, 1991

Parathion

Guzman and Guardia 1978, Jurez and Guzman 1984

Pentachlorophenol

Schuytema *et al.* 1993

Phenanthrene

Lipnick 1989

Phenol

Nagel and Urich 1981

Phthalate esters

Larsen and Thuren 1987

Polychlorinated biphenyls

Dowd *et al.* 1985, Rico *et al.* 1987

2,3,7,8-Tetrachlorodibenzo-p-dioxin

Beatty *et al.* 1976[b], Fanelli *et al.* 1980, Korfmacher *et al.* 1986a, 1986b

Toluene

Ekblom *et al.* 1984, Garavini and Seren 1979

Toxaphene

Dowd *et al.* 1985

Zinc

Beyer *et al.* 1985, Birge *et al.* 1977, Dawson *et al.* 1985, Dmowski and Karolewski 1979, Gale *et al.* 1973, Hall and Mulhern 1984, Kanno *et al.* 1978, Niethammer *et al.* 1985, Nishiuchi 1979, Rico *et al.* 1987, Taban *et al.* 1982

---

[a] Cited in Power *et al.* 1989
[b] Cited in water quality criteria document, but exposure was by injection

Reference List:

Akkermans, L.M.A., J. van den Bercken, J.M. van der Zalm and H.W.M. van Straaten.1974. Effects of dieldrin (HEOD) and some of its metabolites on synaptic transmission in the frog motor end-plate. Pestic. Biochem. Physiol. 4:313-324.

Akkermans, L.M.A., J. van den Bercken and J.M. van der Zalm. 1975a. Effects of aldrin-transdiol on neuromuscular facilitation and depression. Europ. J. Pharmacol. 31: 166-175.

Akkermans, L.M.A., J. van den Bercken and M. Versluijs-Helder. 1975b. Excitatory and depressant effects of dieldrin and aldrin-transdiol in the spinal cord of the toad (*Xenopus laevis*). Europ. J. Pharmacol. 34: 133-142.

Akkermans, L.M.A., J. van den Bercken and M. Versluijs-Helder. 1975c. Comparative effects of DDT, allethrin, dieldrin and aldrin-transdiol on sense organs of *Xenopus laevis*. Pestic. Biochem Physiol. 5: 451-457.

Albright L.J., P.C. Oloffs and S.Y. Szeto. 1980. Residues in cutthroat trout (*Salmo clarki*) and California newts (*Taricha torosa*) from a lake treated with technical chlordane. J. Environ. Sci. Health B15: 333-349.

Ardizzone, C., H. Krokos and C. Lippe. 1990. Actions of carbaryl on the ionic transport across the isolated skin of *Rana esculanta*. Comp. Biochem. Physiol. 97: 49-51.

Baker, K.N. 1985. Laboratory and field experiments on the responses by two species of woodland salamanders to malathion-treated substrates. Arch. Environ. Contam. Toxicol. 14: 685-691.

Barrett, W.C., Jr. 1947. The effects of lead salts on the hemopoietic and histiocytic systems of the larval frog. Amer. J. Anat. 81: 117-136.

Beatty, P.W., M.A. Holsher and R.A. Neal. 1976. Toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin in larval and adult forms of *Rana catesbeiana*. Bull. Environ. Contam. Toxicol. 16: 578-581.

Beck, A.B. 1956. The copper content of the liver and blood of some vertebrates. Austral. J. Zool. 4: 1-18.

Beyer, W.N., O.H. Pattee, L. Sileo, D.J. Hoffman and B.M. Mulhern. 1985. Metal contamination in wildlife living near two zinc smelters. Environ. Pollut. (Series A) 38: 63-86.

Birdsall, C.W., C.E. Grue and A. Anderson. 1986. Lead concentrations in bullfrog *Rana catesbeiana* and green frog *R. clamitans* tadpoles inhabiting highway drainages. Environ. Pollut. (Series A) 40: 233-247.

Birge, W.J., J.A. Black, A.C. Westerman, P.C. Francis and J.E. Hudson. 1977. Embryopathic effects of waterborne and sediment-accumulated cadmium, mercury and zinc on reproduction and survival of fish and amphibian populations in Kentucky. Research Rept. No. 100. Kentucky Water Resources Institute, University of Kentucky, Lexington. PB 264 043.

Blankenmeyer, J.T. and C. R. Heflen. 1990. Effect of naphthalene on sodium active transport in the frog skin. Bull. Environ. Contam. Toxicol. 45: 627-632.

Canton, J.H. and W. Sloof. 1982. Substitutes for phosphate containing washing products: Their toxicity and biodegradability in the aquatic environment. Chemosphere 11: 891-907.

Cicero, R., A. Gallone, I. Maida and G. Pintucci. 1990. Effects of copper on the tyrosinase of liver pigment cells from *Rana esculenta* L. Comp. Biochem. Physiol. 96B: 393-397.

Cooke, A.S. 1971. Selective predation by newts on frog tadpoles treated with DDT. Nature 229: 275-276.

Cooke, A.S. 1973. The effects of DDT, when used as a mosquito larvacide on tadpoles of the frog *Rana temporaria*. Environ. Pollut. 5: 259-273.

Cox, M.F. and H.W. Holm. 1975. Methylmercury and total mercury concentrations in selected stream biota. *In*: D.D. Hemphill (ed) Trace Substances in Environmental Health. Columbia. MO. pp 151-155.

Dawson, A.B. 1933. An experimental study of hemopoiesis in *Necturus*: Effects of lead poisoning on normal and splenectomized animals. J. Morphol. 55: 349-375.

Dawson, D.A., C.A. McCormick and J.A. Bantle. 1985. Detection of teratogenic substances in acidic mine water samples using the frog embryo teratogenesis assay - *Xenopus* (FETAX). J. Appl. Toxicol. 5: 234-244.

Dimond, J.B., R.E.,Kandunce, A.S. Getchell and J.A. Blease. 1968. DDT residue persistance in red-backed salamanders in a natural environment. Bull. Environ. Contam. Toxicol. 34: 194-202.

Dmowski, K., and M.A. Karolewski. 1979. Cumulation of zinc, cadmium, and lead in invertebrates and some vertebrates according to the degree of an area contamination. Ekol. Pol. 27: 333-349.

Dowd. P.F., G.U. Mayfield, D.P. Coulon, J.B. Graves and J.D. Newsome. 1985.Organochlorine residues in animals from three Louisiana watersheds in 1978 and 1979. Bull. Environ. Contam. Toxicol. 34: 832-841.

Dustman, E.H., L.E. Stickel and J.B. Elder. 1972. Mercury in wild animals, Lake St. Clair, 1970. *In*: R.H. Hartung, B.D. Dinman (eds). Environmental Mercury Contamination, Ann Arbor Sci. Publ. Inc. pp 46-52.

Ekblom A., A. Flock, P. Hansson and D. Ottoson. 1984. Ultrastructural and electrophysiological changes in the olfactory epithelium following exposure to organic solvents. Acta Otolaryngol (Stockh.) 98: 351-361.

Fanelli, R., M.G. Castelli, G.P. Martelli, A. Noseda and S. Garattini. 1980. Presence of 2,3,7,8-tetrachlorodibenzo-p-dioxin in wildlife living near Seveso, Italy: A preliminary study. Bull. Environ. Contam. Toxicol. 24: 460-462.

Ferguson, D.E. and C.C. Gilbert. 1967. Tolerances of three species of anuman amphibians to five chlorinated insecticides. J. Miss. Acad. Sci. 13: 135-138.

Finley, R.B. and R.E. Pillmore. 1963. Conversion of DDT to DDE in animal tissue. Bioscience 13: 41-42.

Fonovich de Schroeder, T.M. and A.M. Pechen de D'Angelo. 1991. Dieldrin effects on phospholipid and phosphoinositide metabolism in *Bufo arenarum* oocytes. Comp. Biochem. Physiol. 98C 287-292.

Fox, D.A. and A.J. Sillman. 1979. Heavy metals affect rod, but not cone, photoreceptors. Science 206: 78-80.

Gale, N.L., B.G. Wixon, M.G. Hardie and J.C. Jennett. 1973. Aquatic organisms and heavy metals in Missouri's new lead belt. Water Res. Bull. 9: 673-688.

Garavini, C. and P. Seren. 1978. Hematologic and hemopoitic alterations following experimental benzene exposure in newts (*Triturus cristatus*). Biochem. Exper. Biol. 14: 247-255.

Garavini, C., and P. Seren. 1979. The effect of toluene on the hematopoietic system in newt *Triturus cristatus*. Biochem. Exper. Biol. 15: 341-348.

Georgacakis, E.. S.R. Chandran and M.A.Q. Khan. 1971. Toxicity-metabolism relationship of the photoisomers of cyclodiene insecticides in freshwater animals. Bull. Environ. Contam. Toxicol. 6: 535-538.

Giles, R.H., Jr. 1970. The ecology of a small forested watershed treated with the insecticide malathion-S^{35}. Wildlife Monogr. 24: 1-81.

Goldfisher, S. and B. Schiller. 1970. Copper in hepatocyte lysosomes of the toad *Bufo marinus* L. Nature 228: 172-173.

Görge, G., J. Beyer and K. Urich. 1987. Excretion and metabolism of phenol, 4-nitrophenol and L-methylphenol by the frogs *Rana temporaria* and *Xenopus laevis*. Xenobiotica 17: 1293-1298.

Guzman, J.A. and T. Guardia. 1978. Effects of an organophosphorus insecticide on the cholinesteratic activities of *Bufo arenarum* (H). Bull. Environ. Contam. Toxicol. 20: 52-58.

Hall, R.J. and B.M. Mulhern. 1984. Are anuran amphibians heavy metal accumulators? *In*: R.A. Siegel, L.E. Hunt, J.L. Knight, L. Malaret and N.L. Zuschlag (eds). Vertebrate Ecology and Systematics- A Tribute to Henry S. Fitch. Museum of Nat. Hist., Univ. of Kansas, Lawrence. pp 123-133.

Harri, M.N.E., J. Laitinen and E.L. Valkama. 1979. Toxicity and retention of DDT in adult frogs, *Rana temporaria* L. Environ Pollut. 20: 45-55.

Harri, M.N.E.. 1980. Hepatic mixed function oxidase (MFO) activities during the seasonal life cycle of the frog *Rana temporaria*. Comp. Biochem. Physiol. 67C: 75-78.

Herald, E.S. 1949. Effects of DDT-oil solutions upon amphibians and reptiles. Herpetologica 5: 117-120.

Hillyard, S.D., R. Sera and H.C. Gonick. 1979. Effects of Cd^{++} on short-circuit current across epithelial membranes, II. Studies with isolated frog skin epithelium, urinary bladder, and large intestine. J. Membrane Biol. 46: 283-294.

Hunt, E.G. and A.I. Bischoff. 1960. Inimical effects on wildlife of periodic DDD applications to Clear Lake. Calif. Fish and Game 46: 91-106.

Ireland. M.P. 1977. Lead retention in toads *Xenopus laevis* fed increasing levels of lead-contaminated earthworms. Environ. Pollut. 12: 85-92.

Jabbar Kahn, M.A. 1975. Susceptibility of some important fresh water fauna (Chordates) to synthetic insecticides and indigenous vegetable oils used as mosquito larvacide. Agric. Pak. 26: 393-400.

Johnson, C.R. and J.E. Prine. 1976. The effects of sublethal concentrations of organophosphorus insecticides and an insect growth regulator on temperature tolerance in hydrated and dehydrated western toads, *Bufo boreas*. Comp. Biochem. Physiol. 53A: 147-149.

Jordan, M., K. Rzehak and A. Maryanska. 1977. The effect of two pesticides, Miedzian 50 and Gesagard 50, on the development of tadpoles of *Rana temporaria*. Bull. Environ. Contam. Toxicol. 17: 349-354.

Juarez, A. and J.A. Guzman. 1984. Determination of LD-50 of three rganophosphorus insecticides in *Bufo arenarum*. Communicaciones Biologicas 2: 513.

Kaiser, T.O. and J. Dunham. 1972-1973. The absorption of chlorinated hydrocarbon insecticides by frog skin. Proc. Iowa Acad. Sci. 79: 101-104.

Kanno, Y., T. Yamami, Y. Muneoka and Y. Shiba. 1978. Effects of heavy metal ions on the electrical properties of mucous epithelial cells in the newt stomach. J. Toxicol. Sci. 3: 39-50.

Kasinathan, S., K. Veeraraghavan and S. Ramakrishnan. 1987. Effect of cadmium on the spermatogenesis of *Rana hexadactyla* Lesson. Acta Morphol. Hungarica 35: 183-187.

Kirk, J. 1988. Western spotted frog (*Rana pretiosa*) mortality following forest spraying of DDT. Herp. Rev. 19: 51-53.

Korfmacher, W.A., E.B. Hansen, Jr., and K.L. Rowland. 1986a. Tissue distribution of 2,3,7,8-TCDD in bullfrogs obtained from a 2,3,7,8-TCDD-contaminated area. Chemosphere 15: 121-126.

Korfmacher, W.A., E.B. Hansen, Jr., and K.L. Rowland. 1986b. Use of bullfrogs(*Ranacatesbeiana*) as biological markers for 2,3,7,8-tetrachlorodibenzo-p-dioxin contamination in the environment. Sci. Total Environ. 57: 257-262.

Korschgen, L.G. 1970. Soil-food-pesticide wildlife relationships in aldrin-treated fields. J. Wildl. Manag. 34: 186-199.

Kowsalya, T., K.S. Prasada Rao and K.V. Ramana Rao. 1987. Effect of malathion on some kinesiological parameters of the gastrocnemius muscle of the frog. *Rana hexadactyla* (Lesson) and the antagonistic action of atropine. Toxicol. Lett. 39: 215-221.

Krishnamoorthy, M.S., P. Muthu and M.M. Ahmed. 1987. Cardiotoxicity studies on interaction of lead, digoxin and calcium. Indian J. Med. Res. 86: 792-796.

Licht, L.E. 1976. Postmetamorphic retention of ^{c14}DDT by wood frog tadpoles. Comp. Biochem. Physiol. 55C: 119-121.

Lipnick. R.L. 1989. A quantitative structure-activity relationship study of Overton's data on the narcosis and toxicity of organic compounds to the tadpole *Rana temporaria*. *In*: G.W. Suter and M.A. Lewis (eds). Aquatic Toxicology and Environmental Fate: Eleventh Volume, ASTM STP 1007. American Society for Testing and Materials. Philadelphia. pp. 468-489.

Logier, E.B.S. 1949. Effect of DDT on amphibians and reptiles. Ontario Dept. Land and Forests. Div. of Research Bio. Bull. 2: 49-56.

Marquis, J.K. 1982. Aluminum neurotoxicity: An experimental perspective. Bull. Environ. Contam. Toxicol. 29: 43-49.

Miller, T.G. and W.C. Mackay. 1983. Evidence for an internal mechanism of copper toxicity in aquatic animals. Comp. Biochem. Physiol. 76C: 95-98.

Nagel, R. and K. Urich. 1981. Elimination and distribution of different substituted phenols by frog (*Rana temporaria*) and crayfish (*Astacus leptodactylus*). Bull.Environ. Contam. Toxicol. 26: 289-294.

Niethammer, K.R., R.D. Atkinson, T.S. Baskett and F.B. Samson. 1985. Metals in riparian wildlife of the lead mining district of southeastern Missouri. Arch. Environ. Contam. Toxicol. 14: 213-223.

Nishiuchi, Y. 1979. Toxicity of pesticides to some freshwater organisms. XXXXXX. The Aquiculture/Suisan Zoshoku 27: 56-60 (JPN).

Nishiuchi, Y. 1980a. Toxicity of formulated pesticides to fresh water organisms. LXXII. The Aquiculture/Suisan Zoshoku 27: 238-244 (JPN).

Nishiuchi, Y. 1980b. Toxicity of formulated pesticides to fresh water organisms.LXXIV. The Aquiculture/Suisan Zoshoku 28: 107-112 (JPN).

Olsson, M., C. Hogstrand, A. Dahlberg and S. Berglind. 1987. Acid-shock, aluminum and presence of *Sphagnum aurantiacum* on embrylogical development in the common frog, *Rana temporaria*, and the moor frog, *Rana arvalis*. Bull. Environ. Contam. Toxicol. 39: 37-44.

Pavel, J. and M. Kucera. 1986. Cummulation of heavy metals in the frog (*Rana esculenta*). Ecology (CSSR) 5: 431-440.

Peaslee, M.H. 1970. Influence of DDT upon pituitary melanocyte-stimulating hormone (MSH) activity in the anuran tadpole. Gen. Compar. Endrocrinol. 14: 594-595.

Pramoda, S. and S.K. Saidapur. 1986. Effect of cadmium chloride on the ovary of the frog *Rana tigrina*. Current Sci. 55: 206-208.

Publicover, S.J., C.J. Duncan and J.L. Smith. 1979. The action of lindane in causing ultrastructural damage in frog skeletal muscle. Comp. Biochem. Physiol. 64C: 237-241.

Punzo, F., J. Leveglia, D. Lohr and P.A. Dahm. 1979. Organochlorine insecticide residues in amphibians and reptiles from the southwestern United States. Bull. Environ. Contam. Toxicol. 21: 842-848.

Rajendra, W., C. Sree Ramulu Chetty, R. Anasuya, K. Indira and K.S. Swami. 1980. Insecticide impact on contractile pattern of amphibian skeletal muscle. Current Sci. 49: 502-504.

Rane, P.D. amd D.S. Mathur. 1978. Toxicity of aldrin to *Rana cyanophlyctis* (Schn) Science and Culture 44: 128-130.

Rico, M.C., L.M. Hernandez, M.A. Gonzalez, M.A. Fernandez and M.C. Montero. 1987. Organochlorine and metal pollution in aquatic organisms in the Donana National Park during the period 1983-1986. Bull. Environ. Contam. Toxicol. 39: 1076-1083.

Rosato, P. and D.E. Ferguson. 1968. The toxicity of endrin-resistant mosquitofish to eleven species of vertebrates. Bioscience 18:783-784.

Sampath, K., P. Elango and V. Roseline. 1995. Effect of carbaryl on the levels of protein and aminoacids of common frog *Rana tigrina*. J. Environ. Biol. 16: 61-65.

Schroeder H.A. and I.H. Tipton. 1968. The human body burden of lead. Arch. Environ. Health 17: 965-978.

Schuytema, G.S., A.V. Nebeker, J.A. Peterson and W.L. Griffis. 1993. Effects of pentachlorophenol-contaminated food organisms on toxicity and bioaccumulation in the frog *Xenopus laevis*. Arch. Environ. Toxicol. 24: 359-364.

Shpun, S., J. Hoffman and U. Katz. 1992. Anuran amphibia which are not acclimable to high salt, tolerate high plasma urea. Comp. Biochem. Physiol. 103A: 473-477.

Spiers, J.M. 1949. The relation of DDT spraying to the vertebrate life of the forest. *In*: Forest Spraying and Some Effects of DDT. Ontario Dept. Lands and Forests Division of Res. Bio. Bull. 2: 141-158.

Statham, H.E., C.J. Duncan and S.J. Publicover. 1978. Dual effect of 2,4-nitrophenol on the spontaneous release of transmitter at the frog neuromuscular junction. Biochem. Pharmacol. 27: 2199-2202.

Suzuki, K.T. and H. Akitoma. 1983. Difference in relative isometallothionein ratio between adult and larva of cadmium-loaded bullfrog *Rana catesbeiana*. Comp. Biochem. Physiol. 75C: 211-215.

Suzuki, K.T. and Y. Tanaka. 1983. Induction of metallothionein and effect on essential metals in cadmium-loaded frog *Xenopus laevis*. Comp. Biochem.Physiol. 74C: 311-317.

Suzuki, K.T., N. Itoh, K. Ohta and H. Sunaga. 1986. Amphibian metallothionein induction in the frogs *Rana japonica*, *R. nigromaculata* and *Rhacophorus schlegelii*. Comp. Biochem. Physiol. 83C: 253-259.

Taban, C.H., M. Cathieni and P. Burkard. 1982. Changes in newt brain caused by zinc water-pollution. Experientia 38: 683-685.

Tomar, V. and A.K. Pandey. 1988. Sublethal toxicity of an insecticide to the epidermal melanophores of *Rana* tadpoles. Bull. Environ. Toxicol. 41: 582-588.

Tarzwell, C.M. 1950. Effects of DDT mosquito larvaciding on wildlife. V. Effects on fishes of the routine manual and airplane application of DDT and other mosquito larvicides. Public Health Rept. 65: 231-255.

Terhivuo. J., M. Lodenius, P. Nuorteva and E. Tulisalo. 1984. Mercury content of common frogs (*Rana temporaria*) and common toads (*Bufo bufo* L.) collected in southern Finland. Ann. Zool. Fennici 21: 41-44.

van den Bercken, J. and L.M.A. Akkermans. 1971. Temperature and the effect of DDT on the lateral line organ of *Xenopus laevis*. *In*: E. Broda (ed). Proc. 1st ur. Biophys. Congr. Verlag Wiener Med. Akad., Vienna, Austria. Vol. 5. pp 173-177.

Vinson. S.B., C.E. Boyd and D.E. Ferguson. 1963. Aldrin toxicity and possible cross-resistance in cricket frogs. Herpetologica 19: 77-80.

Webb. G.D., R.W. Sharp and J.D. Feldman. 1979. Effect of insecticides on the short-circuit current and resistance of isolated frog skin. Pestic. Biochem. Physiol. 0: 23-30.

Whitacre. D.M. and G.W. Ware. 1967. Retention of vaporized lindane by plants and animals. J. Agr. Food Chem. 15: 492-496.

Wohlgemuth, E. and J. Trnkova. 1979. Dispersal and effects of a preparation containing endrin in an artificial water reservoir. Folia Zoologica 28: 65-72.

Woodham, D.W., H.F. Robinson, R.G. Reeves, C.A. Bond and H. Richardson. 1977. Monitoring agricultural insecticides in the cooperative cotton pest management program in Arizona, 1971 - first year study. Pestic. Monitor. J. 10: 159-167.

Yasmeen, N. and Nayeemunnisa. 1986. Brain lactate dehydrogenase as a function of methyl parathion exposure in the developing tadpoles of frog, *Rana cyanophlyctis*. Current Sci. 55: 292-294.

Yorio, T. and P.J. Bentley. 1973. The effects of methyl mercury compounds on the skin (*in vitro*) of the leopard frog (*Rana pipiens*). Comp. Gen. Pharmac. 4: 167-174.

Zettergren, L.D., B.W. Boldt and L.S. Schmid. 1988. Cellular and serum immune response to dinitrophenol in adult *Rana pipiens*. Develop. Compar. Immunol. 11: 99-107.