DUKE POWER COMPANY
P.O. BOX 33189
CHARLOTTE, N.C. 28242

WILLIAM A. HALLER
MANAGER
NUCLEAR TECHNICAL SERVICES
(704) 373-8500

November 7, 1989

Ms. Nancy Weatherup
Industrial and Agricultural Wastewater Division
Bureau of Water Pollution Control
Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

Subject: Request for Additional Information
NPDES Permit Renewal for
Catawba Nuclear Station (SC0004278)
File: CN-702.13

Dear Ms. Weatherup:

On July 7, 1989 you requested additional information in order to draft the renewal NPDES permit for the Catawba Nuclear Station. The letter specified that the information was to be submitted within 60 days. On August 14, 1989 we requested a 60-day extension to develop and adequately present the requested information.

Please find attached the requested additional information. This information should be considered as supplemental to the NPDES permit renewal application submitted November 8, 1988.

Should you have any questions or desire additional information, please contact J. S. Carter [(704) 373-2310] or M. C. Griggs [(704) 373-7080.

Sincerely,

W A Haller

W. A. Haller, Manager
Nuclear Technical Services

Attachments

WTG/TSC/rmb:0458

cc: NRC Document Control Desk

C001
1/1

bc: J.S. Carter
M.C. Griggs
T.S. Carpenter
R.E. Lewis
G.S. Rice
R.W. Eaker
S. Biswas
R.M. Propst
C.L. Therrien
S.D. Davenport
R.M. Glover
R.R. Wylie
D.A. Braatz
Staff (route)
CN-3000.02-01

Catawba Nuclear Station
Response to DHEC Request for Additional Information
NPDES Permit SC0004278 Reissuance

1. Request to continue the 316(a) variance.

A 316(a) study was submitted on September 15, 1988. No official response has been received. Plant operating conditions and load factors are unchanged and are expected to remain so for the term of the reissued permit. As a result of discussions with the Department of Health and Environmental Control (DHEC), the biologists of the S.C. Wildlife and Marine Resources Department were consulted on design of a fisheries program. A proposed aquatic environmental monitoring program for Lake Wylie (Attachment 1) was developed and submitted on August 8, 1989 which includes the fishery program. Duke Power Company is not aware of any changes to plant discharges or other discharges in the plant site area which could interact with the thermal discharge. There have been no changes to the biotic community of Lake Wylie that would impact the previous demonstration.

Duke therefore requests a 316(a) variance based on the submitted study.

2. Provide all waste stream sources and their associated daily flows.

The Conventional Wastewater Treatment (WC) System (Discharge 002) receives and treats essentially only low volume waste. The wastes, described in the renewal application submitted November 8, 1988, include water treatment room wastes, floor drains, laboratory drains, process drainage, and equipment leakage and drainage. The only non-low volume waste flows into the system are from three (3) secondary containment sumps and rainfall which falls directly onto the ponds. These sumps contain a volume of 10,000 gallons each, and intercept the yard drain system such that spills of less than 10,000 gallons and minor volumes from rain storms will be routed to the WC System to prevent unauthorized discharges. Significant rainfall flows will still be discharged directly to the Standby Nuclear Service Water Pond (SNSWP) and Lake Wylie. The purpose of allowing significant rain water flow to continue to discharge to the SNSWP and Lake Wylie is to prevent overloading the WC System.

The WC System treats the low volume wastes by batches in the five (5) million gallon settling basins. The only non-low volume waste included in a batch would be approximately 30,000 gallons of rain water from the three (3) sumps and rainfall directly onto the ponds during a storm event.

In addition to the regeneration and surfactant washing of the demineralizer resin described in the November 8, 1988 renewal application, as routine maintenance, each demineralizer bed is cleaned with a solution of common salt (NaCl). The cleaning occurs once or twice a year per demineralizer with a ten (10) percent solution of salt. Each cleaning uses approximately 4500 pounds of salt. The wastewater is discharged to the WC system.

A discharge, additional to those described in the November 8, 1988 renewal application, is the Low Pressure Service Water pump strainer backwash flow. (This is in addition to the intake screen backwash flow described in the renewal application.) Flow is from Lake Wylie through the trash racks, traveling screens, intake pumps, and then the pump strainers prior to entering the plant. There are two (2) strainers. Each strainer is automatically backwashed upon reaching a differential pressure of 4 psi. Design flow is 33,000 gpm into a collection sump that pumps the water to Lake Wylie. The debris collected from the strainers is placed in sanitary containers and transported to a licensed sanitary landfill. No chemicals are used in the backwash water.

3. Provide storm related flows.

The 10 year 24-hour rainfall for the Catawba area is five (5) inches.

i. Rainfall directly on the pond surface.

Surface area of Initial Holdup Pond (IHP) is 11,500 ft^2;
Surface area of each Settling Basin is 103,000 ft^2
Surface area of Final Holdup Pond (FHP) is 33,900 ft^2
Total surface area receiving direct rainfall is 148,400 ft^2

10-year 24-hour rain directly onto ponds

$$\frac{(5\ in)}{(12\ in/ft)}(148{,}400\ ft^2)\frac{(7.48\ gal/ft^3)}{10^6} = 0.46\ MGD$$

ii. All rainfall related flows to the facility

The Catawba Nuclear Station site covers 319 acres. Total runoff, conservatively assuming the ground is totally impervious and there is no infiltration, from the 10-year 24-hour event equals

$$\frac{(5\ in)}{(12\ in/ft)}(319\ acres)(43{,}560\ ft^2/acre)\frac{(7.48\ gal/ft^3)}{10^6} = 43.3\ MGD$$

Of the 43.3 MGD runoff, only 30,000 gallons is routed to the treatment facility; the remainder, by design of the secondary containment system, discharges to the SNSWP and Lake Wylie. (See response 2.)

The normal annual average rainfall is approximately 43 inches/year = 0.1178 inches/day. Runoff would therefore average

$$\frac{(0.1178\ in)}{(12\ in/ft)}(319\ acres)(43{,}560\ ft^2/acre)\frac{(7.48\ gal/ft^3)}{10^6} = 1.02\ MGD$$

iii. Maximum dry weather waste stream flow to the facility

The WC System is used to treat low volume wastes in 5 million gallon batches. When the 10-year 24-hour event occurs, the basin will contain 0.49 million gallons of rain water and 4.51 million gallons of low volume waste. Descriptions of the input waste streams are identified in our NPDES permit renewal application submitted November 8, 1988.

Based on our review and understanding of the requested information, the WC System at the Catawba Nuclear Station provides the minimum level of treatment to meet effluent limitations.

4. List of cooling water additives used or planned to be used in the next five years.

Additives currently used in the cooling towers with the associated discharge concentrations include:

Sulfuric Acid	Discharge pH limits of >6 and <9 Standard Units
Sodium Hypochlorite/ Chlorine	Free available chlorine limits of 0.2/ 0.5 avg./max., respectively, for up to two (2) hours and neither free available nor total residual chlorine for greater than two (2) hours per unit prior to mixing with any other waste stream, per the current NPDES permit.
Buckman Bulab 6002	0.43 mg/l (less than the 96LC50 concentration for general fish populations prior to entering Lake Wylie.)
Calgon PCL-2000	30 mg/l in cooling towers, approved but not discharged to date.
Calgon CL-1245	Approved for use but not discharged to date.

Other biocides approved but not used in the cooling towers to date include the following. The approved discharge concentration is less than the 96LC50 concentration for general fish populations prior to entering Lake Wylie. Discharging at "less than the 96LC50 concentration for general fish populations" is part of the criteria for alternate biocides agreed upon in November 1983 (criteria included in Attachment 2).

Betz Slimicide C79
Calgon H-130
Calgon H-640
Drew Biosperse 216

Drew Biosperse 288

Approved for use in cleaning the Nuclear Service Water System pump bearings are an acid/ammonium biflouride and neutralizer [i.e., sodium carbonate (soda ash)] solutions. Limitations for the pump pit prior to release to Lake Wylie is pH, >6 and <9 standard units and iron and copper concentrations, attributable to cleaning process, <1.0 mg/l, each.

Betz Clam-Trol CT-1 has been approved, but not yet discharged, through the Nuclear Service Water System. The approved discharge concentration is 0.41 mg/l. A higher discharge concentration has been requested based on the results of toxicity testing for intermittent exposures.

The renewal application submitted November 8, 1988 listed the chemicals that are, or may be, in Discharges 002 and 004. The following discussion concerns those classes of chemicals that are, or may be, used in closed cooling systems and discharged through Discharges 002 and/or 004 as a result of equipment leakage and/or system drainage or feed/bleed operations. Those chemicals described in the renewal application that are listed as hazardous are described in the following item 5.

Additives that are, or may be, used in cooling systems that can be discharged through Outfalls 001, 002, and/or 004 include corrosion inhibitors containing, alone or in combination, benzotriazole, borates (i.e., borax, etc.), molybdates, nitrites (i.e., sodium nitrite, etc.), phosphates, polyphosphates, silicates, zinc, mercaptobenzothiazole, sulfite (i.e., sodium sulfite, etc.), tolytriazole, Calgon CS, and Betz Clam-Trol CT-1. Use will be according to the vendors' recommendations, but the discharge concentration is unknown. As described in the November 8, 1988 renewal application, discharge will be the result of equipment leakage and/or system drainage or feed/bleed operations. The discharge concentrations are expected to be low.

The above discussion concerns those additives that are, or may be, used in the next five (5) years. New, better products are constantly being researched and developed by the vendors. As these products are introduced to the market, they are evaluated to determine the effectiveness and economics of use. Should it be decided to utilize any of these new products, approval will be requested prior to their use.

Attached is the available toxicity information on the additives (Attachment 2).

5. List of hazardous substances that are discharged, by outfall.

The following are the hazardous substances located at the Catawba Site that could be discharged in greater than reportable quantities (RQ) in a 24 hour period. These will require identification in this renewal to be considered "federally permitted". The permit renewal application submitted November 8, 1988 provides a more complete description of the outfalls and their associated waste streams.

OUTFALL	HAZARDOUS SUBSTANCE	COMMENTS
001	sodium nitrite	This substance is discharged in low concentrations and is a result of system leaks.
001	sodium hydroxide sodium hypochlorite sulfuric acid	These substances are used in the cooling towers and would be discharged during cooling tower blowdown. They are presently controlled with existing permit effluent limits.
002	hydrazine	The Effluent limit for this substance was obtained November 1, 1988.
002	sodium hypochlorite calcium hypochlorite	These substances can be used for oxidation in the Conventional Wastewater Treatment System (WC) when necessary.
002	sodium hydroxide sulfuric acid	These substances will be effectively neutralized prior to discharge from the Conventional Wastewater Treatment System.
002	Sodium Nitrite	This substance results from the drainage of systems as discussed in the permit renewal application.
003	sodium hypochlorite calcium hypochlorite	These substances are used for disinfection in the Sanitary Waste Treatment System (WT).
004	hydrazine	Effluent limits were obtained for this substance November 1, 1988.
004	sodium nitrite	This substance would be drained from closed loop systems. Refer to section 004 of the permit renewal application.
004	sodium hydroxide sulfuric acid	These substance are used in the laboratories and are also found in the cleansers used in the station.

OUTFALL	HAZARDOUS SUBSTANCE	COMMENTS
004	sodium hypochlorite calcium hypochlorite	These substances will be used for oxidation when such treatment is necessary.
005	sulfuric acid	This acid is used for chemical metals cleaning and would be effectively neutralized prior to discharge.

In addition to the above substances, there are hazardous substances located on site that may be in our systems but that would be discharged in less than reportable quantities. These are listed as Attachment 3. These substances are primarily labaratory chemicals and commercial cleansers and could be subject to change. These chemicals are discharged in very low concentrations.

Also included with Attachment 3 are other chemical substances that are not listed as hazardous but that are used or maintained on site and that may be present in the discharges. They include metals cleaning chemicals, biocides, and other bulk chemicals. A spill or drainage from a system of one of these substances could result in a discharge in low concentrations via the listed outfall. These substances have been identified in the narrative section of the permit renewal application submitted November 8, 1988.

ATTACHMENT 1

316(a) VARIANCE-RELATED INFORMATION

Duke Power Company
NUCLEAR PRODUCTION DEPARTMENT
P.O. BOX 33189, 422 SOUTH CHURCH STREET
CHARLOTTE, N.C. 28242
(704) 373-4011

August 8, 1989

Ms. Nancy Weatherup
South Carolina Department of Health
  and Environmental Control
2600 Bull Street
Columbia, S. C. 29201

Subject: Catawba Nuclear Station
Renewal of NPDES Permit (#SC0004278) and
Approval of 316(a)
File: CN-702.12

Dear Ms. Weatherup:

Per your request, additional information needed for renewal of the National Pollution Discharge Elimination System (NPDES) permit and approval of the 316(a) demonstration for Catawba Nuclear Station (CNS) follows for your review. Included are:

(1) recommendations for alteration of the differential thermal limits for the monthly average water temperature rise above ambient for Outfall 001 in the new NPDES permit, and

(2) a proposal to continue aquatic environmental monitoring of Lake Wylie.

Your agency suggested a reduction of the present differential thermal limits (a monthly average water temperature rise above ambient of 13.2° F from April through September and 36.1° F from October through March), because of the large difference between the current thermal limits and the temperature CNS has actually produced. Based on past and anticipated operation of CNS we concur that the differential thermal limits can be reduced for Outfall 001 and propose the following limits (Attachment 1):

A monthly average water temperature rise above ambient of 13.0° F from May through October and 20.0° F from November through April (ambient water temperature measured at the CNS intake and discharge water temperature measured at Outfall 001).

The proposed aquatic environmental monitoring program for Lake Wylie (Attachment 2) will maintain a continuity with past 316(a) studies. Biologists of the S. C. Wildlife and Marine Resources Department were consulted on design of the fisheries program. Other biological programs and the chemistry program reduce the frequency of sampling of certain variables, while increasing the number of locations monitored throughout the lake.

This proposed sampling within Lake Wylie will increase the utility of data collected during the long-term monitoring program for Duke Power Company, as well as for your agency.

Please forward any questions or concerns to Ron Lewis at (704) 373-5763.

J. S. Carter

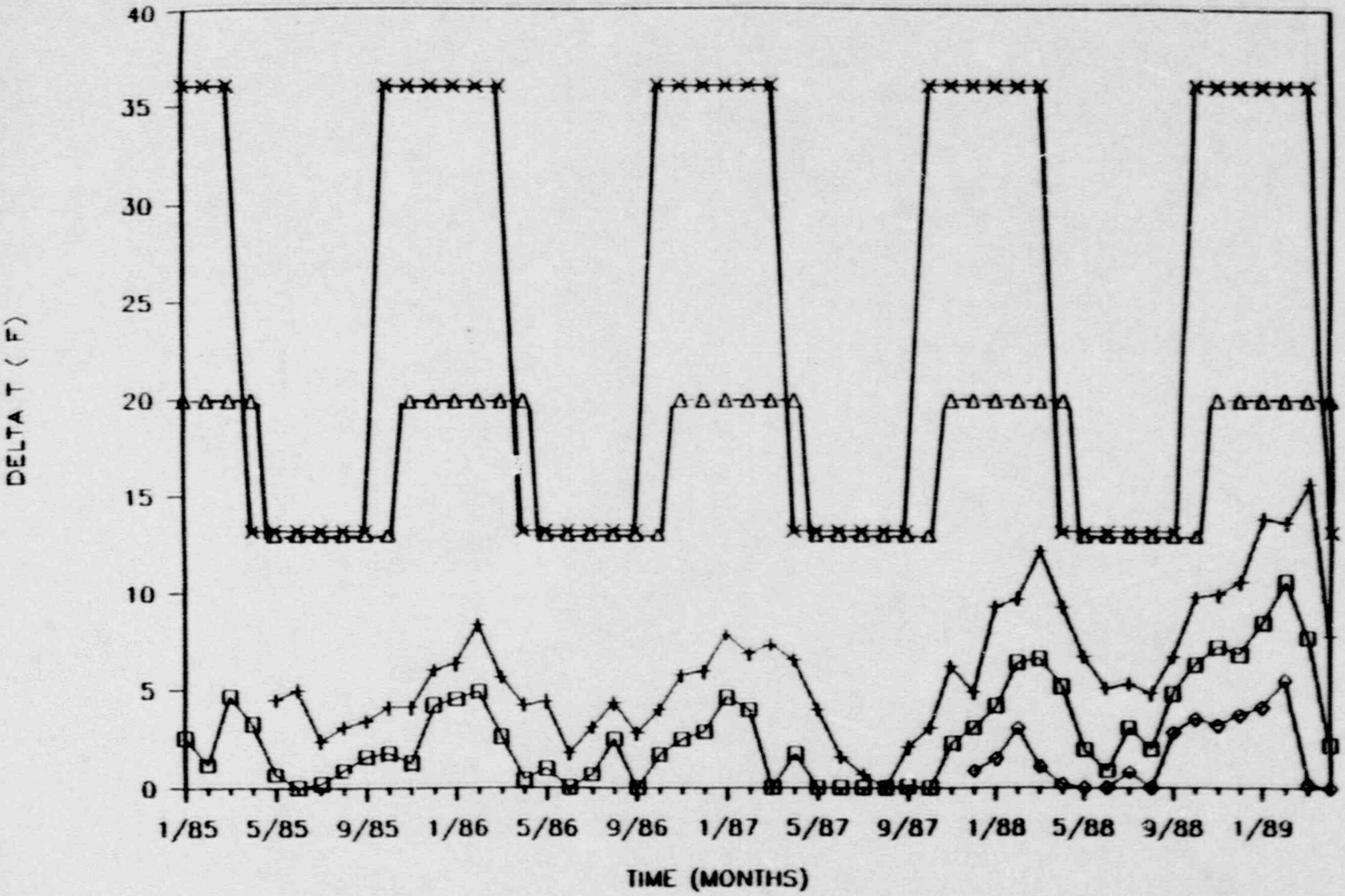
J. S. Carter, Technical System Manager
Nuclear Environmental Compliance

REL/ggb:0246

Attachments

TEMPERATURE VS. TIME & THERMAL LIMITS

CATAWBA NUCLEAR STATION OUTFALL 001



The maximum (plus), minimum (diamond), and average (square) monthly water temperature rise above ambient, Delta T (°F), from January 1985 through January 1989 at Catawba Nuclear Station Outfall 001. X = current and Δ = proposed differential thermal limits.

ATTACHMENT 1

ATTACHMENT 2

LAKE WYLIE

AQUATIC ENVIRONMENTAL MONITORING PROGRAM

July 1989

Duke Power Company
Production Environmental Services
Route 4, Box 531
Huntersville, North Carolina 28078

704-875-5000

WATER QUALITY

The objectives of the Lake Wylie Water Quality Monitoring Program are:

1. To meet the State of South Carolina Department of Health and Environmental Control's requirement to continue a water quality monitoring program on Lake Wylie.

2. To provide continuity of water quality monitoring and data collection for use in assessing nuclear and fossil plant operational impacts on water quality.

3. To provide a database to detect changes in lake water quality that may impact the operation of Duke Power Company facilities.

Details of the water quality monitoring program, including variables, sampling frequency, and station locations, are summarized in Table 1.

Sampling locations are identified on Figure 1.

Sampling and analytical methods will be consistent with EPA approved procedures, and with the Catawba Nuclear Station 316(a) Demonstration.

Table 1. Lake Wylie water quality monitoring program.

Sample Locations/Depths	180.0	200.0	210.0	215.0	220.0	225.0	235.0	242.0	249.0	250.0	260.0	272.0
Parameters	(0.3 m)	(20.0 m)	(15.0 m)	(10.0 m)	(15.0 m)	(15.0 m)	(10.0 m)	(5.0 m)	(5 m)	(5 m)	(0.3 m)	(0.3 m)
In-Situ Analyses												
Temperature	S/T/1	S/P/1	B/P/1	B/P/1	B/P/1	B/P/1	B/P/1	S/P/1	B/T/1	S/P/1	S/T/1	B/T/1
Dissolved Oxygen	S/T/1	S/P/1	B/P/1	B/P/1	B/P/1	B/P/1	B/P/1	S/P/1	B/T/1	S/P/1	S/T/1	B/T/1
pH	S/T/1	S/P/1	B/P/1	B/P/1	B/P/1	B/P/1	B/P/1	S/P/1	B/T/1	S/P/1	S/T/1	B/T/1
Specific Conductance	S/T/1	S/P/1	B/P/1	B/P/1	B/P/1	B/P/1	B/P/1	S/P/1	B/T/1	S/P/1	S/T/1	B/T/1
Redox	S/T/1	S/P/1	B/P/1	B/P/1	B/P/1	B/P/1	B/P/1	S/P/1	B/T/1	S/P/1	S/T/1	B/T/1
Nutrient Analyses												
Ammonia	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Nitrate + Nitrite	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Orthophosphate	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Total Phosphorus	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Chloride	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Silica	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Elemental Analyses												
Aluminum*	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Cadmium	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Calcium*	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Copper	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Chromium	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Iron*	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Lead	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Magnesium*	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Manganese	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Potassium*	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Sodium*	S/T/1	S/TB/1	[illegible]	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Zinc	S/T/1	S/TB/1	Q/P/1	Q/P/1	Q/P/1	S/TB/1	S/TB/1	S/TB/1	S/T/1	S/TB/1		B/T/1
Additional Analyses												
Alkalinity	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Turbidity	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TP/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Sulfate	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Total Organic Carbon	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Total Dissolved Solids	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1
Total Suspended Solids	S/T/1	S/TB/1	B/P/1	B/P/1	B/P/1	B/TB/1	B/TB/1	S/TB/1	B/T/1	S/TB/1		B/T/1

[illegible]

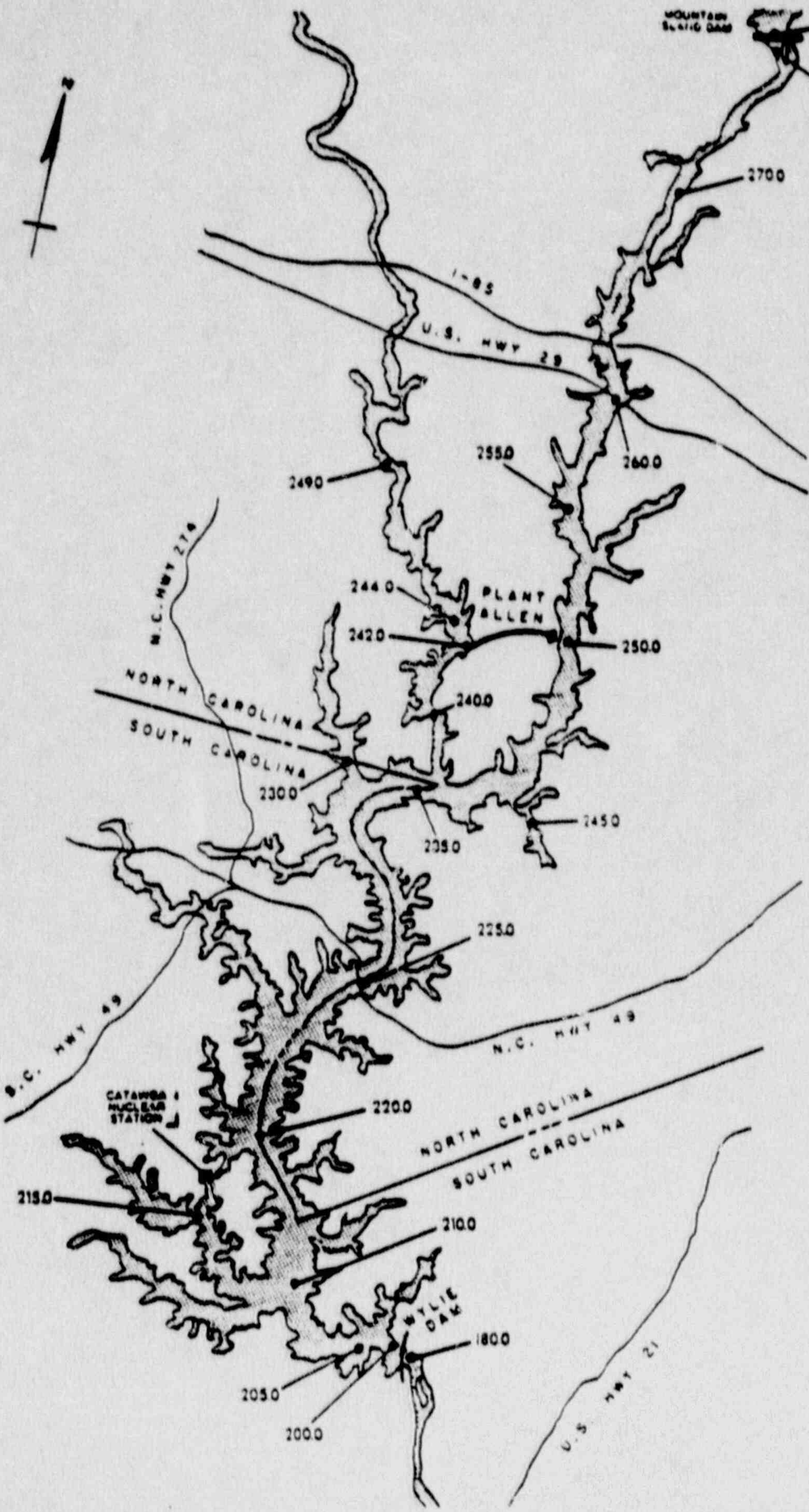


Figure 1. Lake Wylie water quality monitoring stations.

FISHERIES

The objective of the Lake Wylie Fisheries Program is to ensure that power plant operations do not adversely affect the Lake Wylie fish community. This will be accomplished with a fisheries monitoring program, and a fisheries special study program. The monitoring program will be as follows:

1) Shoreline electrofishing at Locations 215 and 225 (SC side). Samples will be collected in a 1000-m shoreline segment at each location during daylight in January, April, July, and October annually. Fish collected will be identified, measured, and returned to the lake. Data will be presented as number of fish per distance sampled by species, species composition, and a length frequency histogram for largemouth bass and bluegill.

2) Fish will be collected from Locations 215 and 225 during the electrofishing sampling for metals and chlorinated hydrocarbon testing of muscle tissue (muscle tissue from largemouth bass and catfish in April, annually).

3) Respond to fish kills and address questions about the fishery as needed.

The special studies may include ary or all of the following:

1) Density and distribution of fish in the thermal plume of CNS during winter and summer. Fish may be attracted to the thermal plume of CNS during the winter, and may move out of the plume during the warmer summer period. Hydroacoustics will be used to determine fish distribution and density during December 1989, and January, February, March, June, July, August, and September 1990 to determine whether fish are attracted to, or avoid the CNS discharge during these periods of the year. Results of this study may require additional studies if avoidance is observed during the summer.

2) Creel survey lakewide in 1991 or 1992. This creel will allow us to determine the overall health of the fishery, compare the fishery with past creels conducted prior to and during the initial startup of CNS, and pinpoint changes in the gamefish community. This creel may be a cooperative program with South Carolina Wildlife and Marine Resources and/or North Carolina Wildlife Resources.

3) Forage fish abundance and distribution lakewide in September 1990 with purse seine and hydroacoustics to measure lakewide distributions, and relate to the densities in the CNS discharge.

MACROINVERTEBRATES

The objectives of the Lake Wylie Macroinvertebrate Monitoring Program are to:

1. Track the density and composition of the benthic community in the vicinity of Catawba Nuclear Station through long-term monitoring.

2. Support the results of toxicity testing at the CNS discharge.

Macroinvertebrate samples will be taken with Petersen grab, in triplicate, in the littoral zone (3-4 m depth). Samples will be taken every March, July, and November, at four locations (Figure 2):

215.0	(SE side of Big Allison Cr.)
210.0	(control)
215.6	(discharge canal)
215.7	(discharge canal)

Macroinvertebrates will be counted and identified to the lowest practical level. Data will be summarized as mean density (Number/m^2) per taxon.

PHYTOPLANKTON AND ZOOPLANKTON

The objective of the Lake Wylie phytoplankton and zooplankton monitoring program is to maintain a degree of continuity with the Catawba Nuclear Station 316(a) Demonstration, in assessing long-term impacts of plant operation on plankton populations.

Phytoplankton and zooplankton populations and chlorophyll a will be sampled bi-monthly at Locations 210.0, 215.0 (Allison Cr. near CNS discharge), 220.0 (mid-channel, out from CNS intake), 235.0 (confluence of South Fork and Catawba R.), 242.0 (Allen disch.), and 250.0 (Allen intake).

Water samples will be collected at five-meter intervals to the bottom at all locations, except location 242.0, where a surface sample will be collected. A single bottom to surface zooplankton tow will be taken at each location.

RESULTS

The Lake Wylie aquatic environmental monitoring results will be summarized on an annual basis, and made available on request.

ATTACHMENT 2

CHEMICAL ADDITIVE

TOXICITY INFORMATION

CATAWBA NUCLEAR STATION

CRITERIA FOR ALTERNATE
BIOCIDES FOR COOLING TOWERS

1. Will be used only when chlorination is ineffective in controlling excessive algae growth (or other microbiological fouling).

2. Contains no heavy metals.

3. Has short term degradation rate (either due to hydrolytic decomposition or biodegradation).

4. Meets limits on the 126 toxic pollutants.

5. Will be discharged to receiving waters at concentrations less than 96 hour LC-50 values for general fish populations.

PWD/nem
11-09-83

NOTE: Criteria for approval of alternate biocides agreed upon in November 10, 1983 meeting between SCDHEC and Duke Power Company.

Buckman

Buckman Laboratories, Inc.
Buckman Laboratories International, Inc.

Toxicity Profile

TP-6002-U (10/83)

BULAB® 6002

Poly[oxyethylene(dimethyliminio)ethylene-(dimethyliminio)ethylene dichloride]

Health and Safety Studies

Acute Oral LD_{50}: *Rats,* male: 3690 mg/kg; female: 1850 mg/kg.

Eye Irritation Study:
Produced minimal transient ocular irritation in the form of erythema, chemosis, and discharge.

Acute Inhalation Study:
Rats survived the 14 day observation period after a one hour exposure to 26.4 mg/L of air with a flow rate of 5 L/min.

Dermal LD_{50}: Greater than 2000 mg/kg, slight skin irritation.

Human Patch Tests: No signs of irritation.

90-Day Chronic Feeding Study:
No toxic effects were noted on rats fed on diets containing 0, 2.7, 27, and 270 ppm over a 90-day period.

Subacute Dermal Toxicity Study:
No gross or histopathological changes of significance in rabbits were noted at 192 and 960 ppm in 21 days.

Skin Sensitization: *Guinea Pigs:* no skin sensitivity.

Teratology Study:
Rats: No effects when administered during organogenesis; some toxic effects due to dosage level when administered during early gestation but no teratogenic effects.

Fish and Wildlife Studies

96-Hour LC_{50} in Fish:
Rainbow Trout: 0.43 ppm.
Bluegill Sunfish: 0.45 ppm.

Acute Oral LD_{50} in Birds: *Bob White Quail:* 1.0 mL/kg.

Dietary LC_{50} in Birds: *Mallard Ducks:* greater than 20,000 ppm.

24-, 48-, and 96-Hour LC_{50} in Invertebrates:
Daphnia: 0.188 ppm, 0.162 ppm, and 0.134 ppm for 24, 48, and 96 hours, respectively.

NOTE: Bulab 6002 is a solution containing 60% active ingredient and the above tests were performed, and the results are expressed, in parts of the 60% active product as received by the testing laboratory.

1256 N. McLean/Memphis, Tenn. 38108 U.S.A./901-278-0330/Telex 5-3868/Cable Bulab
Buckman Laboratories also in: Australia, Belgium, Brazil, Canada, Japan, Mexico, South Africa.

CALGON CORPORATION

SUBSIDIARY OF MERCK & CO., INC.

WATER MANAGEMENT DIVISION CALGON CORPORATION 1515 MOCKINGBIRD LANE SUITE 415 CHARLOTTE, NC 282[illegible] (704) 525-2545

September 19, 1989

Dr. Raj Biswas
Duke Power Company
P. O. Box 33189
Charlotte, NC 28242

Good Morning Raj:

Listed below is the toxicity data for Calgon PCL-2000 Dispersant:

	48 Hr. LC_{50}	96 Hr. LC_{50}
Bluegill Sunfish	19,000 mg/l	16,500 mg/l
Daphnia Magna	590 mg/l	---

I hope this information is suitable and complete. Should further questions arise, please do not hesitate to contact me.

Sincerely,

Ed Perdue

EP/fm

cc: Mr. Gary Ward

CALGON CORPORATION
SUBSIDIARY OF MERCK & CO., INC.

PWD

WATER MANAGEMENT DIVISION CALGON CORPORATION CALGON CENTER BOX 1346 PITTSBURGH, PA 15230 (412) 777-8000

Writer's Direct Dial Number
777-8649

May 7, 1986

Mr. R. W. Eaker
Duke Power Company
Nuclear Production Department
P.O. Box 33189
422 South Church Street
Charlotte, NC 28242

Dear Mr. Eaker:

This is in response to your request for information on our products: pHreeGUARD 2350, pHreeGUARD 2005C, CL-1245 and CL-1624. These products do not contain any of the 126 pollutants as listed in CFR 423.

Concerning the toxicity of these products, the following information is for your confidential use only.

For pHreeGUARD 2350 Table I will provide you with available toxicity information on the ingredients present in the product since toxicity data on the formulated product is not available.

Regarding the pHreeGUARD 2005C, this product is an alkaline solution containing 30% potassium phosphate salts, approximately 35% of a copolymer and small amount of tolytriazole. Because of its alkalinity I would expect it to be irritating to the skin and eyes. The copolymer used is low in toxicity having an LD_{50} greater than 5 g/kg and is non-irritating to the skin and eyes. One of the potassium phosphates was found to be a mild irritant to skin and eyes. Information on the sodium tolytriazole can be found in Table I.

For CL-1245 no mammalian toxicity information is found on the product. Some of the ingredients such as the organic phosphates are found also in pHreeGUARD 2350 and the toxicity information on these ingredients are found in Table I. The aquatic toxicity on CL-1245 is as follows:

Bluegill Sunfish (96 Hour LC_{50})	- 420 ppm
Rainbow Trout (96 Hour LC_{50})	- 620 ppm
Daphnia Magna (48 Hour LC_{50})	- >1000 ppm

Also, toxicity information on a very similar product shows that:

a) It is not toxic through ingestion. The acute oral LD_{50} - rats is > 3.0 ml/kg.

b) It is not toxic through dermal absorption. The acute dermal LD_{50} - rabbits is > 2.0 ml/kg.

c) It is not irritating to the skin. The Primary Irritation Index is 0.0/8.

CL-1624 also contains the organic phosphonates and the sodium tolytriazole. However, this product is more alkaline with additional sodium hydroxide and would be expected to be severely irritating to skin and eyes.

Enclosed are Material Safety Data Sheets covering these products. I trust the above information will be helpful to you. If there is anything further that I can do, please let me know.

Sincerely,

CALGON CORPORATION

Herman A. Birnbaum

Herman A. Birnbaum, Manager
Toxicology & Environmental Science

HAB:cm
(hbre0506)

cc: Mr. Gary Barker
Duke Power Company

TECHNICAL TERBUTHYLAZINE

— data for concentrated active

Chemical Identity: Terbuthylazine: 2-(tert-butylamino)-4-chloro-6-(ethylamino)-s-triazine (CASRN 5915-41-3), 96% min.

Use: This product is registered under FIFRA for use in formulating microbiocides, EPA Reg. No. 40810-8.

Chemical/Physical Properties:

Appearance: White powder
Odor: Slight vanilla-like odor
Melting point: 177-179°C
Vapor pressure: 1.12 x 10^{-6} mm Hg at 20°C
Volatility, saturated vapor concentration: 1.4 x 10^{-2} mg/m^3 at 20°C
Density: 1.19 g/cc at 20°C
Solubility at 20°C: Water - 8.5 ppm (some publications indicate 5 ppm)
Dimethyl formamide - 10%
Ethyl acetate - 4%
Diacetone alcohol - 2%
Isopropanol, xylene - 1%
pK value: 2.0 at 21°C
Octanol/water partition coefficient: log P 3.04 (determined by HPLC)

Ecotoxicological Studies

1. **Acute Fish Toxicity** - The acute 96 hour LC50 was determined:

   Bluegill . . . . 7.6 (7.6-7.6) ppm
   Rainbow trout . . . . 3.6 (3.1-4.2) ppm

2. **Acute Invertebrate Toxicity** - The acute 48 hour EC50 was determined:

   Daphnia magna (Straus 1820) . . . . 39.4 (29.2-56.4) ppm

3. **Acute and Dietary Avian Toxicity**

   Acute oral LD50, Mallard duck . . . . greater than 2510 mg/kg
   Eight-day dietary LC50, Bobwhite quail . . . greater than 5620 ppm
   Eight-day dietary LC50, Mallard duck . . . . greater than 5620 ppm

4. **Hydrolysis Study** - Terbuthylazine was tested at 10 ppm in buffered solutions of pH 5, 7, and 9 at temperatures from 30 to 70°C. There was no significant hydrolysis after 25 days at pH 7 or 9 at any temperature. At pH 5, the half-life ranged from 82 hours at 70°C t 980 hours at 30°C; the respective rate contents are 2.36 x 10^{-6} and 1.97 x 10^{-7}. The major hydrolytic product was 2-(tert-butylamino)-4-(ethylamino)-6-hydroxy-s-triazine.

5. **Photodegradation in Water** - Terbuthylazine was dosed at a level of 5 ppm into bidistilled and buffered water (pH 7.0) at a temperature of 25°C. The solution was exposed to a mercury arc rated 1900 ± 100 Jm^{-2} s^{-1} at 1.3 cm, equipped with UV cutoff sleeve to eliminate wavelengths below 290 nm. The half-life of this product was 115 hours; the rate constant was 1.67 x 10^{-6} s^{-1}. The major photodegradation products were 2-(tert-butylamino)-4-(ethylamino)-6-hydroxy-s-triazine and the dealkylated derivatives.

CALGON
CORPORATION

SUBSIDIARY OF MERCK & CO., INC.

WATER MANAGEMENT DIVISION CALGON CORPORATION 1515 MOCKINGBIRD LANE SUITE 415 CHARLOTTE, NC 28209 (704) 525-2545

November 8, 1983

Mr. Parker Downing
Duke Power Company
P. O. Box 33189
Charlotte, NC 28242

Calgon Microbiocides
Fish Toxicity Values

Dear Mr. Downing:

Listed below are data showing acute TL_{50} - 96-hour fish toxicity values for some of Calgon's Microbiocides that you may want to consider using for algae/bacteria control in your Catawba Nuclear Plant cooling tower system to supplement chlorination.

	Acute TL_{50} - 96-Hour Values - mg/l			
	Flathead Minnow	Blue Gill	Rainbow	Catfish
→ H-130	--	0.5	1.1	2.6
H-133	--	7.8	6.3	--
H-300	Will be sent shortly.			
H-303	--	0.2	0.2	--
H-900	2.2	--	0.8	--

Enclosed are copies of product labels showing EPA registration numbers. Also enclosed is a copy of a paper, "The Biodegradability of Low Concentrations of Certain Quaternary Ammonium Antimicrobials by Bacteria," presented at the American Oil Chemists' Society national meeting at Los Angeles, CA, by Messrs. Gawel and Huddleston which may be of interest to you.

Very truly yours,

WATER MANAGEMENT DIVISION
CALGON CORPORATION

G. E. Starr

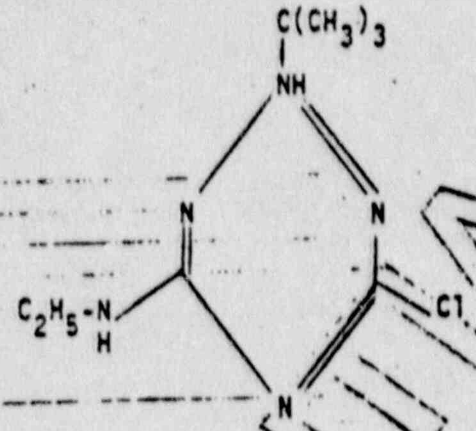
G. E. Starr

GES/fm
Enclosures

COOLING WATER MICROBIOCIDE H-640 FACT SHEET

ACTIVE INGREDIENT: 44.7% Terbuthylazine: 2-(tert-butylamino)-4-chloro-6-(ethylamino)-S-triazine

CHEMICAL STRUCTURE:



MODE OF ACTION: Interferes with ATP production thereby inhibiting photosynthesis.

DECOMPOSITION: Slowly degrades to innocuous species. H-640 hydrolyzes more rapidly at pH <5 or pH >8 or at temperatures >160°F.

TOXICITY:

Mammalian

Acute Oral (LD_{50}) Rats - 1350 mg/kg.
Acute Dermal (LD_{50}) Rabbits - >4400 mg/kg.

Aquatic

Species	Conditions	ppm
Bluegill	96 Hour	7.6 (LC_{50})
Rainbow trout	96 Hour	3.2 (LC_{50})
Daphnia magna	48 Hour	39 (IC^*_{50})

*IC = Immobilization Concentration (no movement of daphnia body or legs under a microscope).

Avian

Species	Test	LC_{50} (ppm)
Bobwhite quail	8-day dietary	5620
Mallard duck	8-day dietary	5620

Irritation

Rabbit - Not an eye or skin irritant.

4/87

CALGON CORPORATION

DEACTIVATION: Rigorous hydrolysis by addition of caustic along with UV irradiation or sustained high level chlorination will deactivate the product.

SAFETY: Refer to H-640 MSDS and product label for detailed information.

REGULATORY APPROVALS: EPA Registration for control of algae in industrial recirculating cooling water systems.

SPECIAL APPLICATION NOTES: H-640 is specific for removal and control of algae. H-640 is used to supplement an existing oxidizing or non-oxidizing biocide program. There are no known treatment incompatibilities between H-640 and Calgon's cooling water biocides. H-640 is synergistic with oxidizing biocides for algae control.

When H-640 is used to supplement another biocide which is fed continuously, feed H-640 as required at a point in the system where there is good mixing.

H-640 may also be dispersed in water and applied evenly around the edge of sump or spray pond.

COMPETITIVE INFORMATION: Drew Algistat 288

BIOSPERSE 216 (As product)

Fish Toxicity LC_{50} in ppm

Bluegill Sunfish			Fat Head Minnows			Channel Cats		
24 hr.	48 hr.	96 hr.	24 hr.	48 hr.	96 hr.	24 hr.	48 hr.	96 hr.
6.1	5.9	5.9	5.0	5.2	5.2	12.1	11.2	11.2

Drew Industrial Division
ASHLAND CHEMICAL COMPANY DIV ASHLAND OIL INC
One Drew Plaza, Boonton, New Jersey 07005

TOXICOLOGY

Extensive studies in rats and fish have determined **BIOSPERSE 288** does not present a toxic hazard under normal conditions of use.

1. Acute Studies

LD_{50}	Rabbit	4 ml/kg
LD_{50}	Rat	1350 mg/kg
LD_{50}	Mallard Duck	2510 mg/kg

2. Dietary Avian - 8 Day

LD_{50}	Mallard Duck	5620 ppm
LC_{50}	Bobwhite Quail	5260 ppm

3. Acute Fish - 96 Hour

LC_{50}	Bluegill	7.6 ppm
LC_{50}	Rainbow Trout	3.2 ppm

4. Acute Invertebrate -48 Hour

EC_{50}	Daphnia Magna	39 ppm

5. Irritation

Not skin sensitizer
Not photo sensitizer
Rabit - Not eye sensitizer
Mild skin sensitizer

NITRITE
(as Sodium Nitrite)

Species	48-hr EC50 (mg NO_2/l)	95% Confidence Interval (mg NO_2/l)
Daphnia pulex	0.94	0.013 - 2.3

Testing Performed by Duke Power Company
Applied Science Center
Bioassay Laboratory

AQUATIC TOXICITY

Calgon Corrosion Inhibitor	Species	Test Duration	Percent Active Product	LC-50
CL-5	Daphnia	48 Hours	25	380 ppm
	Bluegill Sunfish	96 Hours	100	31 ppm
	Rainbow Trout	96 Hours	100	21.4 ppm
	Fathead Minnow	96 Hours	100	15.5 ppm
[CL-5 is sodium tolytriazole (TT)]				
CL-56	Bluegill Sunfish	96 Hours	50	13.3 mg/l
	Rainbow Trout	96 Hours	50	2.88 mg/l
[CL-56 is 50% mercaptobenzothiazole (MBT)]				
CUPROSTAT	Bluegill Sunfish	96 Hours	100	11.3 ppm
	Rainbow Trout	96 Hours	100	7.1 ppm
	Daphnia Magna	48 Hours	100	46.2 ppm
LCS-30	Mosquito Fish	48 Hours	100	7.5 ppm
	Mosquito Fish	96 Hours	100	7.5 ppm
MCS Plus	Saltwater Minnow	96 Hours	100	>1000 ppm
	Mysid Shrimp	48 Hours	100	135-147 ppm

Test data on Calgon CS Corrosion Inhibitor will be forwarded to you when the information is complete.

MEMO

CALGON
SUBSIDIARY OF MERCK & CO.

TO: Ed Perdue
WMD - Charlotte,NC

FROM: Brian Laplante

SUBJECT: Aquatic Toxicity Data

DATE: 6/23/88

The available aquatic toxicity data for the two products you identified are present in the table below:

Product Name	Aquatic Toxicity Data
Corrosion Inhibitor CS	48-hr. LC50 (Daphnia magna): 500 ppm 96-hr. LC50 (bluegill sunfish): 999 ppm
C-39 Corrosion Inhibitor	48-hr. LC50 (Daphnia magna): 32 ppm

Brian T. Laplante
Health & Environmental Affairs

BTL:cm
(blep623)

Aquatic Toxicity: Adsorbed vs. Free Actives

Acute toxicity tests determining LC_{50} values for Clam-Trol CT-1 with 13% active ingredients is provided as follows:

Daphnia magna: 48 hr LC_{50} = 0.41 mg/l (.37 - .49 T.L.)

Fathead minnow: 96 hr LC_{50} = 2.9 mg/l (2.5 - 3.3 T.L.)

Bluegill Sunfish: 96 hr LC_{50} = 4.3 mg/l (4.2 - 6.6 T.L.)

Rainbow trout: 96 hr LC_{50} = 14.7 mg/l (10 - 15.5 T.L.)

The above LC_{50} values represent toxicity levels for the neat formulation when 100% of the "free" actives are available to the aquatic organism (that is, no suspended solids for adsorption of the actives).

Intermittent Exposures to *Daphnia pulex* Ranging from One to Four Hours per Day

Test Dates	Exposure to Toxicant (Hours/Day)	48-Hour EC50 (mg CT-1/L)	95% Confidence Interval (mg CT-1/L)
8/2/89-8/4/89	1	3.10	2.52 - 3.78
8/9/89-8/11/89	2	4.12	3.38 - 5.08
8/23/89-8/25/89	3	3.16	2.67 - 3.75
8/30/89-9/1/89	4	2.34	1.95 - 2.91

PMC Specialties Group, Inc.

COBRATEC® 99

BENZOTRIAZOLE

CORROSION INHIBITOR

FOR COPPER AND COPPER ALLOYS

IMPROVES PERFORMANCE OF OTHER INHIBITORS FOR OTHER METALS

TECHNICAL BULLETIN 3100

GENERAL DESCRIPTION

COBRATEC® 99 is a corrosion inhibitor for copper and copper-base alloys. It functions by reacting with copper oxide on the surface of copper or copper alloys forming a strong, insoluble polymeric complex. This complex formation results in a protective layer or film on the copper surface, 10 to 20 molecules thick, that provides both a mechanical and electrochemical barrier against corrosive attack. This protective layer has a high degree of thermal and oxidative stability and cannot be easily removed. COBRATEC® 99 complexes copper ions in solution, thereby preventing galvanic corrosion of other metals.

SUGGESTED USES

COBRATEC® 99 can be used in many applications for protecting copper and copper alloys.

Direct Treatment such as on mill products, fabricated and decorative items, statuary.

Circulating Cooling Systems such as cooling towers, air conditioning systems, cutting and grinding fluids.

Functional Fluids such as hydraulic fluids, specialty lubricants and automotive coolants.

Wrapping Tissue and box board for wrapping, interleaving, shipping and storing mill products or fabricated items.

Corrosion Preventive Coatings such as lacquers and waxes.

Cleaners such as soaps, detergents and strong alkali or acid cleaners.

METHODS OF APPLICATION

COBRATEC® 99 is incorporated in liquids at concentrations between 0.1% and 2.0%. Liquids may be either aqueous or non-aqueous. It may also be used as a solid or vapor. Convenience forms are available such as CO-20-I, CO-45-I, and CO-35-G solutions.

DESCRIPTION

Chemical Name	Benzotriazole
Synonyms	1,2,3-benzotriazole Azimidobenzene Benzene azimide
Molecular Wt.	119.12
Formula	$C_6H_5N_3$
Code	CO-99F
Order Entry No.	X18BT5585
CAS Registry No.	95-14-7

PROPERTIES

Appearance	Off white to light yellow flake	
Specific Gravity (100°C/25°C)	1.19	
	Specif.	**Typical**
Assay	98.0% min	99.5%
Moisture	0.5% max	0.1%
Ash	0.5% max	0.2%

Solubility, wt.%, 25°C:

Water	1.98
Water (60°C)	7.4
Methanol	71.6
1-Methoxy-2-Propanol	55.0
Isopropanol	53.9
Heptanol	34.6
Ethylene Glycol	50.7
Polyethylene Glycol	47.7
Methyl Ethyl Ketone	46.1
Benzene	1.3
Tetrachloroethylene	0.06
White Mineral Oil *	0.004
Turbine Oil *	0.01

* Petroluem oil formulations containing additives such as tricresyl phosphate alkylbenzenesulfonic acid derivatives will increase the apparent solubility.

AVAILABILITY

Readily available from stock in 200 lb. fiber drums. Other forms available are:

CO-99P	Benzotriazole powder
CO-20-I	20% Benzotriazole in isopropanol
CO-45-I	45% Benzotriazole in isopropanol
CO-35-G	35% Benzotriazole in propylene glycol
BT-PG	Photograde, meets ANSI specification

TOXICITY

The acute toxicity data for benzotriazole are as follows:

LD_{50} Oral (rats)	560 mg/Kg
LD_{50} Dermal (rabbits)	2g/Kg
LC_{50} Inhalation (rats)	5.7 mg/L*
Skin Irritant	Not a skin irritant
Eye Irritant	Severe irritant

*Actual concentration measured at breathing zone.

The acute aquatic toxicity data are:

96 Hr. Tim:	
Bluegill sunfish	28 mg/L.
Minnow	28 mg/L.
96 Hr. LC_{50}	
Rainbow trout	39.0 mg/L.
48 Hr. EC_{50}	
Daphnia Magna	141.6 mg/L.
96 Hr. EC_{50}	
ALGAE	15.4 mg/L.

CARCINOGENICITY:

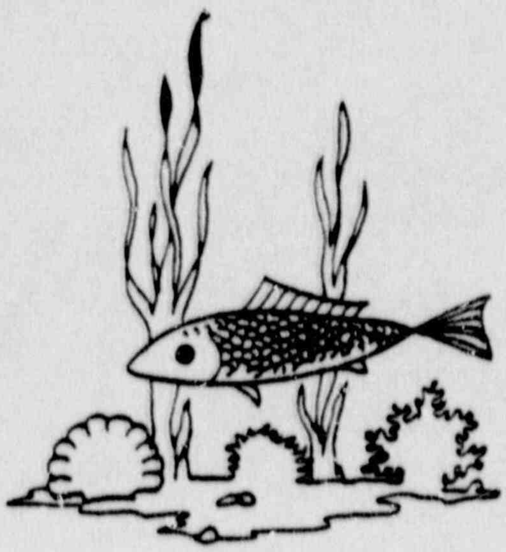
NCI-CG-TR 88 conclude that "there was no convincing evidence that under the conditions of this bioassay lH-benzotriazole was carcinogenic in B6C3F1 mice or Fischer 344 rats of either sex" (NTIS PB-285 202).

SAFE HANDLING

Good ventilation and other engineering controls should be used to minimize exposure to benzotriazole dust. If controls are not adequate, use a respirator approved by NIOSH/MSHA in dust laden areas. Wear protective clothing and gloves. Follow rules of good personal hygiene regarding handling of any chemical such as a shower and change of clothing each day after work.

WASH-1249

TOXICITY of POWER PLANT CHEMICALS to AQUATIC LIFE



JUNE 1973

UNITED STATES ATOMIC ENERGY COMMISSION

A

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sulfuric acid	"sunfish"	FW,LS	12.0	Lethal.	Belding (1927)
	Salvelinus fontinalis		6.25	Lethal in 24 hr.	
	Lepomis macrochirus		24.5	Lethal in 24 hr.	
	"minnows"		20.0	Non-toxic.	
Sulfuric acid	"fish"	FW,LS	6.0-8.0	Minimum lethal dose; distilled water, 20 C.	Leclerc (1960)
			110-120	Minimum lethal dose; hard water, 20 C.	
Sulfuric acid	Gambusia affinis	SB,FW,LS	42.0	24,48 & 96 hr-TLm, acute. (All data in turbid water; 20-24 C.)	Wallen et al. (1957)
Sulfuric acid	"pickerel"	FW	71.2	Lethal.	Anonymous (1950)
	"whitefish"		80.1	Lethal.	
	Carassius auratus		17.0	Non-toxic >4 days; soft water.	
Sulfuric acid	Carassius auratus	SB,FW,LS	169	Survived 50-70 min; hard water.	Ellis (1937)
			143	Survived 120-140 min; hard water.	
			134	Survived over 4 days; hard water.	
			143	Survived 150-317 min; soft water.	
			134	Survived 6-96 hr; soft water.	
	Daphnia magna (cladocera)		50 30-38 20	Survived 1-3 hr; 25 C. Survived 24 hr; 25 C. Survived 7 days; 25 C.	
Sulfuric acid	Clupea pallasi	CB,SW,LS	39	Killed after 8 hr; pH 6.85.	Shelford (1918)
	Cymatogaster aggregatus		65	Killed in 8 hr; pH 6.3.	
Sulfuric acid	"fish"	FW	20.0	Minimum dose lethal in 48 hr; "free" acid, 20 C.	Laurent (1955)
Sulfuric acid	"synthetic sewage"	FW,LS	17.0	50% reduction BOD.	Sheets (1957)
Sulfuric acid	Daphnia magna (cladocera)	SB,FW,LS	88.0	Highest concentration not immobilizing under prolonged exposure, 25 C.	Anderson (1944)
Sulfuric acid	Cyprinus carpio	FW,LS	20.0	Marked change in blood serum in 24 hr.	Fujiya (1961)
Sulfurous acid	Clupea pallasi	CB,SW,LS	2.3-3.7	Killed in 1 hr; pH 7.25-76.	Shelford (1918)
	Cymatogaster aggregatus		3.9-4.2	Killed in 3.5 hr.	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

A-3. REFERENCES

Anderson, B. G. 1946. The toxicity thresholds of various substances found in industrial wastes as determined by the use of Daphnia magna. Sewage Works J. 16(6):1156-1165.

Anonymous. 1950. Ohio River Valley Water Sanitation Commission, Subcommittee on Toxicities, Metal Finishing Industries Action Committee, Report No. 3. ORSANCO, Cincinnati, Ohio.

Applegate, V. C., J. H. Howell, A. E. Hall, Jr. and M. A. Smith. 1957. Toxicity of 4,346 chemicals to larval lampreys and fishes. U.S. Fish Wildlife Service, Spec. Sci. Rept. - Fish., No. 207. 157 pp.

Belding, D. L. 1927. Toxicity experiments with fish in reference to trade waste pollution. Trans. Amer. Fish. Soc. 57:100-119.

Clemens, H. P. and K. E. Sneed. 1959. Lethal doses of several commercial chemicals for fingerling channel catfish. U.S. Fish Wildlife Service, Spec. Sci. Rept. - Fish., No. 316. 10 pp.

Doudoroff, P. and M. Katz. 1950. Critical review of literature on the toxicity of industrial wastes and toxic components to fish. Sewage Ind. Wastes 22:1432-1458.

Ellis, M. M. 1937. Detection and measurement of stream pollution. Bull. Bur. Fish. 48:365-437; Reprint in: Biology of Water Pollution, FWPCA, pp. 129-185 (1967).

Eisler, R., G. R. Gardner, R. J. Henneky, G. LaRoche, D. F. Walsh and P. P. Yevich. 1972. Acute Toxicity of sodium nitrilotriacetic acid (NTA) and NTA-containing detergents to marine organisms. Water Res. 6:1009-1027.

Erickson, S. J., T. E. Maloney and J. H. Gentile. 1970 Effect of nitrilotriacetic acid on the growth and metabolism of estuarine phytoplankton. J. Water Pollut. Control Fed. 42(8):R329-R335.

Fujiya, M. 1961. Use of electrophoretic serum separation in fish studies. J. Water Pollut. Control Fed. 33(3):250-257.

Gohar, H. A. F. and H. El-Gindy. 1961. Tolerance of vector snails of bilharziasis and fascioliasis to so e chemicals. Proc. Egypt. Acad. Sci. 16:37-48.

Gudernatsch, H. 1970. Verhalten von Nitrilotriessigäure in Klärprozess und in Abwasser. GasWassFach 11:511-516. (In German)

Hermann, E. R. 1959. A toxicity index for industrial wastes. Ind. Eng. Chem. 51:84A-87A.

Jancovic, M. and H. Mann. 1969. Experiments on the acute toxicity of nitrilotriacetic acid (NTA). Arch. Fisch - Wiss. 20(2/3):178-181. (In German)

Jones, J. R. E. 1948. A further study of the reactions of fish to toxic solutions. J. Exptl. Biol. 25:22-34.

Laurent, P. J. 1954. Toxicity tests with fish. Bull. Franc. Piscic. 174:5 (In French); Water Pollut. Abst. 28:2339 (1955).

Leclerc, E. 1960. The self-purification of streams and the relationship between chemical and biological tests. pp. 281-316. In: Proc. 2nd Symp. on treatment of Waste Water, Pergamon Press, London. (P. C. G. Issac, ed.)

Lloyd, R. and D. H. M. Jordan. 1964. Some factors affecting the resistance of rainbow trout (Salmo gairdneri) to acid waters. Intl. J. Air Water Pollut. 8(6/7):393-403.

Miller, A. P. 1937. Waste disposal as related to shellfish. Sewage Works J. 9(3):482-492.

Sheets, W. D. 1957. Toxicity studies of metal-finishing wastes. Sewage Ind. Wastes 29(12):1380-1384.

Shelford, V. E. 1918. The relation of marine fish to acids, with particular reference to the Mills Acid Process of sewage treatment. Publ. Puget Sound Biol. Station, Univ. Wash. 2:97-111.

Turnbull, H., J. G. DeMann and R. F. Weston. 1954. Toxicity of various refinery materials to fresh-water fish. Ind. Eng. Chem. 46(2):324-333.

Wallen, I. E., W. C. Greer and R. Lasater. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind. Wastes 29(6):695-711.

Wells, M. M. 1915. Reactions and resistance of fishes in their natural environment to acidity, alkalinity, and neutrality. Biol. Bull. 29:221-257.

Woelke, C. E. 1961. Bioassay--the bivalve larvae tool, pp. 113-123. In: Toxicity in the Aquatic Environment, Proc. 10th Pacific Northwest Symposium on Water Pollution Research, Portland, Ore.

Woelke, C. E. 1972. Development of a receiving water quality bioassay criterion based on the 48-hour Pacific oyster (Crassostrea gigas) embryo. Tech. Rept. 9, Wash. State Dept. Fish., Olympia, Wash. 93 pp.

E.1. SOME RELATIONSHIPS OF BORON TO POWER PLANTS

Boric acid is conventionally added to the primary loops of nuclear power reactors to provide an initial concentration of about 1800 ppm as boron. Boron acts as a shim material in the control of radioactivity because of its high affinity for neutrons. The buildup of neutron poisons in the reactor core is partially offset by controlled chemical removal of boron from the primary coolant.

In a typical reactor operation, the initial boron concentration of about 1800 ppm is reduced to about 10 ppm at the end of the power production cycle. Since prevention of radioactive contamination in the environment is stressed, the discharge from primary loops are always retained in a closed system. Elemental boron is also used in nuclear installations as a shielding material because of its neutron absorbing capacity. The amount of boron or boric acid discharged in the plant effluent is low.

Data on the toxicity of boron and boric acid to aquatic life, where available, is given in Table E.

Boron is never found in nature in its elemental form but occurs as sodium borate (borax) or as calcium borate (colemanite).

Boric acid and boron salts are used extensively in industry and boric acid may be used as a bactericide and fungicide.

Boron in drinking water is not generally regarded as a hazard to human beings, and concentrations up to 30 mg/1 in drinking water are said to be not harmful. Relatively high concentrations are required to produce toxic effects in aquatic life. The pH of the water is not a reliable index of dangerous pollution by boric acid because it can be toxic to freshwater fish without lowering the pH to 5.0.

E

E-2. TABLE E. Toxicity of Boron to Aquatic Biota

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Boric acid	"fish"	FW,LS	18,000-19,000 19,000-19,500	Minimum lethal dose; distilled water, 20 C. Minimum lethal dose; hard water, 20 C.	Leclerc (1960)
Boric acid	Gambusia affinis	SB,FW,LS	18,000 10,500 5,600	24 hr-TLm, turbid water. 48 hr-TLm, turbid water. 96 hr-TLm, turbid water.	Wallen et al. (1957)
Boric acid	Salmo gairdneri	FW	2,000 5,000 20,000 30,000	Harmless in 30 min; 14-15 C. Slight darkening of skin. Distressed, became immobile. Lost equilibrium, recovered in fresh water.	Wurtz (1945)
	Scardinius erythrophthalmus		<80,000 6,250	Unharmed in 30 min; 14-15 C. Died, 18 hr.	
	Hesperoleucas sp.		6,250	Died, 46 hr.	
Boric acid	"sewage organisms"	FW,LS	>1,000	50% inhibition, 5 day B.O.D.; 20 C.	Hermann (1959)
Boric acid	"synthetic sewage"	FW,LS	480	50% reduction, B.O.D; buffered water.	Sheets (1957)
Boron trifluoride	Lepomis macrochirus	SB,FW,LS	15,000	24 hr-TLm; 20 C.	Turnbull et al (1954)
Sodium borate	Gambusia affinis	SB,FW,LS	12,000 8,200 3,600	24 hr-TLm; turbid water. 48 hr-TLm. 96 hr-TLm.	Wallen et al. (1957)
Sodium borate ($\cdot 10H_2O$)	"fish"	FW,LS	2,000-3,300 7,000-7,500	Minimum lethal dose; distilled water, 19 C. Minimum lethal dose; hard water, 17 C.	Leclerc (1960)
Sodium borate	"fish"	FW,LS	1,600-1,700 3,700-4,000	Minimum lethal dose, distilled water, 19 C. Minimum lethal dose; hard water, 17 C.	Leclerc (1960)
Sodium borate	Daphnia magna (cladocera)	SB,FW,LS	<240	Near immobilization threshold, 48 hr; Lake Erie water, 25 C.	Anderson (1946)
Sodium borate	Daphnia magna (cladocera)	FW,LS	120	Immobilization threshold.	Anonymous (1950)
Sodium borate $+H_3BO_4$	Polycelis nigra (planaria)	SB,FW,LS	0.026 M	Toxic threshold, survives 48 hr; pH 7.4, 14-18 C. (M=Molar)	Jones (1941)
Sodium borate	Salmo gairdneri	SB,FW,LS	2,800 1,800	24 hr-TLm; 18 C. 48 hr-TLm; 18 C.	Alabaster (1956)
Sodium perborate	Daphnia magna (cladocera)	SB,FW,LS	<5.2	Near immobilization threshold, 48 hrs; Lake Erie water, 25 C.	Anderson (1946)

1. SB = Static Bioassay, CB = Constant-Flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

E.3. REFERENCES

Alabaster, J. S. 1956. The toxicity of certain weed killers to trout. Proc. 3rd Brit. Weed Contr. Conf. 2:807-808.

Anderson, B. G. 1948. The toxicity thresholds of various sodium salts determined by the use of _Daphnia magna_. Sewage Works J. 18(1):82-87.

Anonymous. 1950. Ohio River Valley Water Sanitations Commission (ORSANCO), Subcommittee on Toxicities, Metal Finishing Industries Action Committee. Cincinnati, Ohio, Report No. 3.

Hermann, E. R. 1959. A toxicity index for industrial wastes. Ind. Eng. Chem. 51:84A-87A.

Jones, J. R. E. 1941. A study of the relative toxicity of anions, with _Polycelis nigra_ as test animal. J. Expl. Biol. 18:170-181.

Leclerc, E. 1960. The self-purification of streams and the relationship between chemical and biological tests, pp.281-316. In: Proc. 2nd Symp. on Treatment of Waste Waters. Pergamon Press, London. (P. C. G. Issacs, ed.)

Sheets, W. D. 1957. Toxicity studies of metal-finishing wastes. Sewage Ind. Wastes 29(12):1380-1384.

Turnbull, H., J. G. DeMann and R. F. Weston. 1954. Toxicity of various refinery materials to freshwater fish. Ind. Eng. Chem. 46(2):324-333.

Wallen, I. E., W. C. Greer and R. Lasater. 1957. Toxicity to _Gambusia affinis_ of certain pure chemicals in turbid waters. Sewage Ind. Wastes 29(6):695-711.

Wurtz, A. 1945. The action of boric acid on certain fish: trout, roach, rudd. Ann. Sta. Cent. Hydrobiol. Appl. 1,179: Water Pollut. 20:1653(1947).

E

F-2. TABLE F. Toxicity of Carbonates and Bicarbonates to Aquatic Biota

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Calcium carbonate	Gambusia affinis	SB,FW,LS	56,000	24, 48 and 96 hr-TLm.; turbid water, pH 7.7-8.5, 19-21 C.	Wallen et al. (1957)
Calcium bicarbonate	No data				
Magnesium carbonate	No data				
Magnesium bicarbonate	No data				
Sodium carbonate	Micropterus salmoides	CB,FW, LS	500	Survived 7-9 hr; pH 10.6.	Sanborn (1945)
			200	Survived 4.3-4.5 days; pH 10.1.	
	Lepomis macrochirus		500	Survived 4.5-11 hr; pH 10.6.	
			200	>7 days survival; pH 10.1.	
	Carassius auratus		500	>7 days survival; pH 10.6.	
Sodium carbonate	Daphnia magna (cladocera)	SB,FW,LS	424	Toxicity threshold for immobilization, prolonged exposure; 25 C.	Anderson (1944)
Sodium carbonate	Daphnia magna (cladocera)	SB,FW,LS	<424	Near immobilization threshold in 48 hr; Lake Erie water 25 C.	Anderson (1946)
Sodium carbonate	Oncorhynchus tshawytscha	SB,FW,LS	68	Minimum lethal concentration, total kill, 5 days; 15.5-19.5 C.	Haydu et al. (1952)
			58	Maximum dose, no injury.	
	O. kisutch		70	Minimum lethal concentration, total kill, 5 days; 12-18 C.	
			44	Maximum dose, no injury	
	Salmo clarki		80	Minimum lethal concentration, total kill, 5 days; 9-15 C.	
			33	Maximum dose, no injury.	
Sodium carbonate	Daphnia magna (cladocera)	SB,FW,LS	524	Immobilized 50%, 100 hr.	Freeman & Fowler (1953)
Sodium carbonate	Lepomis macrochirus	CB,FW,LS	300	96 hr-TLm.	Cairns & Scheier (1955)
Sodium carbonate	Daphnia magna (cladocera)	SB,FW	552.4	Toxicity threshold; dissolved oxygen 6.5 ppm.	Fairchild (1955)
			267.0	Toxicity threshold; dissolved oxygen 1.53 ppm.	
Sodium carbonate	Gambusia affinis	SB,FW,LS	1,200	Toxic in 24 hr; (All data in turbid water, pH 8.6-9.2, 18-25 C.)	Wallen et al. (1957)
			840	Toxic in 48 hr.	
			740	Toxic in 96 hr.	
Sodium carbonate	Lepomis macrochirus	SB,FW,LS	300	96 hr-TLm.	Cairns & Scheier (1959)
Sodium carbonate	Hyallela sp. (amphipod)	SB,FW,LS	360	24 hr-TLm; lake water.	Dowden & Bennett (1965)
			176	48 hr-TLm.	
			67	96 hr-TLm.	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

TABLE F. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium carbonate	*Culex* sp. (mosquito larvae)	SB,FW,LS	1,820 600	24 hr-TLm. 48 hr-TLm.	Dowden & Bennett (1965) - contd
	Daphnia magna (cladocera)		347 265 607 565	24 hr-TLm; lake water. 48 hr-TLm; lake water. 24 hr-TLm; reference water. 48 hr-TLm; reference water.	
	Dugesia sp. (planaria)		384 360	24 hr-TLm; lake water. 48 & 96 hr-TLm.	
	Lepomis macrochirus		384	24 hr-TLm; lake water.	
	Lymnaea sp. (snail, eggs)		403 395	24 & 48 hr-TLm; lake water. 96 hr-TLm.	
	Mollienesia latipinna		405 297	24 hr-TLm; reference water. 48 hr-TLm.	
Sodium carbonate	*Nitzschia linearis* (algae)	SB,FW,LS	242	5 day-TLm.	Patrick et al. (1968)
	Lepomis macrochirus		320	96 hr-TLM; 16-20 C.	
Sodium carbonate	*Daphnia magna* (cladocera)	FW,LS	300	Threshold concentration for immobilization.	Rudolfs et al. (1950)
Sodium carbonate	*Daphnia magna* (cladocera)	FW	300 800	"Minimum lethal concentration." All killed.	Anonymous (1947)
Sodium carbonate	"bass"	FW	200 500	Killed, 4.5 hr. Killed, 0.5-3.0 days.	Keller et al. (1941)
Sodium carbonate	*Notropis atherinoides*	SB,FW, LS	250	"Minimum lethal concentration; 120 hr; 18 C.	Van Horn et al. (1949)
	Notropis spilopterus		250	"Minimum lethal concentration; 120 hr; 18 C.	
Sodium carbonate	"shiners"	SB,FW	250-300	Killed, few hr.	Clark & Adams (1913)
	"suckers"		250-300	Killed, few hr.	
	Cyprinus carpio		250-300	Killed, few hr.	
Sodium carbonate	*Salmo clarki*	FW	33	Not harmed, 5 days	Dimick (1952)
	Oncorhynchus kisutch		44	Not harmed, 5 days.	
	O. tshawytscha		58	Not harmed, 5 days.	
Sodium carbonate	"bass"	FW	100	Not harmed, 7 days.	Keller et al. (1941)
	"sunfish"		200	Not harmed, 7 days	
	Carassius auratus		200-500 500	Not harmed, 7 days. Some harmed, 7 days.	

[1] SB = Static Bioassay, CB = Constant-Flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

F

TABLE F. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium carbonate	Lepomis pallidus	FW	530	Killed in 3 days.	Wells (1915)
Sodium bicarbonate	Polycelis nigra (planaria)	SB,FW,LS	0.085M	Toxicity threshold, survives 48 hr; pH 8.0, 14-15 C (M=Molar).	Jones (1941)
Sodium bicarbonate	Daphnia magna	SB,FW,LS	4,200	Highest concentration not immobilizing under prolonged exposure; 25 C.	Anderson (1944)
Sodium bicarbonate	Daphnia magna (cladocera)	SB,FW,LS	2,350	Immobilized in 48 hr; Lake Erie water, 25 C.	Anderson (1946)
Sodium bicarbonate	Lepomis macrochirus	CB,FW,LS	8,250 8,600 9,000	96 hr-TLm; small fish. 96 hr-TLm; medium fish. 96 hr-TLm; large fish.	Cairns & Scheier (1955)
Sodium bicarbonate	Gambusia affinis	SB,FW,LS	7,550 7,700	48 & 96 hr-TLm; turbid water. 24 hr-TLm; turbid water.	Wallen et al. (1957)
Sodium bicarbonate	Lepomis macrochirus	SB,FW,LS	9,000	96 hr-TLm.	Cairns & Scheier (1959)
Sodium bicarbonate	Nitzschia linearis (algae)	SB,FW,LS	650	5 day-TLm.	Patrick et al. (1968)
	Lepomis macrochirus		8,600	96 hr-TLm; 16-20 C.	
Sodium bicarbonate	Culex sp. (mosquito larvae)	SB,FW,LS	2,000	24 & 48 hr-TLm.	Dowden & Bennett (1965)

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

F.3. REFERENCES

Anderson, B. G. 1944. The toxicity thresholds of various substances found in industrial wastes as determined by the use of Daphnia magna. Sewage Works J. 16(6):1156-1165.

Anderson, B. G. 1946. The toxicity thresholds of various sodium salts determined by the use of Daphnia magna. Sewage Works J. 18(1):82-87.

Anonymous. 1947. The toxicity of Kraft pulping wastes to typical fish food organisms. Tech. Bull. No. 10, Nat'l. Council for Stream Improvement.

Cairns, J. and A. Scheier. 1955. Bioassay studies for the Manufacturing Chemists' Association; the relationship of body size of the bluegill sunfish to the acute toxicity of some common chemicals. Phila. Acad. Natur. Sci., Dept of Limnol. 49 pp. (unpublished report)

Cairns, J. and A. Scheier. 1959. The relationship of bluegill sunfish body size to tolerance for some common chemicals. Proc. 13th. Ind. Waste Conf., Purdue Univ. 43(3):243-252.

Dimick, R. E. 1952. The effects of Kraft mill waste liquors and some of their components on certain salmonid fishes of the Pacific Northwest. Nat'l Council for Stream Improvement, Tech. Bull. 51 pp.

Dowden, B. F. and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Contr. Fed. 37(9):1308-1316.

Ellis, M.M. 1937. Detection and measurement of stream pollution. Bull. Bur. Fish. 48:365-437. Reprint in: Detection and Measurement of Stream Pollution, FWPCA, pp. 129-136 (1967).

Fairchild, E. J. 1955. Low dissolved oxygen: effect upon the toxicity of certain inorganic salts to the aquatic invertebrate Daphnia magna. In: Proc. 4th Ann. Water Symp., March 22-23, 1955. Baton Rouge, La. Eng. Expt. Sta., Bull. No. 51, pp. 95-102.

Freeman, L. and I. Fowler. 1953. Toxicity of combinations of certain inorganic compounds to Daphnia magna Straus. Sewage Ind. Wastes 25:1191-1195.

Haydu, E. P., H. R. Amberg and R. E. Dimick. 1952. The effect of Kraft mill waste components on certain salmonid fishes of the Pacific Northwest. T.A.P.P.I. 35(12):545-549.

Jones, J. R. E. 1941. A study of the relative toxicity of anions, with Polycelis nigra as test animal. J. Expl. Biol. 18:170-181.

Keller, E. L., F. A. Simmonds and P. K. Baird. 1941. Some observations on the effect of alum on certain sheet properties of paper. Paper Trade J. 112; Water Pollut. Absts. 14 (Feb. 1941).

Patrick, R., J. Cairns, Jr. and A. Scheier. 1968. The relative sensitivity of diatoms, snails, and fish to twenty common constituents of industrial wastes. Prog. Fish-Cult. 30(3):137-140.

Rudolfs, W., G. E. Barnes, G. P. Edwards, H. Heukelekian, E. Hurwitz, C. E. Renn, S. Steinberg and W. F. Vaughan. 1950. Review of literature on toxic materials affecting sewage treatment processes, streams, and B.O.D. determinations. Sewage Ind. Wastes 22:1157-1191.

Sanborn, N. H. 1945. The lethal effect of certain chemicals on freshwater fish. Canner 101 (5):13-15.

Van Horn, W. M., J. B. Anderson and M. Katz. 1949. The effect of Kraft pulp mill wastes on some aquatic organisms. Trans. Amer. Fish. Soc. 79:55-63(1950).

Wallen, I. E., W. C. Greer and R. Lasater. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind. Wastes 29(6):695-711.

Wells, M. M. 1915. The reactions and resistance of fishes in the natural environment to acidity, alkalinity and neutrality. Biol. Bull. 29:221-257.

Clark, H. W. and G. O. Adams. 1913. Studies of fish life and water pollution. 44th Ann. Rept., Massachusetts State Bd. of Health (1912); Publ. Doc. No. 34, Mass. State Bd. Health 6:336-345.

F

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium sulfide	O. tshawytscha	SB,FW,LS	3.5	Killed, 5 days; minimum lethal dose, total kill.	Haydu et al. (1952) - contd
			1.8	Maximum dose, no mortality; 17.5 C.	
	Salmo clarki		3.0	Killed, 5 days; minimum lethal dose, total kill.	
			1.0	Maximum dose, no mortality; 12 C.	
Sodium sulfide	Gambusia affinis	SB,FW,LS	750	24, 48 & 96 hr-TLm, acute; 21-25 C, pH 7.6-11.0, high turbidity.	Wallen et al. (1957)
Sodium sulfide	Rasbora heteromorpha	SB,FW,LS	3.0	173 min, mean survival time.	Abram (1964)
Sodium sulfide	Daphnia magna (cladocera)	SB,FW,LS	16.0 13.0 9.0	25 hr-TLm, acute. 50 hr-TLm, acute. 100 hr-TLm, acute.	Dowden & Bennett (1965)
Sodium sulfide	Cyprinus carpio (Juveniles)	CB,FW,LS	0.55	Critical lethal dose, pH 5.2.	Tomiyama & Yamagawa (1950)
			0.95	Critical lethal dose, pH 6.1	
			3.3	Critical lethal dose, pH 7.4.	
			8.0	Critical lethal dose, pH 8.2.	
Sodium sulfide	"fish"	FW,LS	12-13	Minimum lethal dose; distilled water, 25 C.	Leclerc (1960)
			10-11	Minimum lethal dose; hard water, 15 C.	
Sodium sulfide (•$9H_2O$)	"fish"	FW,LS	36-40	Minimum lethal dose; distilled water, 25 C.	Leclerc (1960)
			31-37	Minimum lethal dose; distilled water, 15 C.	
Sodium sulfide	"mayfly larvae"	FW	1-2	Killed.	Anonymous (1949)
	"insect larvae"		1-1,000	Killed.	
	Daphnia magna (cladocera)		9.4-10	Killed or immobilized.	
	Chironomus (midge larvae)		1,000	Resisted.	
Sodium sulfite	Daphnia magna (cladocera)	SB,FW,LS	3,784	Toxicity threshold; just failing to immobilize under prolonged exposure; 25 C.	Anderson (1944)
Sodium sulfite	Daphnia magna (cladocera)	SB,FW,LS	440	Immobilized in 48 hr; Lake Erie water, 25 C.	Anderson (1946)
Sodium sulfite	Gambusia affinis	SB,FW,LS	2,600	24, 48, & 96 hr-TLm, acute; 18-26 C, pH 7.1-7.9, high turbidity.	Wallen et al. (1957)
Sodium sulfite	Daphnia magna (cladocera)	SB,FW,LS	299 273 203	25 hr-TLm, acute. 50 hr-TLm, acute. 100 hr-TLm, acute.	Dowden & Bennett (1965)
Sodium sulfite	Cyprinus carpio (Juveniles)	CB,FW,LS	<268	Harmless, pH 5-9.	Tomiyama & Yamagawa (1950)

1. SB = Static Bioassay, CB = Constant-Flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

TABLE H. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium sulfite	*Carassius auratus*	SB,FW,LS	1,000	Killed in 3 to 72 hr. (All data in hard water, pH 7.7-7.9, 25 C.)	Ellis (1937)
			100	Killed in over 96 hr.	
			10	No kill in 4 days.	
Stannous cloride (salt)	*Carassius auratus*	SB,FW,LS	1,000	Kills in 1.0 to 1.5 hr; very soft water, pH 6.4.	Ellis (1937)
			1,000	Kills in 4 to 5 hr; hard water, pH 7.8.	
Tin (Sn^2)	*Daphnia magna* (cladocera)	SB,FW,LS	55.0	48 hr-TLm, acute; with food.	Biesinger & Christensen (1972)
			42.0	3 wk-TLm, chronic; with food.	
			1.5	50% reproductive loss in 3 wk. (Tests at 18 C, pH 7.4-8.2.)	
Tin Tri-n-butyltin acetate	*Australorbis glabratus* (snail)	SB,FW,LS	0.29	6 hr-TLm, acute; 1.5% alcohol solvent.	Seiffer & Schoof (1967)
			0.57	95% kill, 6 hr.	
Tin bis-(Tri-n-butyltin) oxide	*Australorbis glabratus* (snail)	SB,FW,LS	0.41	6 hr-TLm, acute;	Seiffer & Schoof (1967)
			0.84	95% kill, 6 hr.	
Zinc (ion)	*Daphnia magna* (cladocera)	SB,FW,LS	0.1	48 hr-TLm, acute; without food.	Biesinger & Christensen (1972)
			0.28	48 hr-TLm, acute, with food.	
			0.158	3 week-TLm, chronic, 18 C.	
			0.102	50% reproduction loss in 3 weeks.	
			0.07	16% reproduction loss in 3 weeks. (Tests at 18 C., pH 7.4-8.2.)	
Zinc	*Paracentrotus lividus* (sea urchin)	SW	0.03	Growth of larvae was retarded.	Bougis (1961)
Zinc (Zn^{2+})	*Alternaria tenuis* (fungus)	FW,LS	5.4×10^{-2}M	18 hr-TLm; 25 C. (Molar, a metal ion study.)	Somers (1961)
	Botrytis fabae (fungus)		1.2×10^{-2}M	18 hr-TLm, 25 C.	
Zinc nitrate (Zn)	"tadpoles"	SB,FW,LS	---	Did not check development of ova, but tadpoles emerging in N/5,000 and N/1,000 solutions died immediately. Few tadpoles survived exposure to N/20,000 and survivors were retarded.	Dilling & [illegible] (1926)
Zinc (nitrate)	*Balanus balanoides* (barnacle)	SB,SW,LS	30.0	90% kill of adult barnacles in 2 days.	Clarke (1947)
			8.0	90% kill of adult barnacles in 5 days.	
Zinc (Zn^{2+})	*Lepomis macrochirus*	CB,FW,LS	2.94-3.64	Lowest concentration causing response in fish movement patterns over 96 hr period.	Waller & Cairns (1972)

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	"phytoplankton"	SB,FW,LS	0.1-0.5	Reduced photosynthesis over 12 hr; soft water.	Rabe et al. (1973)
Zinc	*Lepomis macrochirus*	SB,FW,LS	2.55-5.22	No kill, but caused an increase or change in breathing rate of adults.	Sparks et al. (1972a)
			0.035	No effect on reproduction and growth.	
			0.235	Inhibited spawning and killed new fry.	
Zinc	Chlorophyta: (green-algae)	SB,FW,LS			Whitton (1970)
	Stigeoclonium tenue		0.70 1.4	Maximum non-inhibitory. Minimum lethal.	
	Cladophora glomerata		0.08 0.24	Maximum non-inhibitory. Minimum lethal.	
	Oedogonium spp.		0.08-0.46 0.22-0.62	Maximum non-inhibitory. Minimum lethal.	
	Ulothrix spp.		1.2-2.0 1.6-3.0	Maximum non-inhibitory. Minimum lethal.	
	Microspora spp.		2.4-3.0 4.0-4.9	Maximum non-inhibitory. Minimum lethal.	
	Mougeotia spp.		0.5-3.0 0.9-6.0	Maximum non-inhibitory. Minimum lethal.	
	Spyrogyra spp.		0.18-4.0 1.1-6.0	Maximum non-inhibitory. Minimum lethal.	
				(Above values are means or ranges of several populations; culture media, 20 C.)	
Zinc ($ZnSO_4$)	*Limnaea pereger* (snail)	FW	0.2	Highest dose tolerated.	Newton (1944)
	Ancylastrum fluviatile (limpet)		0.2	Highest dose tolerated.	
	Gammarus pulex (amphipod)		0.3	Highest dose tolerated.	
	Chloeon simile (mayfly nymph)		0.2-0.5	Highest dose tolerated.	
	Polycelis nigra (planaria)		30	Highest dose tolerated.	
	"water boatman, stonefly nymph, dragonfly nymph, and caddisfly larvae"		500	Highest dose tolerated.	
Zinc	*Roccus saxatilus*	SB,FW,LS	0.5	24 hr-TLm, acute; 21.1 C, larvae.	Hughes (1969)
			0.1	48 to 96 hr-TLm, acute; larvae.	
			0.20	24 hr-TLm, acute; 21.1 C, juveniles.	
			0.10	48 to 96 hr-TLm, acute; juveniles.	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

TABLE H. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc (Zn^{++})	Lepomis macrochirus	SB,FW,LS	5.6	No kill, 96 hr; 20 C.	Burton et al. (1972)
			10.0	42 hr-TLm; 1 C increase/hr, 20 C.	
			10.0	9.3 hr-TLm, 1.5 C increase/hr, 20 C.	
			32.0	12 hr-TLm; 20 C.	
			5.6	50% kill in 4 hr; 30 C.	
			32.0	4.7 hr-TLm; 30 C.	
Zinc sulfate (Zn)	Anthocidaris sp. (sea urchin)	SW,LS	0.1	No effect on development of eggs, 27 C.	Okubo & Okubo (1962)
			0.32	Effect on development of eggs, 27 C.	
	Crassostrea gigas (oyster)		0.1	No effect on development of eggs, 27 C.	
			0.32	Effect on development of eggs, 27 C.	
Zinc (Zn^{2+})	Lepomis macrochirus	FW	4.0-5.0	Lethal level in water with pH of 7.1 to 8.0 and hardness from 20 to 150 ppm.	Surber (1965)
			≈1.0	Safe level.	
Zinc	Lepomis macrochirus	SB,FW,LS	20.0-40.0	Increase in breathing rate, death in 4 hr.	Sparks et al. (1972b)
			3.0	Significant increase in "cough" frequency, but not lethal in 24 hr.	
Zinc sulfate (Zn)	Salmo gairdneri	SB,FW,LS	2.0	800 min-TLm; soft water (12 ppm $CaCO_3$).	Lloyd (1960)
			5.0	250 min-TLm; soft water (12 ppm $CaCO_3$).	
			2.0	3,000 min-TLm, intermediate water (50 ppm $CaCO_3$).	
			5.0	300 min-TLm, intermediate water (50 ppm $CaCO_3$).	
			2.0	No kill in 10,000 min; hard water (320 ppm $CaCO_3$).	
			5.0	800 min-TLm; hard water (320 ppm $CaCO_3$).	
				(Above data interpolated from graph; high temperatures and low D.O. increase toxicity.)	
Zinc	Salmo salar	CB,FW,LS	0.053	Avoidance threshold; 18.2 C, soft water.	Sprague (1964b)
Zinc	Macrocystis pyrifera (kelp)	CB,SW,LS	10.0	50% inhibition of photosynthesis in 4 days.	Clendenning & N[illegible] (1960)
Zinc sulfate	Cyprinus carpio	SB,FW,LS	0.05 & 0.5	Improves development of embryos and viability of larvae. (All tests at pH 7.8-8.4, 16-24 C.)	Vladimirov (1969)
			5.0	Detrimental to embryos and larvae.	
Zinc	Salmo salar (Juveniles)	FW,FS(river)	0.7	Incipient lethal concentration.	Sprague (1965)
			0.11	"Safe" level (estimated).	
Zinc	Salmo salar (Juveniles)	CB,FW,LS	0.42	Incipient lethal concentration; soft water, 17 C.	Sprague & Ramsay (1965)

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TABLE H. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc ion	Physa heterostropha (snail)	SB,FW,LS	0.79-1.27	96 hr-TLm; soft water, 20 C.	Cairns & Scheier (1958a)
			2.66-5.57	96 hr-TLm; hard water, 20 C.	
			0.62-0.78	96 hr-TLm; soft water, 30 C.	
			2.36-6.36	96 hr-TLm; hard water, 30 C.	
Zinc ion	"fish" (several species of centrarchids)	SB,FW,LS	---	1.5×10^{-4}M, killed; toxicity is the lowest lethal concentration (Molar). Avoidance data are given.	Ishio (1965)
Zinc	"sewage"	SB,FW,LS	0.0001	Toxic at this lowest level; BOD test, 20 C.	Ingols (1956)
			1.0	BOD was 63% of control.	
Zinc	Lepomis macrochirus	SB,FW,LS	2.9-3.8	96 hr-TLm; soft water, 18 C.	Cairns & Scheier (1957)
			10.1-12.5	96 hr-TLm; hard water, 18 C.	
			1.9-3.6	96 hr-TLm; soft water, 30 C.	
			10.2-12.2	96 hr-TLm; hard water, 30 C.	
Zinc	Salmo salar	CB,FW,LS	0.042	24 hr-TLm, acute.	
Zinc	Salmo gairdneri	SB&CB,FW,LS (hatchery)	0.13	Killed in 12-24 hr; 9-12 C, fingerlings.	Affleck (1952)
			0.01	Killed 54% in 28 days; 8-12 C, alevins.	
			0.04	Prevented hatching of eggs; 4-9 C, pH 6.7-6.8.	
	Salmo trutta		0.13	No kill in 24 hr; 9-12 C, fingerlings.	
			0.01	Toxic to ova and alevins of both species; acid water, high mineral content.	
Zinc	Salmo gairdneri	FW,FS(river)	3.2	48 hr-TLm; toxic effluent in a Scotland river.	Herbert et al. (1965)
Zinc	Nizschia closterium (diatom)	SW,LS	0.25	Division rate reduced, minimum dose.	Chipman et al. (1958)
Zinc	Lepomis macrochirus Lepisosteus osseus Dorosoma petense D. cepedianum Alosa chrysochloris Cyprinus carpio Carassius auratus	CB,FW,LS	---	Doses up to 5 ppm were used to define an autopsy method for acute zinc toxicity; 25 C, pH 7.1-7.9. Actual TLm's were not given.	Mount (1964)

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	Lepomis macrochirus	SB,FW,LS	2.86-3.78	50% survival; soft water, 18 C.	Cairns (1965)
			6.60-9.47	50% survival; hard water, 18 C.	
			0.90-2.10	50% survival; soft water, 30 C.	
			6.18-9.50	50% survival; hard water, 30 C.	
Zinc	Paracentrotus lividus (sea urchin)	SW	0.03	Growth of larvae retarded.	Bougis (1961)
Zinc (Zn salts)	Cyprinus carpio	FW,LS	10-12	48 hr-TLm; Bangkok strain, pH 7.0-7.2, 28-30 C.	Sreenivasan & Raj (1963)
			12-15	Total kill.	
			15	60% kill; Doty strain, pH 5.0.	
			15	No effect; Doty strain, pH 9.1.	
	Tilapia mossambica		12-15	48 hr-TLm; pH 7.1-7.5, 25.8-28.5 C.	
			20-22	Total kill.	
Zinc	Oncorhynchus tshawytscha (fry)	CB,FW,FS (hatchery)	0.15	High kill; with 0.030 ppm cadmium.	Hublou et al. (1954)
			0.034-0.037	Normal mortality.	
Zinc	"trout"	FW	0.15	Killed; tank observation.	Schott (1952)
Zinc ($ZnSO_4$)	Gasterosteus aculeatus	SB,FW,LS	0.2	No kill, 20 days; 14-17 C, pH 6.4-6.6.	Jones (1938)
			0.35	Killed in 12 days.	
			0.5	Killed in 4 days. (Data from graph.)	
Zinc	Salmo gairdneri (fingerlings)	FW	0.5	Killed in 3 days; soft water.	Anonymous (1958)
			3.0	Killed in 8 hr; soft water.	
			3.0	No kill in 10 days; hard water.	
Zinc	"sewage"	FW,LS	3.0	10% reduction BOD in 1-5 days; 20 C.	Heukelekian & Gellman (1955)
			30.0	50% reduction BOD in 1 day; 20 C.	
			60.0	90% reduction BOD in 1 day; 20 C.	
Zinc	Planorbis glabratus & Bulinus contortus (snails)	FW	2.2-11.0	Killed in 2-4 days.	Deschiens et al. (1957)
	Carassius auratus		11.0	Remained alive.	
	Elodea canadensis (plant)		11.0	Withered.	
Zinc	Australorbis glabratus (snail)	FW	0.05-0.10	Toxic in distilled water.	Harry et al. (1957)

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TABLE 5. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	*Salmo gairdneri*	SB,FW,LS	2.0	No kill, 24 hr; young fish, tap water.	Goodman (1951)
			4.0	No kill, 24 hr; fingerlings.	
			3-6	Killed in 48 hr; young fish, tap water.	
			6.0	Killed in 14 hr; fingerlings.	
			25-50	Killed in 2 hr; tap water.	
			1.0	Eggs hatched successfully.	
Zinc	*Pimephales promelas*	SB,FW,LS	3.95	24 hr-TLm; eggs.	Pickering & Vigor (1965)
			2.55	48 hr-TLm; eggs.	
			1.83	96 hr-TLm; eggs.	
			1.71	7 day-TLm; eggs.	
			1.63	12 day-TLm; eggs.	
			0.95	24 hr-TLm; fry.	
			0.95	48 hr-TLm; fry.	
			0.87	96 hr-TLm; fry.	
			0.87	7 day TLm; fry.	
Zinc	*Pimephales promelas*	CB,FW,LS	12.5-13.8	96 hr-TLm; pH 6.0, hardness 50.2. (All tests at 24-25 C.)	Mount (1966)
			18.5-25.0	96 hr-TLm; pH 6.0, hardness 100.	
			25.0-39.5	96 hr-TLm; pH 6.0, hardness 200.	
			6.2-13.7	96 hr-TLm; pH 7.0, hardness 50.	
			12.3-12.5	96 hr-TLm; pH 7.0, hardness 100.	
			13.6-19.3	96 hr-TLm; pH 7.0, hardness 200.	
			4.7-6.1	96 hr-TLm; pH 8.0, hardness 50.	
			8.1-10.9	96 hr-TLm; pH 8.0, hardness 100.	
			8.2-21.0	96 hr-TLm; pH 8.0, hardness 200.	
Zinc	*Pimephales promelas*	FW,LS	8.0	Survived 8 hr; soft water.	Doudoroff (1952)
Zinc (chloride)	*Fundulus heteroclitus*	SB,FW,LS	157-180	Sluggish in 2 hr, died in 24-48 hr, acute; 20 C, 24‰ salinity.	Eisler (1967)
			66	TLm value between 48 & 192 hr, calculated.	
			43	Tolerated for 192 hr, 20 C.	
Zinc (sulfate)	"periphyton" (several species included)	CB,FW,LS	0.0	33 species on glass slides in 14 weeks (control).	Williams & Mount (1965)
			0.8-1.5	17 species.	
			1.7-3.9	8 species.	
			3.9-9.6	4 species.	
				(The main influence of zinc was to decrease the number of species and increase the abundance of tolerant species.)	
Zinc	*Gasterosteus aculeatus*	SB,FW,LS	0.1	Said to be "toxic limit."	Hawksley (1967)

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TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	*Lebistes reticulatus*	SB,FW,LS	10.0	Killed; cation toxicity study, no death times; metals forming the most insoluble sulfides are most toxic.	Shaw & Grushkin (1957)
	Bufo valliceps (tadpoles)		10.0		
	Daphnia magna (cladocera)		10.0		
Zinc (sulfate)	*Lebistes reticulatus*	SB,FW,LS	5.0	No acute symptoms but growth was retarded, mortality increased, and sexual maturity delayed. (pH 7.9-8.2, hardness 80 ppm, 25-27 C.)	Crandall & Goodnight (1962)
			10.0	Less than 50% mortality, 90 days.	
Zinc	*Lebistes reticulatus*	CB,FW,LS	1.0	50% kill, 32 hr.	Chen & Selleck (1969)
			0.75	50% kill, 63 hr.	
			0.56	50% kill, 94 hr.	
			0.04	20% kill, 100 hr. (All tests at pH 7.25, 24-24.5 C.)	
Zinc	*Lepomis macrochirus*	CB,FW,LS	6.5-7.5	20 day-TLm; 1.8 mg/ℓ O_2. (All tests, pH 7.7-8.0, 24-26 C.)	Pickering (1968)
			10.5-11.7	20 day-TLm, 3.2 mg/ℓ O_2.	
			9.6-12.7	20 day-TLm, 5.6 mg/ℓ O_2.	
Zinc	*Salmo clarki* (fingerlings)	SB,FW,LS	0.62	24 hr-TLm, acute. (All tests, pH near 7.0.)	Rabe & Sapp... (1970)
			0.27	48 hr-TLm, acute.	
			0.09	96 hr-TLm, acute.	
			0.42	24 hr-TLm, acute.	
Zinc	*Salmo gairdneri*	SB,FW,LS	3.5	48 hr-TLm; total hardness 320 mg/ℓ.	Brown (1968)
			2.8	48 hr-TLm; DO 50% saturation. (Effect varies with hardness and DO.)	
Zinc	*Lepomis macrochirus*	CB,FW,LS	10.0 and 56.0	1-4 hr after exposure, the breathing rate was faster than the heat rate of the test fish. The reverse was true for controls.	Sparks et al. (1969)
Zinc	*Oncorhynchus kisutch* (eggs)	SB,FW,LS	...	70% of total accumulated zinc was bound to clorion, 26% to vitelline fluid, 2% to yolk, and 1% in embryo; 12 C (0.5 mc/mg Zn).	Hedemeyer (1968)
Zinc (Zn^{++})	*Lepomis macrochirus*	SB,FW,LS	2.4	100% survival, 96 hr. (All tests, DO 5-9 ppm, 16-20 C.)	Cairns & Scheier (1968)
			4.2	96 hr-TLm, acute.	
			5.9	Total kill, 96 hr.	

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TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	*Salmo salar*	SB,FW,LS	0.5-1.0	Little or no mortality of fry; 21 days, 15 C, (all species).	Grande (1967)
	S. gairdneri				
	S. trutta				
Zinc	*Salmo salar* (young)	CB,FW,LS	0.60	"Incipient lethal level;" pH 7.1-7.5, 15 C, hard water.	Sprague (1964a)
			2.89	50% kill, 28 hr; 15 C.	
			2.89	50% kill, 28 hr; 5 C.	
			0.89	Total survival, over 8 days; 5 C.	
			0.90	"Incipient lethal level;" pH 7.1-7.5, 5 C.	
Zinc	*Salmo salar*	SB,FW,LS	4.0	48 hr-TLm, acute; 15.3-18.4 C.	Brown & Dalton (1970)
Zinc	*Pimephales promelas*	CB,FW,LS	---	(Long term chronic study, 10 months.)	Brungs (1969)
			2.8	Reduction in growth, 15% early mortality, no spawning.	
			0.18-1.3	Reduction in spawning according to dose.	
			0.18	No effect on spawning.	
			2.8	No hatching success of eggs from control fish.	
			1.3	49 and 70% fry survival, 20 days.	
			0.66	98 and 98% fry survival, 20 days.	
Zinc	*Pimephales promelas* (immature)	FW,LS	12.0-13.0	96 hr-TLm, static bioassays.	Brungs (1969)
			8.4-10.0	96 hr-TLm, constant flow bioassays.	
Zinc (as $ZnCl_2$)	*Lepomis macrochirus*	SB,FW,LS	2.86-3.78	96 hr-TLm, acute; 16-20 C.	Patrick et al. (1968)
	Nitzschia linearis (diatom)		4.3	96 hr-TLm, acute; 16-20 C.	
	Physa heterostropha (snail)		0.79-1.27	96 hr-TLm, acute; 16-20 C.	
Zinc (a) + detergent (b)	*Salmo gairdneri*	CB,FW,LS	0.8(a) 0.49(b)	48 hr-TLm, acute.	Brown et al. (1968)
			0.8(a) 0.34(b)	48 hr-TLm, acute; previously exposed to 0.8 ppm zinc.	
Zinc	*Pimephales promelas*	SB,FW,LS	7.6	96 hr-TLm, acute; pH 6.2, 25 C.	Rachlin & Perlmutter (1968)
			3.2-5.6	"Threshold level," (10% kill), 96 hr.	
	Xiphophorus maculatus		12.0	96 hr-TLm, acute; pH 6.2, 25 C.	
			10.0	10% kill, 96 hr.	

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TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc	*Fundulus heteroclitus*	SB,FW,LS	22.6	24 hr-TLm, acute. (All tests at 17 C, pH 7.8, and 6.5 mg/ℓ DO.)	Rehwoldt et al. (1971)
			20.7	48 hr-TLm, acute.	
			19.1	96 hr-TLm, acute.	
	Roccus saxatilus		11.2	24 hr-TLm, acute.	
			10.0	48 hr-TLm, acute.	
			6.7	96 hr-TLm, acute.	
	Lepomis macrochirus		25.2	24 hr-TLm, acute.	
			21.8	48 hr-TLm, acute.	
			20.0	96 hr-TLm, acute.	
	Roccus americanus		13.6	24 hr-TLm, acute.	
			10.2	48 hr-TLm, acute.	
			14.3	96 hr-TLm, acute.	
	Anguilla rostrata		21.6	24 hr-TLm, acute.	
			20.0	48 hr-TLm, acute.	
			14.6	96 hr-TLm, acute.	
	Cyprinus carpio		14.3	24 hr-TLm, acute.	
			9.3	48 hr-TLm, acute.	
			7.8	96 hr-TLm, acute.	
Zinc	*Watersipora cucullata* (bryozoa)	SW,LS	$5.0x10^{-4}M$	50% mortality, 2 hr; 19-24 C. (Molar concentrations; pH 7.6-8.0, all data.)	Wisely & Blick (1967)
	Bugula neritina (bryozoa)		$8.0x10^{-5}M$	50% mortality, 2 hr; 18-23 C.	
	Spirorbis lamellosa (tubeworm)		$7.5x10^{-5}M$	50% mortality, 2 hr; 19-25 C.	
Zinc (sulfate)	*Salmo gairdneri*	CB,FW,LS	4.6	5 day-TLm, acute. (pH 7.2-7.9, 10.0-15.8 C, all data.)	Ball (1967)
	Perca fluviatilis		16.0	5 day-TLm, acute.	
	Rutilus rutilus		17.3	5 day-TLm, acute.	
	Gobio gobio		8.4	7 day-TLm, acute.	
	Abramis brama		14.3	5 day-TLm, acute.	
Zinc (cloride)	*Daphnia magna* (cladocera)	SB,FW,LS	<<0.15	Threshold concentration, immobilization in 64 hr; Lake Erie water.	Anderson (1948)
Zinc (cloride)	*Lepomis macrochirus*	CB,FW,LS	6.91	96 hr-TLm, acute; large fish.	Cairns & Scheier (1959)
			7.20	96 hr-TLm, acute; medium fish.	
			7.45	96 hr-TLm, acute; small fish. (All data at 19-21 C.)	
Zinc (cloride)	*Ictalurus nebulosus*	SB,FW,LS	<12.0	No apparent damage, 14 days.	Joyner (1961)

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TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc cloride	Lepomis macrochirus	SB,FW,LS	20.0	96 hr-TLm, acute; temperature, DO, and hardness effect toxicity.	Cairns (1957)
Zinc cloride (as Zn^{++})	Lepomis macrochirus	SB,FW,LS	8.02	96 hr-TLm, acute; normal O_2, 17-19 C.	Cairns & Scheier (1958b)
			4.9	96 hr-TLm, acute; low O_2 17-19 C.	
Zinc cloride (as Zn^{++})	Brachydanio rerio	SB,FW,LS	28.0	48 hr-TLm, acute; adults.	Cairns et al. (1965)
			106.0	48 hr-TLm, acute; eggs.	
			8.0	No effect in 96 hrs; adults.	
	Lepomis macrochirus		5.2	48 hr-TLm, acute; adults. (All data at 24 C, soft water.)	
Zinc chloride	Lepomis macrochirus	SB,FW,LS	7.24	24 & 48 hr-TLm, acute.	Pickering & Henderson (1964)
			5.37	96 hr-TLm, acute.	
Zinc chloride (Zn)	Nitzschia linearis (diatom)	SB,FW,LS	4.3	5 day-TLm, acute.	Patrick et al. (1968)
	Physa heterostropha (snail)		0.79-1.27	96 hr-TLm, acute; 18-22 C.	
	Lepomis macrochirus		2.86-3.78	96 hr-TLm, acute; 16-20 C.	
Zinc chloride	Cyprinus carpio	FW	1.0	Killed in 24 hr; young fish, tap water.	Doudoroff & Katz (1953)
	Anguilla sp.		0.14	Highest dose tolerated over 50 hr, young eels.	
			0.65	Killed in about 12 hr.	
	"minnows"		10.0	Killed in 48 hr.	
	"eels"		16.0	Killed in 20 hr.	
	"fish"		100	No kill, 4 days; hard water.	
	"mummichogs"		200	No kill; in seawater. Killed in 2 days, freshwater.	
	"trout"		1,000	Killed in 24 hr.	
Zinc sulfate	Leuciscus phoxinus	FW	0.8	Killed in 144 min.	Carpenter (1927)
			8.1	Killed in 72 min.	
Zinc sulfate	Daphnia magna (cladocera)	SB,FW,LS	0.024	Killed in hard water.	Anderson (1946)
			0.24	Some survival in soft water.	
Zinc sulfate (Zn)	Daphnia magna (cladocera)	SB,FW,LS	1.8	Toxicity threshold, 2 days at 23 C.	Bringmann & Kühn (1959a)
	Escherichia coli (bacteria)		1.4-2.3	Toxicity threshold, 27 C.	
	Scenedesmus quadricauda (diatom)		1.0-1.4	Toxicity threshold, 4 days at 24 C.	

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TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc sulfate (Zn)	Microregma heterostoma (protozoa)	SB,FW,LS	0.33	Toxic threshold; 28 hr, 27 C.	Bringmann & Kühn (1959b)
Zinc sulfate (Zn)	Gasterosteus aculeatus	SB,FW,LS	0.3	Lethal concentration limit, 10 days; 15-18 C.	Jones (1939)
Zinc sulfate (Zn)	Polycelis nigra (planaria)	SB,FW,LS	30	48 hr-TLm; 15-17 C, pH 6.4.	Jones (1940)
Zinc sulfate	Daphnia magna (cladocera)	SB,FW,LS	<48	"Toxicity threshold"-highest dose failing to immobilize under prolonged exposure; 25 C.	Anderson (1944)
Zinc sulfate (Zn)	Salmo gairdneri	SB,FW,LS	25	133 min, mean time to loss of equilibrium.	Grindley (1946)
Zinc sulfate (Zn)	Pygosteus pungitius	CB,FW,LS	0.04N	Prompt negative reaction, survival time ≈85 min (Ionic study, 15 C).	Jones (1947)
			0.003N	Slow negative reaction, survival time ≈190 min.	
			0.0003N	Slight negative reaction (10 ppm Zn), survival time ≈7 hr.	
			0.0001N	Survival time ≈15 hr (3 ppm Zn).	
Zinc sulfate	"synthetic sewage"	FW,LS	920	Reduced BOD values 50%.	Sheets (1957)
Zinc sulfate	Tendipes decorus (midge larvae)	FW,LS	32-56	30% kill in 72 hr, 40-70% kill in 96 hr; hard water.	Wurtz & Bridges (1961)
			5.6	30% kill in 72 hr, 50% kill in 96 hr; hard & soft water.	
			1.0	30% kill in 72 hr, 40% kill in 96 hr; soft water. (All results were highly variable.)	
	Limnodrilus hoffmeisteri (oligochaete)		>10	24, 48, 72 & 96 hr-TLm; hard water (2.26 ppm Zn).	
	Physa heterostropha (snail)		14.0	72 & 96 hr-TLm, hard water.	
			4.9	72 & 96 hr-TLm; soft water.	
	Asellus communis (isopod)		38.5	96 hr-TLm; hard water.	
			56.0	96 hr-TLm; soft water (14.6 ppm Zn).	
	Argia sp. (damselfly nymph)		320	72 hr-TLm; soft water (83.2 ppm Zn).	
			180	96 hr-TLm; soft water.	
Zinc sulfate (Zn)	Physa heterostropha (adult snails)	SB,FW,LS	4.07	24 hr-TLm; hard water, 21.1 C.	Wurtz (1962)
			2.71	24 hr-TLm; soft water, 21.1 C.	
			3.16	96 hr-TLm; hard water, 21.1 C.	
			1.11	96 hr-TLm; soft water, 21.1 C.	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc sulfate (Zn)	Physa heterostropha (young snails)	SB,FW,LS	3.50	24 hr-TLm; hard water, 20.0 C.	Wurtz (1962)- contd
			0.67	24 hr-TLm; soft water, 20.0 C.	
			1.70	96 hr-TLm; hard water, 20.0 C.	
			0.43	96 hr-TLm; soft water, 20.0 C.	
			0.95	24 hr-TLm; hard water, 10.6 C.	
			0.43	24 hr-TLm; soft water, 10.6 C.	
	Helisoma companulata (adult snails)		11.07	24 hr-TLm; hard water, 12.8 C.	
			11.07	24 hr-TLm; soft water, 12.8 C.	
			3.03	96 hr-TLm; hard water, 12.8 C.	
			0.87	96 hr-TLm; soft water, 12.8 C.	
			5.29	24 hr-TLm; hard water, 22.8 C.	
			12.66	24 hr-TLm; soft water, 22.8 C.	
Zinc sulfate (Zn)	Salmo gairdneri	CB,FW,LS	3.86	48 hr-TLm, acute; 17.5 C, hard water.	Herbert & Shurben (1964)
			0.95	48 hr-TLm, acute; 17.7 C, soft water.	
			10.0	50% mortality in ≈370 min; 17.5 C, hard water.	
Zinc sulfate	Brachydanio rerio	SB,FW,LS	2.5-5.0	Threshold concentration for fish aged 3 hr, 6 days and 40 days. (All tests in soft water, pH 6.8-7.2, 25 C.)	Skidmore (1965)
			10.0	Threshold concentration for adults (100 days old).	
			---	Eggs were most resistant, newly-hatched fish were most susceptible. Median survival times are figured for 4 concentrations of Zn.	
Zinc sulfate	Pimephales promelas	SB,FW,LS	0.78-0.96	96 hr-TLm; soft water (24 & 48 hr TLm's are available.)	Pickering & Henderson (1964)
			33.4	96 hr-TLm; hard water.	
	Lepomis macrochirus		4.85-5.82	96 hr-TLm; soft water.	
			40.9	96 hr-TLm; hard water.	
	Carassius auratus		6.44	96 hr-TLm; soft water.	
	Lebistes reticulatus		1.77	96 hr-TLm; soft water.	
Zinc sulfate (Zn)	Brachydanio rerio (embryos)	SB,FW,LS	20.0	Killed in 50 hr. (Embryos with outer egg membranes ruptured survived longer than those normal.)	Skidmore (1966)

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc sulfate	Brachydanio rerio	SB,FW,LS	20.0	Killed in 24 hr. Data are for several dose levels and O_2 uptake. Toxicity to fish of different ages also considered.	Skidmore (1967)
Zinc sulfate (Zn)	"tubificid worms"	SB,FW,LS	≈46.0	24 hr-TLm; pH 7.5, 20 C. TLm's for various pH values ranged from 5.8-9.7; dose more toxic at pH extremes.	Whitley (1968)
Zinc sulfate (Zn)	Salmo gairdneri (yearlings)	FW&SW,LS	20.0	No mortality, 30 hr; freshwater. (All data from graphs.) 24 hr-TLm; freshwater.	Herbert & Wakeford (1964)
	Salmo salar (smolts)		20.0	30 hr-TLm; freshwater.	
			40.0	16 hr-TLm; freshwater.	
	S. salar		15.0	48 hr-TLm; 18% seawater.	
			38.0	48 hr-TLm; 36% seawater.	
	S. gairdneri		28.0	48 hr-TLm; 19% seawater.	
			78.0	48 hr-TLm; 36% seawater.	
Zinc sulfate (Zn^{2+})	Salmo gairdneri	CB,FW,LS	40.0	Respiratory stress, 1 hr or more.	Skidmore (1970)
Zinc sulfate (Zn^{2+})	Salmo gairdneri	CB,FW,LS	40.0	189 min, surfacing. (All data pH 7.1-7.5, 15 C; gill damage.)	Skidmore & Tovell (1972)
			40.0	201 min, loss of equilibrium.	
			40.0	213 min, immobilization.	
Zinc sulfate (Zn^{2+})	Lepomis macrochirus	FW,LS	5.6	No kill, 120 hr; 20 C.	Morgan et al. (1971)
			5.6	Some kill, 120 hr; 30 C.	
			10.0	Kill increased as the rate at which thermal stress increased.	
Zinc sulfate (Zn^{2+})	Lepomis macrochirus	SB,FW,LS	10-32	Killed 0-10% in 96 hr; pH 7.3-8.8.	Cairns et al. (1972)
			10-32	Killed 100% in 96 hr; pH 5.7-7.0. Fish at low temperature (7-9 C) died at a much slower rate than those at high temperatures (21-24 C). Other data are presented.	
Zinc sulfate (as Zn)	Psammechinus miliaris (sea urchin)	SW,LS	0.16	Abnormalities in fertilization and cleavage of eggs.	Cleland (1953)
Zinc sulfate (Zn)	Macrocystis pyrifera (kelp)	SW,LS	1.31	No great effect on photosynthesis, 4 days.	Clendenning & North (1960)
			10.0	50% inactivation of lower fronds, 4 days	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

TABLE M. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Zinc sulfate	*Carassius auratus*	CB,FW,LS	1,000	Survival time 1-4 hr. (All data in hard water, pH 7.8, 25 C.)	Ellis (1937)
			100	Killed some in 5 days.	
			10	Survival time >4 days.	
Zinc sulfate (as Zn)	*Ictalurus punctatus*		12.0	Total kill, 40 hr; 19-24 C.	Lewis & Lewis (1971)
			30.0	Total kill, 6 hr.	

Zinc & Copper — See: Copper & zinc.

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

M-3. REFERENCES

Abram, F. S. H. 1964. An application of harmonics to fish toxicology. Int'l. J. Air Water Pollut. 8(5):325-338.

Affleck, R. J. 1952. Zinc poisoning in a trout hatchery. Aust. J. Mar. Freshwater Res. 2:142-169.

Anderson, B. G. 1944. The toxicity thresholds of various substances found in industrial wastes as determined by the use of Daphnia magna. Sewage Works J. 16(6):1156-1165.

Anderson, B. G. 1946. The toxicity thresholds of various sodium salts determined by the use of Daphnia magna. Sewage Works J. 18(1):82-87.

Anderson, B. G. 1948. The apparent thresholds of toxicity to Daphnia magna for chlorides of various metals when added to Lake Erie water. Trans. Amer. Fish. Soc. 78:96-113.

Anonymous. 1949. The toxicity of Kraft pulping wastes to important fish food species of insect larvae. Natl. Council for Stream Improvement, Tech. Bull. No. 25.

Applegate, V. C., J. H. Howell and A. E. Hall, Jr. 1957. Toxicity of 4,346 chemicals to larval lampreys and fishes. U.S. Fish and Wildlife Service, Spec. Sci. Rept. - Fish. No. 207. 157 pp.

Arthur, J. W. and E. N. Leonard. 1970. Effects of copper on Gammarus pseudolimnaeus, Physa integra, and Campeloma decisum in soft water. J. Fish. Res. Bd. Canada 27(7):1277-1283.

Bachmann, H., A. Birrer and H. Weber. 1933. The poisonous effect of chemical substances on lower water organisms. Zeits. Hydrol. (Zurich) 6,63; Water Pollut. Abst. 9:1141(1936).

Baker, J. T. P. 1969. Histological and electron microscopical observations on copper poisoning in the winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada 26(11):2785-2793.

Ball, I. R. 1967. The relative susceptibilities of some species of freshwater fish to poisons--II. Zinc. Water Res. 1(11/12):777-783.

Batte, E. G., L. E. Swanson and J. B. Murphy. 1951. New molluscicides for the control of freshwater snails. Amer. J. Vet. Res. 12(3):158-160.

Betzer, N. and Y. Kott. 1969. Effect of halogens on algae-II. Cladophora sp. Water Res. 3(4):257-264.

Beyerly, G. B. and J. E. Williams. 1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Prog. Fish - Cult. 29(3):150-155.

Biesinger, K. E. and G. M. Christensen. 1972 Effects of various metals on survival, growth, reproduction, and metabolism of Daphnia magna. J. Fish. Res. Bd. Canada 29(12):1691-1700.

Bougis, P. 1961. The physiological effects of zinc in seawater. Compt. Rend. 253:740-741 (In French); Chem. Abst. 56:1851(1961).

Bougis, P. 1965. Effect of copper on the growth of sea urchin (Paracentrotus lividus) pluteus. Compt. Rend. 260(10):2929-2931 (In French); Chem. Abst. 62:15134(1965).

Bringmann, G. and R. Kühn. 1959a. Comparative water toxicological investigations with aquatic bacteria, algae, and small crustaceans. Gesundheits Ing. 80(4):115-120. (In German)

Bringmann, G. and R. Kühn. 1959b. Water toxicology studies with protozoa as test organisms. Gesundheits - Ing. 80(8):239-242. (In German)

Brown, F. M. 1949. Askern Lake, pp. 22-23. In: Report of the Naturalist's Union for 1948, Naturalist (London) No. 828.

Brown, V. B. 1968. The calculation of the acute toxicity of mixtures of poisons to rainbow trout. Water Res. 2(10):723-733.

Brown, V. M. and R. A. Dalton. 1970. The acute toxicity to rainbown trout of mixtures of copper, phenol, zinc and nickel. J. Fish. Biol. 2(2):211-216.

Brown, V. M., V. V. Mitrovic and G. T. C. Clarke. 1968. Effects of chronic exposure to zinc on toxicity of a mixture of detergent and zinc. Water Res. 2(4):255-263.

Brungs, W. A. 1969. Chronic toxicity of zinc to the fathead minnow, Pimephales promelas Rafinesque. Trans. Amer. Fish. Soc. 98(2):272-279.

Bryan, G. W. and L. G. Hummerstone. 1971. Adaptations of the polychaete Nereis diversicolor to estuarine sediments containing high concentrations of heavy metals. I. General observations and adaptation to copper. J. Mar. Biol. Assoc. U.K. 51(4):845-863.

Burton, D. T., E. L. Morgan and J. Cairns, Jr. 1972. Mortality curves of bluegills (Lepomis macrochirus Rafinesque) simultaneously exposed to temperature and zinc stress. Trans. Amer. Fish Soc. 101(3):435-441.

Cairns, J., Jr. 1957. Environment and time in fish toxicity. Ind. Wastes 2:1-4.

Cairns, J., Jr. 1965. Biological concepts and industrial waste disposal problems. Proc. 20th Ind. Waste Conf., Purdue Univ. 49(4):49-59.

Cairns, J., Jr. and A. Scheier. 1957. The effect of temperature and hardness of water upon the toxicity of zinc to the common bluegill (Lepomis macrochirus Rafinesque). Notulae Natur., No. [illegible] 12 pp.

Cairns, J., Jr. and A. Scheier. 1958a. The effect of temperature and hardness of water upon the toxicity of zinc to the pond snail, Physa heterostropha (Say). Notulae Natur., No. 308. 11 pp.

Cairns, J., Jr. and A. Scheier. 1958b. The effect of periodic low oxygen upon the toxicity of vari[illegible] chemicals to aquatic organisms. Proc. 12th Ind. Waste Conf., Purdue Univ. 42(3):165-176.

Cairns, J., Jr. and A. Scheier. 1959. The relationship of bluegill sunfish body size to tolerance for some common chemicals. Proc. 13th Ind. Waste Conf., Purdue Univ. 43(3):243-252.

Cairns, J., Jr. and A. Scheier. 1968. A comparison of the toxicity of some common industrial waste components tested individually and combined. Prog. Fish-Cult. 30(1):3-8.

Cairns, J., Jr., A. Scheier and J. J. Loos. 1965. A comparison of the sensitivity to certain chemicals of adult zebra danios Brachydanio rerio (Hamilton - Buchanan) and zebra eggs with that of adult bluegill sunfish Lepomis macrochirus Rafinesque. Notulae Natur., No. 381. 9 pp.

Cairns, J., Jr., T. K. Bahns, D. T. Burton, K. L. Dickson, R. E. Sparks and W. T. Waller. 1972. The effects of pH, solubility and temperature upon the acute toxicity of zinc to the bluegill sunfish (Lepomis macrochirus Rafinesque). Trans. Kansas Acad. Sci. [illegible]:81-92.

Carpenter, K. E. 1927. The lethal action of soluble metallic salts on fishes. Brit. J. Exptl. Biol. 4(4):378-390.

Chen, C. W. and R. E. Selleck. 1969. A kinetic model of fish toxicity threshold. J. Water Pollut. Control Fed. (Res. Suppl.) 41(8):R294-R308.

Chipman, W. A., T. R. Rice and T. J. Price. 1958. Uptake and accumulation of radioactive zinc by marine plankton, fish and shellfish. U.S. Fish Wildlife Service, Fish Bull. 135(58):279-292.

Clarke, G. L. 1947. Poisoning and recovery in barnacles and mussels. Biol. Bull., Woods Hole 92(1):73-91.

Cleland, K. W. 1953. Heavy metals, fertilization and cleavage in the eggs of Psammechinus miliaris. Exptl. Cell Res. 4(1):246-248.

Clendenning, K. A. and W. J. North. 1960. Effects of wastes on the giant kelp, Macrocystis pyrifera. pp. 82-91. In: Proc. 1st Intl. Conf. on Waste Disposal in the Marine Environment. Pergamon Press, N.Y.

Cope, O. B. 1966. Contamination of the freshwater ecosystem by pesticides. J. Appl. Ecol. 3(suppl.) 33-44.

Corner, E. D. S. and B. W. Sparrow. 1956. The modes of action of toxic agents. I. Observations on the poisoning of certain crustaceans by copper and mercury. J. Mar. Biol. Assoc. U.K. 35:531-548.

Crance, J. H. 1963. The effects of copper sulfate on Microcystis and zooplankton in ponds. Prog. Fish-Cult. 25(4):198-202.

Crandall, C. A. and C. J. Goodnight. 1962. Effects of sublethal concentrations of several toxicants on the common guppy, Lebistes reticulatus. Limnol. Oceanogr. 7:233-239.

de Calventi, I. B. 1965. Copper poisoning in the snail Helix pomatia and its effect on mucous secretion. Ann. N.Y. Acad. Sci. 118(24):1015-1020.

Deschiens, R., V. Molinari and D. Bertrand. 1957. The action of "zinc water" as a toxic agent on molluscs. Bull. Soc. Path. Exot. 50(1):59-61 (In French); Biol. Abst. 32,5811(1958).

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 on the growth of tadpoles. Ann. Appl. Biol. 13(2):177-188.

Doudoroff, P. 1952. Some recent developments in the study of toxic industrial wastes, pp. 21-25. In: Proc. 4th Ann. Pacific N.W. Ind. Waste Conf., Washington State Univ., Pullman.

Doudoroff, P. and M. Katz. 1953. Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals, as salts. Sewage Ind. Wastes 25(7):802-839. (Review)

Dowden, B. and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Control Fed. 37(9):1308-1316.

Eipper, A. W. 1959. Effects of five herbicides on farm pond plants and fish. N.Y. Fish Game J. 6(1):45-56.

Eisler, R. 1967. Acute toxicity of zinc to the killifish, Fundulus heteroclitus. Chesapeake Sci. 8(4):262-264.

Ellis, M. M. 1937. Detection and measurement of stream pollution. Bull. Bur. Fisheries 48:365-437; Reprint in: Detection and Measurement of Stream Pollution, FWPCA, pp. 129-186 (1967).

Fairchild, E. J. 1955. Low dissolved oxygen: Effect upon the toxicity of certain inorganic salts to the aquatic invertebrate Daphnia magna, pp. 95-102. In: Proc. 4th Ann. Water Symp., Baton Rouge, La., Eng. Expt. Station, Bull. No. 51

Fingal, W. and H. M. Kaplan. 1963. Susceptibility of Xenopus laevis to copper sulfate. Copeia 1963(1):155-156.

Fisher, A. 1956. The effect of copper sulfate on some microorganisms in fish ponds. Badidgen, Bull. Fish Culture in Israel 8(2):21-27.

Fitzgerald, G. P. 1964. An evaluation of potassium permanganate as an algicide for water cooling towers. Ind. Eng. Chem. 56(2):79. (Abstract)

Fitzgerald, G. P. and S. L. Faust. 1963. Factors affecting the algicidal and algistatic properties of copper. Appl. Microbiol. 11(4):345-351.

Fitzgerald, G. P., G. C. Gerloff and F. Skoog. 1952. Studies on chemicals with selective toxicity to blue-green algae. Sewage Ind. Wastes 24(7):888-897.

Freeman, L. and I. Fowler. 1953. Toxicity of combinations of certain inorganic compounds to Daphnia magna Straus. Sewage Ind. Wastes 25(10):1191-1195.

Fujiya, M. 1960. Studies on the effects of copper dissolved in seawater on oysters. Bull. Japan. Soc. Sci. Fish. 26(5):462-468; Biol. Abst. 38:8677(1962).

Fujiya, M. 1961. Use of electrophoretic serum separation in fish studies. J. Water Pollut. Control Fed. 33(3):250-257.

Galtsoff, P. S. 1932. The life in the ocean from a biochemical point of view. J. Wash. Acac. Sci. 22:246-257.

Gohar, H. A. F. and H. El-Gindy. 1961. Tolerance of vector snails of bilharziasis and fasciolasis to some chemicals. Proc. Egypt. Acad. Sci. 16:37-48.

Gooding, D. 1954. Pollution research, toxicity studies, p. 44. In: 64th Annual Report, Wash. State Dept. Fisheries, Olympia.

Goodman, J. R. 1951. Toxicity of zinc for rainbow trout (Salmo gairdneri). Calif. Fish Game 37(2):191-194.

Grande, M. 1967. Effect of copper and zinc on salmonid fishes, pp. 97-111. In: Advances in Water Pollution Research, Proc. 3rd Intl. Conf., Vol. I., Water Pollut. Control Fed., Washington D. C.

Grindley, J. 1946. Toxicity to rainbow trout of some substances known to be present in the waste water discharged to rivers. Ann. Appl. Biol. 33(1):103-112.

Hale, F. E. 1937. The use of copper sulphate in control of microscopic organ... Nichols Copper Co., New York. 35 pp.

Harry, H. W., B. G. Cumbie and J. M. deJesus. 1957. Study on the quality of fresh waters of Puerto Rico relative to the occurrence of Australorbis glabratus. Amer. J. Trop. Med. Hygiene 6(2):313-322.

Hassall, K. A. 1962. A specific effect of copper on the respiration of Chlorella vulgaris. Nature 193:90.

Hawksley, R. A. 1967. Advanced water pollution analysis by a water laboratory. Analyzer 8(1):13-15.

Haydu, E. P., H. R. Amberg and R. E. Dimick. 1952. The effect of Kraft mill waste components on certain salmonid fishes of the Pacific Northwest. T.A.P.P.I. 35(12):545-549.

Hazel, C. R. and S. J. Meith. 1970. Bioassay of king salmon eggs and sac fry in copper solutions. Calif. Fish Game 56(2):121-124.

Helfer, H. 1936. The action of poisons on fish; its investigations by experiment and the value of results. Kl. Mitt. Ver. Wasser-, Boden-, u. Lufthyg. 12:32 (In German); Water Pollut. Abst. 9:1220(1936).

Henderson, C., Q. H. Pickering and J. M. Cohen. 1959. The toxicity of synthetic detergents and soaps to fish. Sewage Ind. Wastes 31(3):295-306.

Herbert, D. W. M. and A. C. Wakeford. 1964. The susceptibility of salmonid fish to poisons under estuarine conditions--I. Zinc sulfate. Intl. J. Air Water Pollut. 8:251-256.

Herbert, D. W. M., D. H. M. Jordon and R. Lloyd. 1965. A study of some fishless rivers in the industrial midlands. J. Proc. Inst. Sewage Purif., London 6:569-582.

Herbert, D. W. M. and D. S. Shurben. 1964. The toxicity to fish of mixtures of poisons. I. Salts of ammonia and zinc. Ann. Appl. Biol. 53:33-41.

Hermann, E. R. 1959. A toxicity index for industrial wastes. Ind. Eng. Chem. 51:84A-87A.

Heukelekian, H. and I. Gellman. 1955. Studies of biochemical oxidation by direct methods. IV. Effect of toxic metal ions on oxidation. Sewage Ind. Wastes 27(1):70-84.

Holland, G. A., J. E. Lasater, E. D. Newmann and W. E. Eldridge. 1960. Toxic effects of organic pollutants on young salmon and trout. State of Washington, Dept. of Fisheries, Res. Bull. No. 5. 264 pp.

Hublou, W. F., J. W. Wood and E. R. Jefferies. 1954. The toxicity of zinc or cadmium for chinook salmon. Ore. Fish Comm., Res. Briefs 5(1):8-14.

Hubschman, J. H. 1967. Effects of copper on the crayfish Orconectes rusticus (Girard). I. Acute toxicity. Crustaceana 12:33-42.

Hughes, J. S. 1969. Toxicity of some chemicals to striped bass (Roccus saxatilus). Proc. 22nd Ann. Conf. Southeastern Assoc. Game Fish Commr., pp. 234(1968).

Hughes, J. S. 1971. Tolerance of stiped bass, Morone saxatilus (Walbaum) larvae and fingerlings to nine chemicals used in pond culture. Proc. 24th Am. Conf. Southeastern Assoc. Game Fish Commr., pp. 431-438(1970).

Hunter, W. R. 1949. The poisoning of Marinogammarus marinus by cupric sulphate and mercuric chloride. J. Exptl. Biol. 26(2):113-124.

Ingols, R. S. 1955. Evaluation of toxicity. Sewage Ind. Wastes (27(1):26-33.

Ingols, R. S. 1956. Toxicity of copper and zinc ions in the dilution B.O.D. tests. Sewage Ind. Wastes 28(9):1168-1169.

Ishio, S. 1965. Behavior of fish exposed to toxic substances, pp. 19-40. In: Advances in Water Pollution Research, Proc. 2nd Intl. Conf., Tokyo, Vol I. Pergamon Press, N. Y., (Aug. 1964).

Jones, J. R. E. 1938b. The relative toxicity of salts of lead, zinc and copper to the stickleback (Gasterosteus aculeatus L.) and the effect of calcium on the toxicity of lead and zinc salts. J. Exptl. Biol. 15:394-407.

Jones, J. R. E. 1939. The relation between the electrolytic solution pressures of the metals and their toxicity to the stickleback (Gasterosteus aculeatus L.). J. Exptl. Biol. 16:425-437.

Jones, J. R. E. 1940. A further study of the relation between toxicity and solution pressure, with Polycelis nigra as test animal. J. Exptl. Biol. 17(4):408-415.

Jones, J. R. E. 1941. A study of the relative toxicity of anions, with Polycelis nigra as test animal. J. Exptl. Biol. 18:170-181.

Jones, J. R. E. 1947. The reactions of Pygosteus pungitius L. to toxic solutions. J. Exptl. Biol. 24:110-122.

Jones, J. R. E. 1948. A further study of the reactions of fish to toxic solutions. J. Exptl. Biol. 25:22-34.

Joyner, T. 1961. Exchange of zinc with environmental solutions by the brown bullhead. Trans. Amer. Fish. Soc. 90(4):444-448.

Kaplan, H. M. and L. Yoh. 1961. Toxicity of copper for frogs. Herpetologica 17(2):131-135.

Kleerekoper, H., G. F. Westlake, J. H. Matis and P. J. Gensler. 1972. Orientation of goldfish (Carassius auratus) in response to a shallow gradient of a sublethal concentration of copper in an open field. J. Fish. Res. Bd. Canada 29(1):45-54.

Klock, J. W. and E. A. Pearson. 1959. Interim report, engineering evaluation and development of bioassay methods. Univ. Calif., Berkeley; See: McKee, J. E. and H. W. Wolf. 1963. Water Quality Criteria, p. 173.

Learner, M. A. and R. W. Edwards. 1963. The toxicity of some substances to Nais (Oligochaeta). Proc. Soc. Water Treat. Exam. 12(3):161-168.

Leclerc, E. 1960. The self-purification of streams and the relationship between chemical and biological tests, pp. 281-316. In: Proc. 2nd Symp. on Treatment of Waste Waters, Pergamon Press, London. (P. C. G. Issac, ed.)

Lewis, S. D. and W. M. Lewis. 1971. The effect of zinc and copper on the osmolality of blood serum of the channel catfish, Ictalurus punctatus Rafinesque, and golden shiner, Notemigonus crysoleucas Mitchill. Trans. Amer. Fish. Soc. 100(4):639-643.

Lloyd, R. 1960. The toxicity of zinc sulfate to rainbow trout. Ann. Appl. Biol. 48(1):84-94.

Lloyd, R. 1961. The toxicity of mixtures of zinc and copper sulfate to rainbow trout. Ann. Appl. Biol. 49:535-538.

Mackereth, F. J. and W. J. P. Smyly. 1951. Toxicity of copper in solution to the stone loach. Nature 168:1130.

Maguire, J. J., W. H. Betz and L. D. Betz. 1956. Biological fouling in recirculating cooling systems. Ind. Eng. Chem. 48(12):2162-2167.

Maloney, T. E. and M. Palmer. 1956. Toxicity of six chemical compounds to thirty cultures of algae. Water Sewage Wks. 103(11):509-513.

Mandelli, E. F. 1969. The inhibitory effects of copper on marine phytoplankton. Contr. Mar. Sci., Univ. Texas 14:47-57.

Marks, G. W. 1938. The copper content and copper tolerance of some species of mullusks of the southern California coast. Biol. Bull. 75(2):224-237.

Marvin, K. T., C. M. Lansford and R. S. Wheeler. 1961. Effects of copper ore on the ecology of a lagoon. U.S. Fish Wildlife Service, Fish. Bull. 184(61):153-160.

McKim, J. M. and D. A. Benoit. 1971. Effects of long-term exposures to copper on survival, growth, and reproduction of brook trout (Salvelinus fontinalis). J. Fish. Res. Bd. Canada 28(5):655-662.

Miller, M. A. 1946. Toxic effects of copper on attachment and growth of Bugula neritina. Biol. Bull. 90(2):122-140.

Morgan, E. L., D. T. Burton and J. Cairns, Jr. 1971. A time until death study of bluegill sunfish (Lepomis macrochirus Raf.) exposed to simultaneous thermal and zinc stress. ABS Bull. 18(2):47.

Mount, D. I. 1964. An autopsy technique for zinc-caused fish mortality. Trans. Amer. Fish. Soc. 93(2):174-182.

Mount, D. I. 1966. The effect of total hardness and pH on acute toxicity of zinc to fish. Intl. J. Air Water Pollut. 10:49-56.

Mount, D. I. 1968a. Chronic toxicity of copper to fathead minnows (Pimephales promelas Rafinesque). Water Res. 2(3):215-223.

Mount, D. I. and C. E. Stephan. 1969. Chronic toxicity of copper to the fathead minnow (Pimephales promelas) in soft water. J. Fish. Res. Bd. Canada 26(9):2449-2457.

Muller, F. M. 1940. On the sensitivity of barnacles, in different stages of development, towards some poisons. Arch. Neerl. Zool. 4:113-132; Biol. Abst. 21:21409(1947); Water Pollut. Abst. 21:976 (1948).

Nebeker, A. V. and A. R. Gaufin. 1964. Bioassays to determine pesticide toxicity to the amphipod crustacean, Gammarus lacustris. Proc. Utah Acad. Sci. 41(1):64-67.

Newton, L. 1944. Pollution of the rivers of west Wales by lead and zinc mine effluents. Ann. Appl. Biol. 31(1):1-11.

Nielsen, E. and S. Wium-Andersen. 1970. Copper ions as poison in the sea and fresh water. Marine Biol. 6(2):93-97.

O'Hara, J. 1971. Alterations in oxygen consumption by bluegills exposed to sublethal treatment with copper. Water Res. 5(6):321-327.

Okubo, K. and T. Okubo. 1962. Study on the bioassay method for the evaluation of water pollution. II. Use of fertilized eggs of sea urchins and bivalves. Bull. Tokai Regional Fish. Res. Lab., No. 32. (in Japanese)

Ozaki, H., K. Uematsu and K. Tanaka. 1970. Survival and growth of goldfish and carp in dilute solutions of copper sulfate. Jap. J. Ichthyol. 17(4):166-172 (Japanese, English resume); Sport Fish. Abst. 13813(1971).

Palmer, C. M. and T. E. Maloney. 1955. Preliminary screening for potential algicides. Ohio J. Sci. 55(1):1-8.

Patrick, R., J. Cairns, Jr. and A. Scheier. 1968. The relative sensitivity of diatoms, snails, and fish to twenty common constituents of industrial wastes. Prog. Fish-Cult. 30(3):137-140.

Pickering, Q. H. 1968. Some effects of dissolved oxygen concentrations upon the toxicity of zinc to the bluegill, Lepomis macrochirus Raf. Water Res. 2(3):195-213.

Pickering, Q. H. and C. Henderson. 1964. The acute toxicity of some heavy metals to different species of warm water fishes. Proc. 19th Ind. Waste Conf., Purdue Univ., Part II. 49(2):578-591.

Pickering, Q. H. and W. N. Vigor. 1965. The acute toxicity of zinc to eggs and fry of the fathead minnow. Prog. Fish-Cult. 27(3):153-157.

Pringle, B. H., D. E. Hissong, E. L. Katz and S. T. Mulawka. 1968. Trace metal accumulation by estuarine molluscs. J. Sanit. Engr. Div., Proc. Amer. Soc. Civil Engs., SA3 94:455-475.

Pyefinch, K. A. and J. C. Mott. 1944. The effects of copper and mercury on the young stages of barnacles. Report N13/44, Marine Corrosion Subcommittee of the Corrosion Committee to the British Admiralty (unpublished); see Zeitoun et al., 1969b.

Rabe, F. W. and C. W. Sappington. 1970. The acute toxicity of zinc to cutthroat trout, Salmo clarki, pp. 1-16. In: Biological Productivity of the Coeur d'Alene River as related to water quality. Completion Rept., Water Resources Res. Inst., Univ. Idaho, Moscow; Sport Fish. Abst. 13665(1971).

Rabe, F. W., R. C. Wissmar and R. F. Minter. 1973. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River; Delta; and Lake. Completion Report, Water Resources Inst., Univ. Idaho, Moscow. 20 pp.

Rachlin, J. W. and A. Perlmutter. 1968. Response of an inbred strain of platyfish and the fathead minnow to zinc. Prog. Fish-Cult. 30(4):203-207.

Raymont, J. E. G. and J. Shields. 1964. Toxicity of copper and chromium in the marine environment, pp. 275-290. In: E. A. Pearson (ed.), Advances in Water Pollution Research, Proc. 1962 Intl. Conf., Vol. 3. MacMillan Co., N.Y.

Rehwoldt, R., G. Bida and B. Nerrie. 1971. Acute toxicity of copper, nickel and zinc ions to some Hudson River fish species. Bull. Envir. Contam. Toxic. 6(5):445-448.

Saunders, R. L. and J. B. Sprague. 1967. Effects of copper-zinc mining pollution on a spawning migration of Atlantic salmon. Water Res. 1(6):419-432.

Schaut, G. G. 1939. Fish catastrophes during droughts. J. Amer. Water Works Assoc. 35(5):771-822.

Scheuring, L. 1950. Experiments on the action of sodium sulfate on fish and other water organisms. Allg. Fisch. Ztg. 75(12):309-310 (In German); Biol. Abst. 25:26463(1951).

Schott, W. 1952. Sensitivity of trout to zinc. Dtsch. Labensmitt Rdsch. 48:62-63 (In German); Water Pollut. Abst. 26:1142(1953).

Schweiger, G. 1954. The toxic action of heavy metal salts on fish and organisms on which fish feed. Arch. Fisch Wiss. 8:54-78 (In German); Water Pollut. Abst. 34:1744(1961).

Scott, D. M. and C. W. Major. 1972. The effect of copper (II) on survival, respiration, and heart rate in the common blue mussel, Mytilus edulis. Biol. Bull. 143(3):679-688.

Seiffer, E. A. and H. F. Schoof. 1967. Tests of 15 experimental molluscicides against Australorbis glabratus. Public Health Repts. 82(9):833-839.

Shaw, T. L. and V. M. Brown. 1971. Heavy metals and the fertilization of rainbow trout eggs. Nature 230(5291):251.

Shaw, W. H. R. and B. Grushkin. 1957. The toxicity of metal ions to aquatic organisms. Arch. Biochem. Biophys. 67(2):447-452.

Sheets, W. D. 1957. Toxicity studies of metal-finishing wastes. Sewage Ind. Wastes 29(12):1380-1384.

Skidmore, J. F. 1965. Resistance to zinc sulfate of the zebrafish (Brachydanio rerio Hamilton-Buchanan) at different phases of its life history. Ann. Appl. Biol. 56(1):47-53.

Skidmore, J. F. 1966. Resistance to zinc sulfate of zebrafish (Brachydanio rerio) embryos after removal or rupture of the outer egg membrane. J. Fish. Res. Bd. Canada 23(7):1037-1041.

Skidmore, J. F. 1967. Oxygen uptake by zebrafish (Brachydanio rerio) at different ages in relation to zinc sulfate resistance. J. Fish. Res. Bd. Canada 24(6):1253-1267.

Skidmore, J. F. 1970. Respiration and osmoregulation in rainbow trout with gills damaged by zinc sulfate. J. Exptl. Biol. 52(2):481-494.

Skidmore, J. F. and P. W. A. Tovell. 1972. Toxic effects of zinc sulfate on the gills of rainbow trout. Water Res. 6(3):217-230.

Smith, M. W. 1939. Copper sulfate and rotenone as fish poisons. Trans. Amer. Fish. Soc. 69:141-157.

Somers, E. 1961. The fungitoxicity of metal ions. Ann. Appl. Biol. 49(2):246-253.

Sparks, R. E., J. Cairnes, Jr. and A. G. Heath. 1972a. The use of bluegill breathing rates to detect zinc. Water Res. 6:895-911.

Sparks, R. E., J. Cairns, Jr., R. A. McNabb and G. Suter, II. 1972b. Monitoring zinc concentrations in water using the respiratory response of bluegills (Lepomis macrochirus Rafinesque). Hydrobiologia 40(3):361-369.

Sparks, R. E., A. G. Heath and J. Cairns, Jr. 1969. Some effects of zinc on the EKG and breathing signal of bluegills (Lepomis macrochirus Rafinesque). ASB Bulletin 16(2):69.

Sprague, J. B. 1964a. Lethal concentrations of copper and zinc for young Atlantic salmon. J. Fish. Res. Bd. Canada 21(1):17-26.

Sprague, J. B. 1964b. Avoidance of copper-zinc solutions by young salmon in the laboratory. J. Water Pollut. Control Fed. 36(8):990-1004.

Sprague, J. B. 1965. Effects of sublethal concentrations of zinc and copper on migration of Atlantic salmon, pp. 332-333. In: Biological Problems in Water Pollution, 3rd Seminar (1962), R. A. Taft Sanitary Eng. Center, Cincinnati, Ohio; USPHS Publ. No. 999-WP-25.

Sprague, J. B. and B. A. Ramsay. 1965. Lethal levels of mixed copper-zinc solutions for juvenile salmon. J. Fish. Res. Bd. Canada 22(2):425-432.

Sprague, J. B. 1968. Promising anti-pollutant: chelating agent NTA protects fish from copper and zinc. Nature 220(5174):1345-1346.

Sreenivasan, A. and R. S. Raj. 1963. Toxicity of zinc to fish. Current Sci. (India) 32(8):363; Chem. Abst. 59:14338b(1963).

Surber, E. W. 1949. Control of aquatic plants in ponds and lakes. U.S. Fish Wildlife Service, Fish. Leaflet No. 344. 26pp.

Surber, E. W. 1960. Cricotopus bicinctus, a midgefly resistant to electroplating wastes. Trans. Amer. Fish. Soc. 88(2)111-116.

Surber, E. W. 1965. Water quality criteria for freshwater fishes, pp. 435-436. In: Proc. 18th Ann. Conf. Southeastern Assoc. Game Fish Commr. (1965). (Abstract)

Surber, E. W. and T. O. Thatcher. 1963. Laboratory studies on the effects of alkyl benzene sulfonate (ABS) on aquatic invertebrates. Trans. Amer. Fish. Soc. 92(2):152-160.

Tarzwell, C. M. and C. Henderson. 1960. Toxicity of less common metals to fishes. Ind. Wastes 5:12.

Trama, F. B. 1954a. The acute toxicity of copper to the common bluegill (Lepomis macrochirus Rafinesque). Notulae Natur. 257:1-13.

Trama, F. B. 1954b. The acute toxicity of some common salts of sodium, potassium and calcium to the common bluegill (Lepomis macrochirus Rafinesque). Proc. Acad. Nat. Sci. Philadelphia 106:185-205.

Tomiyama, T. and A. Yamagawa. 1950. The effect of pH upon toxic effects of sulfide and of sulfite to young carp. Bull. Jap. Soc. Sci. Fish. 15(9):491-495 (in Japanese); Water Pollut. Abst. 26:5,140 (1953).

Turnbull, H., J. G. DeMann and R. F. Weston. 1954. Toxicity of various refinery materials to freshwater fish. Ind. Eng. Chem. 46(2):324-333.

Turnbull-Kemp, P. St. J. 1958. Trout in southern Rhodesia. V. On the toxicity of copper sulfate to trout. Rhodesia Agr. J. 55(6):637-640.

Van Horn, W. M., J. B. Anderson and M. Katz. 1949. The effect of kraft mill wastes on some aquatic organisms. Trans. Amer. Fish. Soc. 79:55-65(1950).

Vivier, P. and M. Nisbet. 1965. Toxicity of some herbicides, insecticides, and industrial wastes, pp. 167-169. In: Biological Problems in Water Pollution, 3rd Seminar (1962), R. A. Taft Sanit. Eng. Center, Cincinnati, Ohio; USPHS Publ. No. 999-WP-25.

Vladimirov, V. I. 1969. Dependence of the embryonic development and viability of the carp on the trace element zinc. Problems in Ichthyology 9(5):681-696. (English Translation).

Wallen, I. E., W. C. Greer and R. Lasater. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid water. Sewage Ind. Wastes 29(6):695-711.

Waller, W. T. and J. Cairns, Jr. 1972. The use of fish movement patterns to monitor zinc in water. Water Res. 6:257-269.

Warrick, L. F., H. E. Wirth and W. Van Horn. 1943. Control of micro-organisms and aquatic vegetation. Water Works Sewage 90(7):267-272; Biol. Abst. 18:1330(1944).

Warrick, L. F., H. E. Wirth and W. Van Horn. 1948. Control of micro-organisms and aquatic vegetation. Water Sewage Works. 95(4):R147-150.

Wedemeyer, G. 1968. Uptake and distribution of Zn^{65} in the coho salmon egg (Oncorhynchus kisutch). Comp. Biochem. Physiol. 26(1):271-279.

Whitley, L. S. 1968. The resistance of tubificid worms to three common pollutants. Hydrobiologia 32(1-2):193-208.

Whitton, B. A. 1970. Toxicity of zinc, copper and lead to Chlorophyta from flowing waters. Arch. Mikrobiol. 72(4):353-360.

Whitworth, W. R. and T. H. Lane. 1969. Effects of toxicants on community metabolism in pools. Limnol. Oceanog. 14(1):53-58.

Williams, L. G. and D. I. Mount. 1965. Influence of zinc on periphyton communities. Amer. J. Bot. 52(1):25-34.

Wilson, R. C. H. 1972. Prediction of copper toxicity in receiving waters. J. Fish. Res. Bd. Canada 29(10):1500-1502.

Wisely, B. and R. A. P. Blick. 1967. Mortality of marine invertebrate larvae in mercury, copper, and zinc solutions. Aust. J. Mar. Freshwater Res. 18:63-72.

Woelke, C. E. 1961. Bioassay - the bivalve larvae tool, pp. 113-123. In: Toxicity in the Aquatic Environment, Proc. 10th Pacific Northwest Symposium on Water Pollution Research, Portland, Ore.

Wurtz, C. B. 1962. Zinc effects on freshwater mollusks. Nautilus 76(2):53-61.

Wurtz, C. B. and C. H. Bridges. 1961. Preliminary results from macro-invertebrate bioassays. Proc. Pa. Acad. Sci. 35:51-56.

Young, R. G. and D. J. Lisk. 1972. Effect of copper and silver ions on algae. J. Water Pollut. Control Fed. 44(8):1643-1647.

Zeitoun, M. A., E. F. Mandelli and W. F. McIlhenny. 1969a. Disposal of the effluents from desalination plants into estuarine waters. Office of Saline Water Research and Development, U.S. Dept. Interior, Washington, D.C. R & D Rept. No. 415 (Contract No. 14-01-001-1161).

Zeitoun, M. A., E. F. Mandelli, W. F. McIlhenny and R. O. Reid. 1969b. Disposal of the effluents from desalination plants: The effect of copper content, heat and salinity. Office of Saline Water Research and Development, U.S. Dept. Interior, Washington, D.C.; R & D Rept. No. 437 (Contract No. 14-01-0001-1161).

Anonymous. 1958. Water pollution research for 1957. Water Pollution Bd., Dept. Sci. Ind. Res., Her Majesty's Stationary Office, London.

P-2. TABLE P. Toxicity of Phosphates to Aquatic Biota

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium phosphate	Polycelis nigra (planaria)	SB,FW,LS	0.026 M	Toxicity threshold, survives 48 hr; pH 7.2, 14-18 C. (M=Molar)	Jones (1941)
Sodium phosphate	Gambusia affinis	SB,FW,LS	720	24, 48 & 96 hr-TLm; 19-23 C, turbid water.	Wallen et al. (1957)
Sodium phospate	Daphnia magna (cladocera)	SB,FW,LS	237 117 126	24 hr-TLm; reference water. 48 hr-TLm; reference water. 96 hr-TLm; reference water.	Dowden & Bennett (1965)
Sodium phosphate	Laccophilus maculosis (aquatic beetle)	CB,FW,LS	0.47 M	Level evoking a reaction from half the animals; 14-18 C. (Molar)	Hodgson (1951)
Sodium phosphate, monobasic	Daphnia magna (cladocera)	SB,FW,LS	<1,560	Just fails to immobilize under 48 hr exposure; Lake Erie water, 25 C.	Anderson (1946)
Sodium phosphate, dibasic	Daphnia magna (cladocera)	SB,FW,LS	<59	Just fails to immobilize in 48 hrs; Lake Erie water, 25 C.	Anderson (1946)
Trisodium phosphate	Polycelis nigra (planaria)	SB,FW,LS	9,860	Toxic threshold concentration.	Jones (1941)
Trisodium phosphate	Daphnia magna (cladocera)	SB,FW,LS	<52	Just fails to immobilize in 48 hrs; Lake Erie water, 25 C.	Anderson (1946)
Trisodium phosphate	Salmo gairdneri	SB,FW,LS	350 300	72 hr-TLm; 20.6-21.1 C. "Threshold concentration"	Liu & Nakatani (1964)
Sodium phosphate tribasic-	Gambusia affinis	SB,FW,LS	467 151	24 & 48 hr-TLm; 17-22 C. 96 hr-TLm; 17-22 C.	Wallen et al. (1957)
Sodium pyrophosphate	Daphnia magna (cladocera)	SB,FW,LS	433 391	24 hr-TLm; lake water. 48 hr-TLm; lake water.	Dowden & Bennett (1965)
Sodium pyrophosphate	Gambusia affinis	SB,FW,LS	1,380	24, 48 & 96 hr-TLm; turbid water.	Wallen et al. (1957)
Sodium pyrophosphate	Salmo gairdneri	FW	1,120	Lethal concentration in 24 hr.	Anonymous (1955)
Sodium hexametaphosphate (Quadratos)	"fish" "oysters"	--- SW	3,500 3,500	Tolerated. Killed.	Rudd & Gevelly (1956)
Sodium hexametaphosphate	"minnows"	FW	>500	TLm value.	Donohue (1971)
Sodium monohydrogen phosphate	Daphnia magna (cladocera)	SB,FW,LS	1,154 1,089 426	24 hr-TLm; reference water. 48 hr-TLm; reference water. 96 hr-TLm; reference water.	Dowden & Bennett (1965)
Sodium polyphosphate	"fish, oysters"	CB,SW,LS	1,500	"Minimum lethal concentration" in 20.5 hrs.	Daugherty (1951)
Sodium tripolyphosphate	Pimephales promelas	SB,FW,LS	140 1300-1500	24, 48 & 96 hr-TLm; soft water, 25 C. 24, 48 & 96 hr-TLm; hard water, 25 C.	Henderson et al. (1959)

P

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field Study

TABLE P. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium tripolyphosphate	*Salmo gairdneri*	FW	1,120	Lethal concentration in 24 hr.	Anonymous (1955)
Zinc phosphate (as Zn)	*Selenastrum capicornutum* (algae)	LS	0.016	No significant effect on growth; culture.	Garton (1972)
			0.064-0.162	Significant effect on growth; culture.	
	Salmo gairdneri	SB,FW,LS	0.016-0.05	No effect, 96 hr; 10 C.	
			0.09	96 hr-Tlm; 10 C.	
Sodium monohydrogen phosphate (a) + Sodium pyrophosphate (b)	*Daphnia magna* (cladocera)	SB,FW,LS	3,580(a) 433(b)	24 hr-TLm; lake water.	Dowden & Bennett (1965)
			3,580(a) 391(b)	48 hr-TLm; lake water.	
	Lymnaea sp. (snail, eggs)		2,685(a) 63(b)	24 hr-TLm; lake water.	
			2,685(a) 248(b)	96 hr-TLm; lake water.	

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

P-3. REFERENCES

Anderson, B. G. 1946. The toxicity thresholds of various sodium salts determined by the use of *Daphnia magna*. Sew. Works J. 18(1):82-87.

Anonymous. 1955. Water Pollution Research, 1954. Her Majestys' Stationary Office, London.

Daugherty, F. M., Jr. 1951. Effects of some chemicals used in oil well drilling on marine animals. Sewage Ind. Wastes 23(10):1282-1287.

Donohue, J. M. 1971. Pollution abatement pressures influence cooling water conditioning. Mat'l Prot. Perf. (Dec. 1971); Betz Laboratories Tech. Paper No. 222.

Dowden, B. F. and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Contr. Fed. 37(9):1308-1316.

Garton, R. R. 1972. Biological effects of cooling tower blowdown. Natl. Environmental Res. Center, Corvallis, Ore. 25 pp. (Presentation, 71st Ann. Meeting, Amer. Inst. Chem. Engrs., Dallas, Texas.)

Henderson, C., Q. H. Pickering and J. M. Cohen. 1959. The toxicity of synthetic detergents and soaps to fish. Few. Ind. Wastes. 31(3):295-306.

Hodgson, E. S. 1951. Reaction thresholds of an aquatic beetle, *Laccophilus maculosis* Germ., to salts and alcohols. Physiol. Zool. 24:131-140.

Jones, J. R. E. 1941. A study of the relative toxicity of anions, with *Polycelis nigra* as test animal. J. Exp. Biol. 18:170-181.

Liu, D. H. W. and R. E. Nakatani. 1964. Toxicity of industrial chemicals to fish, pp. 209-211. In: Biology Research Annual Report for 1963. HW-80500, Hanford Atomic Products Operation, Richland, WA.

Rudd, R. L. and R. E. Gevelly. 1956. Pesticides: their use and toxicity in relation to wildlife. Calif. Dept. Fish and Game, Game Bull. No. 7.

Wallen, I. E., W. C. Greer and R. Lasater. 1957. Toxicity to *Gambusia affinis* of certain pure chemicals in turbid waters. Sew. Ind. Wastes. 29(6):695-711.

Q-2. TABLE Q. Toxicity of Silicates to Aquatic Biota

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium silicate	Daphnia magna (cladocera)	SB,FW,LS	247	Toxicity threshold or 50% immobilized in 100 hr; 9.1 threshold pH.	Freeman & Fowler (1953)
Sodium silicate	Gambusia affinis	SB,FW,LS	2,400	48 hr-TLm, acute. (All data in high turbid water, 21-22 C.)	Wallen et al. (1957)
			3,200	24 hr-TLm, acute.	
			2,320	96 hr-TLm, acute.	
Sodium silicate	Hyallela sp. (amphipod)	SB,FW,LS	895	24 hr-TLm, acute; lake water.	Dowden & Bennett (1965)
			263	48 hr-TLm, acute; lake water.	
			160	96 hr-TLm, acute; lake water.	
	Daphnia magna (cladocera)		575	24 hr-TLm, acute; lake water.	
			494	48 hr-TLm, acute; lake water.	
			216	96 hr-TLm, acute; lake water.	
			247	96 hr-TLm, acute; reference water.	
	Lymnaea sp. (snail, eggs)		630-632	24 to 96 hr-TLm, acute; lake water.	
Sodium silicate	Salmo gairdneri	FW	256	Not lethal; fingerlings.	McKee & Wolf (1963)
Sodium silicate	Salmo gairdneri	FW	>256	Lethal concentration in 24 hr.	Anonymous (1955)
Sodium silicate (a) + Na bisulfite (b)	Daphnia magna (cladocera)	SB,FW,LS	427(a) 177(b)	Toxicity threshold or 50% immobilized in 100 hr; 7.5 threshold pH.	Freeman & [illegible] (1953)
Sodium silicate (a) + Na carbonate (b)	Daphnia magna (cladocera)	SB,FW,LS	85(a) 180(b)	Toxicity threshold or 50% immobilized in 100 hr; 9.3 threshold pH.	Freeman & [illegible] (1953)
Sodium silicate (a) + Na chromate (b)	Daphnia magna (cladocera)	SB,FW,LS	93(a) 0.159(b)	Toxicity threshold or 50% immobilized in 100 hr; 8.7 threshold pH.	Freeman & [illegible] (1953)
Sodium silicate (a) + Na sulfate (b)	Daphnia magna (cladocera)	SB,FW,LS	158(a) 2,899(b)	Toxicity threshold or 50% immobilized in 100 hr; 9.0 threshold pH.	Freeman & [illegible] (1953)
Sodium silicate (a) + Na bisulfite (b)	Daphnia magna (cladocera)	SB,FW,LS	950(a) 14,210(b)	24 hr-TLm, acute; reference water.	Dowden & [illegible] (1965)
			784(a) 11,723(b)	48 hr-TLm, acute; reference water.	
			15(a) 222(b)	96 hr-TLm, acute; reference water.	
Sodium silicate (a) + Na carbonate (b)	Daphnia magna (cladocera)	SB,FW,LS	1,776(a) 265(b)	24 to 96 hr-TLm, acute;	Dowden & [illegible] (1965)
Sodium silicate (a) + Na chromate (b)	Daphnia magna (cladocera)	SB,FW,LS	130(a) 0.21(b)	96 hr-TLm, acute; reference water.	Dowden & [illegible] (1965)

1. SB = Static Bioassay, CB = Cons[illegible]-flow Bioassay, FW = Freshwater, SW = Sea (Salt) water, LS = Lab Study, FS = Field St[illegible]

TABLE Q. (contd)

CHEMICAL COMPOUND	TEST ORGANISM	TEST CONDITIONS[1]	CONCENTRATION (PPM)	REMARKS	REFERENCE
Sodium silicate (a) + Na bisulfite (b) + Na carbonate (c)	Daphnia magna (cladocera)	SB,FW,LS	92(a) 38(b) 194(c)	Toxicity threshold or 50% immobilized in 100 hr; 8.8 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na chromate (b) + Na bisulfite (c)	Daphnia magna (cladocera)	SB,FW,LS	506(a) 0.861(b) 144(c)	Toxicity threshold or 50% immobilized in 100 hr; 6.9 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na bisulfite(b) + Na sulfate (c)	Daphnia magna (cladocera)	SB,FW,LS	126(a) 52(b) 2,308(c)	Toxicity threshold or 50% immobilized in 100 hr; 8.5 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na chromate (b) + Na carbonate (c)	Daphnia magna (cladocera)	SB,FW,LS	86(a) 0.146(b) 182(c)	Toxicity threshold or 50% immobilized in 100 hr; 9.1 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na carbonate (b) + Na sulfate (c)	Daphnia magna (cladocera)	SB,FW,LS	73(a) 155(b) 1,343(c)	Toxicity threshold or 50% immobilized in 100 hr; 8.8 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na chromate (b) + Na sulfate (c)	Daphnia magna (cladocera)	SB,FW,LS	119(a) 0.201 (b) 2,180(c)	Toxicity threshold or 50% immobilized in 100 hr; 8.5 threshold pH.	Freeman & Fowler (1953)
Sodium silicate (a) + Na bisulfite (b) + Na carbonate (c)	Daphnia magna (cladocera)	SB,FW,LS	93(a) 39(b) 198(c)	100 hr-TLm, acute; reference water.	Dowden & Bennett (1965)
Sodium silicate (a) + Na chromate (b) + Na bisulfite (c)	Daphnia magna (cladocera)	SB,FW,LS	506(a) 0.86(b) 224(c)	100 hr-TLm, acute; reference water.	Dowden & Bennett (1965)
Sodium silicate (a) + Na sulfate (b) + Na bisulfite (c)	Daphnia magna (cladocera)	SB,FW,LS	126(a) 2,326(b) 52(c)	100 hr-TLm, acute; reference water.	Dowden & Bennett (1965)
Sodium silicate (a) + Na chromate (b) + Na carbonate (c)	Daphnia magna (cladocera)	SB,FW,LS	88(a) 0.15(b) 187(c)	96 hr-TLm, acute; reference water.	Dowden & Bennett (1965)
Sodium silicate(a) + Na carbonate (b) + Na sulfate (c)	Daphnia magna (cladocera)	SB,FW,LS	76(a) 161(b) 1,396(c)	100 hr-TLm, acute; reference water.	Dowden & Bennett (1965)
Sodium silicate (a) + Na chromate (b) + Na sulfate (c)	Daphnia magna (cladocera)	SB,FW,LS	122(a) 0.28(b) 2,255(c)	100 hr-TLm, acute; reference water.	Dowden & Bennett (1965)

1. SB = Static Bioassay, CB = Constant-flow Bioassay, FW = Freshwater, SW = Sea (Salt) Water, LS = Lab Study, FS = Field Study

Q

Q-3. REFERENCES

Anonymous. 1958. Water Pollution Research, 1954. Her Majesty's Stationary Office, London.

Dowden, B. F. and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Control Fed. 37(9):1308-1316.

Freeman, L. and I. Fowler. 1953. Toxicity of combinations of certain inorganic compounds to Daphnia magna Straus. Sewage Ind. Wastes. 25(10):1191-1195.

McKee, J. E. and H. W. Wolf. 1963. Water Quality Criteria, 2nd ed. Water Resources Control Board, State of California, Publ. No. 3-A. 548 pp.

Wallen, I. E., W. C. Greer and R. Lasater. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind. Wastes. 29(6):695-711.

APPENDIX A

COMMON NAMES AND TAXONOMIC POSITION OF FISH LISTED IN THE TOXICITY TABLES

SCIENTIFIC NAME	COMMON NAME	FAMILY	HABITAT TYPE
Abramis brama	bream	Cyprinidae	freshwater
Alosa chrysochloris	skipjack herring	Clupeidae	anadromous
Amia calva	bowfin	Amiidae	freshwater
Anguilla anguilla	European eel	Anguillidae	catadromous
Anguilla japonica	Japanese eel	Anguillidae	catadromous
Anguilla rostrata	American eel	Anguillidae	catadromous
Astronotus ocellatus	velvet cichlid	Cichlidae	freshwater
Brachydanio rerio	zebra fish	Cyprinidae	freshwater
Campostoma anomalum	stoneroller	Cyprinidae	freshwater
Carassius auratus	goldfish	Cyprinidae	freshwater
Carassius carassius	"European" goldfish	Cyprinidae	freshwater
Catostomus commersoni	white sucker	Catostomidae	freshwater
Clupea harengus pallasi	Pacific herring	Clupeidae	marine
Cristivomer namaycush	• Salvelinus namaycush		
Cymatogaster aggregata	shiner perch	Embiotocidae	marine
Cyprinus carpio	carp	Cyprinidae	freshwater
Dorosoma cepedianum	gizzard shad	Clupeidae	freshwater, marine
Dorosoma petenense	threadfin shad	Clupeidae	freshwater, marine
Ericymba buccata	silverjaw minnow	Cyprinidae	freshwater
Esox lucius	northern pike	Esocidae	freshwater
Fundulus diaphanus	banded killifish	Cyprinodontidae	freshwater, brackish water
Fundulus heteroclitus	mummichog	Cyprinodontidae	freshwater, brackish water
Fundulus similis	longnose killifish	Cyprinodontidae	freshwater, marine
Fundulus notatus	blackstripe topminnow	Cyprinodontidae	freshwater
Gambusia affinis	mosquitofish	Poeciliidae	freshwater, brackish water
Gasterosteus aculeatus	Threespine stickleback	Gasterosteidae	freshwater, brackish water
Gobio gobio	gudgeon	Cyprinidae	freshwater
Hesperoleucus sp.	roach	Cyprinidae	freshwater
Ictalurus melas	black bullhead	Ictaluridae	freshwater
Ictalurus natalis	yellow bullhead	Ictaluridae	freshwater
Ictalurus nebulosus	brown bullhead	Ictaluridae	freshwater
Ictalurus punctatus	channel catfish	Ictaluridae	freshwater
Kuhlia sandvicensis		Kuhliidae	marine
Lagodon rhomboides	pinfish	Sparidae	marine
Lebistes reticulatus	guppy	Cyprinodontidae	freshwater
Lepisosteus osseus	longnose gar	Lepisosteidae	freshwater
Lepomis auratus	redbreast sunfish	Centrarchidae	freshwater
Lepomis cyanellus	green sunfish	Centrarchidae	freshwater
Lepomis gibbosus	pumpkinseed	Centrarchidae	freshwater
Lepomis humilis	orangespotted sunfish	Centrarchidae	freshwater
Lepomis macrochirus	bluegill	Centrarchidae	freshwater
Lepomis pallidus	• L. macrochirus		
Leuciscus phoxinus	• Phoxinus phoxinus		
Micropterus dolomieui	smallmouth bass	Centrarchidae	freshwater
Micropterus salmoides	largemouth bass	Centrarchidae	freshwater

APPENDIX A (Contd)

SCIENTIFIC NAME	COMMON NAME	FAMILY	HABITAT TYPE
Mollienesia latipinna	sailfin molly	Cyprinodontidae	freshwater
Morone americanus	white perch	Percichthyidae	freshwater, marine
Morone saxatilis	striped bass	Percichthyidae	freshwater, marine
Nemachilus barbatulus	European stoneloach	Cobitidae	freshwater
Notemigonus crysoleucas	golden shiner	Cyprinidae	freshwater
Notropis atherinoides	emerald shiner	Cyprinidae	freshwater
Notropis cornutus	common shiner	Cyprinidae	freshwater
Notropis hudsonius	spottail shiner	Cyprinidae	freshwater
Notropis lutrensis	red shiner	Cyprinidae	freshwater
Notropis spilopterus	spotfin shiner	Cyprinidae	freshwater
Notropis umbratilis	redfin shiner	Cyprinidae	freshwater
Notropis whipplei	steelcolor shiner	Cyprinidae	freshwater
Oncorhynchus gorbusca	pink salmon	Salmonidae	anadromous
Oncorhynchus keta	chum salmon	Salmonidae	anadromous
Oncorhynchus kisutch	coho salmon	Salmonidae	anadromous
Oncorhynchus tshawytscha	chinook salmon	Salmonidae	anadromous
Perca flavescens	yellow perch	Percidae	freshwater
Petromyzon marinus	sea lamprey	Petromyzontidae	anadromous
Phoxinus phoxinus	minnow	Cyprinidae	freshwater
Pimephales notatus	bluntnose minnow	Cyprinidae	freshwater
Pimephales promelas	fathead minnow	Cyprinidae	freshwater
Pomoxis annularis	white crappie	Centrarchidae	freshwater
Pseudopleuronectes americanus	winter flounder	Pleuronectidae	marine
Ptychocheilus oregonensis	northern squawfish	Cyprinidae	freshwater
Pungitius pungitius	ninespine stickleback	Gasterosteidae	freshwater, brackish water
Pygosteus pungitius =	Pungitius pungitius		
Rasbora heteromorpha	harlequin fish	Cyprinidae	freshwater
Rhinichthys atratulus	blacknose dace	Cyprinidae	freshwater
Roccus americanus =	Morone americanus		
Roccus saxatilus =	Morone saxatilus		
Rutilus rutilus	European roach	Cyprinidae	freshwater
Salmo clarki	cutthroat trout	Salmonidae	freshwater
Salmo gairdneri	rainbow or steelhead trout	Salmonidae	freshwater or anadromous
Salmo irideus =	S. gairdneri		
Salmo salar	Atlantic salmon	Salmonidae	anadromous
Salmo trutta	brown trout	Salmonidae	freshwater
Salvelinus fontinalis	brook trout	Salmonidae	freshwater
Salvelinus namaycush	lake trout	Salmonidae	freshwater
Scardinius erythrophthalmus	rudd	Cyprinidae	freshwater
Semotilus atromaculatus	creek chub	Cyprinidae	freshwater
Squalus cephalus	chub	Cyprinidae	freshwater
Stenotomus chrysops	scup	Sparidae	marine
Stizostedion vitreum	walleye	Percidae	freshwater
Tilapia mossambica	mozambique mouthbrooder	Cichlidae	freshwater
Tinca tinca	tench	Cyprinidae	freshwater
Xiphophorus maculatus	southern platyfish	Poeciliidae	freshwater

ATTACHMENT 3

LIST OF HAZARDOUS SUBSTANCES

LISTED HAZARDOUS SUBSTANCES THAT WOULD BE DISCHARGED IN LESS THAN RQ AMOUNTS

Substance	Outfall(s)
aluminum sulfate	002, 004
ferric ammonium sulfate	002, 004
sodium phosphate tribasic	001, 002, 003, 004, 005
nitrogen dioxide	002, 004
p-benzene dimethyl p-xylene	002, 003, 004
m-benzene m-xylene	002, 003, 004
mercuric sulfate	002, 004
potassium hydroxide	002, 004
potassium permanganate	002, 004
sodium bisulfite	002, 004
hydrochloric acid	002. 003, 004
phosphoric acid	002, 004
hydrofluoric acid	002, 004
sodium fluoride	002, 004
zinc sulfate	002, 004
sodium phosphate	002, 004
sodium chromate	002, 004
o-benzene o-xylene	002, 004
acetic acid	002, 003, 004
sodium cyanide	002, 004
ammonium thiocyanate	002, 004
nitrophenol	002, 004
ammonium hydroxide	002, 003, 004
sodium azide	002, 004
antimony potassium tartrate	002, 004
chloroform	002, 004
formaldehyde	002, 004
formic acid	001, 002, 003, 004,
sodium phosphate, dibasic	002, 004
dichlorodifluoromethane	002, 004
trichloromonofluoromethane	002, 004
silver nitrate	002, 004
sodium hydroxide	003
sulfuric acid	003

BULK CHEMICAL SUBSTANCES THAT MAY BE DISCHARGED IN LOW CONCENTRATIONS

Substance	Outfall(s)
benzotriazole	001, 002, 004
boric acid	002, 004
Bulab 6002	001, 002, 004
C-1 antifoam	001, 002, 003, 004
citric acid	001, 002, 004, 005
CL-[illegible]5	001, 002, 004,
Clam-Trol CT-1	001, 002, 004
ethylene glycol	002, 004
fire-prep 8265 microbicide	001, 002, 004
H-130	001, 002, 004
H-212 microbicide*	001, 002, 004
H-303 microbicide*	001, 002, 004
H-450*	001, 002, 004
hydrogen peroxide	002, 004
lithium hydroxide monohydrate	002, 004
mercaptobenzothiazole (MBT)	001, 002, 004
morpholine	002, 004
nalcolyte 8103 coagulant	002, 004
PCL-2000	001, 002, 004
potassium phosphate dibasic	002, 004
sodium bicarbonate	001, 002, 003, 004, 005
sodium borate	002, 004
sodium carbonate	002. 003, 004
sodium chloride	002, 004
sure-cool inhibitor	002, 004
triton CF-54 surfactant	001, 002, 003, 004, 005
commercial cleansers	001, 002, 003, 004, 005

*Approval for discharge will be requested at a later date