**The Toxicity of 35 Trace Elements
in Coal to Freshwater Biota: A Data Base
with Automated Retrieval Capabilities**

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ABSTRACT

CUSHMAN, R. M., S. G. HILDEBRAND, R. H. STRAND, and R. M. ANDERSON. 1977. The toxicity of 35 trace elements in coal to freshwater biota: a data base with automated retrieval capabilities. ORNL/TM-5793. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 46 pp.

Data are tabulated on the toxicity to freshwater biota of 35 trace elements with the potential for release to the environment from coal conversion effluents. The entire data base is presented on a microfiche appended to this document, in the interest of portability and accessibility. The data were gathered from a variety of research papers, compendia, and reviews. Details of water chemistry and test conditions are presented when available from the documents consulted. The data base may be used by referring directly to the tabulated data as they appear on the microfiche, or, with appropriate computer facilities, by manipulation (sorting, subsetting, or merging) of the data to meet the particular needs of the investigator. The data may be used as they appear in the data base, or the data base may be used to index the cited original papers.

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INTRODUCTION

At least 30 trace elements have been detected in measurable quantities¹ in potential aqueous effluents from coal conversion processes. For elements such as chromium, copper, and zinc, there exists an extensive literature describing the toxic effects on aquatic biota. However, for the majority of elements, the data are less abundant, less available, and scattered throughout a diverse literature of compendia, review papers, and papers describing original research. It is, therefore, difficult for an individual to readily assemble the available toxicity data in order to assess, for example, the potential toxicity of a given concentration of a particular element. Reliance upon one or more of the standard compendia restricts data extraction to that information contained in the compendia. Furthermore, details of the experimental conditions (water chemistry, type of bioassay employed, etc.) may or may not be provided. Maintaining a current knowledge of the burgeoning toxicity literature is also unrealistic for most researchers, if only because of the time consumed.

This effort represents the gathering of trace element toxicity data from a wide variety of sources into a single computerized data base. Data were gathered both from original research papers and from summary and review documents. The 35 elements listed in Table 1 were used in the literature search for available toxicity information, as they had potential for release to the environment from coal conversion process effluents and they could be toxic to freshwater biota. The concentration of the element and details of the bioassay or field conditions were extracted. Such conditions as water chemistry, life stage, and observed toxic effect were extracted in addition to other useful information. In our data extractions from the literature, we consistently sought values for the set of variables in the computerized data base. Table 2 lists and defines the variables used in the data base. Certain variables unique to a research paper were not included in the data base due to space requirements.

Details of the bioassay or field situation used in the paper were extracted when available since water chemistry and test conditions would be necessary for interpretation and application of the data. However, details such as these were frequently not included in summary documents. Table 3 shows the percent frequency of occurrence over all observations for which a value for each of the variables described in Table 2 was

¹S. G. Hildebrand, R. M. Cushman, and J. A. Carter. The potential toxicity and bioaccumulation in aquatic systems of trace elements present in aqueous coal conversion effluents. Proc. of 10th Ann. Conf. on Trace Substances in Environmental Health, Columbia, MO, June 8-10, 1976, D. D. Hemphill, ed., in press.

reported. These percentages are listed by element and range from 0 to 100% depending on the element and the variable. Where additional descriptions of the research are desired, we refer the user to the original references.

This report describes the data base we have formulated and computerized and shows a typical use and application of the data base for determining the effects of certain trace elements on biota. Since the data base is in the preliminary stages, we expect that (a) the user will find documents from which we have not extracted data, (b) this data base will be expanded as funding permits, and (c) applications will be more extensive and useful as more data are added. We present the data base in an abbreviated form below to show the user what kinds of data were extracted. The complete data base, together with concise descriptions of the variables, the frequency table (Table 3), and references are supplied on microfiche in the pocket insert (inside back cover). We believe that this form of the entire data base is more portable and accessible than a voluminous printout of the entire data base. With proper attention paid to this report, the reader should be able to use just the microfiche for subsequent access to the data base.

DATA BASE CONTENTS

What follows is a description of what is contained in the data base as presented in its entirety on the microfiche contained in the pocket insert. We will describe the data base as an item contained within the microfiche. The microfiche includes:

- Item 1. definitions of the variable names used in the data tables;
- Item 2. a table of frequency of occurrence of data for each of the variables in the data base, by element;
- Item 3. the entire data base in tabular form, with an observation number assigned to each record;
- Item 4. the observations sorted alphabetically by organism, with the element, its chemical form, and a cross-reference to the observation number in the entire data base (Item 3); and
- Item 5. the list of references from which data were extracted and which are listed as variables in the entire data base (Item 3) to provide a cross-reference between the data base and the references.

Items 1, 2, 4, and 5 are descriptions, definitions, or rearrangements of the entire data base (Item 3). They are necessary for completing the microfiche as an exportable and usable data base. We have presented a sample of the entire data base in Table 4.

Data are presented both for lethal and sublethal effects. Data in the form LCX signify the lethal concentration for X percent of the organisms tested in the stated time period, if a time is specified, as in a 96-hr LC50. Endpoints reported as ILL (incipient lethal level) indicate threshold effects or concentrations causing mortality with theoretically infinite exposure. Sublethal effects include impairment of reproduction, growth, behavior, etc. For a rigorous discussion of bioassays and toxicity terminology the reader is referred to the series "Measurement of pollutant toxicity to fish," by J. B. Sprague, published in three parts:

- (1969) I. Bioassay methods for acute toxicity. Water Research 3:793-821.
- (1970) II. Utilizing and applying bioassay results. Water Research 4:3-32.
- (1971) III. Sublethal effects and "safe" concentrations. Water Research 5:245-266.

In addition to the element and its concentration (mg/l), test organism (species and life stage), and toxicity end point, we have tabulated water chemistry parameters and other test conditions, including:

- (1) type and source of dilution water
- (2) whether the test was static or continuous flow
- (3) temperature ($^{\circ}\text{C}$)
- (4) hardness (mg/l)
- (5) pH
- (6) calcium concentration (mg/l)
- (7) magnesium concentration (mg/l)
- (8) dissolved oxygen (DO) (mg/l)
- (9) total dissolved solids (TDS) (mg/l)
- (10) alkalinity (mg/l)
- (11) miscellaneous comments
- (12) form of element or chemical compound used

For some of the variables (concentration, temperature, hardness, pH, dissolved oxygen, total dissolved solids, and alkalinity), a range of values was reported, and minimum and maximum values of the variable(s) are tabulated in the data base. However, where only a single value appears (as either a minimum or a maximum) a range was not reported, and the listed value does not necessarily represent a minimum or a maximum. Where a value for a variable was not present in the report, a period is recorded in the data tables.

For each observation, two reference citations are given, one representing the source(s) from which we directly obtained the data (variables OUR_REF1, OUR_REF2, and OUR_REF3), and the other representing

the source(s) in which the data first were reported (variables REF1ORIG, REF2ORIG, and REF3ORIG). The values for these variables, tabulated in the data base (Item 3), correspond to the numbers preceding each reference in the list of references (Item 5). Thus, the cross-reference between the two items in the data base. Table 5 lists the scientific (and common) names used in the data base, grouped into fish, protozoa, algae, other plants, crustacea, insecta, mollusca, and other animals. Table 6 relates the printout of the chemical form symbols as they appear on the microfiche to the appropriate chemical formulas. Table 7 is the list of references, which also appears in the microfiche output.

DATA BASE PREPARATION

Following the selection of a reference and the itemization of the test conditions used in the bioassay, the data were encoded in a format with a varying amount of space allowed for each variable. Once computerized, each observation consisted of multiple 80-column card images. An initial file was maintained a MODCOMP II/25 computer where editing was performed. This file was then transferred to an IBM 360/91 where management of the data base is currently maintained. The Statistical Analysis System (SAS)² was the main computer software used for producing the microfiche output included in the pocket insert.

DATA BASE USE

The data base was prepared to allow for manipulation and display of any of the variables. Some of the manipulations include sorting, e.g., sorting the data base by manganese concentration, subsetting, e.g., separating those observations where a specific water type and/or lifestage are desired, and merging, e.g., adding new observations to the file.

A specific example manipulation of the data base is shown in Table 8. Here we show an entire program listing, less computer-installation-specific job control statements, of statements written in the SAS language, and a portion of the corresponding output, used to subset the data base for a group of organisms (crustaceans). The syntax of this language uses semicolons to end statements. Thus the code which precedes each semicolon constitutes a single instruction. This particular example creates a data set called EFFECTS. The variables are then defined, using mnemonic names, as they occur in columns of the

²A. J. Barr, J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A User's Guide to SAS 76. SAS Institute, Inc., P. O. Box 10522, Raleigh, NC.

input cards. Variables with character, rather than numeric, values are defined by a dollar sign on the input definition statement. The set of "IF" statements is used to include the observations with the desired organisms. A title card is used to label the printed output. This example illustrates how the data base can be subset for a particular organism to determine the effects, compounds, and test conditions which have been observed and included in the data base.

The example presented in Table 8 requires a set of data in the form described by the input statements. If the format changes for additional data, programs will have to be devised to manipulate the new format and merge the old and new data. The data base presented in the pocket insert has a format as described in the SAS input statements. A user who might be interested in manipulating the data base or implementing the data base on his computer should initially contact the third author for the availability of the data base and its available form.

In summary, our data base is an initial step towards expediting the tedious job of extracting, synthesizing, and tabulating, in numeric form, the current data available on toxic effects to aquatic organisms from trace elements in coal conversion process effluents. We feel this kind of effort is important to understanding the state-of-the-art with respect to inorganic toxic substances in aquatic systems. We emphasize the flexibility and ease of use of the computer methodology which we have developed for manipulating and displaying the data base. Researchers will find that the data base will ease the burden of literature search and evaluation. It will provide a starting point for directing researchers to current publications in toxic effects work and also provide a baseline for future research efforts.

Table 1. Elements included in the toxicity data base

Ag (silver)	Mn (manganese)
Al (aluminum)	Mo (molybdenum)
As (arsenic)	Ni (nickel)
Au (gold)	Pb (lead)
B (boron)	Rb (rubidium)
Ba (barium)	Sb (antimony)
Be (beryllium)	Se (selenium)
Br (bromine)	Sn (tin)
Cd (cadmium)	Sr (strontium)
Ce (cerium)	Th (thorium)
Co (cobalt)	Ti (titanium)
Cr (chromium)	Tl (thallium)
Cu (copper)	U (uranium)
Fe (iron)	V (vanadium)
Hg (mercury)	W (tungsten)
La (lanthanum)	Zn (zinc)
Li (lithium)	Zr (zirconium)
Mg (magnesium)	

Table 2. Variables and variable definitions used in the data base.

ALK_MAX = MAXIMUM ALKALINITY OF SOLUTION (MG/L)
 ALK_MIN = MINIMUM ALKALINITY OF SOLUTION (MG/L)
 CA_ION = CALCIUM ION CONCENTRATION IN WATER (MG/L)
 CHEMPFORM = CHEMICAL FORM OF ELEMENT
 CCMMENTS = COMMENTS ABOUT BIOASSAY
 CONC_MAX = MAXIMUM CONCENTRATION OF ELEMENT (MG/L)
 CCNC_MIN = MINIMUM CONCENTRATION OF ELEMENT (MG/L)
 DO_MAX = MAXIMUM DISSOLVED OXYGEN CONCENTRATION (MG/L)
 DO_MIN = MINIMUM DISSOLVED OXYGEN CONCENTRATION (MG/L)
 ELEMENT = ELEMENTAL CONSTITUENT OF COMPOUND IN BIOASSAY
 EXP_END = THE END POINT OF BIOASSAY
 EXP_TIME = THE DURATION OF THE BIOASSAY
 HARD_MAX = MAXIMUM WATER HARDNESS (MG/L)
 HARD_MIN = MINIMUM WATER HARDNESS (MG/L)
 LIFE_STG = THE LIFE STAGE OF THE ORGANISM
 MG_ION = MAGNESIUM ION CONCENTRATION (MG/L)
 OEGANISM = SCIENTIFIC OR COMMON NAME OF ORGANISM
 OUR_REF1 = FIRST REFERENCE NUMBER FROM WHICH TABULATED DATA WERE OBTAINED
 OUR_REF2 = SECOND REFERENCE NUMBER FROM WHICH TABULATED DATA WERE OBTAINED
 OUR_REF3 = THIRD REFERENCE NUMBER FROM WHICH TABULATED DATA WERE OBTAINED
 PH_MAX = MAXIMUM PH VALUE
 PH_MIN = MINIMUM PH VALUE
 RECON_FQ = SOLUTION RECONCENTRATION FREQUENCY
 REF1ORIG = THE FIRST REFERENCE IN WHICH DATA WERE ORIGINALLY REPORTED
 REF2ORIG = THE SECOND REFERENCE IN WHICH DATA WERE ORIGINALLY REPORTED
 REF3ORIG = THE THIRD REFERENCE IN WHICH DATA WERE ORIGINALLY REPORTED
 TDS_MAX = MAXIMUM TOTAL DISSOLVED SOLIDS (MG/L)
 TDS_MIN = MINIMUM TOTAL DISSOLVED SOLIDS (MG/L)
 WATER_TY = TYPE AND SOURCE OF DILUTION WATER
 WTMP_MAX = MAXIMUM WATER TEMPERATURE (DEGREES C)
 WTMP_MIN = MINIMUM WATER TEMPERATURE (DEGREES C)

Table 3. Frequency of occurrence of water chemistry and test conditions variables for each element. Each value represents the percent of the N observations (listed under column heading N) for which data were reported for each of the elements and listed variables.

E L E M E N T	N	C H E M - F Q	L I P S T - F Q	E I P - F Q	W A T T Y - F Q	R E C F Q	W T - F Q	W T - F Q	H R D M X - F Q	H R D M X - F Q	P H - F Q	P H - F Q	C A - F Q	H G - F Q	D O - F Q	D O - F Q	T D S M X - F Q	T D S M X - F Q	A L K M X - F Q	A L K M X - F Q
AG	27	81	11	67	37	30	33	37	0	0	19	19	0	0	0	0	0	0	0	0
AL	34	100	3	79	82	32	21	38	0	15	0	9	0	0	0	0	0	0	0	0
AS	140	93	1	46	53	36	9	21	0	2	2	8	2	0	0	0	0	0	0	0
AU	9	100	0	89	89	67	56	89	0	33	0	0	0	0	0	0	0	0	0	0
B	22	100	0	64	50	55	27	64	0	0	0	5	0	0	0	0	0	0	0	0
BA	43	93	14	67	49	19	16	49	0	12	12	12	0	0	0	0	0	0	0	0
BE	19	100	0	100	100	100	0	0	0	58	58	58	0	0	0	0	0	0	0	0
BR	11	36	0	64	82	100	0	0	0	0	0	18	0	0	0	0	0	0	0	0
CD	82	72	23	78	54	52	20	46	9	21	13	26	0	0	7	11	0	0	0	0
CE	5	100	0	100	0	20	0	40	0	0	0	0	0	0	0	0	0	0	0	0
CO	34	85	6	82	47	41	21	62	9	26	26	38	0	0	9	9	0	0	0	0
CR	208	100	10	80	44	60	16	55	1	7	8	13	0	0	4	4	0	0	0	2
CU	357	79	15	67	38	52	10	51	2	15	6	21	0	0	1	13	0	0	0	1
FE	94	90	17	82	44	15	2	16	3	9	6	12	0	0	3	3	0	0	0	0
HG	95	92	5	66	22	23	8	18	4	12	13	14	0	0	3	3	0	0	0	0
LA	4	100	0	100	100	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0
LI	11	100	0	64	18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HG	47	100	9	91	66	26	11	23	0	11	11	11	0	0	0	0	0	0	0	0
MN	80	96	24	57	44	34	6	32	0	5	6	6	0	0	0	0	0	0	0	0
MO	5	40	0	40	60	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	61	87	3	67	44	34	10	34	5	25	16	28	0	0	5	16	0	0	0	0
PB	108	80	2	78	59	39	13	33	3	22	20	33	0	0	3	8	4	4	0	0
RB	2	100	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE	13	77	0	62	69	38	0	23	0	0	0	0	0	0	0	0	0	0	0	0
SE	13	100	0	85	85	23	23	46	0	23	23	23	0	0	0	0	0	0	0	0
SN	12	92	0	75	75	25	0	42	0	42	0	8	0	0	0	0	0	0	0	0
SR	24	100	0	75	54	38	21	46	0	21	21	21	0	0	0	0	0	0	0	0
TH	4	100	0	75	75	25	0	50	0	0	0	0	0	0	0	0	0	0	0	0
TI	6	83	0	83	100	33	0	33	0	0	0	0	0	0	0	0	0	0	0	0
TL	8	0	0	50	0	0	13	13	0	25	0	0	0	0	0	0	0	0	0	0
U	9	89	0	44	100	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V	7	86	0	86	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	4	100	0	100	100	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0
ZN	352	53	20	81	41	61	19	62	2	20	15	31	4	3	1	14	0	0	0	1
ZR	6	100	0	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3 (continued). Definitions of variables used in the frequency-of-occurrence table, representing percent frequency of non-blank data.

<u>Column Heading</u>	<u>Variable (see Table 2)</u>
ALKMN_FQ	ALK_MIN
ALKMX_FQ	ALK_MAX
CA____FQ	CA_ION
CHFM__FQ	CHEMFORM
DO_MN_FQ	DO_MIN
DO_MX_FQ	DO_MAX
EXP_T_FQ	EXP_TIME
HRDMN_FQ	HARD_MIN
HRDMX_FQ	HARD_MAX
LIFST_FQ	LIFE_STG
MG____FQ	MG_ION
PH_MN_FQ	PH_MIN
PH_MX_FQ	PH_MAX
RECFQ_FQ	RECON_FQ
TDSMN_FQ	TDS_MIN
TDSMX_FQ	TDS_MAX
WATTY_FQ	WATER_TY
WT_MN_FQ	WTMP_MIN
WT_MX_FQ	WTMP_MAX

Table 4. Sample page from data base.

O E S	E L E M E N T S	C O N C E N T R A L	C O N C E N T R A L	C O N C E N T R A L	O R G A N I S M	L I F E S P E C I E S	E X P E R I M E N T	E X P E R I M E N T														
1	1	AG	.	0.0030	AGN03	GASTEROSTEUS ACULEATUS		ILL														
2	4	AG	.	0.0032	AGN03	DAPHNIA MAGNA		LETHAL														
3	2	AG	.	0.0040	AGN03	GASTEROSTEUS ACULEATUS	7 DAY	SURVIVAL														
4	3	AG	.	0.0043	AGN03	LEBISTES BETICULATUS		LC50														
5	5	AG	.	0.0100	AGN03	GASTEROSTEUS ACULEATUS	4 DAY	SURVIVAL														
6	8	AG	.	0.0100		LEBISTES BETICULATUS		LETHAL														
7	6	AG	.	0.0200	AGN03	GASTEROSTEUS ACULEATUS	2 DAY	SURVIVAL														
8	9	AG	.	0.0250	AGN03	ONCORHYNCHUS TSHAWYTSCHA	48 HR	PARTLY LETHAL														
9	7	AG	.	0.0300	AGN03	DAPHNIA MAGNA	96 HR	ILL														
10	10	AG	.	0.0300	AGN03	MICROREGMA	96 HR	ILL														
11	11	AG	.	0.0400	AGN03	ESCHERICHIA COLI	96 HR	ILL														
12	12	AG	.	0.0500	AGN03	SCHEDESMUS	96 HR	ILL														
13	13	AG	.	0.1000	AGN03	GASTEROSTEUS ACULEATUS	1 DAY	SURVIVAL														
14	16	AG	.	0.1000		BUFO VALLICEPS	TADPOLES	LETHAL														
15	17	AG	.	0.1000		DAPHNIA MAGNA		LETHAL														
16	15	AG	.	0.1500	AGN03	POLYCELIS NIGRA		ILL														
17	14	AG	.	0.2800	AGN03	SALMON	48 HR	LETHAL														
18	18	AG	.	0.3000	AGN03	SEWAGE ORGANISMS		50% B.O.D. REDUCTION														
O B S	W A T E R T E M P E R A T U R E	R E C O N D I T I O N	W T E R T E M P E R A T U R E	W T E R T E M P E R A T U R E	H A R D N E S S	H A R D N E S S	P H	P H	C A	M G	D O	D O	T D	T D	A L	A L	C O M M E N T S	R E P O R T E D R E S U L T S	R E P O R T E D R E S U L T S	R E P O R T E D R E S U L T S	O U T P U T	O U T P U T
1	TAP VERY SOFT	RENEWED DAILY	18	14.0	6.8	6.0	.	.	.	.	.	.	.	.	.	.	.	117	118	75		
2	LAKE ERIE	.	.	25.0	.	.	.	.	.	.	.	.	.	.	.	.	.	7		159		
3	TAP VERY SOFT	RENEWED DAILY	18	14.0	6.8	6.0	.	.	.	.	.	.	.	.	.	.	.	117	118	75		
4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	218		159		
5	TAP VERY SOFT	RENEWED DAILY	18	14.0	6.8	6.0	.	.	.	.	.	.	.	.	.	.	.	117	118	75		
6	.	STATIC	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	217		126		
7	TAP VERY SOFT	RENEWED DAILY	18	14.0	6.8	6.0	.	.	.	.	.	.	.	.	.	.	.	117	118	75		
8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	153		75		
9	RIVER	.	25	23.0	.	.	.	.	.	.	.	.	.	.	.	.	.	35		159		
10	RIVER	.	27	23.0	.	.	.	.	.	.	.	.	.	.	.	.	.	36		159		
11	RIVER	.	27	23.0	.	.	.	.	.	.	.	.	.	.	.	.	.	35		159		
12	RIVER	.	27	23.0	.	.	.	.	.	.	.	.	.	.	.	.	.	35		159		
13	TAP VERY SCPT	RENEWED DAILY	18	14.0	6.8	6.0	.	.	.	.	.	.	.	.	.	.	.	117	118	75		
14	.	STATIC	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	217		126		
15	.	STATIC	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	217		126		
16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	119		159		
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	153		159		
18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	219		126		

Table 5. Scientific and common names of organisms in toxicity table.

Fish

Abramis brama (bream)
Anguilla japonica (Japanese eel)
Anguilla rostrata (American eel)
Brachydanio rerio (zebra fish)
Carassius auratus (goldfish)
Carassius carassius (European goldfish, European carp)
Cyprinus carpio (carp)
Fundulus diaphanus (banded killifish)
Fundulus heteroclitus (mummichog)
Gambusia affinis (mosquitofish)
Gasterosteus aculeatus (threespine stickleback)
Gobio gobio (gudgeon, gobie)
Hesperiroleucus (roach)
Ictalurus nebulosus (brown bullhead)
Ictalurus punctatus (channel catfish)
Lebistes reticulatus (guppy)
Lepomis cyanellus (green sunfish)
Lepomis gibbosus (pumpkinseed)
Lepomis macrochirus (bluegill)
Micropterus dolomieu (smallmouth bass)
Micropterus salmoides (largemouth bass)
Morone americanus (white perch)
Morone saxatilis (striped bass, rockfish)
Nemachilus barbatulus (European stone loach)
Notemigonus crysoleucas (golden shiner)
Notropis cornutus (common shiner)
Notropis hudsonius (spottail shiner)
Oncorhynchus gorbusca (pink salmon)
Oncorhynchus keta (chum salmon)
Oncorhynchus kisutch (coho salmon)
Oncorhynchus nerka (sockeye salmon)
Oncorhynchus tshawytscha (chinook salmon)
Orizias latipes (Japanese medaka)
Perca flavescens (yellow perch)
Perca fluviatilis (Eurasian perch)
Petromyzon marinus (sea lamprey)
Phoxinus phoxinus (minnow, red-sided shiner)
Pimephales promelas (fathead minnow)
Pomoxis (crappie)
Pungitius pungitius (ninespine stickleback)
Rutilus rutilus (roach)
Salmo clarki (cutthroat trout)
Salmo gairdnerii (rainbow or steelhead trout)
Salmo salar (Atlantic salmon)
Salmo trutta (brown trout)
Salvelinus fontinalis (brook trout)
Salvelinus namaycush (lake trout)
Scardinius erythrophthalmus (rudd)
Semotilus atromaculatus (creek chub)
Tilapia mossambica (mozambique mouthbrooder)
Tinca tinca (tench)
Xiphophorus maculatus (southern platyfish)

Table 5. (Continued)

Protozoa

Euglena gracilis
Lepocinclis steinii
Microregma heterostoma
Paramecium
Uroglena

Algae

Anabaena circinalis
Anabaena flos-aqua
Anabaena variabilis
Anacystis
Ankistrodesmus
Asterionella
Calothrix
Cladophora glomerata
Chlamydomonas
Chlorella pyrenoidosa
Chlorella sorokiniana
Chlorella variegata
Chlorella vulgaris
Chlorococcum humicola
Clathrocystes
Closterium
Cylindrospermum licheniforme
Gloeotrichia echinulata
Gomphonema parvulum
Hydrodictyon
Microcystis aeruginosa
Microspora
Mougeotia
Navicula seminulum
Nitzschia linearis
Nitzschia palea
Nostoc
Oedogonium
Oocystis
Oscillatoria
Pandorina
Phormidium ambiguum
Phormidium inundatum
Pithophora
Plectonema
Scenedesmus obliquus
Scenedesmus quadricauda
Selanestrum capricornutum
Spirogyra
Stigeoclonium tenue
Synedra
Synura
Tribonema
Ulothrix
Vaucheria
Zygnema

Table 5. (Continued)

Other Plants

Alisma (water plantain)
Alternaria tenuis (fungus)
Anarcharis canadensis (waterweed)
Bacopa (water hyssop)
Botrytis fabae (fungus)
Ceratophyllum (coontail)
Elodea canadensis (Canadian pondweed)
Escherichia coli (fecal bacterium)
Heteranthera (mud plantain)
Hippurus (mare's tail)
Ludvigia (false loosestrife)
Myriophyllum spicatum (Eurasian watermilfoil)
Najas flexilis (pondweed)
Potamogeton crispus (pondweed)
Potamogeton foliosus (pondweed)
Ranunculus (water crowfoot, spearwort)
Sphaerotilus (bacterium)
Utricularia (bladderwort)

Crustacea

Asellus aquaticus (isopod)
Asellus communis (isopod)
Cyclops vernalis (copepod)
Daphnia longispina (cladoceran)
Daphnia magna (cladoceran)
Daphnia pulex (cladoceran)
Diaptomus oregonensis (copepod)
Gammarus lacustris (amphipod)
Gammarus pseudolimnaeus (amphipod)
Gammarus pulex (amphipod)
Hyalella knickerbockeri (amphipod)
Leptodora kindtii (cladoceran)
Mesocyclops leuckarti (copepod)
Orconectes rusticus (decapod)
Simonephalus serrulatus (cladoceran)

Insecta

Acroneuria lyctorias (stonefly)
Argia (damselfly)
Caenis diminuta (mayfly)
Callibaetis (mayfly)
Chloeon simile (mayfly)
Ephemerella subvaria (mayfly)
Hydropsyche betteni (caddisfly)
Ischnura verticalis (damselfly)
Laccophilus maculosus (predaceous diving beetle)
Libellula (dragonfly)
Pteronarcys californica (stonefly)
Stenonema rubrum (mayfly)
Tendipes decorus (midge)

Table 5. (Continued)

Mollusca

Ancylastrum fluviatile
Australorbis glabratus
Biomphalaria alexandrina
Biomphalaria biossyi
Bulinus contortus
Bulinus truncatus
Campelema decisum
Gyraulus circumstriatus
Helisoma companulata
Lymnaea palustris
Planorbis glabratus
Physa heterostrophia
Physa integra

Other Animals

Bufo valliceps (frog)
Limnodrilus hoffmeisteri (oligochaete)
Nais (oligochaete)
Polycelia nigra (planarian)
Rana pipiens (frog)
Xenopus laevis (toad)

Table 6. Chemical form symbols as they appear on the microfiche and the corresponding chemical formulas.

PRINTOUT SYMBOL	CHEMICAL FORMULA	PRINTOUT SYMBOL	CHEMICAL FORMULA
AGNO3	AgNO ₃	LAAC3	LaAc ₃ or La(C ₂ H ₃ O ₂) ₂
AL(NO3)3	Al(NO ₃) ₃	LICL	LiCl
ALCL3	AlCl ₃	LIF	LiF
ALK(SO4)2	AlK(SO ₄) ₂	MEHG	MeHg or CH ₃ Hg
ALNH4(SO4)2	AlNH ₄ (SO ₄) ₂	MEHGCL	MeHgCl or CH ₃ HgCl
AL2(SO4)3	Al ₂ (SO ₄) ₃	MG(NO3)2	Mg(NO ₃) ₂
ASO2-	AsO ₂ ⁻	MGCL2	MgCl ₂
ASO4-3	AsO ₄ ⁻³	MGN03	MgNO ₃
AS2O3	As ₂ O ₃	MGSIF6	MgSiF ₆
BA(NO3)2	Ba(NO ₃) ₂	MGS04	MgSO ₄
BACL2	BaCl ₂	MN(NO3)2	Mn(NO ₃) ₂
BAF2	BaF ₂	MNCL2	MnCl ₂
BE(NO3)2	Be(NO ₃) ₂	MNCL3	MnCl ₃
BECL2	BeCl ₂	MNF2	MnF ₂
BES04	BeSO ₄	MNSO4	MnSO ₄
BF3	BF ₃	MOO3	MoO ₃
B4O7=	B ₄ O ₇ ⁻²	NAASO2	NaAsO ₂
CD(NO3)2	Cd(NO ₃) ₂	NABO3	NaBO ₃
CDCL2	CdCl ₂	NABR	NaBr
CDSO4	CdSO ₄	NABRO3	NaBrO ₃
CECL3	CeCl ₃	NA2ASO4	Na ₂ AsO ₄
CE2(SO4)3	Ce ₂ (SO ₄) ₃	NA2B4O7	Na ₂ B ₄ O ₇
CO(NO3)2	Co(NO ₃) ₂	NA2CR04	Na ₂ CrO ₄
COCL	CoCl	NA2CR2O7	Na ₂ Cr ₂ O ₇
COCL2	CoCl ₂	NA2HASO4	Na ₂ HA ₅ O ₄
COS04	CoSO ₄	NA2SE03	Na ₂ SeO ₃
CRCL3	CrCl ₃	NA2WO4	Na ₂ WO ₄
CR03	CrO ₃	NA3ASO4	Na ₃ AsO ₄
CR04=	CrO ₄ ⁻²	(NH4)2CR04	(NH ₄) ₂ CrO ₄
CR2(SO4)3	Cr ₂ (SO ₄) ₃	(NH4)2CR2O7	(NH ₄) ₂ Cr ₂ O ₇
CR2O7=	Cr ₂ O ₇ ⁻²	NI(NO3)2	Ni(NO ₃) ₂
CU(NO3)2	Cu(NO ₃) ₂	NICL2	NiCl ₂
CUCL2	CuCl ₂	NISO4	NiSO ₄
CUSO4	CuSO ₄	PB(NO3)2	Pb(NO ₃) ₂
FECL2	FeCl ₂	PBAC2	PbAc ₂ or Pb(C ₂ H ₃ O ₂) ₂
FECL3	FeCl ₃	PBCL2	PbCl ₂
FEO	FeO	PBSO4	PbSO ₄
FES	FeS	PBO	PbO
FES03	FeSO ₃	PHENYL HGOH	Phenyl HgOH or C ₆ H ₅ OHg
FES04	FeSO ₄	PHENYL HGAC	Phenyl HgAc or C ₆ H ₅ O ₂ Hg
FE2(SO4)3	Fe ₂ (SO ₄) ₃	PHENYL HGN03	Phenyl HgNO ₃ or C ₁₂ H ₁₁ OHgNO ₃
FE2O3	Fe ₂ O ₃	RBCL	RbCl
HAUCL4	HAuCl ₄	SBCL3	SbCl ₃
HBO3	HBO ₃	SBF3	SbF ₃
H3BO4	H ₃ BO ₄	SBKTARTRATE	SbKTartrate or KSbOC ₄ H ₄ O ₆
HG(NO3)2	Hg(NO ₃) ₂	SEO2	SeO ₂
HGAC2	Hg c ₂ or Hg(C ₂ H ₃ O ₂) ₂	SEO3-2	SeO ₃ ⁻²
HGCL2	HgCl ₂	SNCL2	SnCl ₂
HGNO2	HgNO ₂	SNCL4	SnCl ₄
HGS04	HgSO ₄	SR(NO3)2	Sr(NO ₃) ₂
KCR(SO4)2	KCr(SO ₄) ₂	SRCL2	SrCl ₂
KCR2O7	KCr ₂ O ₇	SRF2	SrF ₂
KMNO4	KMnO ₄	TH(NO3)4	Th(NO ₃) ₄
K2CR04	K ₂ CrO ₄	THCL4	ThCl ₄
K2Cr2O7	K ₂ Cr ₂ O ₇	TICL2	TiCl ₂

Table 6. (Continued)

<u>PRINTOUT SYMBOL</u>	<u>CHEMICAL FORMULA</u>
Ti2(SO4)3	Ti2(SO4)3
UO2(NO3)2	VO2(NO3)2
UO2AC2	UO2Ac2 or UO2(C2H3O2)2
UO2SO4	UO2SO4
VOSO4	VO5O4
V2O5	V2O5
ZN(NO3)2	Zn(NO3)2
ZNCL2	ZnCl2
ZNSO4	ZnSO4
ZR(SO4)2	Zr(SO4)2
ZROCL2	ZrOCl2

Table 7. List of references used to document the data presented in the toxicity data base. (Entire list of references also appears on microfiche in pocket insert on inside back cover.)

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Table 8. Program and output listing to subset data base for only those records with an organism name within crustaceans.

A. Program listing

```
DATA EFFECTS;
INFILE CARDS;
INPUT ELEM_CRD 11-13 SEQ 14 ELEMENT $ 26-27 CONC_MIN 28-36 4 CONC_MAX 38-45 4
CHEMFORM $ 47-66 #2 ORGANISM $ 16-45 LIFE_STG $ 47-71 #3 EXP_TIME $ 16-25
EXP_END $ 27-56 WATER_TY $ 58-78 #4 RECON_FQ $ 16-35 WTMP_MAX 37-40 WTMP_MIN $
42-45
HARD_MAX $ 47-56 HARD_MIN $ 58-67 PH_MAX 69-71 PH_MIN $ 73-76 #5 CA_ION 16-23
MG_ION 25-32 DO_MAX 35-39 DO_MIN 41-45 TDS_MAX 47-52 TDS_MIN 54-59 #6 ALK_MAX
16-25 ALK_MIN 27-36 COMMENTS $ 38-67 #7 REF1ORIG $ 16-19 REF2ORIG $ 21-24
REF3ORIG $ 26-29 OUR_REF1 $ 31-34 OUR_REF2 $ 36-39 OUR_REF3 $ 41-44;
```

```
COMMENT THESE IF STATEMENTS ARE USED FOR INCLUDING ONLY THOSE ORGANISMS
WITH THE NAME INDICATED WITHIN THE SINGLE QUOTES,
```

```
IF ORGANISM EQ 'ASELLUS AQUATICUS' THEN RETURN;
IF ORGANISM EQ 'ASELLUS COMMUNIS' THEN RETURN;
IF ORGANISM EQ 'CLADOCERANS' THEN RETURN;
IF ORGANISM EQ 'CRUSTACEA' THEN RETURN;
IF ORGANISM EQ 'CYCLOPS VERNALIS' THEN RETURN;
IF ORGANISM EQ 'DAPHNIA' THEN RETURN;
IF ORGANISM EQ 'DAPHNIA LONGISPINA' THEN RETURN;
IF ORGANISM EQ 'DAPHNIA MAGNA' THEN RETURN;
IF ORGANISM EQ 'DAPHNIA PULEX' THEN RETURN;
IF ORGANISM EQ 'DIAPTOMUS OREGONENSIS' THEN RETURN;
IF ORGANISM EQ 'GAMMARUS' THEN RETURN;
IF ORGANISM EQ 'GAMMARUS LACUSTRIS' THEN RETURN;
IF ORGANISM EQ 'GAMMARUS PSEUDOLIMNAEUS' THEN RETURN;
IF ORGANISM EQ 'GAMMARUS PULEX' THEN RETURN;
IF ORGANISM EQ 'HYALELLA KNICKERBOCKERI' THEN RETURN;
IF ORGANISM EQ 'LEPTODORA KINDTII' THEN RETURN;
IF ORGANISM EQ 'MESOCYCLOPS LEUKARTI' THEN RETURN;
IF ORGANISM EQ 'ORCONECTES RUSTICUS' THEN RETURN;
IF ORGANISM EQ 'SHRIMP, FRESH WATER' THEN RETURN;
IF ORGANISM EQ 'SIMOCEPHALUS SERRULATUS' THEN RETURN;
IF ORGANISM EQ 'AMPHIPODS' THEN RETURN;
```

```
DELETE;
```

```
CARDS;
```

```
TITLE TOXIC EFFECTS FOR CRUSTACEANS;
PROC PRINT DATA=EFFECTS;
```

Table 8 (cont'd). B. Portion of output from previous program.

OBS	ELM	SE	ELM	CONC	CONC	CH	OR	L	E	E
S	D	Q	T	N	X	M	S	G	P	P
1	4	1	AG	0.0032	.	AGN03	DAPHNIA MAGNA			LETHAL
2	7	1	AG	0.0300	.	AGN03	DAPHNIA MAGNA	96 HR		ILL
3	17	1	AG	0.1000	.		DAPHNIA MAGNA			LETHAL
4	6	1	AL	0.3200	.	ALCL3	DAPHNIA MAGNA	3 WK		16% REPRODUCTIVE IMPAIRMENT
5	7	1	AL	0.6800	.	ALCL3	DAPHNIA MAGNA	3 WK		50% REPRODUCTIVE IMPAIRMENT
6	8	1	AL	0.6200	.	ALCL3	DAPHNIA MAGNA	3 WK		38% WEIGHT LOSS
7	9	1	AL	1.4000	.	ALCL3	DAPHNIA MAGNA	3 WK		LC50
8	10	1	AL	3.9000	.	ALCL3	DAPHNIA MAGNA	2 DAY		LC50
9	22	1	AL	21.5000	.	AL2(S04) 3	DAPHNIA MAGNA			LETHAL
10	23	1	AL	16.8000	.	AL2(S04) 3	DAPHNIA MAGNA			LETHAL
11	33	1	AL	21.7000	.	ALNH4(S04) 2	DAPHNIA MAGNA			LETHAL
12	34	1	AL	21.6000	.	ALK(S04) 2	DAPHNIA MAGNA			LETHAL
13	3	1	AS	0.5200	.	NA2HAS04	DAPHNIA MAGNA	3 WK		16% REPRODUCTIVE IMPAIRMENT
14	4	1	AS	0.9960	.	NA2HAS04	DAPHNIA MAGNA	3 WK		18% WEIGHT LOSS
15	5	1	AS	0.9960	.	NA2HAS04	DAPHNIA MAGNA	3 WK		15% PROTEIN LOSS
16	15	1	AS	0.8100	.	NAAS02	SIMOCEPHALUS SERRULATUS	48 HR		LC50
17	19	1	AS	7.4000	.	NA2HAS04	DAPHNIA MAGNA	48 HR		LC50
18	20	1	AS	1.4000	.	NA2HAS04	DAPHNIA MAGNA	3 WK		50% REPRODUCTIVE IMPAIRMENT

OBS	WATER	CONC	TEMP	WIND	HA	HA	P	P	C	M	D	D	T	T	A	A	C	R	R	R	O	O	O
S	Y	Q	X	N	X	N	X	N	N	N	X	N	X	N	X	N	S	G	G	G	1	2	3
1	LAKE ERIE			25.0													7				159		
2	RIVER			25.0	23.0												35				159		
3		STATIC															217				126		
4	LAKE (UNFILTERED)			18	45												28				28		
5	LAKE (UNFILTERED)			18	45												28				28		
6	LAKE (UNFILTERED)			18	45												28				28		
7	LAKE (UNFILTERED)			18	45												28				28		
8	LAKE (UNFILTERED)			18	45												28				28		
9	LAKE ERIE	STATIC															5				126		
10	LAKE ERIE																5				159		
11	LAKE ERIE	STATIC															5				126		
12	LAKE ERIE	STATIC															5				126		
13	LAKE (UNFILTERED)			18.	45												28				28		
14	LAKE (UNFILTERED)			18.	45												28				28		
15	LAKE (UNFILTERED)			18.	45												28				28		
16																	LAB	64			24		
17	LAKE (UNFILTERED) HARD																28				28		
18	LAKE (UNFILTERED) HARD																28				28		

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