Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381

AUG 26 1994

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2 - DOCUMENTS SUPPORTING REVIEW OF ENVIRONMENTAL INFORMATION (TAC NOS M88691 AND M88692)

This letter documents that the material referenced on the enclosed list was provided to the NRC as requested during the July 27, 1994, environmental information audit. The referenced material was sent to the NRC's WBN Environmental Project Manager, Scott Flanders on August 9, 1994.

This action was discussed with Mr. Flanders in a teleconference on August 22, 1994. If you should have any questions concerning this matter, please telephone John Vorees at (615)-365-1824.

Sincerely,

Dwight E. Nunn
Vice President
New Plant Completion
Watts Bar Nuclear Plant

Enclosure
cc: See page 2

DFO1 Add: P. Tam 4, Encl 1 0
1/1 O14B-21

[redacted]

per Linda Lueder

AUG 26 1994

cc (Enclosure):
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ENCLOSURE

WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2
ENVIRONMENTAL INFORMATION
REFERENCE DOCUMENTS

The following reports were requested by the NRC reviewers in the July 27, 1994, environmental information audit. These documents were sent to the NRC on August 9, 1994.

1. EPA - EMF IN YOUR ENVIRONMENT - Magnetic Field Measurements of Everyday Electrical Devices,Report No 402-R-92-008, 12/92.

2. EPA - QUESTIONS AND ANSWERS ABOUT ELECTRIC AND MAGNETIC FIELDS (EMFs), 12/92.

3. EPRI - ASSESSMENT OF CHILDREN'S LONG-TERM EXPOSURE TO MAGNETIC FIELDS (THE ENERTECH STUDY), EPRI Report TR-101407, Project 2966-06, 11/92.

4. WATTS BAR NUCLEAR PLANT - ESSENTIAL RAW COOLING WATER PIPELINE SEASONAL HIGH GROUND-WATER LEVELS - Report No. WR29-2-85-103, J. Mark Boggs, 1/82.

5. WATTS BAR GROUNDWATER IMPACTS OF EVAPORATION/PERCOLATION POND, Report No. WR28-1-85-133, Kathy Lindquist, 7/90.

6. RIVER BASIN OPERATIONS WATER RESOURCES - STATUS OF THE WHITE CRAPPIE POPULATION IN CHICKAMAUGA RESERVOIR FINAL PROJECT REPORT, Johnny P. Buchanan and Thomas A. McDonough, 10/90.

7. TVA WATTS BAR NUCLEAR PLANT ENVIRONMENTAL CONTROL MANUAL, CHAPTER 4 - EROSION/STORM WATER POLLUTION PREVENTION PLAN, REVISION 2, Effective Date 11/1/93.

8. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 4, Cynthia L. Russell, 10/15-22/92.

9. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 5, Cynthia L. Russell, 11/18-25/92.

10. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 6, Cynthia L. Russell, 12/15-23/92.

11. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 7, Cynthia L. Russell, 1/15-22/93.

12. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 8, Cynthia L. Russell, 2/11-18/93.

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13. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 9, Cynthia L. Russell, 3/19-26/93.

14. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 10, Cynthia L. Russell, 4/16-23/93.

15. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 11, Cynthia L. Russell, 5/12-19/93.

16. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 12, Cynthia L. Russell, 6/9-16/93.

17. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 13, Cynthia L. Russell, 7/15-22/93.

18. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 14, Cynthia L. Russell, 8/19-26/93.

19. STANDARD REPORT FORM - STATIC RENEWAL TESTS USING PIMEPHALES PROMELAS (FATHEAD MINNOWS) AND CERIODAPHNIA DUBIA (DPHNIDS), Test WBN Experiment 15, Cynthia L. Russell, 9/25/93 - 10/2/93.

20. RIVER BASIN OPERATIONS WATER RESOURCES - CHICKAMAUGA RESERVOIR 1993 FISHERIES MONITORING COVE ROTENONE RESULTS, Wayne K. Wilson and Andy Sawyer, 3/94.

21. RIVER BASIN OPERATIONS WATER RESOURCES - DENSITY, MOVEMENT PATTERNS, AND SPAWNING CHARACTERISTICS OF SAUGER (STIZOSTEDION CANADENSE) IN CHICKAMAUGA RESERVOIR, TENNESSEE - 1988, Gary D. Hickman, Kerry W. Hevel, Edwin M. Scott, 7/89.

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22. OFFICE OF NATURAL RESOURCES AND ECONOMIC DEVELOPMENT DIVISION OF AIR AND WATER RESOURCES - PREOPERATIONAL ASSESSMENT OF WATER QUALITY AND BIOLOGICAL RESOURCES OF CHICKAMAUGA RESERVOIR, WATTS BAR NUCLEAR PLANT, 1973-1985, Volume I and APPENDICES, Volume II, William B. Wrenn, Coordinator, 12/96.

23. SUMMARY OF TOXICITY BIOMONITORING RESULTS TENNESSEE VALLEY AUTHORITY WATTS BAR NUCLEAR PLANT (WBN) JANUARY 1991-MARCH 1994, Toxicity Testing Laboratory Water Management, 6/94.

24. STATIC RENEWAL TESTS USING ANODONTA IMBECILLIS (FRESHWATER MUSSEL) AND BARACHIONUS CALYCIFLORUS (ROTIFER), Acute Toxicity of CT-1 (CLAMTROL), TVA Water Management, 7/94.

25. REPORT OF RESULTS CHRONIC TOXICITY EVALUATIONS CLAM-TROL CT-1 prepared for the Tennessee Wildlife Resources Agency, EMPE, INC., 6/94.

26. COMPARISON OF ACUTE9 - DAY TOXICITY TESTS USING CLAMTROL ON ANODONTA IMBECILIS AND ELLIPTIO ARCTATA - Presbyterian College - Department of Biology/Aquatic Toxicity Testing Laboratory, 7/18/94.

27. FINAL ENVIRONMENTAL IMPACT STATEMENT - TENNESSEE RIVER AND RESERVOIR SYSTEM OPERATION AND PLANNING REVIEW - REPORT NO. TVA/RDG/EQS-91/1 - 12/90.

28. THE EFFECTS OF AQUATIC MACROPHYTES ON FISH POPULATIONS OF CHICKAMAUGA RESERVOIR COVES, 1970-90 - TVA Water Management Services - 9/93.

29. Excerpts pertaining to Chickamauga and Watts Bar Reservoirs from various reports on the results of TVA'S vital signs and use impairment monitoring program from beginning in 1990 - 1993:

- °REPORT TVA/WR/AB--91/4 - FISH COMMUNITY RESULTS - 5/91.
- °REPORT TVA/WR-92/5 - FISH COMMUNITY RESULTS - 7/92
- °RESERVOIR VITAL SIGNS MONITORING - 1992 - FISH COMMUNITY RESULTS TABLES
- °RESERVOIR VITAL SIGNS MONITORING - 1993 - FISH COMMUNITY RESULTS TABLES
- °REPORT TVA/WR/WQ--91/10 - PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER & SEDIMENT - 1990 - MAY 1991.
- °REPORT TVA/WR--92/1 - PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER & SEDIMENT - 1991 - JULY 1992.
- °RESERVIOR VITAL SIGNS MONITORING - 1992 - PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER & SEDIMENT - 1992 - OCTOBER 1993.
- °TENNESSEE VALLEY RESERVOIR & STREAM QUALITY - 1993 - PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER RESERVOIR VITAL SIGNS MONITORING - JUNE 1994.

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WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2
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REFERENCE DOCUMENTS

°REPORT TVA/WR/AB--91/6 - BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS - 1990 - JUNE 1991

°REPORT TVA/WR-92/3 - BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS - 1991 - AUGUST 1992.

°RESERVOIR MONITORING - 1992 - BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS - JUNE 1993.

°TENNESSEE VALLEY RESERVOIR & STREAM QUALITY - 1993 - BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS - MAY 1994.

°REPORT TVA/WR--91/1 - RESERVOIR MONITORING - 1990 - SUMMARY OF VITAL SIGNS & USE IMPAIRMENT MONITORING ON TENNESSEE VALLEY RESERVOIRS - AUGUST 1991.

°REPORT TVA/WR--92/8 - RESERVOIR VITAL SIGNS MONITORING - 1991 - SUMMARY OF VITAL SIGNS & USE IMPAIRMENT MONITORING ON TENNESSEE VALLEY RESERVOIRS - JULY 1992.

°RESERVOIR MONITORING - 1992 - SUMMARY OF VITAL SIGNS & USE SUITABILITY MONITORING ON TENNESSEE VALLEY RESERVOIRS - AUGUST 1993.

°TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993 - SUMMARY OF VITAL SIGNS & USE SUITABILITY MONITORING - MAY 1994.

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DOCUMENTS 1 THRU 19 OF DOCUMENTS SUPPORTING REVIEW OF ENVIRONMENTAL INFORMATION

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United States
Environmental Protection
Agency

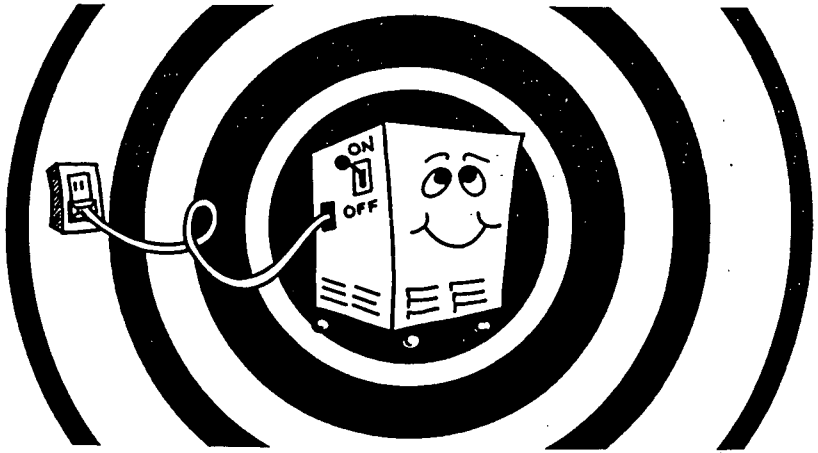
Office Of Radiation
And Indoor Air
(6603J)

2-R-92-008
cember 1992

EPA

EMF In Your Environment

Magnetic Field Measurements Of Everyday Electrical Devices



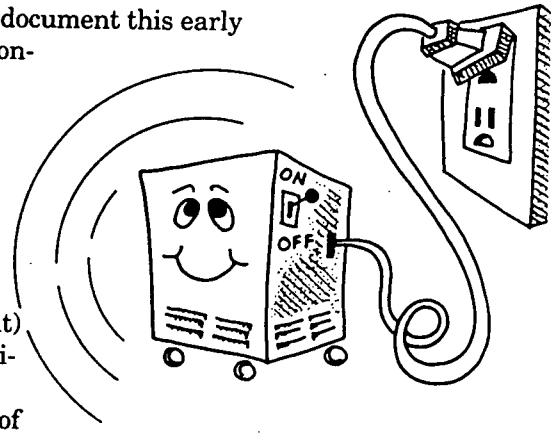
Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

CONTENTS

EMF IN YOUR ENVIRONMENT

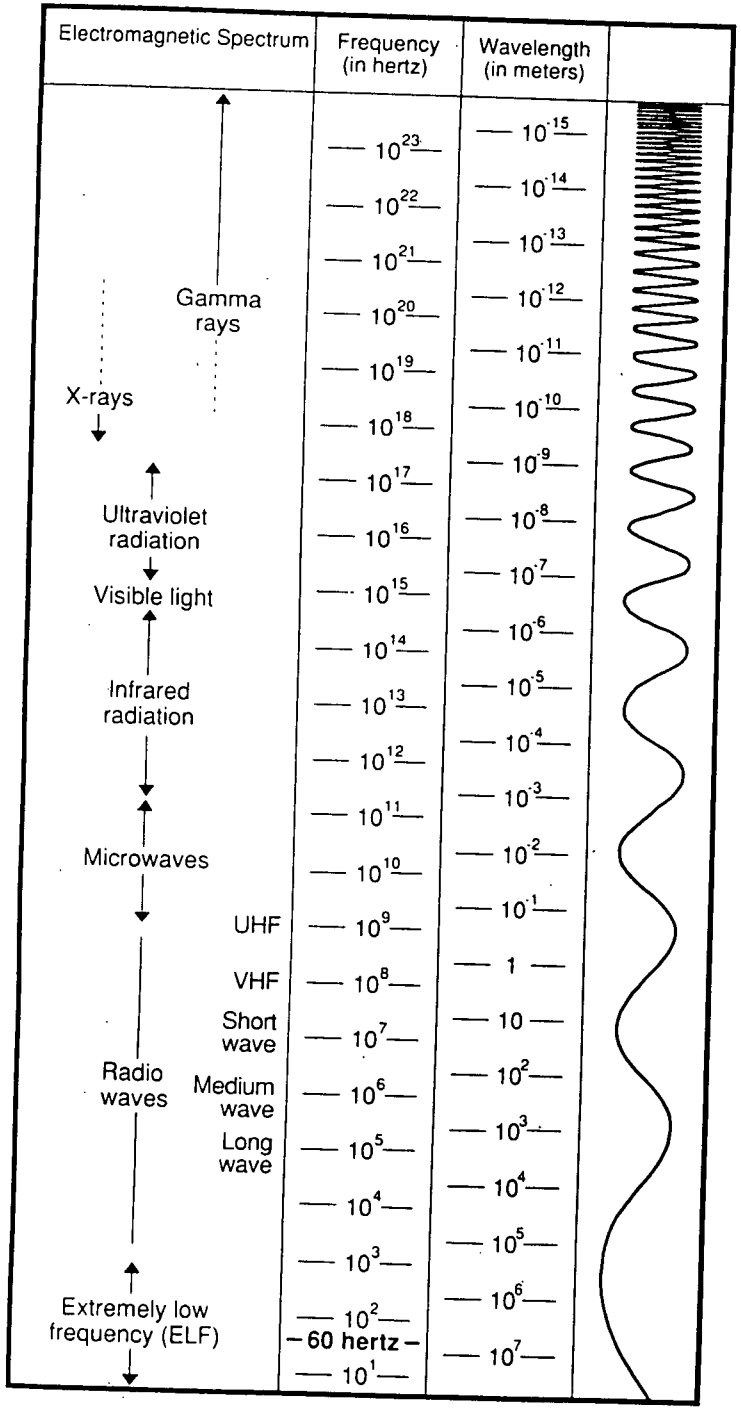
What are electric and magnetic fields (EMFs)? What common EMF sources do we encounter during a typical day? This publication compares the strength of 60 hertz magnetic fields produced by common electrical items and shows you how their strength diminishes as you move farther away from them.

We still have a great deal to learn about electric and magnetic fields (EMFs). We really don't know if typical, everyday exposures to EMFs affect human health. Some studies indicate that they might – others suggest otherwise. Most of the recent research on possible biological effects of 60 hertz EMFs suggests that the magnetic, rather than the electric, fields are more likely to produce significant effects. Therefore, this publication focuses on them. The information presented here has to do with the **strength** of the magnetic field; however, we aren't certain that the strength of the field is the only important consideration. It may turn out that other factors are also important, such as how long the exposure lasts or whether particular characteristics of the field change rapidly. Future research is likely to reveal that the information given in this publication is only part of the story – that is the chance we take in providing a public information document this early in the study of a complex environmental health issue.



What Are Electric and Magnetic Fields ?

Electric charges create electric fields. Electric charges which move (i.e., electric current) create magnetic fields. An appliance that is plugged in, and therefore connected to a source of electricity, has an electric field



◀ This illustrates the point that the higher the frequency, the shorter the wavelength. The wavelengths are infinitely long at the bottom and infinitessimally short at the top of the spectrum so, obviously, the drawing cannot be done to scale.

even when the appliance is turned off. To produce a magnetic field, however, the appliance must be not only plugged in, but also operating, so that the current is flowing.

The electric current we use in our everyday life produces certain kinds of electric and magnetic fields. There are many other kinds of electric and magnetic fields as well, found throughout nature. The term "electromagnetic" field implies that the electric and magnetic fields are interrelated.

These fields can be characterized by either their **wavelength** or their **frequency**, which are related. The amount of energy an electric or magnetic field can carry depends on the frequency and wavelength of the field. The wavelength describes how far it is between one peak on the wave and the next peak. The frequency, measured in hertz, describes how many wave peaks pass by in one second of time.

The Electromagnetic Spectrum

If you take all the different kinds of electromagnetic fields we know about and place them on a chart, from the lowest frequency (i.e., lowest energy) to the highest, you have a chart of the electromagnetic spectrum. (See chart on the previous page.) The low end of the spectrum includes electric and magnetic fields produced by everyday electrical appliances. At the top of the spectrum are X-rays and gamma rays.

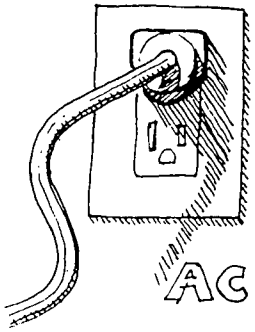
When you hear about "EMFs" in the news media, the term usually refers to electric and magnetic fields at the extremely low frequency (or ELF) end of the spectrum, such as those associated with our use of electric power. The term "EMF" can be used in a much broader sense as well, encompassing electromagnetic fields across the spectrum. When we use "EMF" in this brochure we mean extremely low frequency (ELF) electric and magnetic fields. We should note that in the ELF range, electric and magnetic fields are

not coupled or interrelated in the same way that they are at higher frequencies, so it is actually more accurate to refer to them as "electric and magnetic fields" rather than as "electromagnetic fields." In the popular press, however, you will see both terms used, abbreviated as "EMF."

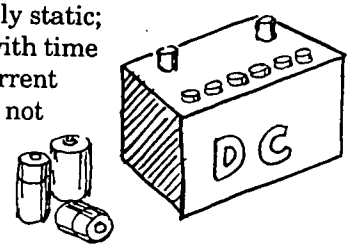
Electric fields from most appliances primarily create charges or current on or near the surface of the body and not in the internal organs. Magnetic fields, however, pass through the body and actually induce electric currents within the body. We don't know exactly what effect, if any, this has on the different internal organs, but many studies are now underway to try to find out.

60 Hertz Electric And Magnetic Fields

It is relatively easy to shield people from exposure to electric fields using commonly available materials. Magnetic fields, however, can pass through anything. Even though both are present around appliances and power lines, more recent interest and research have focused on potential health and biological effects of magnetic fields of various strengths.



This publication presents information regarding magnetic fields associated with 60 hertz alternating current (AC) electric power – that is, the kind of electric power we use in North America which flows back and forth or alternates at a rate of 60 times per second (60 hertz). We will not focus here on equipment that is powered by "direct current" (DC) such as battery-operated appliances. The magnetic fields created by direct current are primarily static; that is, they do not vary with time as do AC fields. Direct current (DC) magnetic fields have not raised as many questions about potential health concerns as have the time-varying fields created by alternating current (AC). We should point out, however, that some DC-powered equipment can produce alternating magnetic fields, but these are usually not 60 hertz fields.



Other Electromagnetic Frequencies

Although the information presented here has to do with the low frequency magnetic fields associated with 60 hertz electrical current, we should note that some appliances, such as microwave ovens, baby monitors, and video display terminals, use 60 hertz electrical energy to create other electromagnetic frequencies.

The measurements we give for microwave ovens, for example, describe the magnetic field that results from the 60 hertz electrical current used to operate the oven. We are not describing the magnetic field associated with the approximately three billion hertz microwaves inside the oven which heat the food and from which people are protected when the door is secured properly.

Oddly enough, we can be easily shielded from the higher frequency microwaves' magnetic fields, but not from the 60 hertz magnetic fields. This is because even though the microwave's **frequency** is higher, its **length** is much, much shorter (about 1 cm) than the wavelength of a 60 hertz field (about 5000 kilometers). The shorter wave can be blocked by materials such as thin metal sheets, whereas the much longer wave cannot.

Potential Health Concerns Associated With Electric and Magnetic Fields

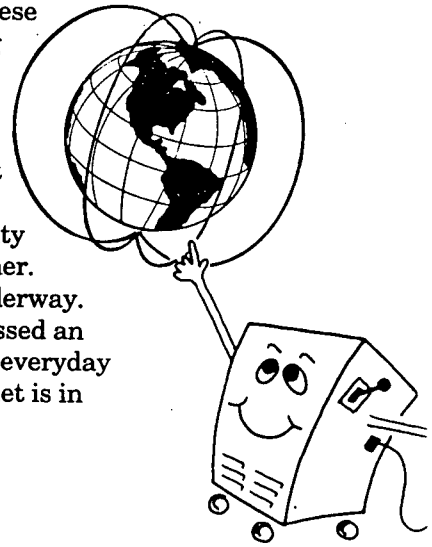
Electric and magnetic fields from 60 hertz electric power (as well as microwaves and radio waves) are sometimes called non-ionizing radiation. The term "radiation" simply means energy

transmitted by waves. "Ionizing" radiation has enough energy to strip electrons from atoms. (X-rays are a form of ionizing radiation.) Extremely low frequency EMF cannot do this. Higher frequency non-ionizing radiation, such as microwaves, can heat up biological tissue by vibrating molecules. The lower frequency 60 hertz EMFs cannot. Because of their relatively lower energy, 60 hertz EMFs were not, until recently, thought to be connected with any potential health problems.

There are no national standards in the United States for exposure to 60 hertz electromagnetic fields. Several states have formally adopted standards to limit the permissible magnetic field strength along rights of way of electric transmission lines. Federal legislation has been enacted to establish and support national EMF research and public information programs, but no exposure standards have been pro-

Some recent scientific studies have suggested a link – a statistical association – between exposure to 60 hertz EMFs and specific types of cancer, primarily leukemia and brain cancer. Other studies have found no such association (see Appendix B). In a sense, this can be compared to circumstantial evidence in a court of law. Laboratory studies have shown electromagnetic fields to affect cells in various ways, but whether these effects are important in terms of human health is still not clear. Almost everyone involved in EMF research agrees that much more needs to be learned before conclusions can be reached about the relative safety or harm of 60 hertz EMF exposure.

Some people doubt that the EMFs generated by 60 hertz electrical appliances and internal household wiring have any significant effect on human health, because they know that the earth's magnetic field, to which we are all constantly exposed, is stronger (sometimes over 100 times stronger) than the magnetic fields produced by many of the appliances listed in this publication. However, the earth's magnetic field is primarily a DC field rather than a time-varying field. Our bodies seem to react differently to these different types of fields so comparing them can be misleading.



At this point, we are not at all sure that exposure to EMFs such as we find in our everyday environment has an adverse effect on our health. However, we cannot say with certainty that such exposure is safe for us, either. More research is needed – and is underway. Meanwhile, many people have expressed an interest in having information about everyday sources of EMF exposure. This booklet is in response to that interest.

MAGNETIC FIELD MEASUREMENTS OF EVERYDAY ELECTRICAL DEVICES

This publication gives information about the strength of the magnetic fields generated by everyday 60 hertz electrically powered equipment. It shows how the magnetic field strength diminishes with increased distance from the object.

Appliances and Magnetic Field Strengths

Magnetic fields from individual appliances can vary considerably, depending on the way they were designed and manufactured. One brand of toaster, for example, may generate a much stronger magnetic field than another. The strength of the magnetic field is measured in units of **gauss** (G) or **milligauss** (mG). A milligauss is 1/1000th of a gauss. (The international standard unit is microtesla which is the same as 10 milligauss.)

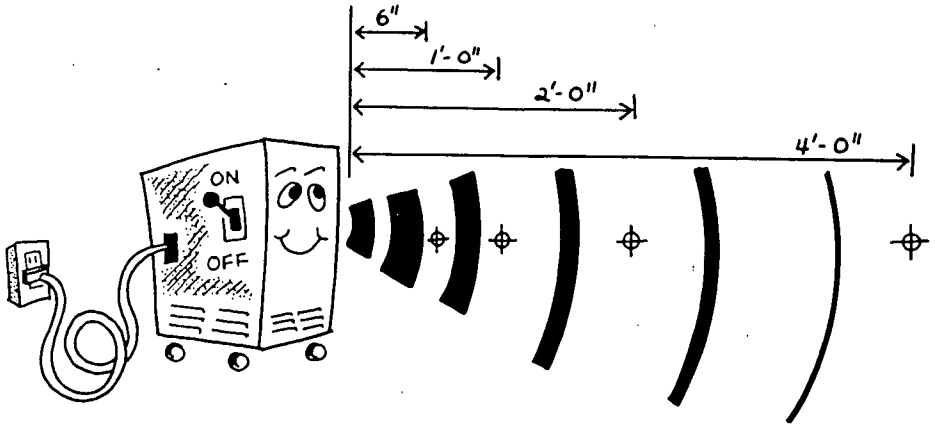
It is important to keep in mind that a typical

American home has a background magnetic field level (away from any appliances) ranging from 0.5 mG to 4 mG. The actual strength of the field at a given place in a room depends upon the number and kinds of sources, how far away they are, and how many are operating at one time. Walls generally do not block magnetic fields. An electrical appliance located near a wall extends its magnetic field into the room on the other side of the wall as well.

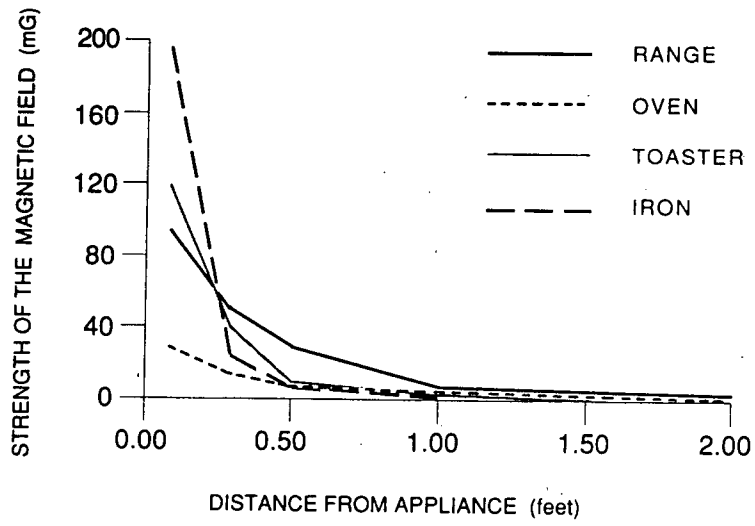
How Magnetic Field Measurements Were Taken

The data in the tables (beginning on page 13) came from three different organizations: the Electric Power Research Institute (EPRI), the Illinois Institute of Technology Research Institute (IITRI), and the U.S. Environmental Protection Agency (EPA). What we present here will give you an idea of the relative strength of magnetic fields produced by electrical items you are likely to use in your home or at work.

The strength of the magnetic fields has been measured at 6 inches from the item, and then at distances of 1, 2, and 4 feet. These distances do not, in every case, correspond to the distance you would typically be from the appliance when you use it, but we kept the measurements consistent so that the magnetic field strength could be compared from appliance to appliance. It should also be mentioned that different body parts will be exposed to different magnetic field levels from the same appliance, depending on how far that part of the body is from the appliance when it is in use. An electric shaver when used, for example, may be three inches from the brain and two feet from the liver. Notice in the chart below how the strength of the magnetic field diminishes dramatically just a foot or two away from the appliance.



MEDIAN MAGNETIC FIELD STRENGTHS OF FOUR TYPICAL ELECTRIC APPLIANCES



TABLES

In the following tables, you will see three numbers listed for each appliance at each distance. First is the lowest measurement we have, followed by the median, and then the highest measurement taken. For some appliance categories, hundreds of individual items were measured. In other cases, the data gathering was less extensive. The median measurement is simply the middle number in a series of measurements.

The appliances are organized according to where you might encounter them during the day (in the kitchen, the office, the bedroom, etc). The magnetic field strength is measured in milligauss (mG).

For a detailed description of the methodology used by each of the three groups that conducted these measurements, please refer to Appendix A. Also in Appendix A is a reference chart showing the source of the data.

BATHROOM SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
HAIR DRYERS				
Lowest	1	-	-	-
Median	300	1	-	-
Highest	700	70	10	1
ELECTRIC SHAVERS				
Lowest	4	-	-	-
Median	100	20	-	-
Highest	600	100	10	1

Magnetic field measurements in units of milligauss (mG)

The dash (–) in the above table means that the magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

KITCHEN SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
BLENDERS				
Lowest	30	5	-	-
Median	70	10	2	-
Highest	100	20	3	-
CAN OPENERS				
Lowest	500	40	3	-
Median	600	150	20	2
Highest	1500	300	30	4
COFFEE MAKERS				
Lowest	4	-	-	-
Median	7	-	-	-
Highest	10	1	-	-
CROCK POTS				
Lowest	3	-	-	-
Median	6	1	-	-
Highest	9	1	-	-
DISHWASHERS				
Lowest	10	6	2	-
Median	20	10	4	-
Highest	100	30	7	1
FOOD PROCESSORS				
Lowest	20	5	-	-
Median	30	6	2	-
Highest	130	20	3	-

Magnetic field measurements in units of milligauss (mG)

The dash (–) in the above table means that the magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

KITCHEN SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
GARBAGE DISPOSALS				
Lowest	60	8	1	-
Median	80	10	2	-
Highest	100	20	3	-
MICROWAVE OVENS				
Lowest	100	1	1	-
Median	200	40	10	2
Highest	300	200	30	20
MIXERS				
Lowest	30	5	-	-
Median	100	10	1	-
Highest	600	100	10	-
ELECTRIC OVENS				
Lowest	4	1	-	-
Median	9	4	-	-
Highest	20	5	1	-
ELECTRIC RANGES				
Lowest	20	-	-	-
Median	30	8	2	-
Highest	200	30	9	6
REFRIGERATORS				
Lowest	-	-	-	-
Median	2	2	1	-
Highest	40	20	10	10
TOASTERS				
Lowest	5	-	-	-
Median	10	3	-	-
Highest	20	7	-	-

Magnetic field measurements in units of milligauss (mG)

LIVING/FAMILY ROOM SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
CEILING FANS				
Lowest		-	-	-
Median		3	-	-
Highest		50	6	1
WINDOW AIR CONDITIONERS				
Lowest		-	-	-
Median		3	1	-
Highest		20	6	4
TUNERS/TAPE PLAYERS				
Lowest	-	-	-	-
Median	1	-	-	-
Highest	3	1	-	-
COLOR TVs				
Lowest		-	-	-
Median		7	2	-
Highest		20	8	4
BLACK AND WHITE TVs				
Lowest		1	-	-
Median		3	-	-
Highest		10	2	1

Magnetic field measurements in units of milligauss (mG)

LAUNDRY/UTILITY ROOM SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
ELECTRIC CLOTHES DRYERS				
Lowest	2	-	-	-
Median	3	2	-	-
Highest	10	3	-	-
WASHING MACHINES				
Lowest	4	1	-	-
Median	20	7	1	-
Highest	100	30	6	-
IRONS				
Lowest	6	1	-	-
Median	8	1	-	-
Highest	20	3	-	-
PORTABLE HEATERS				
Lowest	5	1	-	-
Median	100	20	4	-
Highest	150	40	8	1
VACUUM CLEANERS				
Lowest	100	20	4	-
Median	300	60	10	1
Highest	700	200	50	10

Magnetic field measurements in units of milligauss (mG)

The dash (–) in the above table means that the magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

BEDROOM SOURCES

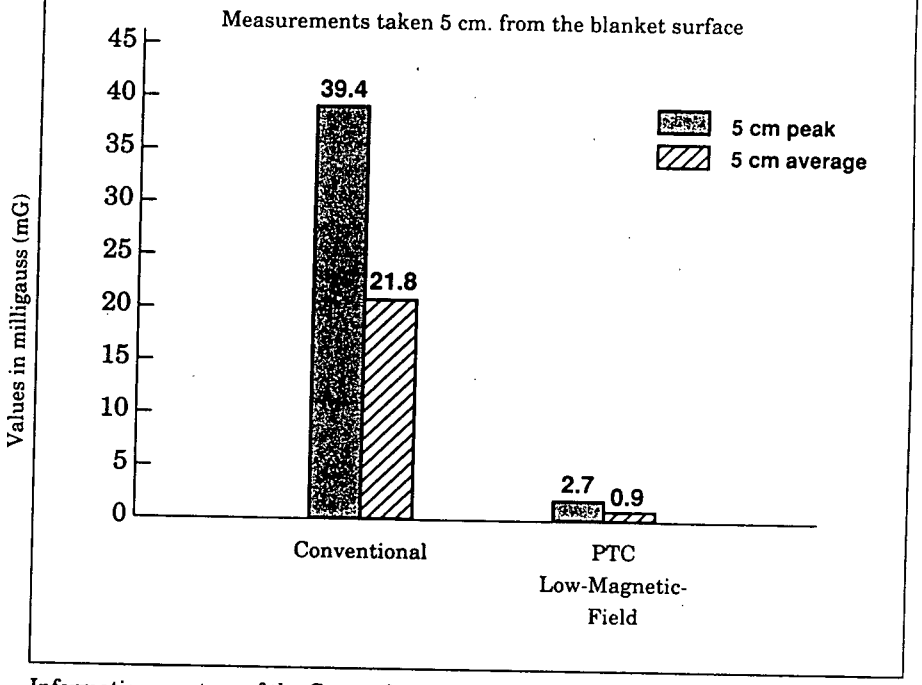
Distance from Source	6"	1'	2'	4'
DIGITAL CLOCKS				
Lowest		-	-	-
Median		1	-	-
Highest		8	2	1
ANALOG (CONVENTIONAL CLOCK-FACE) CLOCKS				
Lowest		1	-	-
Median		15	2	-
Highest		30	5	3
BABY MONITORS				
Lowest	4	-	-	-
Median	6	1	-	-
Highest	15	2	-	-

Magnetic field measurements in units of milligauss (mG)

The clocks described in the above table are electrically powered using alternating current (AC), as are all the appliances described in these tables. The measurements for baby monitors were taken for the unit nearest the child.

The dash (–) in the above table means that the magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

ELECTRIC BLANKETS



Information courtesy of the Center for Devices and Radiological Health, U.S. Food and Drug Administration

The above graph presents information regarding magnetic fields produced by electric blankets, including conventional 110 volt electric blankets as well as the newer model PTC (Positive Temperature Coefficient) Low Magnetic Field blankets. The fields were measured at a distance of five centimeters (a little less than 2 inches) from the surface of the blanket, roughly approximating the distance from the blanket to the users' internal organs. Because of the way blankets are wired, magnetic field strengths vary from point to point on the blanket. The graph reflects this and gives you both the peak as well as the average measurement.

OFFICE SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
AIR CLEANERS				
Lowest	110	20	3	-
Median	180	35	5	1
Highest	250	50	8	2
COPY MACHINES				
Lowest	4	2	1	-
Median	90	20	7	1
Highest	200	40	13	4
FAX MACHINES				
Lowest	4	-	-	-
Median	6	-	-	-
Highest	9	2	-	-
FLUORESCENT LIGHTS				
Lowest	20	-	-	-
Median	40	6	2	-
Highest	100	30	8	4
ELECTRIC PENCIL SHARPENERS				
Lowest	20	8	5	-
Median	200	70	20	2
Highest	300	90	30	30
VIDEO DISPLAY TERMINALS (PCs WITH COLOR MONITORS) (See note on following page)				
Lowest	7	2	1	-
Median	14	5	2	-
Highest	20	6	3	-

Magnetic field measurements in units of milligauss (mG)

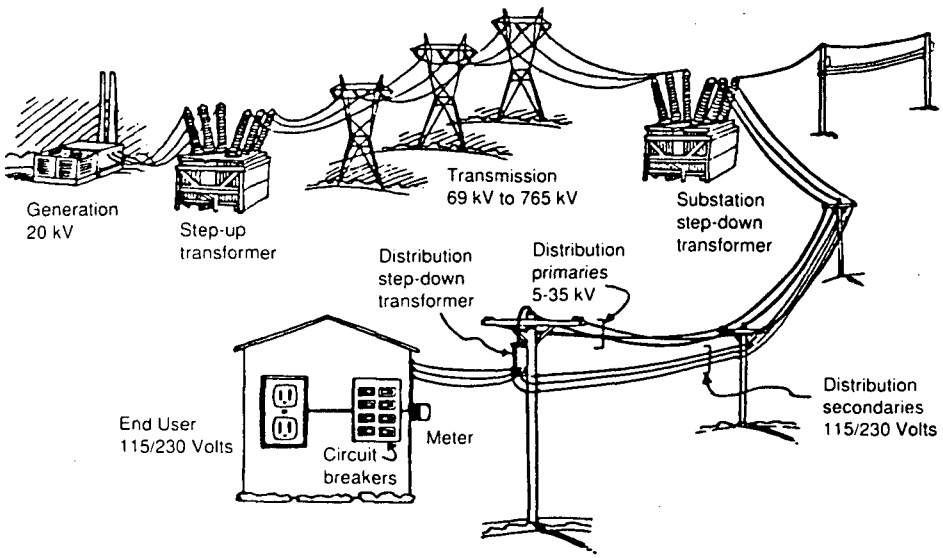
The dash (–) in the above table means that the magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

WORKSHOP SOURCES				
Distance from Source	**6"**	**1'**	**2'**	**4'**
BATTERY CHARGERS				
Lowest	3	2	-	-
Median	30	3	-	-
Highest	50	4	-	-
DRILLS				
Lowest	100	20	3	-
Median	150	30	4	-
Highest	200	40	6	-
POWER SAWS				
Lowest	50	9	1	-
Median	200	40	5	-
Highest	1000	300	40	4
ELECTRIC SCREWDRIVERS (while charging)				
Lowest	-	-	-	-
Median	-	-	-	-
Highest	-	-	-	-

Magnetic field measurements in units of milligauss (mG)

Although the U.S. has set no standards for magnetic fields from video display terminals (VDTs), the Swedish government has. Its standard of 2.5 milligauss (mG) at a distance of 50 centimeters (about 1.8') from the VDT has become a de facto standard in the VDT industry worldwide.

Another obvious source of everyday exposure to 60 hertz EMFs is from electric power lines.



From Carnegie Mellon brochure: Electric and Magnetic Fields from 60 Hertz Electric Power, 1989.

Substations: Some people are particularly concerned about the magnetic fields generated by electric substations. In fact, as with appliances, the fields produced by substation equipment quickly diminish in strength a short distance away and do not extend beyond the substation boundaries. However, magnetic fields near substations can be stronger than those in other parts of the neighborhood because the power lines drop down closer to the ground as they go in and out of the substation, bringing their accompanying magnetic fields closer to people on the ground.

The next table (see page 24) gives typical magnetic field measurements for several types of single circuit electric power lines at varying distances from the lines, both at times of average electricity usage and at peak usage times. A single circuit power line is actually a set of three lines. If you see more than three lines, it means that more than one circuit runs along the same right-of-way (ROW), in which case higher fields are possible. The first measurement on the table gives the maximum magnetic field strength measured within the power line ROW. The next four measurements are at distances of 50', 100', 200', and 300'. Power line ROW widths vary among utilities. All measurements were taken at a height of one meter above the ground.

The measurements shown here are from electric "transmission" lines, which use very high voltages and go long distances. The electrical lines you see in typical neighborhoods are "distribution" lines, which usually carry less voltage than transmission lines. Voltage is not, however, the critical issue with regard to magnetic field strength. Rather, magnetic field strength is directly proportional to current, which can be high in distribution lines as well as in transmission lines. Residential exposures to distribution lines are usually under 5 mG, but have been reported to be as high as 50 mG where the lines pass within a few feet of living space in densely populated areas.

It is interesting to note that the highest magnetic field strength measurement we have directly on the right of way of 500 kV transmission lines during peak usage is lower than the median measurement we have for magnetic field strength within 6 inches of many household appliances, such as hair dryers and vacuum cleaners. However, the duration of exposure to EMFs from power lines near a home is typically much longer than the duration of exposure to EMFs from most appliances. Is this an important distinction? We just don't know yet.

ELECTRIC POWER LINES

Types of Transmission Lines	Maximum on Right-of-Way	Distance from lines			
		50'	100'	200'	300'
115 Kilovolts (kV)					
Average usage	30	7	2	0.4	0.2
Peak usage	63	14	4	0.9	0.4
230 Kilovolts (kV)					
Average usage	58	20	7	1.8	0.8
Peak usage	118	40	15	3.6	1.6
500 Kilovolts (kV)					
Average usage	87	29	13	3.2	1.4
Peak usage	183	62	27	6.7	3.0

Magnetic field measurements in units of milligauss (mG)

Information courtesy of Bonneville Power Administration.

Burying power lines underground often does reduce their magnetic fields. This is not because they are underground, however, since dirt does not act as a shield. Instead, the lower magnetic field is due to the way lines are arranged and encased when they are buried, which can have the effect of cancelling part of the field. Underground power lines are still capable of exposing you to magnetic fields if you are very close to them.

TRANSPORTATION SOURCES: CARS AND TRAINS

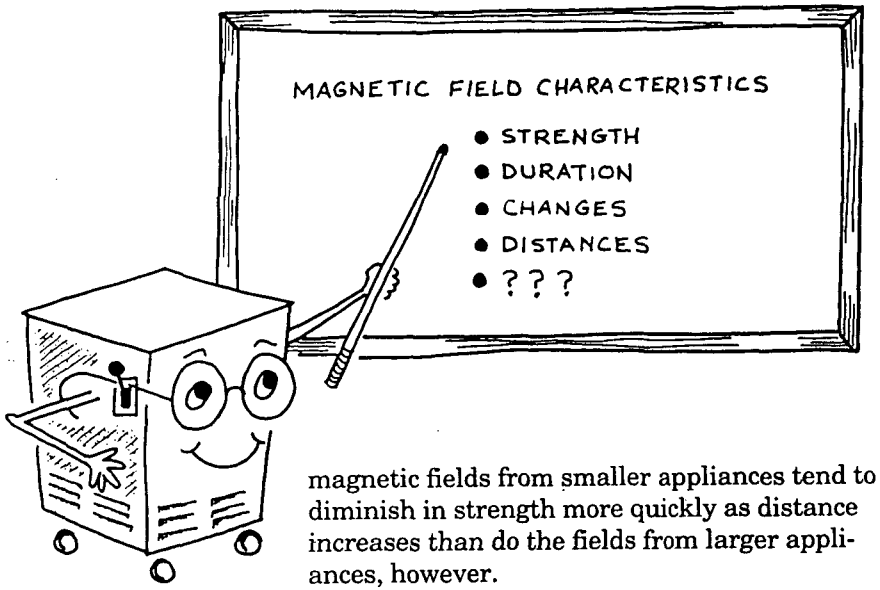
Inside a car, the dominant sources of 60 hertz magnetic field exposure are those you pass by (or under) as you drive, such as power lines. Car batteries involve direct current (DC), rather than alternating current (AC). Car phones are also battery-powered and are therefore not sources of 60 hertz magnetic fields, although they do transmit and receive fields in the radio frequency range. Some car components, such as alternators, can create alternating fields, but not necessarily in the 60 hertz frequency.

Trains present a more complicated picture. Some electrically powered trains operate on alternating current, such as the New York City subway and the Baltimore/Washington commuter train. Measurements taken on the Baltimore/Washington train in 1991* showed 25 hertz magnetic field strengths as high as 500 mG in the passenger areas at seat height. Other trains, such as the Washington D.C. Metro and the San Francisco Bay Area Rapid Transit (BART), run on direct current, but even these trains are not free of AC fields. Areas of strong AC magnetic fields have been measured on the Washington D.C. Metro, close to the floor, presumably near equipment located underneath some train cars. Train motors and other equipment create some very intense alternating fields at higher than 60 hertz frequencies. In addition to sources of magnetic field exposure from the train itself, train passengers are exposed to magnetic fields from sources the train passes on its route.

* *24-Hour Exposure Measurements to 60 Hertz Magnetic Fields: A Pilot Project,* presented by Lynne Gillette, U.S. EPA, at the Air and Waste Management Association Annual Meeting, June 1992.

HOW CAN I USE THIS INFORMATION?

Many people are surprised when they compare magnetic field measurement data from appliance to appliance and see that magnetic field strength does not depend on how large, complex, powerful or noisy the appliance is. In fact, the magnetic fields near large appliances are often weaker than those near smaller devices. There are many reasons why this can happen, all of them related to product design. The stronger



magnetic fields from smaller appliances tend to diminish in strength more quickly as distance increases than do the fields from larger appliances, however.

If you are trying to determine your potential exposure to a magnetic field from a particular appliance, it is important that you consider how close you are to the appliance and how long you use it. The electric alarm clock at the head of your bed may expose you to a magnetic field of 15 mG for 7 or 8 hours each night. The electric can opener in the kitchen is also capable of producing a magnetic field of 15-20 mG at a distance of one foot away, but your potential exposure to that field is for a much shorter duration.

Does it matter how long we are exposed to a magnetic field? We don't know. Magnetic fields that are cycled on and off repeatedly, such as those from photocopiers, may have a different kind of effect on us than those from appliances that run constantly, such as alarm clocks.

Obviously, many remaining questions about EMF need to be answered before we can say what is safe or unsafe. The government and the private sector are currently working together to sponsor research that attempts to answer some of these questions.

This publication presents what we hope are some helpful pieces of the EMF puzzle – information about how magnetic field strengths of various everyday appliances compare with each other and how their strength diminishes the farther away you are from the appliances. In many instances, you can substantially reduce your exposure to magnetic fields by simply putting more distance between yourself and EMF sources.

APPENDIX A

Technical Notes

The data in the tables came from three different organizations: the Electric Power Research Institute (EPRI), J.R. Gauger of the Illinois Institute of Technology Research Institute (IITRI), and the U.S. Environmental Protection Agency (EPA). Each set of data was collected in a different manner.

EPRI DATA

The EPRI data comes from the September 1992 Interim Report of EPRI's nationwide Survey of Residential Magnetic Field Sources. (EPRI TR-100194, Project 2942-06.) The survey involved 707 homes. Data was collected with Star magnetic field instruments at different distances from the appliances' front surfaces, at a height of 3 feet from the ground. The Star magnetic field meter measures only 60 hertz magnetic fields. EPRI did not measure magnetic field strengths at a distance of 6 inches from the appliance, as did IITRI and EPA. Therefore, the missing 6 inch measurements for appliances covered in the EPRI survey was provided either by ITTRI or by the EPA. It is important to note that although the tables in this publication give measurements at distances of 6 inches, 1 foot, 2 feet, and 4 feet from the source, the EPRI measurements were actually made at slightly closer distances from the appliances: approximately 10.5", 22.3", and 46". The number of appliances of each type measured by EPRI ranged from 60 to 400. EPRI researchers collected information on manufacturer and model of the appliances they measured, but they did not report that information.

IITRI DATA

The IITRI data set is from a 1984 report by J.R. Gauger of IITRI, prepared for the U.S. Naval Electronic Systems Command, entitled "Household Appliance Magnetic Field Survey" Technical Report E06549-3, Contract No. N00039-84-C-0070. IITRI used measurement equipment of their own design. They measured the maximum 60 hertz magnetic field for appliances in the location in which they were normally used, and turned off or otherwise minimized all other EMF sources in the vicinity of the appliance being measured. The IITRI data set is based on a smaller sample of appliances than EPRI used. About five appliances of each type were measured.

EPA DATA

EPA staff conducted measurements of commonly used electrical appliances for which data had not already been collected. At least five different types of a given appliance were measured. The measurement protocol used by the EPA in its data collection was the following:

1) Equipment consisted of a measuring tape and an Emdex II magnetic field meter measuring in the broadband magnetic field resultant mode every 1.5 seconds.

2) Sources being measured were left in their original positions in the environment. Other operating sources within 3 feet of the object source were turned off when the measurements were taken.

3) Measurement sites were at given distances from the center of the source surface closest to the most likely source user position. The measurement sites were on a line from the center of this surface, in the direction of the user position and parallel to the floor.

4) For each of the measurement sites, before turning on the source to be measured, an initial measurement of the background EMF was taken. This measurement was based on the average of ten consecutive Emdex II readings, rounded to the nearest tenth of a milligauss. With the source operating at its maximum output, the measurements were taken with the same averaging technique. Background measurements were taken again after the source was turned off.

5) In cases where the source field changed periodically (such as with some copy machines) the measurements were taken during the period of operation when the field was strongest.

The following chart shows, for each appliance listed in the publication, which organization provided the data.

DATA SOURCES			
	EPRI	IITRI	EPA
BATHROOM			
Hair Dryers		✔	
Electric Shavers		✔	
KITCHEN			
Blenders		✔	
Can Openers		✔	
Coffee Makers		✔	
Crock Pots		✔	
Dishwashers		✔	
Food Processors			✔
Garbage Disposals		✔	
Microwave Ovens	✔	*	
Mixers		✔	
Electric Ovens		✔	
Electric Ranges	✔	*	
Refrigerators	✔	*	
Toasters		✔	
LAUNDRY/UTILITY ROOM			
Clothes Dryers		✔	
Clothes Washers		✔	
Irons		✔	
Portable Heaters		✔	
Vacuum Cleaners		✔	

** Indicates Source of 6" Measurements*

DATA SOURCES

	EPRI	IITRI	EPA
WORKSHOP			
Battery Chargers			✔
Drills		✔	
Power Saws		✔	
Screw Drivers			✔
LIVING / FAMILY ROOM			
Ceiling Fans	✔		
Window Air Conditioners	✔		
Stereo Tuners			✔
Color Televisions	✔		
Black & White Televisions	✔		
OFFICE SOURCES			
Air Cleaners			✔
Copy Machines			✔
Fax Machines			✔
Fluorescent Lights	✔	*	
Electric Pencil Sharpeners			✔
Video Display Terminals			✔
BEDROOM			
Digital Clocks	✔		
Analog Clocks	✔		
Baby Monitors			✔

* Indicates Source of 6" Measurements

APPENDIX B

Additional Reading and Information Sources

Public Information Brochures

Electric and Magnetic Fields from 60 Hertz Electric Power: What do we know about possible health risks?, Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213, 1989. Available from Carnegie Mellon: (412) 268-2670. ($3.00)

Electric Magnetic Fields Brochures Series, Edison Electric Institute (EEI). A series of brochures targeted for various audiences (consumers, employees, realtors, teachers, physicians, etc.). Available from EEI: (202) 508-5424. ($1.25+)

Research Reviews

Biological Effects of Power Frequency Electric and Magnetic Fields-Background Paper, Office of Technology Assessment, May 1989. OTA-BP-E-53. Available from the U.S. Government Printing Office: (202) 783-3238. GPO# 052-003-01152-2. ($4.70+)

Electric and Biological Effects of Transmission Lines: A Review, Bonneville Power Administration, 1989. Available from BP: 1-800-622-4520. Publication number: DOE/BP-945. Free. 107 pages.

Basic Science

Electric and Magnetic Field Fundamentals: An EMF Health Effects Research Paper, Electric Power Research Institute (EPRI), January 1991. Available from EPRI: (510) 934-4212. Publication number: EN-7066. ($5.00)

Basic Electromagnetic Theory, by Demetrius T. Paris and F. Kenneth Hurd, McGraw Hill, 1969. Available in public libraries and bookstores.

For more information contact:

Office of Radiation and Indoor Air
Radiation Studies Division
U.S. Environmental Protection Agency
(6603J)
Washington, D.C. 20460

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DOCUMENTS SUPPORTING REVIEW OF ENVIRONMENTAL INFORMATION, NUMBERS 23 THRU 29.

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SUMMARY OF TOXICITY BIOMONITORING RESULTS
TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT (WBN)
JANUARY 1991 - MARCH 1994

Tennessee Valley Authority
Toxicity Testing Laboratory
Water Management

June 1994

SUMMARY OF TOXICITY BIOMONITORING RESULTS
TENNESSEE VALLEY AUTHORITY, WATTS BAR NUCLEAR PLANT (WBN)
JANUARY 1991-MARCH 1994

TEST DATE	ORGANISM	CONTROL/ DILUTION	TREATMENT		COMMENTS
			OUTFALL 101*	CONC. (%)	
Jan. 11-18, 1991					Initial baseline test of Outfall 101. Isco composite 24-h samples.
	Pimephales promelas	TR†	Not toxic, s & g§	100, 50	
	Ceriodaphnia dubia	TR	Not toxic, s & r§	100, 50, 25	
	Selenastrum capricornutum	TR	Not toxic, g§	100, 50, 25	
Apr. 9-21, 1991					Test conducted during discharge of ice melt water w/ 2,000 ppm sodium tetraborate (20 gpm). Boron concentration range = 0.22-2.20 mg/L. Also effluent spiked with 9.0 ppm boron (nominal concentration). Isco composite 24-h samples.
	Pimephales promelas	TR	Not toxic, s & g	100, 30, 9, 2.7	9.0 ppm boron not toxic (12-d embryo-larval test).
	Ceriodaphnia dubia	TR	Not toxic, s & r	100, 30, 9, 2.7	9.0 ppm boron toxic (reproduction only)
	Selenastrum capricornutum	TR	Toxic (NOEC = 9%), g	100, 30, 9, 2.7	*Intake source of toxicity*; 9.0 mg B/L was not toxic.
Jul. 31- Aug. 9, 1991					Tested 100% Outfall 101 alone (treatment 2) and with respective high & low concentrations each of: A. TVA06#, TVA07#, Betz 30K# (treatments 3 & 4) B. TVA06, TVA07, Betz 30K, Copper-Trol# (treatments 5 & 6) C. TVA06, TVA07, Betz 30K, Clam-Trol# (treatments 7 & 8) Treatments 5-8 were exposed to Copper-Trol & Clam-Trol only during the initial 24 hours of testing.
	Ceriodaphnia dubia	WBN Intake/ Outfall 101	Acute (24-h) toxicity of treatments 7 & 8 Chronic toxicity of treatments 5 (s) and 3 (r)	See Study Comments	100% mortality in 24-h for treatments 7 & 8. Only high concentrations of A & B affected.

TEST DATE	ORGANISM	CONTROL/ DILUTION	TREATMENT		COMMENTS
			OUTFALL 101*	CONC. (%)	
(Cont.)	*Anodonta imbecillis* (Juvenile freshwater mussels, Paper Pondshell, 8-9 days old post transformation, 9-day test exposure)	WBN Intake/ Outfall 101	Not toxic, s	See Study Comments	9-day survival in ranged from 89% (reference) to 98% (treatment 7). All treatments contained ~ 600-800 mg silt/L (dry weight).
Sept. 19-26, 1991					Follow up study that Tested 100% Outfall 101 alone (treatment 2) and with respective high & low concentrations each of : A. TVA06, TVA07, Betz 30K (treatments 3 & 4) B. TVA06, TVA07, Betz 30K, Clam-Trol (5 & 6) Treatments 5 & 6 were exposed to CT-1 only during the initial 24 hours of testing.
	Pimephales promelas	WBN Intake/ Outfall 101	Not toxic, s, g.	See Study Comments	
	Ceriodaphnia dubia	WBN Intake/ Outfall 101	Acute (24-h) toxicity of treatment 5 and chronic (6-day) toxicity of treatment 6 (s)	See Study Comments	CT-1 toxic at both high and low concentrations tested. No other toxicity observed.
Apr. 9-16, 1992					Second baseline evaluation of Outfall 101 alone and spiked w/ Copper-Trol® for the algal test.
	Pimephales promelas	WBN Intake	Toxic (NOEC < 50%), s	100% & 50%	*Intake source of toxicity*;
	Ceriodaphnia dubia	WBN Intake	Not toxic, s, r	100%, 75%, 50%, 25%	
	Selenastrum capricornutum	WBN Intake	Toxic (NOEC = 50%; IC25 = 63%), g 100%-spiked Outfall 101 not toxic, g	100%, 75%, 50%, 25%. Also, with Copper-Trol®-spiked & trsted @ 100%, 30%, 9%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:83 minimum for the study).
June 25-July 2, 1992					Third baseline assessment of Outfall 101.
	Pimephales promelas	WBN Intake	Not toxic, s, g	100%, 50%	
	Ceriodaphnia dubia	WBN Intake	Not toxic, s, r	100%, 75%, 50%, 25%	
	Selenastrum capricornutum	WBN Intake	Toxic (NOEC = 75%), g	100%, 75%, 50%, 25%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:117 minimum for the study).

TEST DATE	ORGANISM	CONTROL/ DILUTION	TREATMENT		COMMENTS
			OUTFALL 101*	CONC. (%)	
Oct. 15-22, 1992					First operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	TR	Not toxic, s, g	100%, 50%, 25%, 12.5%	
	Ceriodaphnia dubia	TR	Not toxic, s, r	100%, 50%, 25%, 12.5%	
Nov. 18-25, 1992					Second operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	TR	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	TR	Not toxic, s, r	100%, 50%, 25%, 2%	
	Selenastrum capricornutum	TR	Toxic (NOEC = 2%), g	100%, 50%, 25%, 2%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:404 minimum for the study).
Dec. 16-23, 1992					Third operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Jan. 15-22, 1993					Fourth operational assessment during injection of anti fouling chemicals. *CT-1 injected during study.*
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Feb. 11-18, 1993					Fifth operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
	Selenastrum capricornutum	TR	Toxic (NOEC = 2%), g	100%, 50%, 25%, 2%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:831 minimum for the study).

TEST DATE	ORGANISM	CONTROL/ DILUTION	TREATMENT		COMMENTS
			OUTFALL 101*	CONC. (%)	
Mar. 19-26, 1993					Sixth operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Apr. 16-23, 1993					Seventh operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
May 12-19, 1993					Eighth operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
	Selenastrum capricornutum	Intake/TR	Toxic (NOEC = 2%), g	100%, 50%, 25%, 2%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:159 minimum for the study).
Jun. 9-16, 1993					Ninth operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Intake/ Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Jul. 15-22, 1993					Tenth operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Aug. 19-26, 1993					Eleventh operational assessment during injection of anti fouling chemicals.
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	

TEST DATE	ORGANISM	CONTROL/ DILUTION	TREATMENT		COMMENTS
			OUTFALLS 101 & 112*	CONC. (%)	
(Cont.)	*Ceriodaphnia dubia*	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
	Selenastrum capricornutum	Synthetic water	Toxic (NOEC = 1.1%), g	100%, 50%, 25%, 2%	Instream acute and chronic (CMC & CCC) toxicity criteria not exceeded due to dilution (1:424 minimum for the study).
Sep. 25-Oct. 2, 1993					Twelfth operational assessment during injection of anti fouling chemicals. *CT-1 injected during study.*
	Pimephales promelas	Synthetic water	Not toxic, s, g	100%, 50%, 25%, 2%	Growth reduction in 25% & 50% treatments but not in undiluted Outfall 101.
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 50%, 25%, 2%	
Feb. 2-9, 1994					First semi-annual compliance monitoring of Outfalls 101 and 112 under renewed NPDES permit TN0020168.
Outfall 101	*Pimephales promelas*	Synthetic water	Not toxic, s, g	100%, 9.8%, 7.8%, 2.9%, 2.3%	
	Ceriodaphnia dubia	Synthetic water	Toxic (NOEC = 9.8%), r	100%, 9.8%, 7.8%, 2.9%, 2.3%	*Permit limit not exceeded.*
Outfall 112	*Pimephales promelas*	Synthetic water	Toxic (NOEC = 25%), s	100%, 80%, 50%, 25%, 12.5%	*Permit limit exceeded.*
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 80%, 50%, 25%, 12.5%	
Feb. 18-25, 1994					Repeat test of Outfall 112 due to fish toxicity exceeding permit limit.
Outfall 112	*Pimephales promelas*	Synthetic water	Toxic (NOEC = 25%), g	100%, 80%, 50%, 25%, 12.5%	*Permit limit exceeded* (based on 0.1 µg of fish weight in 100% Outfall 112 treatment).
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 80%, 50%, 25%, 12.5%	
Mar. 23-30, 1994					Repeat test due to fish toxicity exceeding permit limit in the previous test.
Outfall 112	*Pimephales promelas*	Synthetic water	Not toxic, s, g	100%, 80%, 50%, 25%, 12.5%	
	Ceriodaphnia dubia	Synthetic water	Not toxic, s, r	100%, 80%, 50%, 25%, 12.5%	

Footnotes on following page

Footnotes:

Test types: **3-brood *Ceriodaphnia dubia* chronic test (EPA protocol), 7-day *Pimephales promelas* chronic test (EPA protocol), 9-day *Anodonta imbecillis* acute test (TVA protocol).**

*Outfall 101 = Diffuser pipe at TRM 527.9; Outfall 112 = Runoff holding pond to unnamed tributary to Yellow Creek

†TR = Non-toxic dilution water collected from outdoor channels at TVA's Toxicity Testing Laboratory, Wheeler Reservoir once-through water pumped from upstream of the Browns Ferry Nuclear Plant (TRM 293).

§s = survival (fish, daphnids, & mussels), g = growth (fish & algae), r = reproduction (daphnids).

#Chemical additives:

TVA06 = HPS-1 copolymer dispersant
TVA07 = zinc sulfate
Betz 30K = tetra potassium pyro phosphate
Copper-Trol = tolyltriazole
Clam-Trol = CT-1.

STANDARD REPORT FORM

STATIC RENEWAL TESTS USING *ANODONTA IMBECILLIS* (FRESHWATER MUSSEL) AND *BRACHIONUS CALYCIFLORUS* (ROTIFER)

ACUTE TOXICITY OF CT-1 (CLAMTROL®)

TENNESSEE VALLEY AUTHORITY
WATER MANAGEMENT
JULY 1994

STANDARD REPORT FORM

STATIC RENEWAL TESTS USING ANODONTA IMBECILLIS (FRESHWATER MUSSEL) AND BRACHIONUS CALYCIFLORUS (ROTIFER)

Test Title: Anodonta imbecillis and Brachionus calyciflorus Acute Toxicity of CT-1 (Clamtrol®)

Principle Investigator: Damien J. Simbeck

Starting Date: June 7, 1994

Ending Date: June 16, 1994

1.0 EXECUTIVE SUMMARY

Toxicity testing of CT-1 (Clamtrol®) using juvenile freshwater mussels (Anodonta imbecillis) and the rotifer (Brachionus calyciflorus) was conducted by TVA to determine the effects of this biofoulant control chemical on non-target organisms. This test was conducted as part of a larger evaluation by TVA and two other laboratories, which included testing of additional species: Ceriodaphnia dubia (daphnid), Pimephales promelas (fathead minnow) and Elliptio arctata (freshwater mussel). Tests at TVA's Toxicity Testing Laboratory were designed to determine the LC_{50} values for the two species tested, as well as to test the detoxification potential of an organic sediment.

Testing of juvenile mussels using serial dilutions of CT-1 was conducted from June 7-16, 1994. Results showed LC_{50} values of 0.14 mg/L for liquid phase protocol/without sediment and 1.07 mg/L for liquid phase protocol/with silt during a 9-day exposure. No survival was found at 12.8 mg/L using the solid phase protocol. EC_{50} values, with stress or death as the effect, were 0.12 mg/L liquid phase/without silt and 0.96 mg/L liquid phase/with silt. The addition of silt reduced toxicity in the mussel test by a factor of approximately 8. Testing of rotifers resulted in an LC_{50} value for 24-hr exposure of 1.8 mg/L.

2.0 SAMPLE COLLECTION/TREATMENTS

2.1 Test Sample Identification (Chemical/Effluent/Elutriate, etc.): The samples used for biomonitoring were daily prepared serial dilutions of CT-1 in Moderately Hard Reconstituted Water (MHRW).

2.2 Control and/or Dilution Water: Moderately Hard Reconstituted Water

2.3 Sample Date: Fresh samples were prepared daily

2.4 Sampling Method: Not applicable

2.5 Sample Transport: Concentrated CT-1 was shipped to TVA's Toxicity Testing Laboratory (TTL) on May 27, 1994 from Betz Laboratories, Inc., Trevose, PA via Federal Express overnight courier.

2.6 Sample Storage/Handling: All concentrated sample was stored at room temperature in its original container throughout the test. A diluted stock solution (1:1000) was prepared daily for sample pour-up.

2.7 Sample Pretreatment/Preparation:

2.7.1 Liquid phase protocol/without silt: Fresh samples were prepared daily by adding appropriate amounts of a CT-1 stock solution to MHRW. Samples were then warmed to 24°C in a warm water bath

2.7.2 Liquid phase protocol/with silt: Fresh samples were prepared daily by adding appropriate amounts of a CT-1 stock solution to MHRW and adding 100 µm-filtered silt (~800 mg/L dry weight) to the control water and each treatment. Samples were then warmed to 24°C in a warm water bath. Samples were stirred thoroughly after the addition of silt, and before renewal.

2.7.3 Solid phase protocol: Filtered sediment (20 mL 100 µm-filtered non-toxic sediment) and 150 mL MHRW were placed in each replicate dish (four dishes per treatment) on June 6. The dishes were placed in the test incubator 24-hr prior to test initiation to allow settling and temperature equilibration. Fresh samples of overlying water were prepared daily by adding appropriate amounts of a CT-1 stock solution to MHRW. Samples were then warmed to 24° C in a warm water bath

2.8 Test treatments:

2.8.1 Mussels:

2.8.1.1 Liquid phase protocol/without silt: CT-1 concentrations of 0.1 mg/L, 0.4 mg/L, 1.6 mg/L, 6.4 mg/L, and 12.8 mg/L were tested.

2.8.1.2 Liquid phase protocol/with silt: CT-1 concentrations of 0.1 mg/L, 0.4 mg/L, 1.6 mg/L, 6.4 mg/L, 12.8 mg/L and 25.6 mg/L were tested with 100 µm-filtered non-toxic sediment (800 mg/L, dry weight) added.

2.8.1.3 Solid phase protocol: CT-1 samples of 12.8 mg/L were tested.

2.8.2 Rotifers: CT-1 concentrations of 0.1 mg/L, 0.4 mg/L, 1.6 mg/L, 3.2 mg/L and 6.4 mg/L were tested.

3.0 TEST ORGANISMS/CULTURING CONDITIONS

3.1 Species: Anodonta imbecillis, freshwater mussel

3.1.1 Culture of Test organisms

3.1.1.1 Source: In vitro culture, May 24-31, 1994, TVA Toxicity Testing Laboratory. The gravid adults from which glochidia were extracted were obtained from Haleyville City Reservoir, Haleyville, Alabama, on April 26, 1994. Adults were maintained in a 200-L fiberglass tank with approximately 10 L non-toxic sediment from Taylor's ponds (Town Creek, Alabama) and 150 L Tennessee River water. Water (≈20-40 L) was renewed at least once per week with bloomed phytoplankton water and sediment was renewed monthly.

3.1.1.2 Culture medium: Mussel culture medium used to transform larvae (glochidia) into juveniles consisted of a 2:1 mixture of cell culture medium (MEM) and 0.22 µm- filtered catfish plasma. Antibiotics and antimycotics were added in small concentrations to prevent bacterial and fungal contamination. [1]

3.1.1.3 Temperature of culture: 24°C ± 1°C

3.1.2 Maintenance of Test Organisms:

3.1.2.1 Culture water: After transformation of larval mussels (May 31), the free-living juveniles were placed in 100 µm-filtered TR water with bloomed indigenous algae (phytoplankton). Non-toxic sediment (100 µm-filtered) was added to provide additional food and substrate for healthy growth of juvenile mussels. [2]

3.1.2.2 Temperature of culture: 24° ± 1°C

3.1.2.3 General Maintenance: Cultures were maintained in 200-mL Nalgene® trays in 24-hr dark incubators. From June 1-6, cultures were changed out daily with fresh phytoplankton water and silt. Cultures were also fed a concentrated phytoplankton (20 mL/L) daily. Health and survival of the culture were checked by microscopic examination of animals when culture water was renewed.

3.1.3 Food Preparation

3.1.3.1 Phytoplankton preparation: Phytoplankton was bloomed in 20-L glass aquaria 4-7 days (until dark green). Blooms were initiated by adding concentrated solids from TTL channel water and/or Taylor's Pond water to filtered (100 µm) TR water. Algal nutrients used for Selenastrum cultures were added (1 mL/L) to boost algal blooms. [3] Blooms were allowed to settle in a refrigerator or were centrifuged at 4°C at 3000 rpm to concentrate the algal cells into a dark green suspension, obtaining about 0.5 L per aquarium. Prepared phytoplankton concentrate was refrigerated until used.

3.1.3.2 Sediment preparation: Whole, non-toxic sediment from Taylor's Catfish ponds, Town Creek, Alabama, was filtered through a 100-µm nylon mesh filter. Filtered sediment was stored at ≤4° until used.

3.2 Species: Brachionus calyciflorus, rotifer

3.2.1 Test Organism Preparation:

3.2.1.1 Culture Medium: Moderately hard reconstituted water was pH adjusted to 7.5 using 0.1 N HCl.

3.2.1.2 Rotifer Cyst Hatching: Organisms used in the test were obtained by overnight hatching of commercially obtained rotifer cysts. Cysts were emptied from vials into glass test tubes containing 10-15 mL of pH adjusted culture medium approximately 20 hours prior to test initiation. Tubes were capped and cysts were incubated in light conditions (≅400 ft.c.) at 25° C. Cysts were viewed hourly, using a microscope, for hatching beginning approximately 18 hours after start of incubation. Test initiation occurred within two hours of peak hatching to assure that starvation was not a factor in test results. Starvation begins to cause mortality approximately 32 hours after hatching.

4.0 TEST METHODS

4.1 Mussels, Anodonta imbecillis, Survival Test, TVA Test Method, SOP-22, liquid and solid phase protocols. [3]

4.1.1 Modification/Deviations to SOP-22:

4.1.1.1 Liquid phase protocol: No sediment was added to one set of serial dilutions.

4.1.1.2 Solid phase protocol: Test sediment (20 mL per replicate) with overlying moderately hard reconstituted water (150 mL per replicate) was placed into dishes 24 hr prior to test initiation and placed in the incubator to allow settling and temperature equilibration. This sediment was not renewed during the 9-day test period.

4.1.2 Date/Time Test Initiated: June 7, 1994/0930 CDT

4.1.3 Date/Time Test Terminated: June 16, 1994/0930 CDT

4.1.4 Age of Test Organisms: 7 days old

4.1.5 Test Chamber: 50 mm-diameter glass cylinder (75 mm tall) with 100-µm nylon mesh bottom, placed in 200-mL crystallizing dish

4.1.6 Volume per Chamber:

4.1.6.1 Liquid phase protocol: 150 mL water

4.1.6.2 Solid phase protocol: 150 mL water, 20 mL sediment

4.1.7 Number of Organisms Per Replicate: 10

4.1.8 Number of Replicates Per Treatment: 4

4.1.9 Test Controls:

4.1.9.1 Liquid phase protocol/without silt: Moderately Hard Reconstituted Water

4.1.9.2 Liquid phase protocol/with silt: Moderately Hard Reconstituted Water with 800 mg/L (dry weight) filtered sediment

4.1.9.3 Solid phase protocol: Moderately Hard Reconstituted Water with 20 mL filtered sediment.

4.1.10 Dilution Water: Moderately Hard Reconstituted Water

4.1.11 Overlying Water (Solid phase protocol): Moderately Hard Reconstituted Water

4.1.12 Test Temperature: 24° ± 1°C

4.1.13 Photoperiod: 24-h dark

4.1.14 Renewal period: 24-hr

4.1.15 Renewal method:

4.1.15.1 Liquid phase protocol: Test cylinder was removed from crystallizing dish and placed in petri dish with MHRW for microscopic examination. After examination, final water was poured from dish into a 600-mL beaker for chemical analyses and the dish was rinsed with MHRW. Fresh test medium (150 mL) was added to the dish, and the cylinder was returned to the dish.

4.1.15.2 Solid phase protocol: Following removal of 125 mL of the overlying water for chemical analyses, each test chamber was placed in a petri dish with MHRW for microscopic examination. After examination, the cylinder was returned to the same crystallizing dish, and 125 mL fresh test medium was poured into the test vessel through the cylinder. Test sediment was not renewed during this test.

4.1.16 Feeding Regime During Test: Concentrated phytoplankton (6 mL/L) was added to each test solution before renewal. Silt (100 µm-filtered; 800 mg/L dry weight) was added to the liquid phase/with silt treatments.

4.1.17 Physical and Chemical Parameters Measured: Parameters measured daily ("initial") on fresh samples and overlying water (following addition of algae and silt) were temperature (temperature adjusted to equal "final" temperature before renewal), DO, pH, and conductivity. Alkalinity, hardness and un-ionized ammonia was measured daily in the control, low and high concentrations of each serial dilution.

"Final" measurements of temperature, DO, and pH were taken daily in one replicate per treatment before renewal. "Final" measurements of conductivity, alkalinity, hardness and un-ionized ammonia were measured in a combination of water from all replicates after renewal. The test solutions (100 mL) were preserved with 1:4 H_2SO_4 and refrigerated until sent to TVA's Environmental Chemistry Laboratory in Chattanooga, Tennessee, for ammonia analyses using the automated alkaline phenate methodology.

4.1.18 Test Endpoint Determination:

4.1.18.1 Survival: Test animals were counted as dead when microscopic examination revealed valves gaped open and no observable internal movement or an empty shell.

4.1.18.2 Stress: Test animals were counted as stressed when microscopic examination revealed valves gaped open and some slow, inhibited movement was observed.

4.1.19 Statistics: Revised statistical procedures contained in the fourth edition of EPA's acute toxicity methods require a decision process for testing statistical assumptions before selecting a specific statistical test to determine toxicity endpoints. [5] The statistical analysis necessary for these sets of data was the Trimmed Spearman-Karber method.

4.2 Rotifers, Brachionus calyciflorus, Survival Test, Rotox® [6][7]

4.2.1 Modifications/Deviations: None

4.2.2 Date/Time Test Initiated: June 9, 1994/1210 CDT

4.2.3 Date/Time Test Terminated: June 10, 1994/1210 CDT

4.2.4 Age of Test Organisms: <8 hours old

4.2.5 Test Chambers: Test was conducted in 24-well plastic tissue culture plates. The plate was arranged in six rows of four wells. This arrangement allowed for control and five treatments to be tested per plate.

4.2.6 Volume per Chamber: 1 mL

4.2.7 Number of Organisms per Replicate: 5

4.2.8 Number of Replicates per Treatment: 4

4.2.9 Test Control: Moderately hard reconstituted water

4.2.10 Dilution Water: Moderately hard reconstituted water

4.2.11 Test Temperature: 25° ± 1°C

4.2.12 Photoperiod: 24-h dark

4.2.13 Renewal Period: None

4.2.14 Feeding Regime During Test: No feeding is required during rotifer incubation or testing (24-h)

4.2.15 Physical and Chemical Parameters Measured: Parameters measured ("initial") on fresh samples were DO, pH, and conductivity. Alkalinity and hardness were measured in the control and low concentrations of the serial dilution. Water (1 mL/replicate) was placed into test wells approximately 4 hr prior to test initiation and placed into incubator for temperature stabilization near 25°C.

"Final" measurements of temperature were taken in four cups placed along side the tray in the incubator, since low volume in the test wells would not allow for accurate readings.

4.2.16 Test Endpoint Determination: Test animals were counted as dead when microscopic examination revealed no observable internal or external movement.

4.2.17 Statistics: Revised statistical procedures contained in the fourth edition of EPA's acute toxicity methods require a decision process for testing statistical assumptions before selecting a specific statistical test to determine toxicity endpoints. [5] The statistical analysis necessary for these sets of data was the graphical method.

5.0 QUALITY ASSURANCE

5.1 All phases of the study including, but not limited to, sample collection, handling and storage; glassware preparation; test organism culturing/acquisition and acclimation; test organism handling during test; and maintaining appropriate test conditions were conducted according to the protocol as described in this report, the TTL Quality Assurance Plan and SOP Manual, and EPA/600/4-89/001. [3][4] Any known deviations were noted the study and are reported herein.

5.2 Physical and Chemical Methods

5.2.1 Reagents, Titrants, Buffers, etc.: All chemicals were certified products used before expiration dates (where applicable). All TTL chemicals are recorded in a bound Laboratory Chemical Logbook and specific chemicals used were documented on a chemical record sheet contained in the study notebook.

5.2.2 Instruments: All identification, service and calibration information retaining to TTL laboratory instruments is contained in bound Laboratory Instrument Logbooks and specific instruments used were documented on an instrument record sheet, along with daily calibration record sheets, contained in the study notebook.

5.2.3 Temperature was measured using mercury thermometers. The instrument was standardized and inspected with readings made according to TVA procedure ES-42.11. [8]

5.2.4 Dissolved oxygen was measured using a YSI Model 57 oxygen meter. The instrument was standardized (using the Winkler method) and readings were taken according to TVA procedures ES-43.6 and ES-42.4, respectively. [8]

5.2.5 The pH was measured using an Orion Model 250 meter equipped with an Orion Ross combination electrode. The instrument was standardized and readings were made according to TVA procedure ES-43.7 and ES-42.8, respectively. [8]

5.2.6 Conductance was measured using a YSI Model 32 SCT meter. The instrument was standardized and readings were made according to TVA procedures ES-43.3 and ES-42.3, respectively. [8]

5.2.7 Alkalinity was measured by titration of 100 mL samples with 0.02 N H_2SO_4 to an endpoint of 4.5 according to TVA procedure ES-42.1. [8]

5.2.8 Hardness was determined by titration of 50 mL samples with EDTA to a colormetric endpoint using an indicator (Instructions provided by Reagent Manufacturer [Calgon]), Schwarzenbach Method.

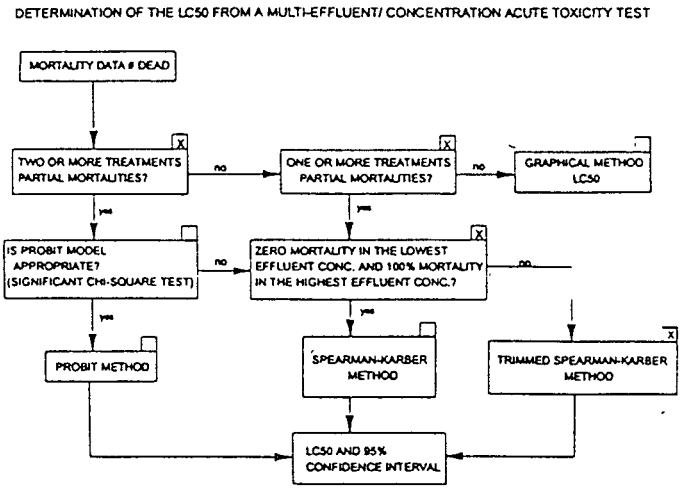
6.0 RESULTS

6.1 Summary of Results: Nine-day exposure of juvenile freshwater mussels, Anodonta imbecillis, to serial dilutions of CT-1 showed LC_{50} values of 0.14 mg/L for liquid phase protocol/without silt and 1.07 mg/L for liquid phase protocol/with silt. No survival was seen after nine-day (100% mortality after 4 days) exposure to 12.8 mg/L CT-1 with the solid phase protocol. EC50 values, with stress and death as the effect, were 0.12 mg/L without silt added and 0.96 mg/L with silt added. Exposure (24-hr) of rotifers, Brachionus calyciflorus, to serial dilutions of CT-1 showed an LC_{50} of 1.8 mg/L.

6.2 Results, Mussels, Survival Data:

6.2.1 Liquid phase protocol/without silt: LC_{50}=0.14 mg/L, 95% confidence limits are not calculable. EC_{50}=0.12 mg/L, 95% confidence limits are not calculable.

6.2.1.1 Statistical Decision Process for Determining Toxicity Endpoints for 9-day Exposure of the Juvenile Mussel, Anodonta imbecillis, to Test Solutions Without Silt, June 7-16, 1994



6..2.1.2 Daily Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

	Total Daily % Survival								
Treatment	1	2	3	4	5	6	7	8	9
Control	100	100	98	98	98	98	98	98	98
0.1 mg/L	100	100	100	100	98	98	95	85	68 *
0.4 mg/L	100	100	93	44	2	0	0	0	0
1.6 mg/L	100	38	0	0	0	0	0	0	0
6.4 mg/L	58	0	0	0	0	0	0	0	0
12.8 mg/L	0	0	0	0	0	0	0	0	0

*58% Alive, 10% Stressed

6.2.1.3 Nine-day Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

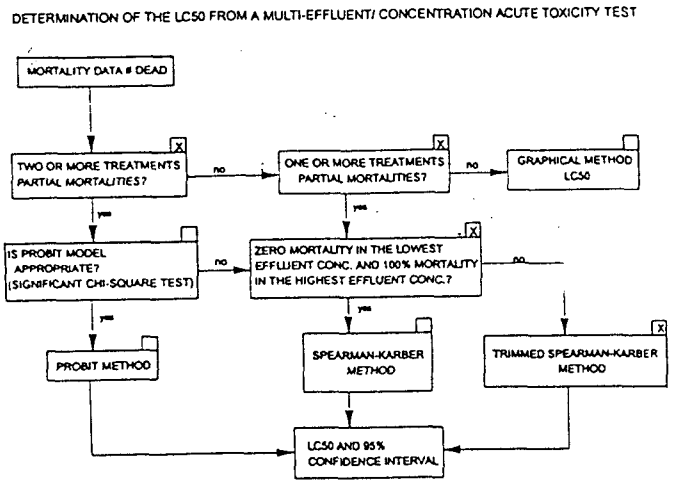
Mussel Survival Data (% Survival)

	Replicate										
Treatment	1	2	3	4	5	6	7	8	9	10	Mean
Control	100	100	90	100							98
0.1 mg/L	80	50	80	60							68 *
0.4 mg/L	0	0	0	0							0
1.6 mg/L	0	0	0	0							0
6.4 mg/L	0	0	0	0							0
12.8 mg/L	0	0	0	0							0

*58% Alive, 10% Stressed

6.2.2 Liquid phase protocol/ with silt: LC_{50}=1.07, 95% Confidence Limits: Lower=0.87 mg/L, Upper=1.32 mg/L. EC_{50}=0.96 mg/L, 95% Confidence Limits: Lower=0.80 mg/L, Upper=1.15 mg/L.

6.2.2.1 Statistical Decision Process for Determining Toxicity Endpoints for 9-day Exposure of the Juvenile Mussel, Anodonta imbecillis, to Test Solutions With Silt, June 7-16, 1994



6..2.2.2 Daily Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

	Total Daily % Survival								
Treatment	1	2	3	4	5	6	7	8	9
Control	98	98	98	98	98	98	98	98	98
0.1 mg/L	100	100	100	98	98	98	98	95	95
0.4 mg/L	100	100	100	100	100	100	100	100	98
1.6 mg/L	100	100	100	98	90	78	48	35	25 *
6.4 mg/L	98	93	13	3	0	0	0	0	0
12.8 mg/L	98	56	0	0	0	0	0	0	0
25.6 mg/L	95	0	0	0	0	0	0	0	0

*18% Alive, 7% Stressed

6.2.2.3 Nine-day Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

Mussel Survival Data (% Survival)

	Replicate										
Treatment	1	2	3	4	5	6	7	8	9	10	Mean
Control	100	90	100	100							98
0.1 mg/L	90	100	90	100							95
0.4 mg/L	100	90	100	100							98
1.6 mg/L	10	30	40	20							25 *
6.4 mg/L	0	0	0	0							0
12.8 mg/L	0	0	0	0							0
25.6 mg/L	0	0	0	0							0

*18% Alive, 7% Stressed

6.2.3 Solid phase protocol:

6.2.3.1 Statistical Decision Process for Determining Toxicity Endpoints for 9-day Exposure of the Juvenile Mussel, Anodonta imbecillis, to Test Solutions Solid Phase, June 7-16, 1994

Not applicable

6..2.3.2 Daily Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

	Total Daily % Survival								
Treatment	1	2	3	4	5	6	7	8	9
Control	100	100	98	98	98	98	98	98	98
12.8 mg/L	100	85	30	0	0	0	0	0	0

6.2.3.3 Nine-day Percent Survival Summary for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

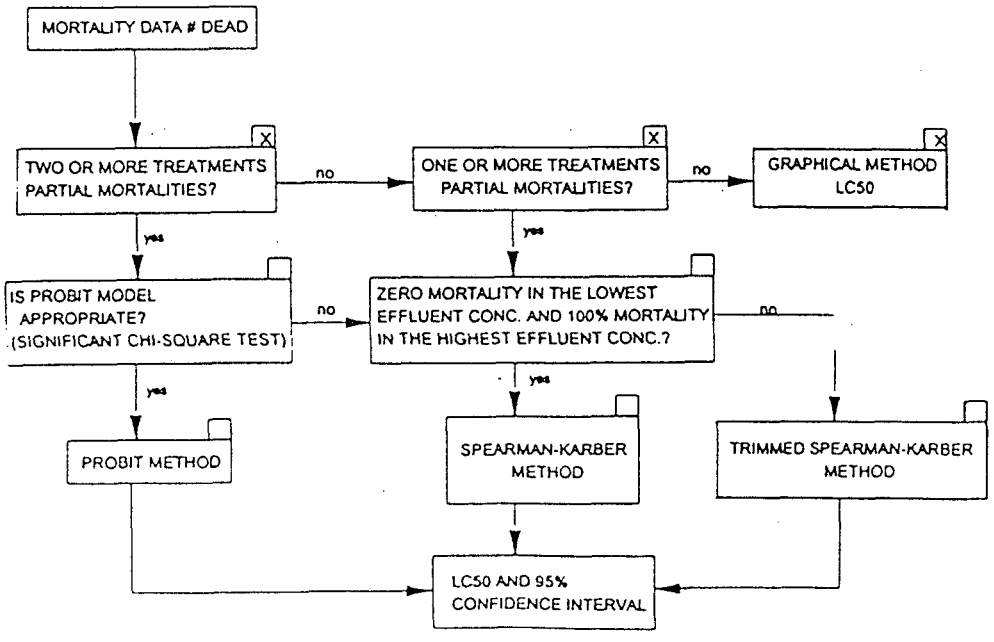
Mussel Survival Data (% Survival)

	Replicate										
Treatment	1	2	3	4	5	6	7	8	9	10	Mean
Control	90	100	100	100							98
12.8 mg/L	0	0	0	0							0

6.3 Results, Survival Data, Rotifers:

6.3.1 Statistical Decision Process for Determining Toxicity Endpoints for 24-h Exposure of the Rotifer, Brachionus calyciflorus, to Test Solutions, June 9-10, 1994.

DETERMINATION OF THE LC50 FROM A MULTI-EFFLUENT/ CONCENTRATION ACUTE TOXICITY TEST



6.3.2 Percent Survival Summary for Brachionus calyciflorus, CT-1 Study 1, June 9-10, 1994

Rotifer Survival Data (% Survival)

Treatment	Replicate 1	2	3	4	5	6	7	8	9	10	Mean
Control	100	100	100	100							100
0.1 mg/L	100	100	100	100							100
0.4 mg/L	100	100	100	100							100
1.6 mg/L	60	60	60	60							60
3.2 mg/L	0	0	0	0							0
6.4 mg/L	0	0	0	0							0

6.4 Water Chemistry Summary for Anodonta imbecillis and Brachionus calyciflorus, CT-1 Study 1, June 7-16, 1994.

6.4.1 Test Temperature, Mussels: 24.1°C (23.2°-24.9°C)

6.4.2 Test Temperature, Rotifers: 25.2°C (24.8°-25.6°C)

6.4.3 See: Appendix A Water Chemistry Mean Values and Ranges for Anodonta imbecillis, CT-1 Study 1, June 7-16, 1994.

6.4.4 See: Appendix B Water Chemistry Mean Values and Ranges for Brachionus calyciflorus, CT-1 Study 1, June 7-16, 1994.

7.0 CONCLUSION

Testing of juvenile mussels using serial dilutions of CT-1 was conducted from June 7-16, 1994. Results showed LC_{50} values of 0.14 mg/L for liquid phase protocol/without sediment and 1.07 mg/L for liquid phase protocol/with silt during a 9-day exposure. No survival was found at 12.8 mg/L using the solid phase protocol. EC_{50} values, with stress or death as the effect, were 0.12 mg/L liquid phase/without silt and 0.96 mg/L liquid phase/with silt. . The addition of silt reduced toxicity in the mussel test by a factor of approximately 8. Testing of rotifers resulted in an LC_{50} value for 24-hr exposure of 1.8 mg/L.

8.0 REFERENCES

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6. Rotifer Toxicity Screening Test for Fresh Water, Standard Operational Procedure, G. Persoone and T. W. Snell, State University of Ghent, Ghent, Belgium, and University of Tampa, Tampa, Florida.

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Appendix A

Water Chemistry Mean Values and Ranges for Anodonta imbecillis
CT-1 Study 1, June 7-16, 1994

Treatment	Temperature		Dissolved Oxygen		pH		Conductivity		Alkalinity		Hardness		Ammonia	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
	(°C)	(°C)	(mg/L)	(mg/L)	(S.U.)	(S.U.)	(µmhos)	(µmhos)	*	*	*	*	(mg/L)	(mg/L)
Without Silt														
Control	23.9 (23.6-24.0)	24.0 (23.2-24.7)	8.5 (8.3-8.6)	8.0 (7.8-8.2)	8.2 (8.0-8.3)	8.2 (8.0-8.2)	338 (328-343)	360 (354-373)	67 (64-71)	72 (70-75)	92.4 (90.0-94.0)	98.0 (96.0-100.0)	<0.001 (<0.001-0.002)	0.003 (0.002-0.004)
0.1 mg/L	24.0 (23.8-24.2)	24.1 (23.8-24.4)	8.5 (8.3-8.6)	8.0 (7.8-8.1)	8.2 (8.1-8.2)	8.2 (8.0-8.2)	337 (328-341)	354 (345-364)	68 (65-70)	71 (68-73)	93.3 (92.0-96.0)	96.9 (94.0-100.0)	<0.001 (<0.001-0.001)	0.003 (0.001-0.004)
0.4 mg/L	24.0 (24.0-24.1)	24.1 (23.9-24.3)	8.4 (8.3-8.5)	7.9 (7.8-8.0)	8.2 (8.1-8.2)	8.2 (8.1-8.2)	336 (328-338)	352 (342-362)	69 (68-69)	72 (71-72)	92.0 (92.0-92.0)	96.0 (94.0-98.0)	<0.001 (<0.001-0.001)	0.003 (0.003-0.003)
1.6 mg/L	24.0 (23.9-24.0)	24.0 (23.9-24.0)	8.4 (8.3-8.5)	7.9 (7.8-8.0)	8.2 (8.2-8.2)	8.1 (8.1-8.2)	333 (327-337)	352 (347-354)	-	68 (68-68)	-	94.0 (94.0-94.0)	-	0.003 (0.003-0.003)
6.4 mg/L	24.0 (24.0-24.0)	23.9 (23.8-24.0)	8.4 (8.3-8.4)	7.9 (7.8-8.0)	8.2 (8.2-8.2)	8.2 (8.1-8.2)	332 (328-334)	347 (346-348)	-	69 (69-69)	-	96.0 (96.0-96.0)	-	<0.001 (<0.001-<0.001)
12.8 mg/L	24.0 (23.9-24.0)	24.1 (24.1-24.1)	8.4 (8.3-8.5)	7.8 (7.8-7.8)	8.2 (8.2-8.2)	8.1 (8.1-8.1)	332 (326-337)	348 (348-348)	66 (65-69)	69 (69-69)	93.2 (92.0-94.0)	98.0 (98.0-98.0)	<0.001 (<0.001-0.002)	0.003 (0.003-0.003)
Whole Sediment														
Control	23.9 (23.6-24.0)	24.1 (23.7-24.6)	8.5 (8.3-8.6)	5.9 (5.5-6.8)	8.2 (8.0-8.3)	7.6 (7.5-8.0)	338 (328-343)	351 (329-365)	67 (64-71)	65 (60-70)	92.4 (90.0-94.0)	93.3 (84.0-100.0)	<0.001 (<0.001-0.002)	<0.011 (<0.001-0.068)
12.8 mg/L	24.0 (23.9-24.0)	24.0 (23.8-24.2)	8.4 (8.3-8.5)	6.2 (5.8-6.6)	8.2 (8.2-8.2)	7.7 (7.5-8.0)	332 (326-337)	336 (326-347)	66 (65-69)	63 (61-66)	93.2 (92.0-94.0)	84.5 (82.0-86.0)	<0.001 (<0.001-0.002)	0.032 (0.010-0.010)

* mg/L as $CaCO_3$

Appendix A (Continued)

Water Chemistry Mean Values and Ranges for Anodonta imbecillis
CT-1 Study 1, June 7-16, 1994

Treatment	Temperature		Dissolved Oxygen		pH		Conductivity		Alkalinity		Hardness		Ammonia	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
	(°C)	(°C)	(mg/L)	(mg/L)	(S.U.)	(S.U.)	(µmhos)	(µmhos)	*	*	*	*	(mg/L)	(mg/L)
With Silt														
Control	24.0 (23.8-24.3)	24.2 (23.2-24.9)	7.9 (7.7-8.1)	7.8 (7.6-8.0)	7.8 (7.7-8.0)	8.1 (8.0-8.1)	338 (329-346)	352 (345-365)	66 (63-69)	68 (66-71)	90.4 (88.0-94.0)	93.3 (90.0-96.0)	0.006 (0.005-0.007)	<0.004 (<0.001-0.008)
0.1 mg/L	23.9 (23.7-24.1)	24.0 (23.4-24.6)	7.9 (7.7-8.1)	7.9 (7.6-8.0)	7.8 (7.7-8.0)	8.1 (8.0-8.3)	341 (326-359)	360 (340-381)	66 (63-68)	69 (65-72)	90.9 (90.0-94.0)	95.1 (92.0-98.0)	0.006 (0.005-0.007)	<0.004 (<0.001-0.007)
0.4 mg/L	24.0 (23.9-24.2)	24.1 (23.6-24.8)	7.9 (7.7-8.1)	7.9 (7.7-8.0)	7.8 (7.7-8.1)	8.1 (8.0-8.2)	346 (326-392)	362 (344-405)	-	-	-	-	-	-
1.6 mg/L	24.0 (23.9-24.1)	24.2 (23.9-24.8)	8.0 (7.7-8.1)	7.9 (7.7-8.0)	7.8 (7.6-8.1)	8.1 (8.0-8.2)	344 (323-368)	358 (339-380)	67 (66-68)	69 (68-70)	89.5 (88.0-90.0)	95.2 (94.0-98.0)	0.007 (0.006-0.008)	0.007 (0.003-0.008)
6.4 mg/L	24.0 (24.0-24.0)	23.8 (23.4-24.2)	7.9 (7.7-8.1)	7.8 (7.7-8.0)	7.8 (7.7-8.1)	8.1 (8.0-8.1)	346 (325-385)	364 (341-397)	65 (65-65)	70 (70-70)	90.0 (90.0-90.0)	92.0 (92.0-92.0)	0.010 (0.010-0.010)	0.003 (0.002-0.004)
12.8 mg/L	24.0 (23.9-24.0)	23.9 (23.9-24.0)	7.8 (7.7-7.9)	7.4 (7.1-7.7)	7.8 (7.7-8.1)	7.9 (7.8-8.1)	337 (321-363)	352 (337-376)	67 (67-67)	64 (64-64)	90.0 (90.0-90.0)	94.0 (94.0-94.0)	0.006 (0.006-0.006)	<0.001 (<0.001-<0.001)
25.6 mg/L	24.0 (24.0-24.0)	23.8 (23.6-23.9)	7.8 (7.7-8.0)	7.4 (7.0-7.7)	7.8 (7.7-8.1)	8.0 (7.8-8.1)	336 (322-360)	362 (348-375)	63 (63-63)	65 (64-66)	90.0 (88.0-92.0)	95.0 (94.0-96.0)	0.009 (0.006-0.014)	<0.003 (<0.001-0.005)

* mg/L as $CaCO_3$

Appendix B

Water Chemistry Mean Values and Ranges for Branchionus calyciflorus
CT-1 Study 1, June 7-16, 1994

Treatment	Temperature Final	Dissolved Oxygen Initial	pH Initial	Conductivity Initial	Alkalinity Initial	Hardness Initial
	(°C)	(mg/L)	(S.U.)	(µmhos)	*	*
Control	25.2 (24.8-25.6)	8.5	8.2	328	64	92.0
0.1 mg/L	25.2 (24.8-25.6)	8.4	8.2	328	66	92.0
0.4 mg/L	25.2 (24.8-25.6)	8.4	8.2	328	-	-
1.6 mg/L	25.2 (24.8-25.6)	8.4	8.2	327	-	-
3.2 mg/L	25.2 (24.8-25.6)	8.3	8.2	328	-	-
6.4 mg/L	25.2 (24.8-25.6)	8.4	8.2	328	-	-

* mg/L as $CaCO_3$

TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY, 1993

BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS

RESERVOIR VITAL SIGNS MONITORING

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Chattanooga, Tennessee

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INTRODUCTION

Benthic macroinvertebrates within Tennessee River system reservoirs are being collected in a Reservoir Monitoring program as one part of the assessment of the ecological health of aquatic resources. These reservoirs contain a wide variety of benthic habitats, but surprisingly little is known about the communities which inhabit these areas. During the first two years of the Reservoir Monitoring program (1990 and 1991), baseline data were collected and analyzed to identify similarities and differences among the benthic macroinvertebrate communities[1 2]. Benthic macroinvertebrate data collected in 1992 was compiled into data summary tables[3]. In 1993, collections were taken between February 24 and April 16 by three crews working throughout the valley. This report provides a summary of the benthic macroinvertebrate data collected in 1993. Summary tables are presented by reservoir, by zone, and a 4 year zone summary. The evaluation and by reservoir comparison of the data are presented along with similar treatments of physical, chemical, and other biological components, in Summary Report on the overall health (integrity) of TVA reservoirs[4].

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[1] Jenkinson, J.J. 1991. Reservoir Vital Signs Monitoring - 1990 Benthic Macroinvertebrate Community Results. TVA, Aquatic Biology Department, TVA/WR/AB--91/6.

[2] Masters, A.M. 1992. Reservoir Vital Signs Monitoring - 1991 Benthic Macroinvertebrate Community Results. TVA, Water Resources, TVA/WR,--92/3.

[3] Masters, A.M. 1993. Reservoir Monitoring - 1992 Benthic Macroinvertebrate Community Results. TVA, Water Management, June 1993.

[4] Dycus, D.L. 1993. Tennessee Valley Reservoir and Stream Quality - 1993 Summary of Vital Signs and Use Suitability Monitoring. TVA, Water Management, May 1994.

METHODS

Reservoirs were identified as having three typical zones: forebays, areas of maximum impoundment effect; transition zones, areas with a mixture of impoundment and river-like habitats; and inflows, impounded areas with the most river-like habitat conditions[5]. For the purpose of tributary reservoirs, forebays which were consistently sampled, were called lower reservoir zones and upper reservoirs were the areas indicated as above the area of maximum impoundment effect. Each of these zones was sampled on most reservoirs. An additional sampling zone was established on reservoirs with two major river inflows and the inflow zone was dropped on tributary reservoirs which already had fixed station monitoring programs in place.

In addition, four embayments were included in 1993. A total of 70 sites in 30 reservoirs and the Kentucky Dam tailwater were sampled in spring 1993 (Table 1). All of the sites sampled in 1992 were revisited with the following exceptions: Wheeler Reservoir TRM 294.1 was moved to TRM 295.9, Tellico Reservoir LTRM 21 was moved to LTRM 15, Fort Loudoun Reservoir forebay TR 605.5 was kept while the TRM 603.2 was dropped, and the Cheroke Reservoir transition HRM 76 was dropped. Sixteen additional tributary reservoirs were added in 1993.

At each sample location, a line-of-sight transect was established across the reservoir. Ten evenly spaced samples

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5 Thornton, K.W., B.L. Kimmel and F.E. Payne, Editors. 1990. Reservoir Limnology: Ecological Perspectives. John Wiley & Sons, Inc. New York.

collected along the length of each transect, typically excluding a 50-foot zone out from each bank. Most samples were taken using a Ponar dredge, however, a Peterson dredge was used where rocky substrates predominated.

A single dredge sample was collected at each interval along the transect. Locations of these sample sites were estimated as a percentage of the reservoir width from the left descending bank. Each dredge sample used was required to include a substantial quantity of bottom material and the dredge jaws must have closed completely. Dredge hauls which failed to meet these requirements were discarded. Additional drops were made until an acceptable sample was collected or it became clear that sampling was not possible at that interval location.

River water was used to wash each sample from the dredge onto a 533 um mesh sorting screen. Large substrate materials were hand scrubbed and visually inspected for invertebrates before being discarded. Water was then used to concentrate the remaining material in the sample to one edge of the screen and the sample was transferred to a labeled jar. Each sample was fixed in the field with 10 percent buffered formalin solution. Large freshwater mussels or large quantities of Asiatic clams (Corbicula) were identified, counted, and returned to the river rather than being preserved with the rest of the sample. Pictures of mussels were taken for later verification of the field identifications. Returned specimens were noted on labels which were placed in the sample jar and in field notes. Field notes also included the river mile location, percent distance

from left (descending) shoreline, water depth, gear type, and a qualitative characterization of the substrate composition (i.e. sand, silt, gravel) encountered in each sample.

Preserved samples were transported to the laboratory for sorting and identification. Organisms were separated from the remaining substrate material using lighted magnifiers and dissecting microscopes. Each dredge sample was processed separately. Specimens were sorted, counted, and identified to the lowest practical taxon (typically genus or species) by individuals familiar with the Tennessee River drainage fauna. Appropriate reference works and keys were consulted as necessary to complete these identifications.

Identification and count data from each sample were entered into TVA mainframe computer files for summarization. The planktonic species Chaoborus sp. was excluded from all evaluations so that analyses represented resident benthic life at the sampling locations.

Table 1. Locations of basic reservoir monitoring stations and embayments for Vital Signs activities during 1993

Reservoir	Forebay	Transition	Inflow
Kentucky Tailwater			TRM 15.0
Kentucky	TRM 23.0	TRM 85.0	TRM 200.0
Pickwick	TRM 207.3	TRM 230.0	TRM 253.2
Wilson	TRM 260.8	(NONE)	TRM 273.0
Wheeler	TRM 277.0	TRM 295.9	TRM 347.0
Guntersville	TRM 350.0	TRM 375.2	TRM 420.0
Nickajack	TRM 425.5	(NONE)	TRM 469.0
Chickamauga	TRM 472.3	TRM 490.5	TRM 518.0
Watts Bar	TRM 531.0	TRM 560.8	TRM 600.0
			CRM 19.0
Fort Loudoun	TRM 605.5	TRM 624.6	TRM 652.0
Tellico	LTRM 1.0	LTRM 15.0	(NONE)
Melton Hill	CRM 24.0	CRM 45.0	CRM 58.8

Reservoir	Embayment	
Kentucky	Big Sandy River	7.4
Pickwick	Bear Creek	8.4
Wheeler	Elk River	6.0
Chickamauga	Hiwassee River	8.5

River Abbreviations: C - Clinch, FB - French Broad, H - Holston, L - Little Tennessee, P - Powell,

(Sampling locations identified by river miles. If no abbreviation is specified, location is on the mainstem Tennessee River)

Table 9. continued

			Tennessee River		Hiwassee River
	Taxonomic Identification		518.0	518.0Q	8.5
		Nanocladius sp.	1.80		5.00
		Orthocladius sp.			3.33
		Parachironomus sp.	1.80		
		Parakiefferiella bathophila	0.90		
		Parametriocnemus lundbecki			1.67
		Paratendipes sp.		0.90	5.00
		Phaenopsectra sp.			60.00
		Polypedilum sp.		0.90	41.67
		Procladius sp.			21.67
Diptera	Chironomidae	*Rheocricotopus sp.*			1.67
		Rheotanytarsus sp.		1.80	30.00
		Tanytarsus sp.		1.80	31.67
		Tribelos sp.			11.67
		Tvetenia bavarica sp. gp.			1.67
		Xenochironomus xenolabis	1.80	0.90	
		Zalutschia zalutschicola			3.33
	Empididae	*Chelifera sp.*			1.67
Coleoptera					
	Elmidae	*Dubiraphia sp.*			6.67
		Promoresia elegans			
Hydrachnellae					
	Hydrachnidae	*Hydrachna sp.*			3.33
Mesogastropoda	Hydrobiidae				
	Pleuroceridae	*Pleurocera sp.*	0.90		
	Viviparidae	*Campeloma sp.*			1.67
Veneroida	Corbiculidae	*Corbicula fluminea*	111.80	197.20	41.67
	Sphaeriidae				
		Eupera cubensis			
		Musculium transversum	10.00	8.10	401.67
		Pisidium sp.			60.00
		Sum	845.40	1779.00	2311.67
		Number of species	21	27	49
		Number of ept taxa	2	2	7
		Sum of area	1.10	1.10	0.60

Table 9. Results of spring 1993 benthic sampling from Chickamauga Reservoir. Values for each taxon have been converted to number per meter of substrate examined.

Taxonomic Identification			Tennessee River			
			472.3	472.3Q	490.5	490.5Q
Nematoda						
Hydroida	Hydridae	*Hydra americana*				
Tricladida	Planariidae	*Dugesia tigrina*				
Haplotaxida	Naididae	*Chaetogaster sp.*				
		Dero sp.				
		Nais sp.				
	Tubificidae		141.67	143.30	160.00	165.00
		Branchiura sowerbyi		8.30	1.60	
		Limnodrilus sp.				
		Limnodrilus hoffmeisteri				
Lumbriculida	Lumbriculidae		3.33			
Hirudinea						
Rhynchobdellida	Glossiphoniidae	*Helobdella triserialis*				
Pharyngobdellida	Erpobdellidae					
		Mooreobdella sp.				
Isopoda	Asellidae	*Caecidotea sp.*				
Amphipoda			1.67			
	Crangonyctidae	*Crangonyx sp.*				
	Gammaridae	*Gammarus sp.*				
		Gammarus fasciatus			8.30	1.67
Odonata	Gomphidae					
Ephemeroptera	Caenidae	*Caenis sp.*				
	Ephemeridae	*Hexagenia limbata*	173.33	145.00	236.60	263.33
Trichoptera						
	Brachycentridae	*Brachycentrus sp.*				
	Hydropsychidae	*Cheumatopsyche sp.*			1.60	
	Hydroptilidae	*Hydroptila sp.*				
	Leptoceridae	*Nectopsyche candida*				
		Oecetis sp.				
	Polycentropodidae	*Cyrnellus fraternus*		1.60		
Megaloptera	Sialidae	*Sialis sp.*				5.00
Diptera					1.60	
	Ceratopogonidae	*Bezzia sp.*			1.60	
	Chironomidae				3.30	
		Ablabesmyia annulata	33.33	33.30	36.60	38.33
		Ablabesmyia sp.	5.00			
		Axarus sp.	3.33			
		Chironomus sp.	1.67	3.30	1.60	3.33
		Cladopelma sp.				
		Coelotanypus sp.	248.33		23.30	
		Coelotanypus tricolor		253.30	125.00	106.67
		Cricotopus sp.				
		Cryptochironomus sp.	11.67	11.60	18.30	15.00
		Dicrotendipes sp.			1.60	
		Epoicocladius sp.	1.67		8.30	5.00
		Eukiefferiella devonica	8.33			
		Glyptotendipes sp.				

Table 9. continued

		Taxonomic Identification	Tennessee River 472.3	472.3Q	490.5	490.5Q
		Nanocladius sp.				
		Orthocladius sp.	15.00		1.60	
		Parachironomus sp.				
		Parakiefferiella bathophila	1.67			
		Parametriocnemus lundbecki				
		Paratendipes sp.				
		Phaenopsectra sp.				
		Polypedilum sp.				
		Procladius sp.	25.00	38.30	48.30	60.00
Diptera	Chironomidae	*Rheocricotopus sp.*				
		Rheotanytarsus sp.				
		Tanytarsus sp.				
		Tribelos sp.				
		Tvetenia bavarica sp. gp.	1.67			
		Xenochironomus xenolabis				
		Zalutschia zalutschicola				
	Empididae	*Chelifera sp.*				
Coleoptera					1.60	1.67
	Elmidae	*Dubiraphia sp.*				
		Promoresia elegans	3.33			
Hydrachnellae				1.60	3.30	25.00
	Hydrachnidae	*Hydrachna sp.*				
Mesogastropoda	Hydrobiidae				1.60	1.67
	Pleuroceridae	*Pleurocera sp.*				
	Viviparidae	*Campeloma sp.*				
Veneroida	Corbiculidae	*Corbicula fluminea*	160.00	121.60	133.30	106.67
	Sphaeriidae				18.30	
		Eupera cubensis		1.60		
		Musculium transversum	6.67	36.60	58.30	70.00
		Pisidium sp.				15.00
		Sum	846.67	800.00	896.60	883.33
		Number of species	19	13	23	16
		Number of ept taxa	1	2	2	1
		Sum of area	0.60	0.60	0.60	0.60

Table 9. continued

Taxonomic Identification			Tennessee River 518.0	Tennessee River 518.0Q	Hiwassee River 8.5
Nematoda					48.33
Hydroida	Hydridae	*Hydra americana*	54.50	432.70	
Tricladida	Planariidae	*Dugesia tigrina*	38.10	40.90	3.33
Haplotaxida	Naididae	*Chaetogaster sp.*	115.40	663.60	
		Dero sp.		0.90	
		Nais sp.		0.90	
	Tubificidae		75.40	66.30	830.00
		Branchiura sowerbyi			53.33
		Limnodrilus sp.		191.80	170.00
		Limnodrilus hoffmeisteri	44.50		
Lumbriculida	Lumbriculidae				10.00
Hirudinea				0.90	1.67
Rhynchobdellida	Glossiphoniidae	*Helobdella triserialis*	0.90		
Pharyngobdellida	Erpobdellidae		5.40	0.90	3.33
		Mooreobdella sp.		0.90	
Isopoda	Asellidae	*Caecidotea sp.*			1.67
Amphipoda				10.90	
	Crangonyctidae	*Crangonyx sp.*		2.70	3.33
	Gammaridae	*Gammarus sp.*	32.70	120.90	
		Gammarus fasciatus	302.70		
Odonata	Gomphidae				3.33
Ephemeroptera	Caenidae	*Caenis sp.*			1.67
	Ephemeridae	*Hexagenia limbata*			200.00
Trichoptera			0.90		
	Brachycentridae	*Brachycentrus sp.*			1.67
	Hydropsychidae	*Cheumatopsyche sp.*			1.67
	Hydroptilidae	*Hydroptila sp.*		0.90	
	Leptoceridae	*Nectopsyche candida*			1.67
		Oecetis sp.			1.67
	Polycentropodidae	*Cyrnellus fraternus*	17.20	3.60	1.67
Megaloptera	Sialidae	*Sialis sp.*			
Diptera				0.90	
	Ceratopogonidae	*Bezzia sp.*			23.33
	Chironomidae				3.33
		Ablabesmyia annulata			16.67
		Ablabesmyia sp.			10.00
		Axarus sp.		6.30	
		Chironomus sp.		0.90	88.33
		Cladopelma sp.			3.33
		Coelotanypus sp.			3.33
		Coelotanypus tricolor	0.90		6.67
		Cricotopus sp.			1.67
		Cryptochironomus sp.			75.00
		Dicrotendipes sp.	12.70	9.00	6.67
		Epoicocladius sp.			
		Eukiefferiella devonica			
		Glyptotendipes sp.	14.50	10.90	

Table 37. continued.

Location	Taxa	Long-lived	EPT	% Chiron.	% Tubif.	Dominance	Total	Rating
Chickamauga Reservoir								
TRM 472.3	5	5	3	3	5	5	26	Excellent
TRM 472.3Q	5	5	5	3	5	5	28	Excellent
TRM 490.5	5	3	5	3	5	5	26	Excellent
TRM 490.5Q	5	3	5	3	5	5	26	Excellent
HiRM 8.5	5	5	5	5	3	5	28	Excellent
TRM 518	3	1	3	5	5	3	20	Fair
TRM 518Q	3	1	1	5	5	1	16	Fair
Watts Bar Reservoir								
TRM 531	5	5	3	1	5	5	24	Good
TRM 560.8	3	1	5	3	5	5	20	Fair
CRM 19	1	1	1	3	5	1	12	Poor
CRM 19Q	3	3	1	3	3	3	16	Fair
TRM 600	1	1	1	3	5	1	12	Poor
Fort Loudoun Reservoir								
TRM 605.5	5	3	1	1	3	5	18	Fair
TRM 624.6	5	1	3	1	3	5	18	Fair
TRM 652	1	1	1	3	3	1	10	Very Poor
Tellico Reservoir								
LTRM 1	1	3	1	5	1	3	14	Poor
LTRM 1Q	1	1	1	5	1	1	10	Very Poor
LTRM 15	3	1	1	1	3	5	14	Poor
Melton Hill Reservoir								
CRM 24	3	1	1	1	5	3	14	Poor
CRM 45	3	1	1	1	3	3	12	Poor
CRM 58.8	3	1	1	1	1	5	12	Poor
Norris Reservoir								
CRM 80.4	3	5	1	5	1	3	18	Fair
CRM 125	3	1	3	3	3	1	14	Poor
PRM 30	5	1	3	3	3	5	20	Fair
Cherokee Reservoir								
HoRM 53	5	1	3	1	3	3	16	Fair
HoRM 91	5	5	5	3	5	5	28	Excellent

TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management

RESERVOIR MONITORING - 1992

BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS

Prepared by

Anita E. Masters

Chattanooga, Tennessee

June 1993

INTRODUCTION

Benthic macroinvertebrates within Tennessee River system reservoirs are being collected in a Reservoir Monitoring program as one part of the assessment of the ecological health of aquatic resources. These reservoirs contain a wide variety of benthic habitats, but surprisingly little is known about the communities which inhabit these areas. During the first two years of the Reservoir Monitoring program (1990 and 1991), baseline data were collected and analyzed to identify similarities and differences among the benthic macroinvertebrate communities[1] [2]. In 1992, collections were taken between March 10 and May 5 by two crews working throughout the valley. This report provides just a summary of the benthic macroinvertebrate data collected in 1992. Summary tables are presented by reservoir, by zone, and a 3-year zone summary. The evaluation and by reservoir comparison of the data are presented along with similar treatments of physical, chemical, and other biological components, in Summary Report on the overall health (integrity) of TVA reservoirs[3].

METHODS

Reservoirs were identified as having three typical zones: forebays, areas of maximum impoundment effect; transition zones,

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[1] Jenkinson, J.J. 1991. Reservoir Vital Signs Monitoring - 1990 Benthic Macroinvertebrate Community Results. TVA, Aquatic Biology Department, TVA/WR/AB--91/6.

[2] Masters, A.M. 1992. Reservoir Vital Signs Monitoring - 1991 Benthic Macroinvertebrate Community Results. TVA, Water Resources, TVA/WR,--92/3.

[3] Meinert, D.L. et al. 1992. Reservoir Vital Signs Monitoring - 1992 Summary of Vital Signs and Use Impairment Monitoring on Tennessee Valley Reservoirs. TVA, Water Resources, TVA/WR--93/.

areas with a mixture of impoundment and river-like habitats; and inflows, impounded areas with the most river-like habitat conditions[4]. Each of these zones was sampled on most reservoirs. An additional sampling zone was established on reservoirs with two major river inflows and the inflow zone was dropped on tributary reservoirs which already had fixed station monitoring programs in place. In all, a total of 41 sites on fourteen reservoirs and the Kentucky Dam tailwater were sampled in 1992 (Table 1). All of the sites which had been sampled in 1991 were revisited with five exceptions. Three transition locations were moved (Kentucky Reservoir TRM 112 was moved to TRM 85, Wheeler Reservoir TRM 307.5 was moved to TRM 294.1, and Guntersville Reservoir TRM 375.2 was moved to TRM 396.8) to better represent the transition zones in these reservoirs. The transition zone on Nickajack Reservoir (TRM 433) was dropped because the reservoir is too short to show an actual zone of transition. An additional site was added at the Fort Loudoun forebay to determine if it would better represent that part of the reservoir.

At each sample location, a line-of-sight transect was established across the reservoir. Ten evenly spaced samples were collected along the length of each transect, typically excluding a 50-foot zone out from each bank. Most samples were taken using a Ponar dredge, however, a Peterson dredge was used where rocky substrates predominated.

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[4] Thornton, K.W., B.L. Kimmel and F.E. Payne, Editors. 1990. Reservoir Limnology: Ecological Perspectives. John Wiley & Sons, Inc. New York.

A single dredge sample was collected at each interval along the transect. Locations of these sample sites were estimated as a percentage of the reservoir width from the left descending bank. Each dredge sample used was required to include a substantial quantity of bottom material and the dredge jaws must have closed completely. Dredge hauls which failed to meet these requirements were discarded. Additional drops were made until an acceptable sample was collected or it became clear that sampling was not possible at that interval location.

River water was used to wash each sample from the dredge onto a 533 um mesh sorting screen. Large substrate materials were hand scrubbed and visually inspected for invertebrates before being discarded. Water was then used to concentrate the remaining material in the sample to one edge of the screen and the sample was transferred to a labeled jar. Each sample was fixed in the field with 10 percent buffered formalin solution. Large freshwater mussels or large quantities of Asiatic clams (Corbicula) were identified, counted, and returned to the river rather than being preserved with the rest of the sample. Pictures of mussels were taken for later verification of the field identifications. Returned specimens were noted on labels which were placed in the sample jar and in field notes. Field notes also included the river mile location, percent distance from left (descending) shoreline, water depth, gear type, and a qualitative characterization of the substrate materials (i.e. sand, silt, gravel) encountered in each sample.

Preserved samples were transported to the laboratory for sorting and identification. Organisms were separated from the

remaining substrate material using lighted magnifiers and dissecting microscopes. Each dredge sample was processed separately. Specimens were sorted, counted, and identified to the lowest practical taxon (typically genus or species) by individuals familiar with the Tennessee River drainage fauna. Appropriate reference works and keys were consulted as necessary to complete these identifications.

Identification and count data from each sample were entered into TVA mainframe computer files for summarization. The planktonic species Chaoborus sp. was excluded from all evaluations so that analyses represented resident benthic life at the sampling locations.

Table 1. Locations of reservoir monitoring stations for Vital Signs benthic sampling, spring 1992

Reservoir	Forebay	Transition	Inflow
Kentucky Tailwater			TRM 15.0
Kentucky	TRM 23.0	TRM 85.0	TRM 200.0
Pickwick	TRM 207.3	TRM 230.0	TRM 253.2
Wilson	TRM 260.8	(NONE)	TRM 273.0
Wheeler	TRM 277.0	TRM 294.1	TRM 347.0
Guntersville	TRM 350.0	TRM 375.2	TRM 420.0
Nickajack	TRM 425.5	(NONE)	TRM 469.0
Chickamauga	TRM 472.3	TRM 490.5	TRM 518.0
Watts Bar	TRM 531.0	TRM 560.8	TRM 600.0
			CRM 19.0
Fort Loudoun	TRM 603.2	TRM 624.6	TRM 652.0
	TRM 605.5		
Tellico	LTRM 1.0	LTRM 21.0	(NONE)
Cherokee	HRM 53.0	HRM 76.0	HRM 91.0
Douglas	FBRM 33.0	FBRM 60.7	(NONE)
Melton Hill	CRM 24.0	CRM 45.0	CRM 66.0
Norris	CRM 80.4	CRM 125.0	(NONE)
		PRM 30.0	

River Abbreviations: C - Clinch, FB - French Broad, H - Holston, L - Little Tennessee, P - Powell,

(Sampling locations identified by river miles. If no abbreviation is specified, location is on the mainstem Tennessee River)

Table 8. Results of spring 1992 benthic sampling from Chickamauga Reservoir. Values for each taxon have been converted to number per meter of substrate examined.

Taxonomic Identification			Tennessee River Miles 472.3	490.5	518
Tricladida	Planariidae	*Dugesia sp.*	.	.	1.82
Haplotaxida	Tubificidae		96.67	101.67	37.27
		Branchiura sowerbyi	.	5.00	.
		Limnodrilus hoffmeisteri	1.67	.	0.91
Pharyngobdellida	Erpobdellidae		.	.	10.91
Amphipoda	Gammaridae	*Gammarus fasciatus*	.	.	35.45
		Gammarus sp.	.	.	77.27
Ephemeroptera	Ephemeridae	*Hexagenia limbata*	325.00	423.33	.
Trichoptera	Polycentropodidae	*Cyrnellus fraternus*	1.67	.	2.73
Diptera	Chironomidae	*Ablabesmyia annulata*	35.00	33.33	.
		Ablabesmyia sp.	3.33	5.00	.
		Axarus sp.	6.67	.	.
		Chironomus sp.	.	5.00	.
		Coelotanypus sp.	210.00	176.67	0.91
		Cryptochironomus sp.	8.33	1.67	0.91
		Dicrotendipes sp.	3.33	.	2.73
		Epoicocladius sp.	.	1.67	.
		Parachironomus sp.	.	.	5.45
		Polypedilum sp.	.	1.67	.
		Procladius sp.	33.33	71.67	.
Veneroida	Corbiculidae	*Corbicula fluminea*	150.00	235.00	756.36
	Sphaeriidae	*Musculium transversum*	25.00	35.00	.
			.	215.00	.
		Area sampled m^2	0.60	0.60	1.10
		Total number of organisms/m^2	900.00	1311.68	932.72
		Number of species	13	14	12
		Number of EPT taxa	2	1	1

Table 19. Comparison of benthic communities at Tennessee River reservoir monitoring locations based on laboratory evaluations of spring 1990, 1991, and 1992 data

LOCATION	1990		1991		1992	
	taxa	#/m2	taxa	#/m2	taxa	#/m2
FOREBAYS						
Ky 23	10	545	11	782	16	790
Pi 207.3	11	454	13	552	24	577
Wi 260.8	9	396	11	813	12	682
We 277	10	536	11	437	14	440
Gu 350	16	663	12	1033	15	748
Ni 425.5	13	325	17	780	18	785
Ck 472.3	12	614	12	797	13	900
Wb 531.0	8	498	11	455	19	693
Fl 603.2	7	560	8	611	11	125
Fl 605.5	-	-	-	-	9	121
Te L 1.0	-	-	6	489	15	191
Ch H 53	4	529	4	270	12	551
Do FB 33	5	789	4	260	7	282
Mh C 24	-	-	11	348	21	689
No C 80.4	6	406	11	723	23	680
TRANSITION ZONES						
Ky 112	7	349	5	106	29	1247
Pi 230	7	422	16	390	26	591
Wh 307.5	12	174	9	35	23	740
Gu 396.8	9	132	7	37	21	1182
Ck 490.5	11	956	10	1283	14	1312
Wb 560.8	11	316	12	750	16	868
Fl 624.6	7	892	13	648	13	478
Te L 21.0	-	-	5	38	15	297
Ch H 76.0	5	109	7	493	9	214
Do FB 60.7	2	75	5	89	7	11
Mh C 45.0	-	-	12	500	22	277
No C 125	7	351	8	550	14	701
No P 30	10	596	9	1012	23	1102
INFLOWS						
Ky 15	21	429	25	716	28	675
Ky 200	22	328	15	56	33	583
Pi 253.2	12	232	11	39	17	760
Wi 273	17	680	18	1030	31	1028
We 347	15	407	20	345	26	638
Gu 420	10	171	14	662	41	1719
Ni 469	10	652	19	296	26	904
Ck 518	6	191	8	492	12	933
Wb 600	3	42	13	513	23	547
Wb C 19	11	58	21	545	20	335
Fl 652	3	184	6	513	17	2433
Ch H 91	6	134	11	418	16	265
Mh C 58.8	-	-	12	27	28	824

River Abbreviations: L - Little Tennessee, H - Holston, FB - French Broad, C - Clinch
(Sampling locations identified by river miles. If no abbreviation is specified, location is on the mainstem Tennessee River)

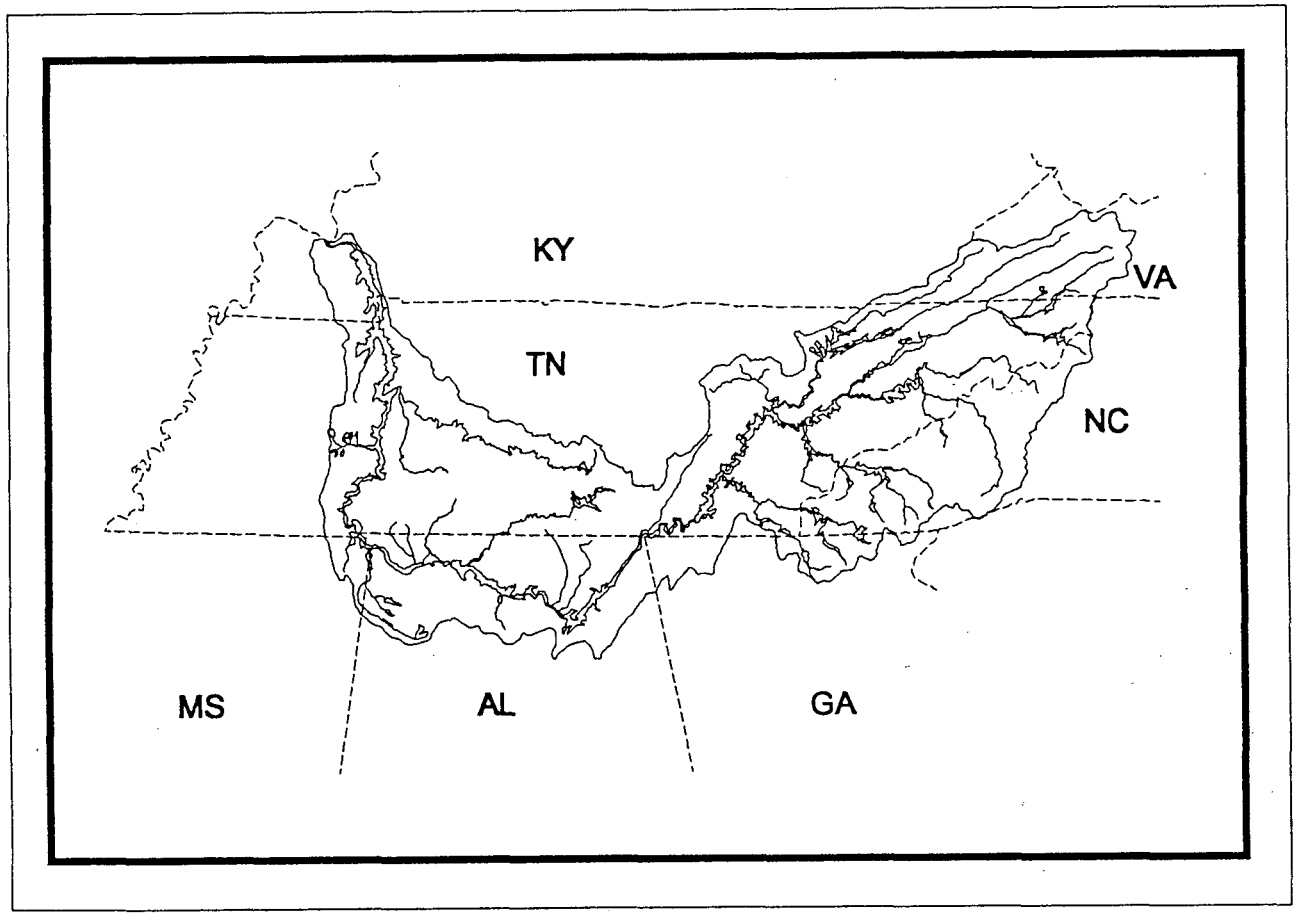
Tennessee Valley Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR-92/3
August 1992

RESERVOIR VITAL SIGNS MONITORING - 1991

BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS



WATER RESOURCES &
ECOLOGICAL MONITORING

WATER RESOURCES MANAGEMENT

INTRODUCTION

Benthic macroinvertebrates within the Tennessee Valley system are being monitored as part of the Reservoir Monitoring program to assess the ecological health of aquatic resources. The Tennessee Valley system has a variety of habitats, but only a limited data base for benthic reservoir species. During the first year of the Reservoir Monitoring program (1990), baseline data on benthic life was collected. Jenkinson (1991) summarized the 1990 results for the benthic macroinvertebrate communities. This report provides the 1991 information on the benthic macroinvertebrate communities at monitoring stations within Tennessee Valley Authority reservoirs. The benthic information is combined in a summary report with similar data on other physical, chemical, and biological components, to describe the overall health (integrity) of these reservoirs in a summary report (Dycus and Meinert, 1992).

METHODS

Reservoirs were identified as having three typical zones: forebays, areas of maximum impoundment effect; transition zones, areas with a mixture of impoundment and river-like habitats; and inflows, impounded areas with the most river-like habitat conditions (Thornton et al. 1990). Each zone was sampled on most reservoirs. This scheme was modified in reservoirs with two major rivers, and only the forebay and transition zones were sampled in the tributary reservoirs which already had fixed station monitoring programs in place. A total of 41 sites in

fourteen reservoirs and the Kentucky Dam tailwater were sampled in spring 1991 (Table 1). All of the sites sampled in 1990 were revisited. In addition, Melton Hill and Tellico reservoirs were included in the 1991 collections.

At each sample location, a line-of-sight transect was established across the reservoir. Ten evenly spaced samples were collected along the length of each transect. Typically a 50-foot zone out from each bank was not sampled. Most samples were taken using a Ponar dredge, however, a Peterson dredge was used where rocky substrates predominated.

A single dredge sample was collected at each interval along the transect. Locations of these sample sites were estimated as a percentage from the left descending bank. Each dredge sample used was required to include a substantial quantity of bottom material and the dredge jaws must have closed completely. Dredge hauls which failed to meet these requirements were discarded. Additional drops were made until an acceptable sample was collected or it became clear that sampling was not possible at that interval location.

Each sample was washed from the dredge with river water onto a 533 um mesh sorting screen. Large substrate materials were hand scrubbed and visually inspected for remaining invertebrates before being discarded. Water was then used to concentrate the remaining material in the sample to one edge of the screen before it was transferred to a labeled jar. Each sample was fixed in the field with 10 percent buffered formalin solution.

On occasion, samples contained extensive amounts of fine gravel or detritus from which the living animals could not be easily separated. When this occurred, only part of the sample was retained as a subsample. At other times, large freshwater mussels and large quantities of Asiatic clams (Corbicula) were identified, counted, and returned to the river rather than being preserved with the rest of the sample. Descriptions of these events were recorded in field notes and on labels which were placed in the sample jar.

Field notes included the river mile location, percent distance from left (descending) shoreline, water depth, gear type, and a qualitative characterization of the substrate composition (i.e. sand, silt, gravel). Field notes also included counts required to determine four rapid assessment metrics. These metrics are presented in Table 2. Their formulation and evaluation are presented as part of the Results and Discussion.

Preserved samples were transported to the laboratory for sorting and identification. Organisms were separated from the remaining substrate material using lighted magnifiers and dissecting microscopes. Unlike 1990, each dredge sample was processed separately. Specimens were sorted, counted, and identified to the lowest practical taxon (typically genus or species) by a taxonomist familiar with the Tennessee River drainage fauna. Appropriate reference works and keys were consulted as necessary to complete these identifications.

Identification and count data from each sample were entered into TVA mainframe computer files for summarization and analysis.

For statistical analysis, the number of each species found per square meter was transformed using $\text{Log}_{10}(x + 1)$. Principal component analyses of the transformed abundance data using covariance matrices and average linkage cluster analyses were performed for the forebays, transition zones, and inflows, and for all locations combined. Rare taxa were not included in the analyses.

For all zone summary tables, taxa are counted only once per location even though some taxa might have been represented at more than one taxonomic level. For example, Hexagenia limbata and Hexagenia sp. identified at the same location equals one taxon and Chironomidae, Chironomus sp., and Procladius sp. equal a two taxon count. Taxa identified as Chironomidae and Hexagenia sp. were usually not identified further due to the small instar developmental stage. For the summary tables it was assumed the species identified at a higher level were already represented in the lower level identification. The planktonic species Chaoborus sp. was excluded from all evaluations so that analyses represented resident benthic life at the sampling locations.

RESULTS AND DISCUSSION

Sampling was conducted at the 41 locations between March 19, and April 12, 1991 by two crews. Crews worked together at the same locations on Chickamauga Reservoir to agree on procedural details before separating to work opposite ends of the Valley. A total of 395 dredge samples were collected, with a combined area of 28.68/m^2 of reservoir substrate. These samples yielded 9,209

Table 1. Vital Signs benthic sampling locations, spring 1991

Reservoir	Abbrev.	Sampling Locations		
		Forebay	Transition	Inflow
Kentucky Tailwater	DKy			15.0
Kentucky	Ky	23.0	112.0	200.0
Pickwick	Pi	207.3	230.0	253.2
Wilson	Wi	260.8	(none)	273.0
Wheeler	We	277.0	307.5	347.0
Guntersville	Gu	350.0	396.8	420.0
Nickajack	Ni	425.5	433.0	469.0
Chickamauga	Ck	472.3	490.5	518.0
Watts Bar	Wb	531.0	560.8	600.0
				C 19.0
Fort Loudoun	Fl	603.2	624.6	652.0
Tellico	Te	L 1.0	L 21	(none)
Cherokee	Ch	H 53.0	H 76.0	H 91.0
Douglas	Do	FB 33.0	FB 60.7	(none)
Melton Hill	Mh	C 24.0	C 45.0	C 58.8
Norris	No	C 80.4	C 125.0	(none)
			P 30.0	(none)

River Abbreviations: C - Clinch, FB - French Broad, H - Holston, L - Little Tennessee, P - Powell,

(Sampling locations identified by river miles. If no abbreviation is specified, location is on the mainstem Tennessee River)

Table 2. Rapid bioassessment metrics applied to reservoir benthic samples collected during spring 1991.

Metric	Description	Field Procedure
Total Abundance	A metric describing the relative abundance of macroinvertebrate life at the site.	Count the number of live organisms observed on the screen after the sample has been washed.
Species Richness	A metric indicating the diversity of benthic species present.	Count the number of obviously different taxa present in the sample or at the location. If in doubt when applying this metric, substantially different sizes of otherwise similar organisms should be assumed to be separate species.
Long-lived Species	A metric suggesting the long-term suitability of the benthic habitat.	Count the taxa represented by live individuals more than one year old. This metric requires the evaluator to know life history and growth rate information for species likely to be found in benthic samples.
White to Red "Chironomid" Ratio	A metric comparing the percent of individual chironomids with or without red pigmented blood.	Count the individual worm-like insect larvae with red pigment and without red pigment. Count light red or pink being red.

Table 9. Results of spring 1991 benthic sampling from Chickamauga Reservoir. Values for each taxon have been converted to number per square meter of the substrate examined.

Taxonomic Identification			Tennessee River Miles		
			472.3	490.5	518
AMPHIPODA	GAMMARIDAE	Gammarus sp.	3.33	.	65.71
COLEOPTERA	ELMIDAE	Dubiraphia sp.	.	1.67	0.95
DIPTERA	CHIRONOMIDAE	Ablabesmyia philosphagnos	28.33	.	.
		Ablabesmyia sp.	.	23.33	.
		Chironomus sp.	55.00	5.00	.
		Coelotanypus sp.	318.33	176.67	.
		Cricotopus tremulus gp.	.	1.67	.
		Cryptochironomus sp.	1.67	.	.
		Glyptotendipes sp.	.	.	0.95
		Procladius sp.	60.00	56.67	.
EPHEMEROPTERA	CAENIDAE	Caenis sp.	.	1.67	0.95
	EPHEMERIDAE	Hexagenia limbata	161.67	278.33	.
HAPLOTAXIDA	TUBIFICIDAE		53.33	106.67	10.48
TRICHOPTERA	POLYCENTROPODIDAE	Cyrnellus fraternus	.	.	13.33
TRICLADIDA	PLANARIIDAE	Dugesia sp.	.	.	4.76
VENEROIDA	CORBICULIDAE	Corbicula fluminea	93.33	631.67	395.24
	SPHAERIIDAE	Musculium transversum	10.00	.	.
		Sphaerium fabale	3.33	.	.
		Sphaerium sp.	8.33	.	.
		Area sampled m^2	.60	.60	1.05
		Total number of organisms/m^2	796.67	1283.33	492.38
		Total number of Taxa	12	10	8

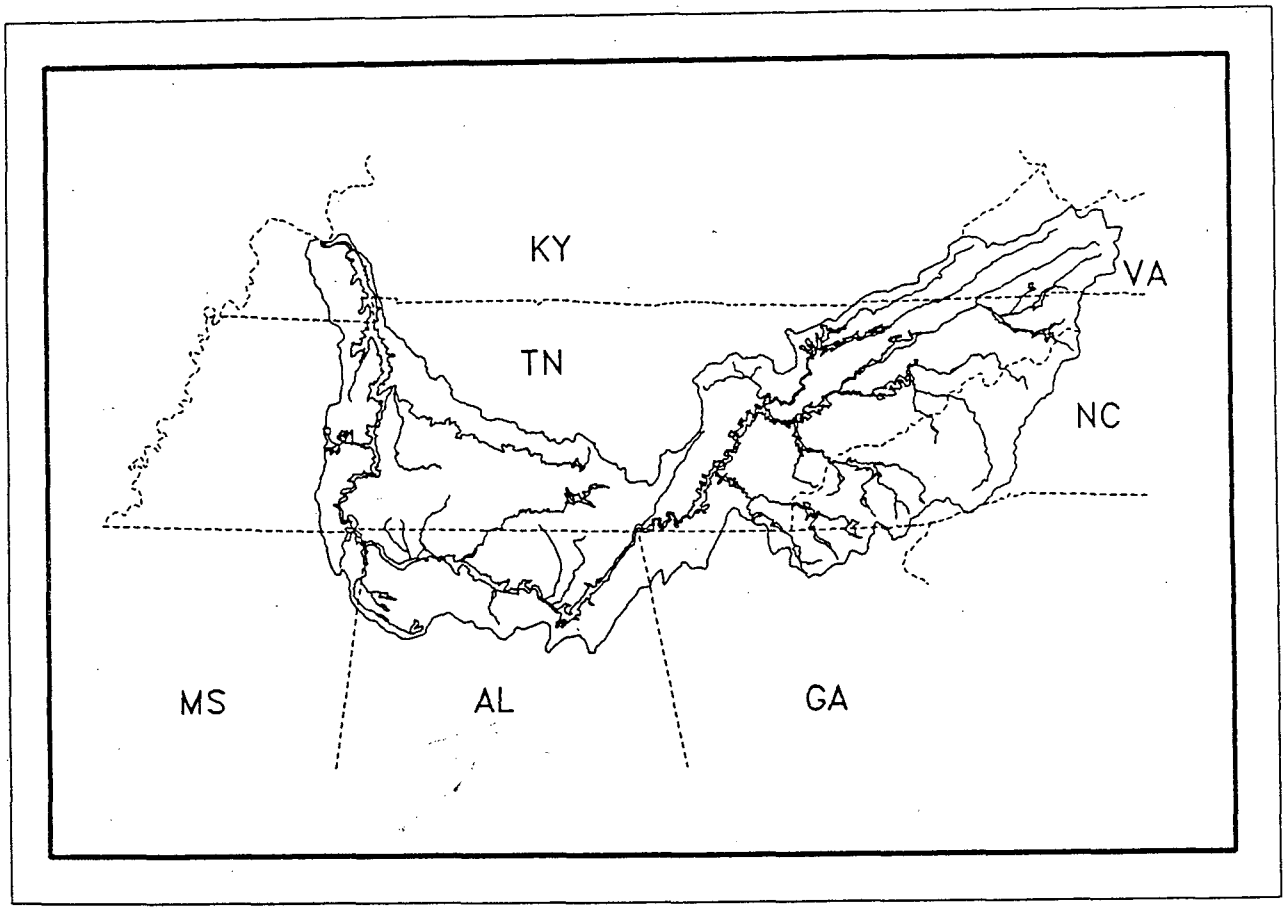
Tennessee Valley Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR/AB--91/6
June 1991

RESERVOIR VITAL SIGNS MONITORING - 1990

BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS



WATER RESOURCES &
ECOLOGICAL MONITORING

WATER RESOURCES MANAGEMENT

METHODS

At each sample location, a line-of-sight transect was established across the width of the reservoir. Ten dredge samples were collected at even intervals along the length of this transect, typically excluding a 50-foot zone out from each bank. Most samples were taken using Ponar dredges; however, a Petersen dredge was used for some samples where rocky substrates predominated. The dredges were operated using gasoline-powered winches.

A single dredge sample was collected at each interval along the transect. That sample, however, was required to include a substantial amount of bottom material and the dredge jaws must have closed completely. Dredge hauls which failed to meet these requirements were discarded and additional drops were made until an acceptable sample was collected or it became clear that sampling was not possible at that location.

Once on board the dredge boat, each sample was washed out of the dredge onto an 800 mm mesh sorting screen using river water propelled by a gasoline-powered pump. Wash water also was used to clean off large substrate materials and wash away fine sediments that were present in the sample. After being cleaned into the screen, the larger non-living components of the sample were discarded. Finally, water was used to associate the remaining material in the sample on one edge of the screen before it was transferred to a labeled bottle. Each sample was fixed in the field with 10 percent buffered formalin solution.

On occasion, some samples contained extensive amounts of fine gravel or detritus from which the living animals could not be easily separated. When this occurred, only part of the sample was retained as a subsample.

At other times, large freshwater mussels and large lots of Asiatic clams were identified, counted, and returned to the river from the dredge boat rather than being preserved with the rest of the sample. Each time one of these atypical events occurred, a detailed label was placed in the sample bottle and the information was included in the field notes.

Field notes typically recorded concerning each sample included the river mile location, percent distance from left (descending) shoreline, water depth, and a brief description of the substrate composition. The field notes also included the scoring of each sample for three rapid assessment metrics. These metrics are presented in table 2. Their formulation and evaluation are presented as part of the Discussion.

The preserved field samples were returned to the laboratory for sorting and identification. Animals were separated from the remaining substrate material under lighted magnifiers and dissecting microscopes. In an attempt to reduce identification costs, all samples from a given river mile location were combined. Specimens in these combined samples were sorted, counted, and identified to the lowest practical taxon (typically genus or species) by an identification specialist familiar with the Tennessee River drainage fauna. Appropriate identification guides were consulted as necessary to complete these identifications.

Identification and count data from each site were entered into TVA mainframe computer files for summarization and analysis. For statistical analysis, the number of each species found per square meter were transformed using $\text{Log}_{10}(x + 1)$. Principal components analyses were performed on the covariance matrices for the forebay, transition, and inflow locations, and for all locations combined.

Table 1. Vital Signs benthic sampling locations, spring 1990

Reservoir	Abbrev.	Sampling Locations		
		Forebay	Transition	Inflow
Kentucky Tailwater	DKy		15.0	
Kentucky	Ky	23.0	112.0	200.0
Pickwick	Pi	207.3	230.0	253.2
Wilson	Wi	260.8	(none)	273.0
Wheeler	We	277.0	307.5	347.0
Guntersville	Gu	350.0	396.8	420.0
Nickajack	Ni	425.7	433.0	469.0
Chickamauga	Ck	472.3	490.5	518.0
Watts Bar	Wb	531.0	560.8	600.0
			C 19.0	
Fort Loudoun	Fl	603.2	624.5	652.0
Cherokee	Ch	H 53.0	H 76.0	H 91.0
Douglas	Do	FB 33.0	FB 60.7	(none)
Norris	No	C 80.0	C 125.0	(none)
		P 30.0	(none)	

River Abbreviations: C - Clinch, FB - French Broad, H - Holston, P - Powell
(If no abbreviation is specified, location is on the mainstem Tennessee River)

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Table 2. Rapid bioassessment metrics applied to reservoir benthic samples collected during spring 1990.

Metric	Description	Field Procedure
Total Abundance	A metric describing the relative abundance of macrobenthic invertebrate life at the site.	Count the number of live animals observed on the screen after the sample has been washed.
Species Richness	A metric indicating the diversity of benthic species present.	Count the number of obviously different taxa present in the sample or at the location. If in doubt when applying this metric, substantially different sizes of otherwise similar organisms should be assumed to be separate species.
Long-lived Species	A metric suggesting the long-term suitability of the benthic habitat.	Count the taxa represented by live individuals more than one year old. This metric requires the evaluator to know life history and growth rate information for species likely to be found in benthic samples.

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Table 9. Results of spring 1990 benthic sampling from Chickamauga Reservoir. Vlaues for each taxon have been converted to number per square meter of substrate examined.

Taxonomic Identification			Tennessee River Miles 472	490	518
HAPLOTAXIDA	Tubificidae	Tubificidae	65.41	150.8	93.87
		Branchiura sowerbyi	12.72	39.97	-
AMPHIPODA	Gammaridae	*Gammarus minus*	10.90	30.89	15.14
ODONATA	Coenagrionidae	*Enallagma sp.*	-	-	6.06
EPHEMEROPTERA	Ephemeridae	*Hexagenia limbata*	83.58	154.43	-
TRICHOPTERA	Psychomyiidae	*Lype diversa*	-	3.63	-
		Cryptotendipes sp.	1.82	-	-
	Chaoboridae	*Chaoborus sp.*	7.27	-	-
	Chironomidae	*Ablabesmyia mallochi*	32.70	41.79	-
		Chironomidae	1.82	-	-
		Chironomus sp.	1.82	10.90	-
		Coelotanypus sp.	187.14	176.23	-
		Cryptochironomus fulvus	5.45	1.82	-
		Nanocladius sp.	-	-	3.03
		Procladius sp.	59.96	38.15	-
		Stenochironomus sp.	1.82	-	-
		Stictochironomus sp.	-	-	6.06
VENEROIDA	Corbiculidae	*Corbicula fluminea*	83.58	170.78	66.62
	Sphaeriidae	*Musculium transversum*	65.41	136.26	-
		Area sampled m^2	.55	.55	.33
		Total number of organisms/m^2	621.40	955.65	190.78
		Total number of Taxa	15	12	6