Guidelines for Chemical Control of Copepod Populations

In

Dracunculiasis Eradication Programs

World Health Organization Collaborating Center
for Research, Training, and Control of Dracunculiasis
at the
Centers for Disease Control
Atlanta, Georgia 30333

These guidelines are intended to help persons involved with dracunculiasis eradication programs make decisions about chemical control of copepod populations in sources of drinking water. To improve the usefulness of these guidelines, please send comments and suggestions to the address below.

WHO Collaborating Center for Research,
Training, and Control of Dracunculiasis
Centers for Disease Control
Division of Parasitic Diseases F22
Atlanta, Georgia 30333

CONTENTS

Page

Introduction....1

Section I. Using Chemicals to Control Copepod Populations....3

Section II. Selecting Drinking Water Sources for Treatment....7

Section III. Interacting with the Community About Application of Temephos....11

Section IV. Applying Temephos and Evaluating Treatment....13

Section V. Summary....24

Appendix 1. Nomograms:
Area (m^2) for Values of Average Length, and Average Width
Volume (m^3) for Values of Area and Average Depth....26

Appendix 2. Nomogram: Volume of Water (m^3) of Cylindrically Shaped Impoundments....28

Appendix 3. Table: Amount of Temephos Required for Specified Volumes of Water....29

Appendix 4. Notes About Measurements....30

Appendix 5. Sample Form: Temephos Application Record....31

Appendix 6. Temephos Technical Information, Manufacturer's Label and Safety Precautions....33

Appendix 7. Notes on Cyclopoid Copepods....36

Selected References....38

INTRODUCTION

Dracunculiasis (guinea worm disease) is a disabling infection caused by the parasite *Dracunculus medinensis*. Infection is acquired by persons who drink water that contains cyclopoid copepods or, more generically, water fleas that have ingested *D. medinensis* larvae. Infected persons remain free of symptoms until about 1 year postinfection when adult female worms in the connective tissue provoke the formation of a painful blister in the skin. The blister rapidly becomes an ulcer through which the worm protrudes to release larvae when stimulated by contact with water. In about 90% of cases the worm emerges from a lower limb. The 70- to 100-cm long worm dies and must be extracted, usually by winding a few centimeters on a stick each day, a very painful process which may last many weeks. Disability from infection lasts for weeks to months, depending on the number of worms and where they emerge.

The annual incidence is estimated at 5 to 10 million cases per year, and approximately 140 million people are at risk. Dracunculiasis occurs in West Africa, extends across Sahelian countries into East Africa (a total of 19 countries). In Asia dracunculiasis is endemic in Pakistan, and western India.

Transmission usually occurs seasonally, during the dry or rainy season (depending on the local ecology), and the impact on the productivity of agricultural workers may be dramatic. Incidence is highest in the 19- to 40-year old age group. Impact on school attendance is also substantial. Infected persons do not develop immunity. There is no known animal reservoir. Neither effective drugs nor vaccine exist.

Dracunculiasis was declared eliminated from southern USSR (Turkestan) in the 1930s, from Iran in the 1970s, and from Tamil Nadu State in India in 1984. During the International Drinking Water Supply and Sanitation Decade (1981-1990) a major initiative to eradicate dracunculiasis has steadily gained momentum. The ultimate goal is global eradication of dracunculiasis. The intermediate goal is the elimination of endemic dracunculiasis from each endemic country. This goal is planned in the World Health Organization's (WHO) Global Medium Term Program for Parasitic Diseases (covering the period 1984 to 1989; PDP/MTP/83.3); it was declared in April 1981 and November 1987 by the Steering Committee of the International Drinking Water Supply and Sanitation Decade; and it was proclaimed in the resolutions "Elimination of Dracunculiasis" (adopted by the World Health Assembly in 1986, WHA39.21), and "Eradication of Dracunculiasis" (adopted by the Regional Committee for Africa in 1988, AFR/RC38/19/WP17).

There is a growing realization that dracunculiasis can be eradicated soon. The methods of control are simple. Affected populations can be educated about the origin of this disease and what they can do to prevent it, and can be provided with new sources of safe drinking water. Existing unsafe sources of drinking water can be safely treated with chemicals to control copepod populations. This manual provides guidelines and considerations for the application of these chemicals.

I. Using Chemicals to Control Copepod Populations

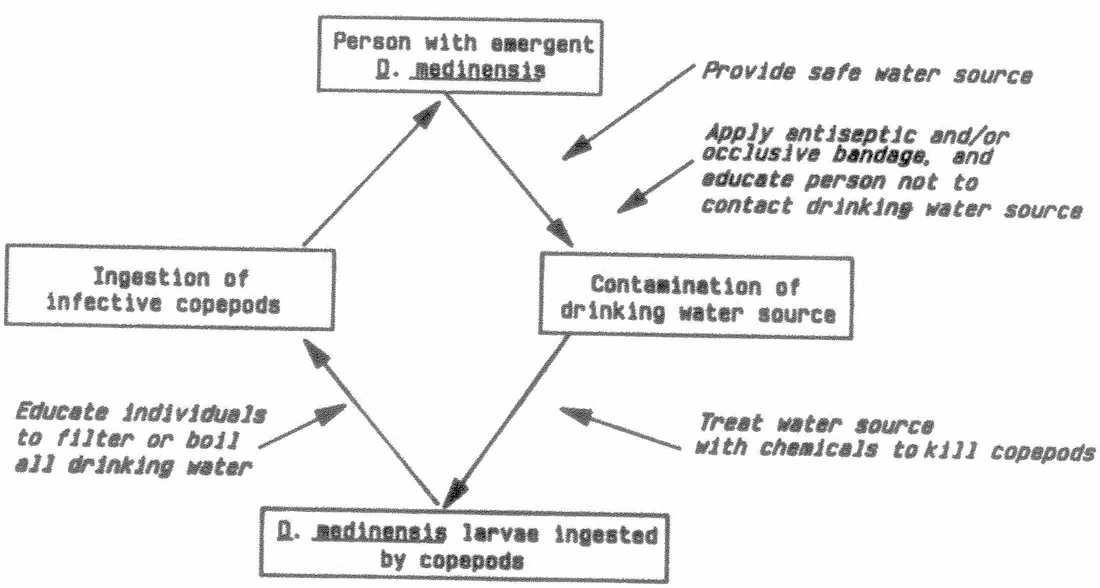
Breaking the Transmission Cycle

There are three recognized ways of interrupting transmission of D. medinensis to eliminate endemic dracunculiasis from villages.

- Provide safe (copepod-free) sources of drinking water.
- Teach residents that the disease comes from their drinking water and instruct them to use filters to remove copepods and/or to boil drinking water.
- Apply chemicals to control copepod populations in sources of drinking water.

The points of intervention in the transmission cycle are indicated in the figure below.

Figure 1.
D. medinensis Life Cycle
Points of Intervention Against Dracunculiasis



Choosing the Best Method

There is no single best intervention strategy. It is important to use the most judicious mix of available interventions, especially when permanent sources of safe drinking water are not present and when their provision is not forthcoming. In such instances, if both resources and commitment allow, chemical control of copepods may be used to complement health education. All interventions must be implemented so that interference with normal village activities is minimal.

When to Use Chemicals

Consider using chemicals to control copepods when the following conditions apply.

- When unsafe sources of drinking water are few, small to moderate in volume (500 m^3 or less) and shared by many people.
- Where provision of permanent sources of safe drinking-water is not feasible, either for geological reasons or because the community is too small or remote, and when the volume of water to be treated is 500 m^3 or less.
- Where health education compliance is poor.
- During outbreaks of dracunculiasis, to reduce incidence while villagers wait for the provision of permanent sources of safe drinking water.
- When an additional security measure is needed to prevent transmission in areas where elimination is imminent or recently achieved.

Cost Considerations

Hypothetical benefit-cost ratios have been formulated for selected interventions in an inland West African country (Paul, et al., 1986). A program which used epidemiological surveillance, started health education and community participation, made health care available, and provided underground sources of drinking water, yielded a benefit-cost ratio of 2.61 (a return of more than twice the investment). When chemical control of copepods with temephos (Abate*) was used instead of underground sources of drinking water, the benefit to cost ratio increased to 4.14.

Which Chemical to Use

Several chemical disinfectants and pesticides have been shown under field conditions to control copepod populations in sources of drinking water. The one recommended is temephos; its efficacy has been evaluated in laboratory studies and under field conditions in Africa and Asia. Experience with the chemical in other vector-borne disease-control programs has shown that it is safe for people to use and has low toxicity to mammals.

A number of chemical compounds, e.g., chlorine, potassium permanganate, DDT, and zinc carbamate, have been evaluated for efficacy against copepods. However, for reasons of safety of use, relative efficacy, cost and/or toxicity to mammals, these chemicals are not recommended for use in dracunculiasis control.

*The use of trade names is for identification only and does not constitute endorsement by the Public Health Service, the U.S. Department of Health and Human Services, or the World Health Organization.

Temephos

Temephos was introduced in 1965 by American Cyanamid Co. as a mosquito larvicide (Brooks et al., 1965; Schoof, 1967; Laws et al., 1968). It is commercially available in several formulations, but 50% emulsifiable concentrate (EC) is the most readily available and cost-effective formulation for copepod control. One liter of 50% EC costs approximately US $20 (1988 prices). For additional information about temephos, see Appendix 6.

Safety. Temephos has been extensively evaluated in potable water supplies, and its toxicity to mammals is very low (Laws et al., 1967). The WHO Expert Committee on Pesticides declared temephos safe for use in actual or potential sources of drinking water at a dosages not exceeding 1 part per million; e.g., 1 mg/l (WHO, 1973).

Efficacy. In laboratory studies, temephos was found to be the most promising of several candidate pesticides evaluated for their toxicity to copepods (Muller, 1970). A concentration of 0.1 mg/l killed 100% of *Acanthocyclops vernalis* (= *Cyclops vernalis*). The lethal concentrations calculated for 50% and 90% mortality were 0.002 and 0.006 mg/l, respectively. More recent laboratory studies in India (Sharma et al., 1981) using *Mesocyclops leuckarti* yielded results similar to those of Muller.

Mode of Action. Temephos inhibits production of an enzyme (cholinesterase) essential to synaptic transmission of nerve impulses in living organisms. Cholinesterase levels in copepods begins to reduce within 12 hours of exposure to a 1 mg/l temephos concentration. Copepods become progressively less able to swim and feed normally; within 72 hours, depleted cholinesterase levels cause paralysis and the organisms settle to the bottom where they probably become food for other organisms. Laboratory data suggest that the impact of temephos on copepods is greater during the naupliar and adult stages than the intermediate copepodid stage.

II. Selecting Drinking Water Sources for Treatment

Types of Sources

In areas of endemic dracunculiasis, every unprotected source of drinking water is a potential source of infection. This is so particularly where the availability of water is seasonal and the number of sources are few, small-to-moderate in size, and shared by many people. In such areas, temephos is useful, and transmission of infection may be effectively interrupted at a reasonable cost. However, where the rainy season is long and sources of drinking water are many, less ephemeral and/or very large, it is critical to determine which sources are most likely to support transmission and whether temephos is a cost-effective way to interrupt transmission.

Drinking water sources other than those located in the village may be very important sources of infection with D. medinensis. In a study in northwest Burkina Faso, a dry savannah zone, more than 90% of people with dracunculiasis indicated that their drinking water often came from small, man-made ponds in or near agricultural fields away from their village (Steib and Mayer, 1988). These ponds were most frequently incriminated as sources of significant copepod populations (Table 1). Thus, to control dracunculiasis in such an area, emphasis may be placed on chemical treatment of these sources and on health education to promote filtration of water obtained from these ponds.

Table 1
TYPES OF WATER SOURCES POSITIVE FOR COPEPODS AND ASSOCIATION WITH TRANSMISSION OF DRACUNCULIASIS
(After Steib & Mayer, 1988)

	Dimensions of source		Sampling for Copepods			Percent of
Type of water source	Diameter (in meters)	Maximum depth (in meters)	No. of sources sampled	No. of samples examined	No. of samples positive	cases using source*
Draw well	2	5	3	30	0	–
Periodic stream	10	2.5	1	5	0	–
Large natural pond	50–200	1–3	3	48	0	8.5
Small natural pond	7–15	0.3	3	41	0	4.7
Small man-made pond	4–9	0.3–0.6	5	63	7	84.9
Cattle watering source	17–45	0.5–0.8	3	43	1	1.9

– Considered insignificant in this study

* Calculated from 106 cases (of a total of 123) who worked in the field and obtained water from pond and cattle watering sources

Deciding Which Sources to Treat

To determine whether a drinking-water source should be treated with temephos, consider the following:

- o Presence of dracunculiasis in a village.
- o Frequency with which a given water source is used by villagers.
- o Presence of a barrier that prevents people from entering the source.
- o Estimated volume of drinking-water source.

The decision to treat an individual source is made by the treatment-team leader and, perhaps, senior supervisors at the time of inspection. The decision is guided by the priorities of the national program, the resources available, and the current degree of transmission. For example, a single 500 m^3 body of water requires 1 liter of temephos at a cost of approximately US$20 per application. This cost does not include labor, transportation, and handling expenses, and must be carefully considered with factors such as the total program budget and the expected efficacy of treatment.

Deciding When to Treat Them

Transmission occurs when infected persons who have skin lesions with protruding _D. medinensis_ come into contact with sources of drinking water. _D. medinensis_ larvae are released and copepods become infected.

Depending on the area, transmission may be limited to a few (3 to 4) or most (6 to 8) months of the year. Muller (1970) observed differences in disease prevalence related to rainy and dry seasons. In semiarid regions that have distinct wet and dry seasons and minimal rainfall within 3 to 4 consecutive months, incidence of dracunculiasis coincided with the rainy season. In areas with longer periods of rainfall, dracunculiasis is patent for as many as 8 months of the year, but most cases of dracunculiasis occur in the latter half of the dry season and continue into the rainy season. The seasonal pattern of transmission related to that of rainfall has been described by many others, including McCullough (1982), Desfontaine and Prod'Hon (1986), Guiguemde (1986), WHO (1986), Chippaux (1988), and Steib and Mayer (1988).

In either case it is critical to time the first temephos application at least 1 month before the expected appearance of lesions in the community.

Potential Obstacles

Some potential obstacles to successful use of chemicals in sources of drinking water are described below.

- Attitudes and beliefs of the community about the use of chemicals in their drinking water.
- Lack of acceptance or tolerance by the community of perceived changes in color, odor, or taste of drinking water which may be attributed to the chemical.
- Lack of adherence by control teams to principles of safe and effective use of chemicals for control of copepods.

Before applying temephos to a village water source, establish clear and courteous communication with village authorities. Get approval from the village chief or authorities to treat water, and ask for their schedule preferences. Their approval facilitates local working conditions and allows teams to obtain information pertinent to the control program.

The introduction of a foreign substance to a village drinking-water source provokes community interest. Thoroughly explain the effects of temephos, particularly the taste and color of the water after treatment, so that hostility, suspicion, and even reluctance to use the water do not result. Villagers must be assured that the treated water will not harm them, their children, or their livestock. The control program can be seriously undermined if villagers do not accept temephos or if an accident is blamed on poor application.

Timing the application also is important. For example, if water is most often fetched during the morning, then treatment can be made in the afternoon. An interval between application of temephos and use of water allows the temporary coloration, odor, or taste imparted by temephos to dissipate.

IV. Applying Temephos and Evaluating Treatment

Introduction

The information in this section helps with 3 activities.

- To prepare for applying temephos.
- To calculate the volume of water and amount of temephos to add.
- To evaluate treatment.

The instructions for field activities are designed so that they can be copied from this manual and distributed to treatment teams.

Preparing for Application

Outfit field teams with the following supplies and equipment.

- Maps of the areas in which the teams are working (suitable for adding field notations).
- Graduated cylinders for measuring temephos (preferably 100-ml and 1-liter capacity).
- Instruments for measuring length, width, and depth of water sources (e.g., meter stick, measuring tape, calibrated length of rope).
- Field-record book and/or field-record form for calculating and recording volume of water sources, temephos dosages, and related data (see Appendix 5).
- Nomograms of water volume for sources of specified dimensions (see Appendices 1 and 2).
- Chart for determining the amount of temephos needed (see Appendix 3).
- Plastic bucket and mug (for dispensing temephos).

- Bar of hand soap (for washing temephos from hands) and towels.
- Wide mouth vessel (1-liter capacity); fine mesh filter (100 to 200 micrometer pore size); small, glass sample bottle with screw cap; 70% alcohol or 10% formalin; and labels (for samples).

Procedures for Calculating Volume of Water and Amount of Temephos

> **CAUTION**
>
> Be sure you know the precautions for handling, storing, and applying temephos. Pesticide use is governed by the label, and restrictions placed on the chemical by the manufacturer are stated there (shown in Appendix 6).
>
> The amount of temephos to add depends on the volume of water. A few casual measurements or estimates may result in gross overestimate or underestimate of volume. An accurate estimate insures that a safe amount of temephos is added.

Ponds, pools and other irregularly-shaped sources:

When the water source has an irregular shape, it is more difficult and less accurate to estimate the volume of water. Estimates are based on average length, width, and depth. The accuracy of the estimate depends on the number of measurements taken. Follow the instructions below.

Cisterns, step wells, and other sources with a cylindrical shape:

You can made a fairly accurate estimate of the volume of water in a source that has a regular or geometric shape. Measure the width, or diameter and depth of the body of water, as described below.

Using instruments. You can prepare simple instruments made from locally-available materials to take the required measurements. For example, mark a rope (30- to 50-m long) with knots, ribbons, or other markers at intervals of 1 m or less. Use it to measure length and width. If you attach a weight to one end of this rope, depth can be measured as well. You can also measure depth of shallow ponds with a stick calibrated in centimeters.

Measuring irregularly shaped sources. Follow the steps described below.

Step	Description
1	Measure the length of your stride, in meters, with a meter stick.
2	Get a rough estimate of width and length by pacing off the water source.
3	See how many measurements of width and length to make by referring to the table below.

If dimension of source (in meters) is:	Interval between parallel transects (in meters) is:
<5	0.5
5-10	1
11-20	2
21-30	3
31-40	4
41-50	5

Create a grid over the pond of lines of width and length (transects).

Step	Description
4	Measure each transect of width.
5	Measure depth along each width transect, at the intersection with each length transect.
6	Calculate average width. Add all measurements of width and divide the sum by the number of measurements.
7	Calculate average depth. Add all measurements of depth and divide the sum by the number of measurements. Be sure to include zero values.
8	Measure each transect of length. Add all measurements of length and divide the sum by the number of measurements.
9	Calculate average length.
10	Estimate volume by multiplying average width, average depth, and average length, or by using nomograms in Appendices 1 and 2 (see example below).

Example

This example uses the pond illustrated below. The topography and bottom contours are as shown.

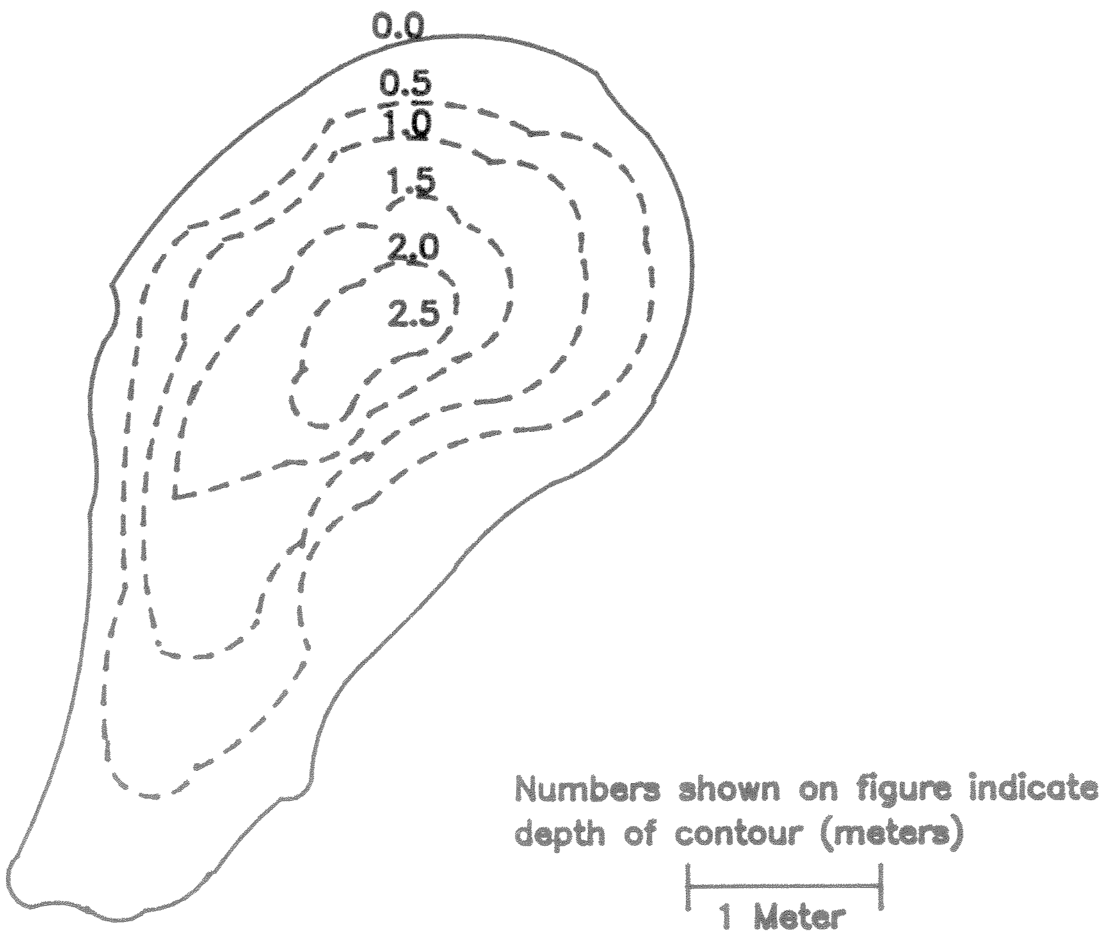


FIGURE 2.

Step	Description
1	An inspector's stride is 0.5-m long.
2	He paces the pond and finds it to be approximately 3.5-m wide and 5-m long.

3 According to the table above, transects of width are drawn every 0.5 m and those of length every 1 m, to create a grid 9 x 3.

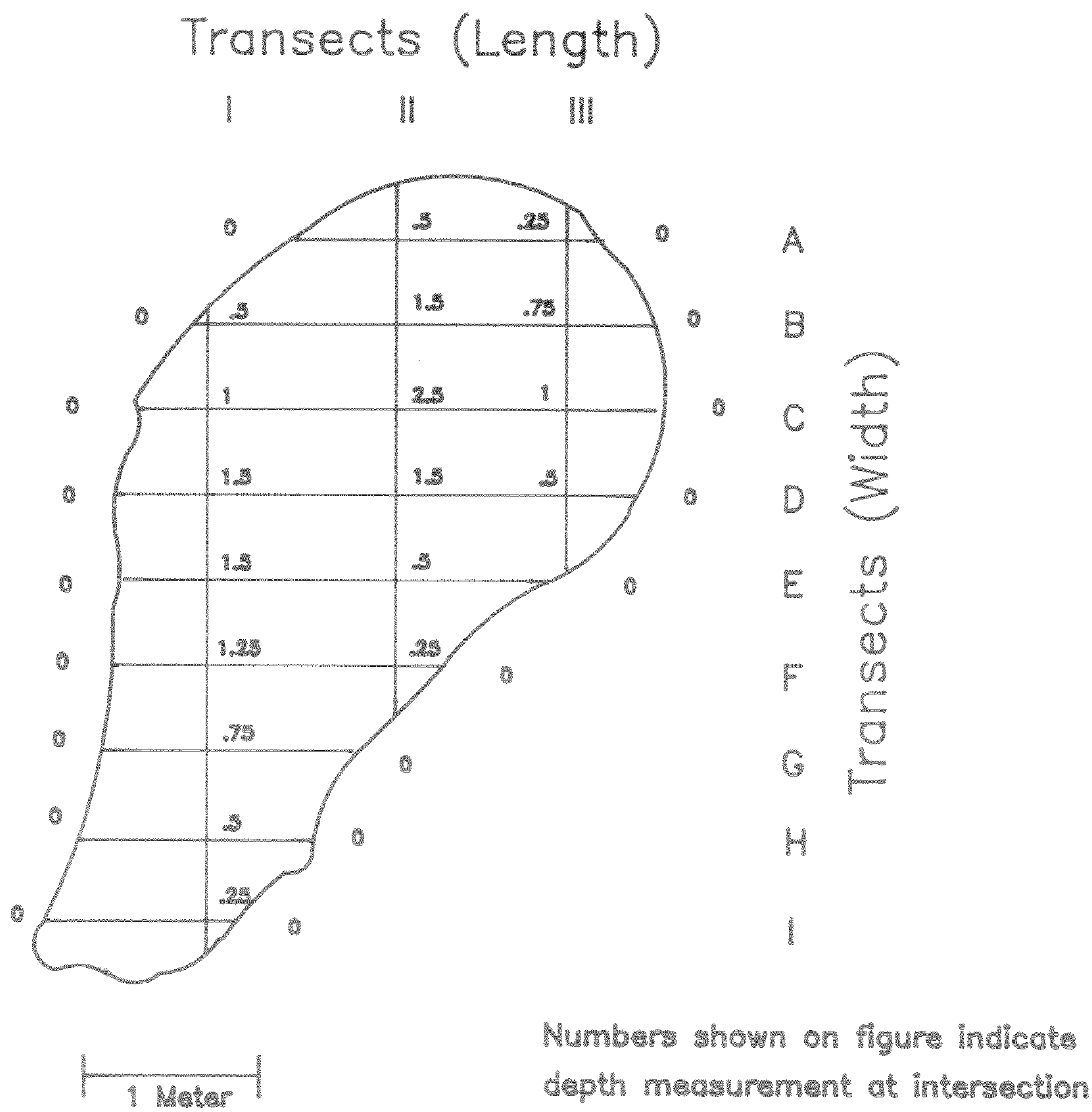


FIGURE 3.

4 Using a calibrated rope, width is measured for each of 9 transects. The width measurements are shown below.

Transect		Width (in meters)
A		2.0
B		2.8
C		3.1
D		3.0
E		2.4
F		1.9
G		1.4
H		1.4
I		1.1
	Sum	19.1 meters

5 Sum of all width measurements = 19.1 m

Number of all depth measurements = 9

Average width $= \frac{19.1}{9} = 2.12$ m

6 Depth is measured at the edges of the pond and at each intersection of the depth and width transects (1-m intervals). The depth measurements are shown below.

Depth (in meters) along width transects

	A	B	C	D	E	F	G	H	I
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.25	0.75	1.00	0.50	0.50	0.25	0.75	0.50	0.25
	0.50	1.50	2.50	1.50	1.50	1.25	0.00	0.00	0.00
	0.00	0.50	1.00	1.50	0.00	0.00	----	----	----
	----	0.00	0.00	0.00	----	----	----	----	----
Sum	0.75	2.75	4.50	3.50	2.00	1.50	0.75	0.50	0.25

7 Sum of all depth measurements = 16.5 m

Number of depth measurements = 36

Average depth = $\frac{16.5}{36}$ = 0.46 meters.

Caution: To compute average depth, we include zero values, i.e., the depth of water at the beginning and end of each transect. In this example, if we omitted these values, the estimate of average depth would be 16.5 divided by 18 measurements or 0.92 meters, **a 200% overestimate**.

8 The length measurements are shown below.

Transect	Length (in meters)
I	4.1
II	3.2
III	1.9
Sum =	9.2 meters

9 Sum of all length measurements = 9.2 m

Number of length measurements = 3

Average length = $\frac{9.2}{3}$ = 3.1 meters.

10 The estimated volume (V) in cubic meters is calculated as follows.

V = **average width** x **average depth** x **average length**

V = 3.1 x 2.12 x 0.46 = 3.0 m^3.

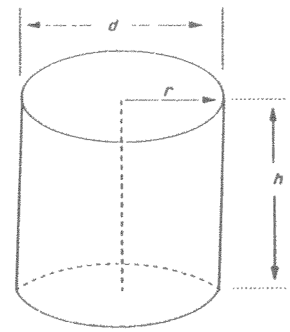
Note: The approach to estimating the volume of water in irregularly shaped sources derives from Simpson's Rule for irregular areas (Chemical Rubber Company, 1978).

11 As an alternative, once the impoundment's average dimensions have been estimated, refer to the nomograms in Appendix 1. To calculate volume, refer to page 2, Appendix 1. First, locate 6.6 m^2 on the area scale. Second, locate average depth (0.46 meters) on the corresponding scale. Third, with a straight edge, draw a line between the 2 points. The point at which this line intersects the volume scale is the estimated volume of the pond (3 m^3).

Measuring cylindrical sources. For cylindrical water reservoirs, such as a hand-dug well, determine the diameter and depth, then calculate the volume (V) of water using the formula below or the nomogram in Appendix 2. The formula is as follows: $V = Pi\ r^2\ h$; where Pi = 3.1, r is the radius or half the diameter (d), and h is depth.

For example, assume a diameter of 2 m and a water depth of 5 m.

$$\text{Volume} = Pi\ r^2 h$$
$$= 3.1 \times 1 \times 1 \times 5$$
$$= 15.5\ m^3.$$



(For additional information about circles, see Appendix 4.) Now refer to Appendix 2. Locate the value for depth (5 m) on the corresponding scale. Locate the value for radius squared (1 m^2) on the corresponding scale. With a straight edge, draw a line between the 2 points. The point at which this line intersects the volume scale indicates the volume (15.5 m^3) of the impoundment.

Another way to estimate the surface area of **nearly circular** ponds is by pacing off the distance around the reservoir. If, for example, there are 35 paces around a reservoir, and the pace of the inspector is 0.6 m, then the circumference (c) is 21 m (35 paces X 0.6 m/pace). Derive the area as follows: $A = c^2/4\ Pi$.

To determine volume, first estimate average depth as described in steps 5 and 7 for irregularly shaped sources. Then, use the formula V = area x average depth.

Determining how much temephos to add. A single application to 500 m^3 of water requires 1 liter of temephos (50% EC). This is costly.

When the volume of the water source is greater than 500 m^3, the source should probably not be treated with temephos. In Appendices 1 and 2 the greatest volume given is 500 m^3.

Appendix 3 gives the amount of temephos to add for given volumes of water. Refer to the appendix or calculate the amount as follows. Add 2 ml temephos 50% EC per cubic meter of water to obtain a 1 mg/l concentration.

In the example for the irregularly shaped source, the volume of water was 3 m^3. Thus,

$2\ ml/m^3$ temephos 50% EC x $3\ m^3$ = 6 ml of temephos.

Add 6 ml temephos 50% EC.

In the example for the cylindrical pond, the volume was 15.5 m^3. Thus,

$2\ ml/m^3$ temephos 50% EC x $15.5\ m^3$ = 31 ml of temephos.

Add 31 ml temephos 50% EC.

Mix the amount of temephos required with sufficient water in a vessel or sprayer. Then distribute the emulsion as uniformly as possible over the entire surface area of the impoundment.

Caution: Inaccurate measurements of water volume result in an overdose or underdose of temephos. Avoid **overdosing** so that villagers are not exposed to levels of temephos that exceed the maximum recommended dose, and so that the chemical is not wasted. Avoid **underdosing** because copepod control could be ineffective and the cost of the chemical and labor wasted.

Recalculating Depth. In areas of endemic dracunculiasis, the availability and quantity of drinking water fluctuates significantly during the transmission season. As the water level rises or falls in the reservoir, the surface area and depth change, and so does the volume of water. Depending on the source, a small fluctuation in the water level may cause a significant change in volume of water. **To apply the correct amount of temephos, control**

personnel must determine the dimensions of the drinking source before each treatment. During the first visit to the impoundment (time 1 or t_1) the water level can be recorded on a permanent bench mark (or an immovable landmark), then the depth of water at t_2, t_3, etc., can be quickly reestimated without having to measure depth again. For Example A, suppose that the average depth of 0.46 m at t_1 was painted on a rock, as a bench mark; at t_2, the water level receded 0.10 m from the benchmark. Then the average depth at t_2 is calculated as follows:

$$-0.10 \times 0.460 = -0.046 + 0.460 = 0.414 \text{ m.}$$

Unless the bench mark disappears, depth need not be recalculated by the laborious process in Example A. However, average length and width (surface area) may dramatically increase or decrease with changes in water level and may need to be estimated each time.

Evaluating Treatment

After the initial application, treat the water again at fixed intervals during the transmission season. Retreatment is required approximately every 4 to 6 weeks after the initial application. Residual effects of temephos are diminished by that time and both copepod populations and the potential for dracunculiasis transmission increase.

Collecting copepods. To measure the impact of temephos on copepod populations, compare the pre- and post-treatment population level, in a least a few water sources, 1 week before and at 2, 4, and 6 weeks after treatment. To collect copepods, take a surface sample of water as follows.

1. Sample a known volume of water in a wide-mouthed vessel (e.g., a bottle or bucket of at least 1-liter capacity). Alternatively, the funnel net developed by the National Institute of Communicable

Diseases (NICD) for the Guineaworm Eradication Programme in India can be conveniently used in most habitats (Division of Helminthology, NICD, 1985).

2. Take 3 to 5 water samples, at the same time of day, at different points around the source.
3. Lower the vessel just below the water surface and allow it to fill quickly (thus drawing in the rapidly-swimming copepods).
4. Concentrate the organisms by pouring the water through a fine-mesh cloth filter, similar to one used by local people to filter drinking water.
5. Backwash filter into a smaller bottle.
6. Preserve organisms with 70% alcohol or 10% formalin.

Analyzing the collection. Live collections contain various organisms in addition to copepods; the latter are easily distinguished by their characteristic swimming motion (jerky, sudden movements). Do not count nauplii because organisms in this stage can be found in crustaceans; only copepodids (i.e., organisms in immature and adult stages shaped like the organism shown in Appendix 7) should be counted and, if necessary, staged (based on number of abdominal segments)*. Several species of copepods may be collected from the same site, and adults may differ greatly in size. Record the total number of copepods counted, the volume of water filtered, the village name or code for water source, and the date of collection.

Specific identification of copepods requires detailed analysis of spine morphology and distribution and is beyond the scope of this document.

*A slide set, "The Guinea Worm" (WHO, 1986) contains illustrations of the external anatomy of cyclopoid copepods. This slide set is currently available from WHO, Geneva.

V. Summary

1. List villages with endemic dracunculiasis, and rank them by incidence, if known. Determine the usual time of year when guinea worms begin to emerge.

2. Ensure that community leaders are aware of the aims and safety of the temephos applications and gain their collaboration (see Section A, page 9).

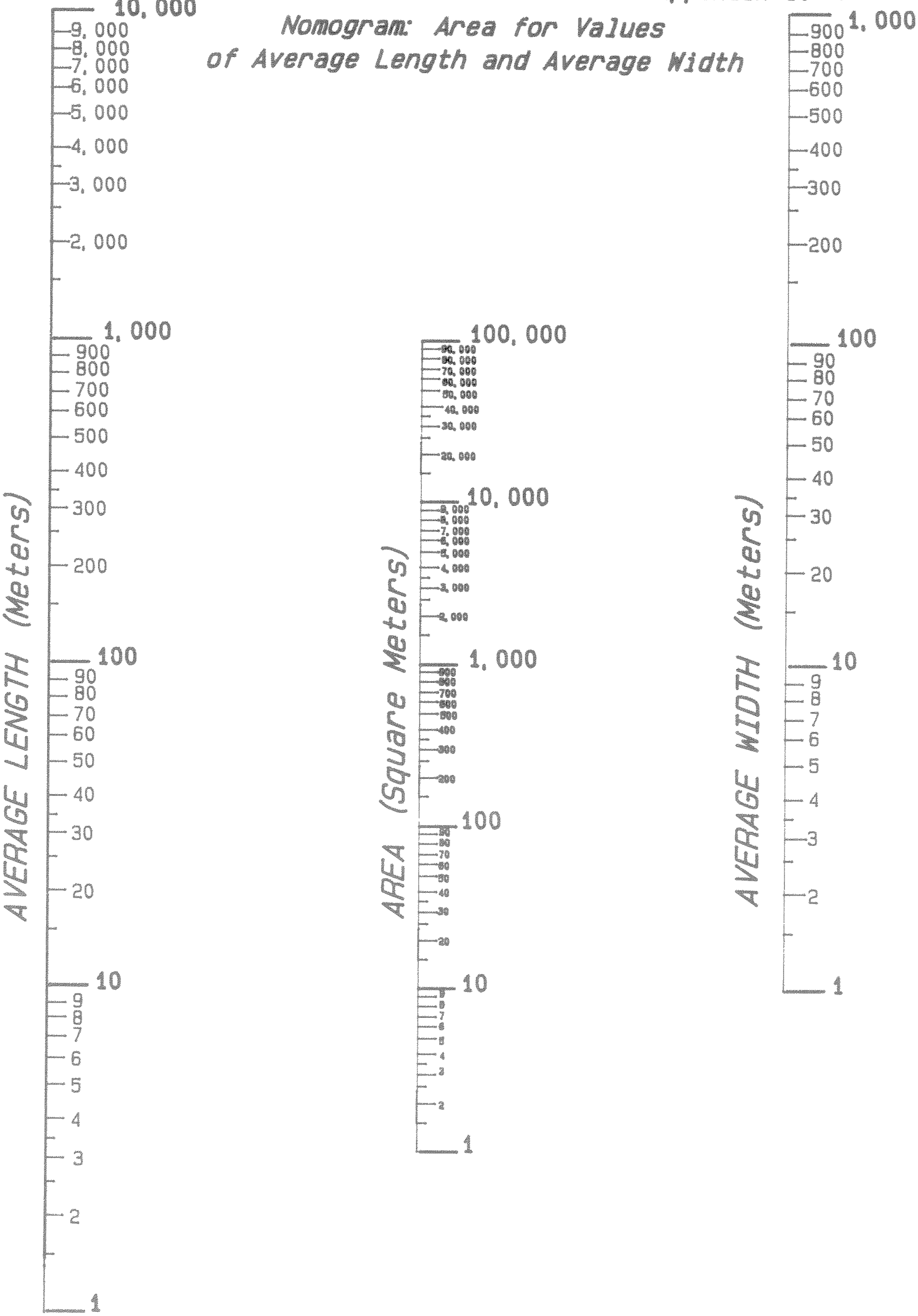
3. Locate all drinking sources (within each village and related hamlets or farming area) used by villagers and characterize drinking sources as to type (pond, lake, pool, well, etc.). Prepare a map that shows where sources are relative to the village.

4. Determine the frequency of use by the population of sources of drinking water, especially during the transmission season.

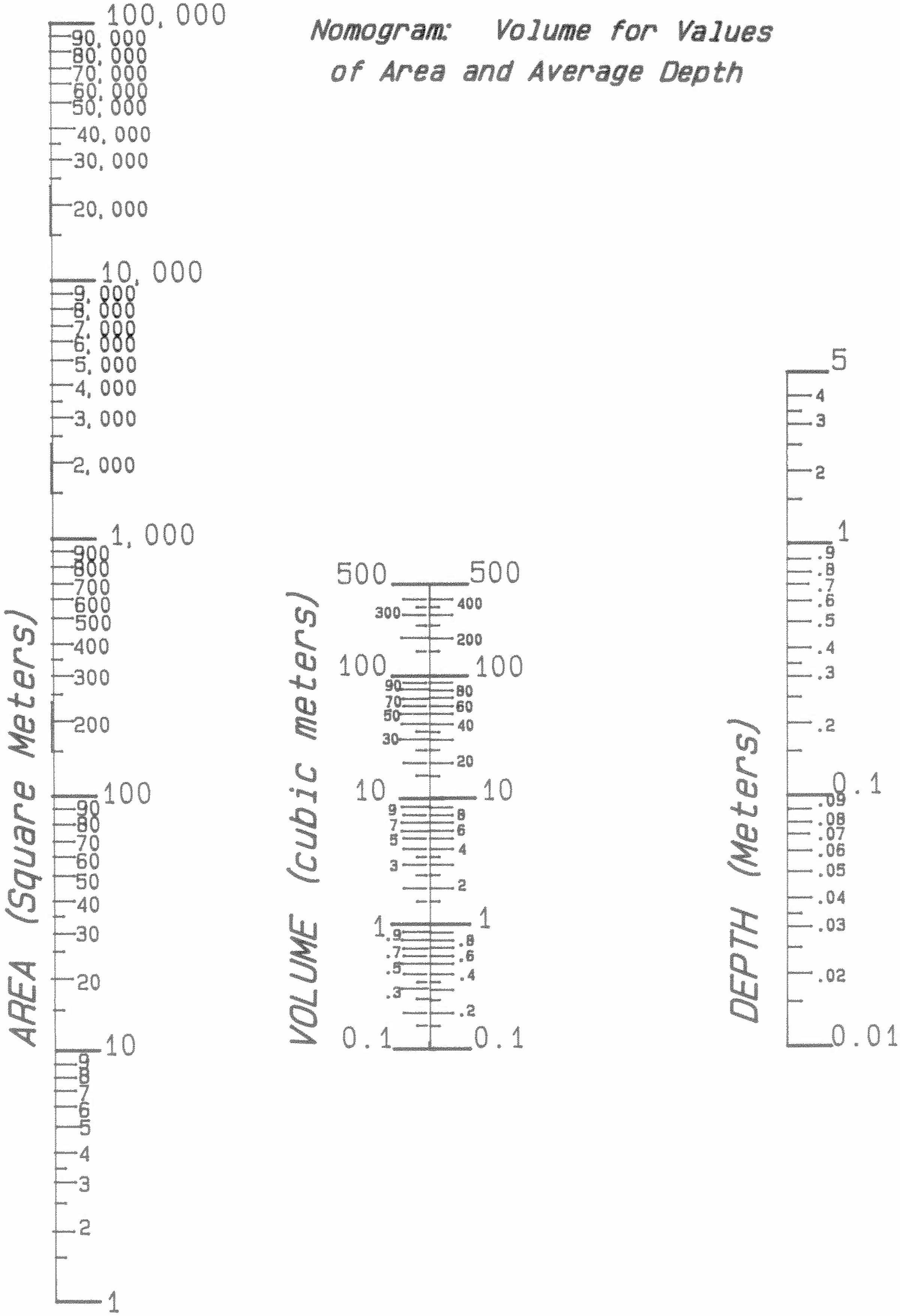
5. Train personnel to map; estimate water volume; use, handle and store temephos; and sample water for copepods.

APPENDICES

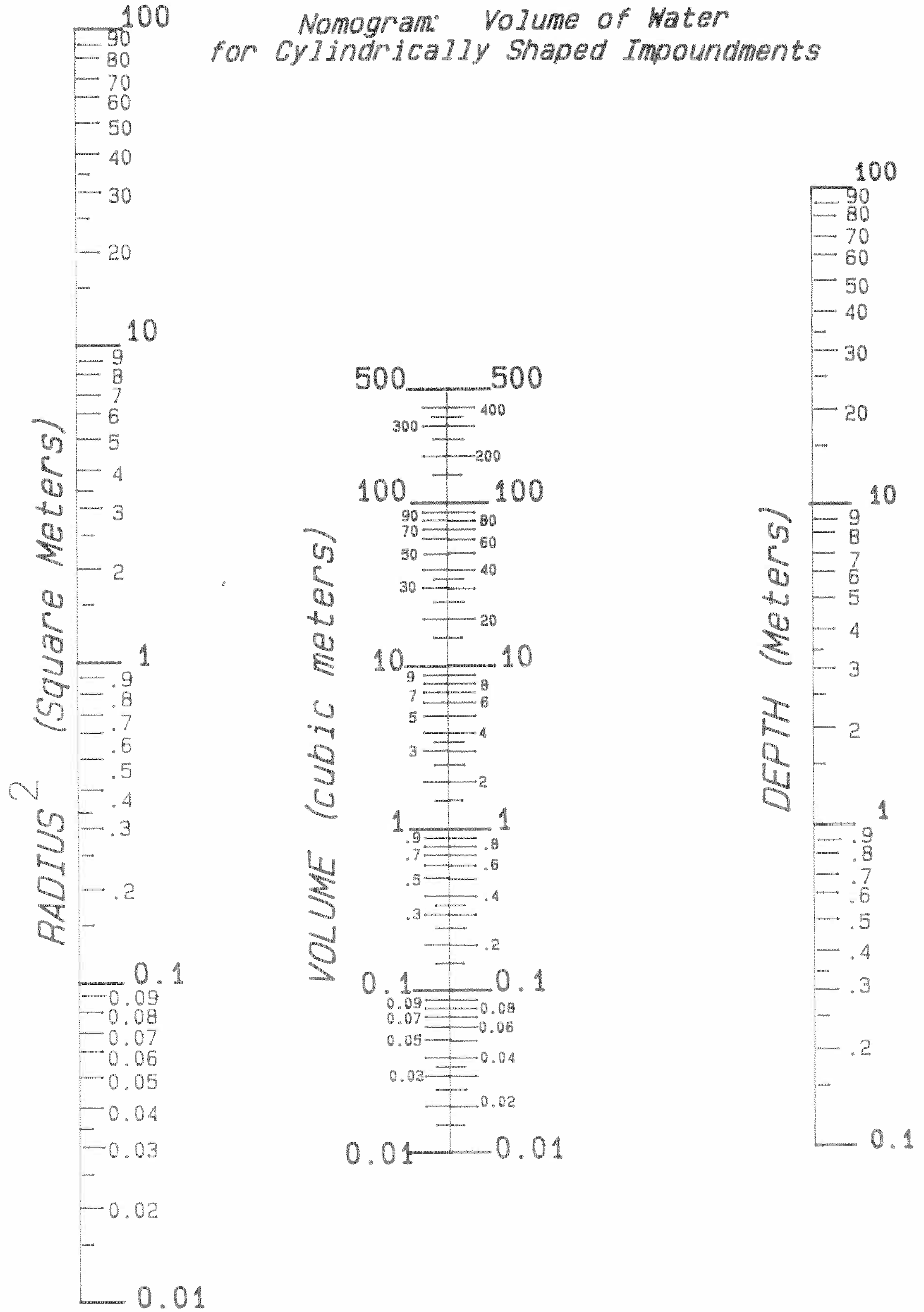
Nomogram: Area for Values of Average Length and Average Width



Nomogram: Volume for Values of Area and Average Depth



Nomogram: Volume of Water for Cylindrically Shaped Impoundments



Appendix 3

MILLILITERS OF TEMEPHOS 50% EC NEEDED FOR 1 mg/LITER CONCENTRATION

[1 mg/liter concentration = 2 ml of temephos 50% EC per m^3 of water]

Volume of water (in cubic meters)	Volume of water (in liters)	ml of 50% EC Required
0.5	500	1
1	1,000	2
2	2,000	4
3	3,000	6
4	4,000	8
5	5,000	10
6	6,000	12
7	7,000	14
8	8,000	16
9	9,000	18
10	10,000	20
20	20,000	40
30	30,000	60
40	40,000	80
50	50,000	100
60	60,000	120
70	70,000	140
80	80,000	160
90	90,000	180
100	100,000	200
200	200,000	400
300	300,000	600
400	400,000	800
500	500,000	1,000

Appendix 4

NOTES ABOUT MEASUREMENTS

Circles

Diameter of a circle = circumference x 0.31831

Area of a circle = Pi x radius squared
= diameter squared x 0.7854
= $\frac{\text{circumference squared}}{4 \times \text{Pi}}$

Circumference of a circle = 2 x Pi x radius.

Pi = 3.1

Parts per million

Concentration, expressed in parts per million (ppm), signifies a weight-to-weight relationship between one part of a substance added to 1,000,000 parts of water. For example, 1.0 mg of a pesticide or disinfectant containing 100% active ingredient added to 1.0 kg of water is 1 ppm. Since 1-liter of water weighs exactly 1 kg, then 1 ppm is equivalent to 1 mg/l of water.

1 m^3 = 1000 l
1 ml weighs 1 gram (1000 mg)
1 g or 1 ml per m^3 of water = 1 mg/l

Temephos 50% EC contains only 50% active ingredient, hence 2 ml are needed per m^3 of water.

Appendix 5 (p. 1)

GUINEA WORM ERADICATION PROGRAM TEMEPHOS APPLICATION RECORD

1. Village name ____________________
2. District ____________________
3. Date ____________________
4. Inspector ____________________
5. Type of water source: Pond______ Well_____ Cistern_____ Spring_____ Other____________________
6. Location of water source: Within village__ Outside Village__ Identification ______________ (Code, symbol, or other identifier)
7. Sketch the outline of the water source ("bird's eye" view).

8. If source of drinking water is cylindrical, record diameter ________(m), and depth ________(m), then volume ______________(m^3); use Pi r^2h or refer to Appendix 2.

9. If source of drinking water is rectangular or irregular in shape, estimate maximum width and length by pacing.

   Maximum width __________ (m) Maximum length ____________(m)

10. Refer to table below to determine intervals at which measurements will be made.

If dimension of source (in meters) is:	Interval between parallel transects (in meters) is:
<5	0.5
5-10	1
11-20	2
21-30	3
31-40	4
41-50	5

No. transects of width ________ No. transects of length ________

GUINEA WORM ERADICATION PROGRAM TEMEPHOS APPLICATION RECORD

11. Measure width and length of each transect. Record each measurement below.

WIDTH	LENGTH

SUM ____ /# ____ = AVG. ____ SUM ____ /# ____ = AVG. ____

DEPTH ALONG WIDTH TRANSECTS

SUM										

SUM OF ALL COLUMNS (GRAND TOTAL)

NUMBER OF MEASUREMENTS

AVERAGE DEPTH = SUM OF ALL COLUMNS DIVIDED BY TOTAL NUMBER OF MEASUREMENTS.

12. To determine volume, refer to Appendix 1, or use the following calculation:
    average length x average width x average depth = volume (m^3)

13. Calculate amount of temephos required as follows, or refer to Appendix 3.

    Volume ____ x 2 = ____ (Amount, in milliliters, of 50% EC required to obtain a 1 mg/liter concentration)

14. Mix temephos with sufficient pond water in a vessel or sprayer, and distribute solution as uniformly as possible over the entire surface.

TECHNICAL INFORMATION ON TEMEPHOS (ABATE™)

Chemical names.	0,0,0',0'-tetramethyl 0,0'-thiodi-p-phenylene phosphorothioate [IUPAC] 0,0'-(thiodi-4, 1-phenylene) bis (0,0-dimethylphosporothioate) [CA].
Common name.	Temephos [BSI, ANSI, ISO].
Empirical formula.	C16 H20 06 P2 S3.
Molecular weight.	466.5.
Color and state.	Analytical grade: white crystalline solid. Technical grade: amber liquid that may contain temephos crystals below 30C.
Purity.	Technical grade: 90% minimum.
Melting point.	Analytical grade: 30.0 to 30.5C. Technical grade: 25 to 30C.
Boiling point.	Technical grade: decomposes at 120 to 125C.
Refractive index.	Technical grade: n 25/D = 1.586 to 1.588.
Specific gravity.	Technical grade: 1.32 at 22 to 23C.
Solubility.	Soluble in acetonitrile, carbon tetrachloride, diethyl ether, ethylene dichloride, lower alkyl ketones, and toluene. Essentially insoluble in hexane, methylcyclohexane, and water (1 ppm).
Vapor pressure.	7.17 x 10 to the minus 8mm Hg at 25C.
Viscosity.	3000 Centipoise at 5C; 300 at 25C; 180 at 40C; 30 at 80C.
Stability.	Stable at 25C for at least 2 years. Decomposes rapidly at 120-125C. Good chemical stability in natural fresh and saline water. Moderately stable to hydrolysis with aqueous alkali; no observed hydrolysis at pH 8 and 25C for several weeks, or at pH 11 and 40C for several hours; hydrolysis at high pH (greater than 9) for prolonged periods may be expected. A highly acidic pH (greater than 2) can promote hydrolytic decomposition.
Toxicity.	Oral LD50 of active ingredient for male laboratory rats (8,600 mg/kg of body weight) of 2% temephos is 20g per kg.
Formulations.	50% weight/volume emulsifiable concentrate (EC) containing 500 g. active ingredient (a.i.)/liter. 20% weight/volume EC containing 200 g. a.i./liter. 1-SG. A formulation containing 2% a.i. on sand granules.

WARNING!

AY BE HARMFUL IF SWALLOWED, INHALED, OR ABSORBED THROUGH SKIN.

AUSES EYE AND SKIN IRRITATION.

oid breathing mist.
oid contact with eyes, skin, and clothing.
ep container closed.
e with adequate ventilation.
ish thoroughly after handling.
ep out of reach of children.

FIRST AID

swallowed, do not induce vomiting. Call a ysician immediately.

case of contact, immediately flush eyes with nty of water for at least 15 minutes. Call a ysician. Flush skin with water.

EPA Est. No. 241-NJ-2

879 R11 1M 7 81 LN

DIRECTIONS FOR USE

For control of mosquito larvae in lakes, ponds, marshe drain ditches, irrigation ditches or other mosquito breedir areas, use ABATE 500 E Insecticide at the rate of:

0.5 to 1.5 fl. oz. per acre
or
40 to 120 ml. per hectare

Apply as a uniform spray in sufficient water for good cove are. The higher rate should be used in areas of hea vegetation or where water contains high amounts of orga matter. Repeat applications as necessary.

The label instructions for the use of this product refle the opinion of experts based on field use and tests. Th directions are believed to be reliable and should be follo carefully. However, it is impossible to eliminate all risl inherently associated with use of this product. Ineffectiv ness or other unintended consequences may result becau of such factors as weather conditions, presence of oth materials, or the manner of use or application all of whi are beyond the control of American Cyanamid Compan All such risks shall be assumed by the user. America Cyanamid Company warrants only that the material co tained herein conforms to the chemical description on th label and is reasonably fit for the use therein describ when used in accordance with the directions for use subje to the risks referred to above.

Any damages arising from a breach of this warranty sh be limited to direct damages and shall not include cons quential commercial damages such as loss of profits values or any other special or indirect damages.

American Cyanamid Company makes no other express implied warranty, including any other express or implie warranty of FITNESS or of MERCHANTABILITY.

AMERICAN CYANAMID COMPANY
AGRICULTURAL DIVISION
WAYNE, NEW JERSEY, U. S. A.

PRECAUTIONS FOR HANDLING, STORING & APPLYING TEMEPHOS

American Cyanamid Company, Princeton, New Jersey

When used in accordance with label instructions, Abate™ larvicide has a low degree of hazard to mammals, birds, fish, and other nontarget organisms, combined with a high degree of activity against various insect disease vectors and copepods. However, as with all organophosphorous pesticides, the following precautions should be observed during handling or application of the product:

When mixing and applying temephos:

- Keep away from food.
- Keep out of the reach of children.
- Avoid splashing on skin or eyes.
- Mark all containers and utensils used so that they will not be used for any other purpose.

After applying temephos:

- Thoroughly wash hands and any other body part that came into contact with the temephos.
- Change clothing if any temephos splashed on it.
- Do not reuse empty cans which contained temephos. Wash cans with 5% caustic potash or triple rinse with water; break container to make it unusable and bury in the ground.
- Wash equipment and facilities with soap.
- Properly label all temephos containers.

When storing temephos:

- Keep chemical out of the reach of children.
- Keep away from food.
- Store temephos in a secure, cool, well-ventilated place to avoid degradation due to excessive heat.
- Always use the temephos with the closest expiration date.
- Storage building should be weatherproof and secured by a lock and/or watchman.

When transporting temephos:

- Make sure there are no leaks in the container.
- Keep away from food and clothing.

For treating emergencies:

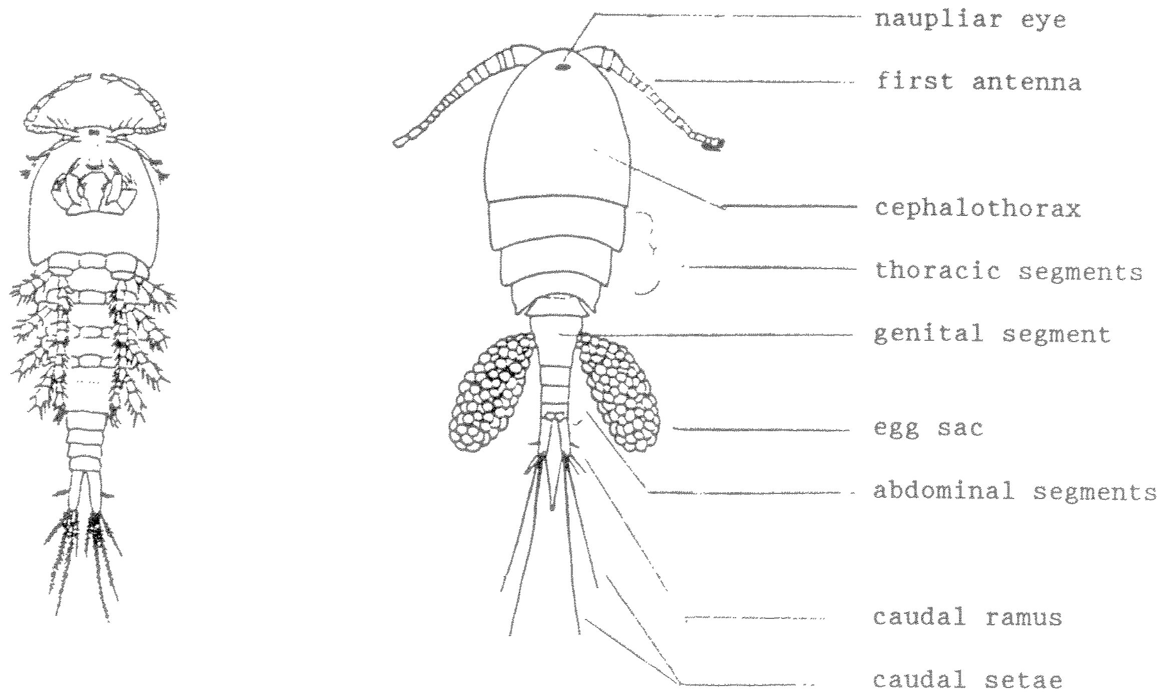
- **IN CASE OF CONTACT TO EYES OR SKIN**, immediately flush with plenty of water for at least 15 minutes. Seek immediate medical attention.

- **IF SWALLOWED**, DO NOT induce vomiting. Seek immediate medical attention.

Appendix 7

NOTES ON CYCLOPOID COPEPODS

Generalized view of a fresh water, free-living adult male and adult female cyclopoid copepod (after Yeatman, 1959).



Ventral view, adult male

Dorsal view, adult female

Cyclopoid copepods belong to the phylum Arthropoda, class Crustacea, subclass Copepoda, order Cyclopoida, family Cyclopidea. Copepods are important constituents of plankton and food chains in bodies of fresh water.

Important host species include:

Mesocyclops leuckarti
M. aequatorialis
M. minutus
Thermocyclops hyalinus
T. inopinus
T. neglectus
T. nigerianus

M. leuckarti is frequently cited as an intermediate host in studies of African dracunculiasis. A recent redefinition of African Mesocyclops (Van de Velde, 1984) states that the species is not found in Africa, indicating changes in taxonomic status. Literature that mentions M. leuckarti as a host species in Africa requires careful interpretation.

Adult females typically have a pair of egg sacs, each containing 40 to 50 eggs. After fertilization, eggs hatch to release the nauplius stage, usually within a few days (12 hours to 3 to 4 days). After passing through 5 to 6 naupliar stages, the organisms progress into the copepodid stages and take on general adult morphologic characteristics. Copepodids pass through 5 stages before emerging as mature adults. The female adult cyclopoid copepod is larger than the male and ranges from 1 to 3 mm in length. In addition to being smaller, the male is distinguished from the female by the recurving configuration of the first antennae. The entire life cycle ranges from 7 to 365 days, depending on species and environmental conditions. Many genera are macroscopic, but microscopic magnification is required to make specific identification.

During periods of adverse environmental conditions, such as drought, copepodids may become inactive and encyst. The cysts withstand desiccation and survive when the habitat is dry. They are able to regenerate rapidly, and certain adult copepods have been found within 2 days after a previously dry water source has been refilled by rainfall. The rapidity with which adult copepod stages reappear indicates that encysting takes place in an advanced copepodid stage. It has been reported that adult copepods have been found in a previously dry water source 2 hours after it is filled with rain. In this case, encysting could have occurred in the adult stage.

Adult copepods readily ingest free-swimming first-stage larvae of D. medinensis. Larvae die within approximately 5 days if not ingested by copepods. The larvae must undergo development in copepods before becoming infective. Once ingested, the 1st stage larvae penetrate into the copepod body cavity and molt 2 times. The 2 molts are completed in about 14 days, and the resultant third-stage larvae are infective for humans. Larvae can be seen inside the transparent copepods by microscopic magnification. When people ingest copepods in drinking water, copepods are destroyed through digestion. The larvae are liberated in the process, penetrate the intestinal wall, and develop into mature adults.

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