

Workshop on
Opportunities
for Control
of Dracunculiasis



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Washington, D.C.

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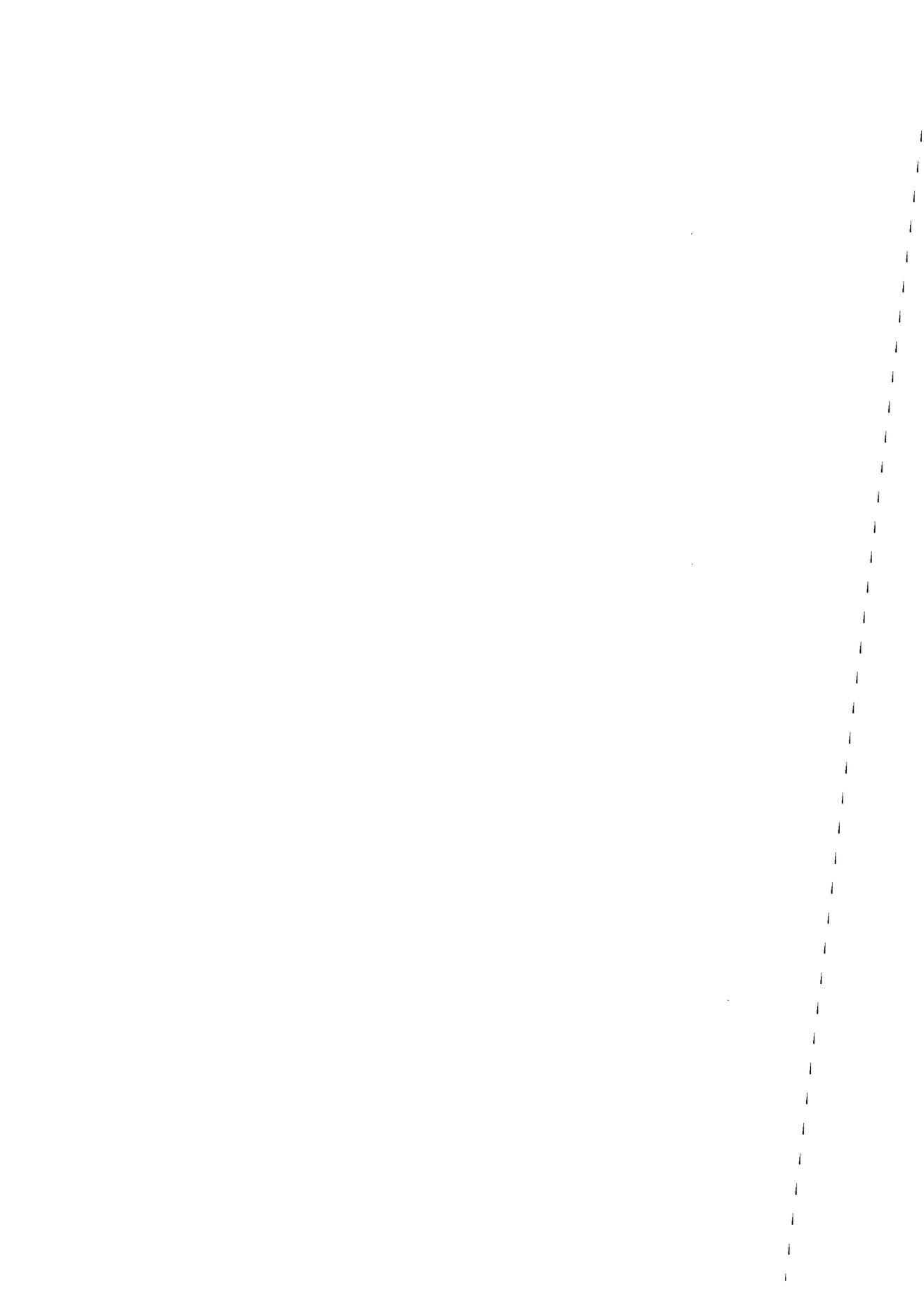
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PREFACE

Dracunculiasis (guinea worm disease, Medina worm, dracontiasis) is one of the oldest parasitic diseases known to man. Since biblical times, this disease has caused human suffering and has impeded economic development in rural areas of Africa, India, and the Middle East. It is only recently, however, that it has been the subject of sustained research or control efforts. Dracunculiasis owes its neglect largely to the fact that it does not kill, but temporarily disables inhabitants of remote rural areas. The elimination of this crippling disease will result in a dramatic improvement in the health, agricultural productivity, and general well-being of millions of affected people living in endemic areas of the developing world.

Fortunately, international awareness of dracunculiasis has increased in the last few years, stemming from initiation of an eradication program in India and the advent of the International Drinking Water Supply and Sanitation Decade (IDWSSD). The steering committee for the Decade has endorsed the idea of using dracunculiasis control as an indicator of the Decade's impact on health in endemic regions. In May 1981, the World Health Assembly adopted a resolution on the IDWSSD which mentioned dracunculiasis in the following context:

The Decade presents an opportunity to eliminate dracunculiasis . . . as a public health problem in affected areas, where the prevalence of the disease could serve as a uniquely visible and measurable indicator of progress for the Decade. (WHA Resolution 34.25, May 22, 1981)

INTERNATIONAL WORKSHOP

In 1982, in response to expressions of interest from international and domestic agencies, the National

Research Council's Board on Science and Technology for International Development (BOSTID), in collaboration with the World Health Organization, convened an international Workshop on Opportunities for Control of Dracunculiasis.* This workshop was organized by the BOSTID advisory committee on health, biomedical research, and development and was held June 16-19, 1982, in Washington, D.C. Financial support from the Office of the Science Advisor, U.S. Agency for International Development, made the workshop possible.

The papers contained in this volume were prepared by participants in the workshop, and were either presented at the gathering or served as background documents for its deliberations. They describe the following aspects of dracunculiasis: parasite life cycle and clinicopathology, epidemiology, control methods, control programs, and social and economic aspects of the disease. Each paper was edited by a consultant to BOSTID.

A bibliography that lists the known literature on dracunculiasis is being published simultaneously with this collection of papers. It was kindly furnished by Dr. Ralph Muller, director of the Commonwealth Institute of Parasitology, Great Britain.

Approximately 30 experts in parasitic diseases, vector biology, epidemiology, communicable disease control, health education, and sanitary engineering took part in the dracunculiasis workshop. Participants included two WHO staff members from Geneva and one from the WHO regional office in Brazzaville, Congo Republic, a representative from the Organisation Centrale contre les Grandes Endémies (OCCGE) based in the Ivory Coast, and nationals from Ghana, India, Nigeria, France, Togo, Great Britain, and the United States.

At the workshop, these participants were asked to:

- o Review current knowledge of dracunculiasis--its epidemiology, surveillance, control, and economic impact
- o Assess the economic, social, and administrative feasibility of mounting dracunculiasis control efforts in conjunction with primary health care and water and sanitation projects

*See: National Research Council, 1983. Opportunities for Control of Dracunculiasis: Report of a Workshop. National Academy Press, Washington, D.C.

- o Review alternative methods for control, with special emphasis on their cost-effectiveness
- o Identify basic, field, and operational research needed to develop, implement, and evaluate control activities.

The published Report of the Workshop and these Contributed Papers have accomplished these objectives. They demonstrate the basis for the broader objective of eliminating dracunculiasis as a public health problem, through intensified campaigns in endemic areas. This objective can be achieved, just as health organizations and governments worked together during the past decade to achieve a world free of smallpox. In every age, our concepts of health grows broader. In every age, we uncover a formerly unrecognized form of oppression that can be prevented. Now is the time to dedicate our energies toward the liberation of mankind from the suffering caused by dracunculiasis, thereby contributing to nobler and more fulfilling lives for all.

Myron G. Schultz
Workshop Chairman

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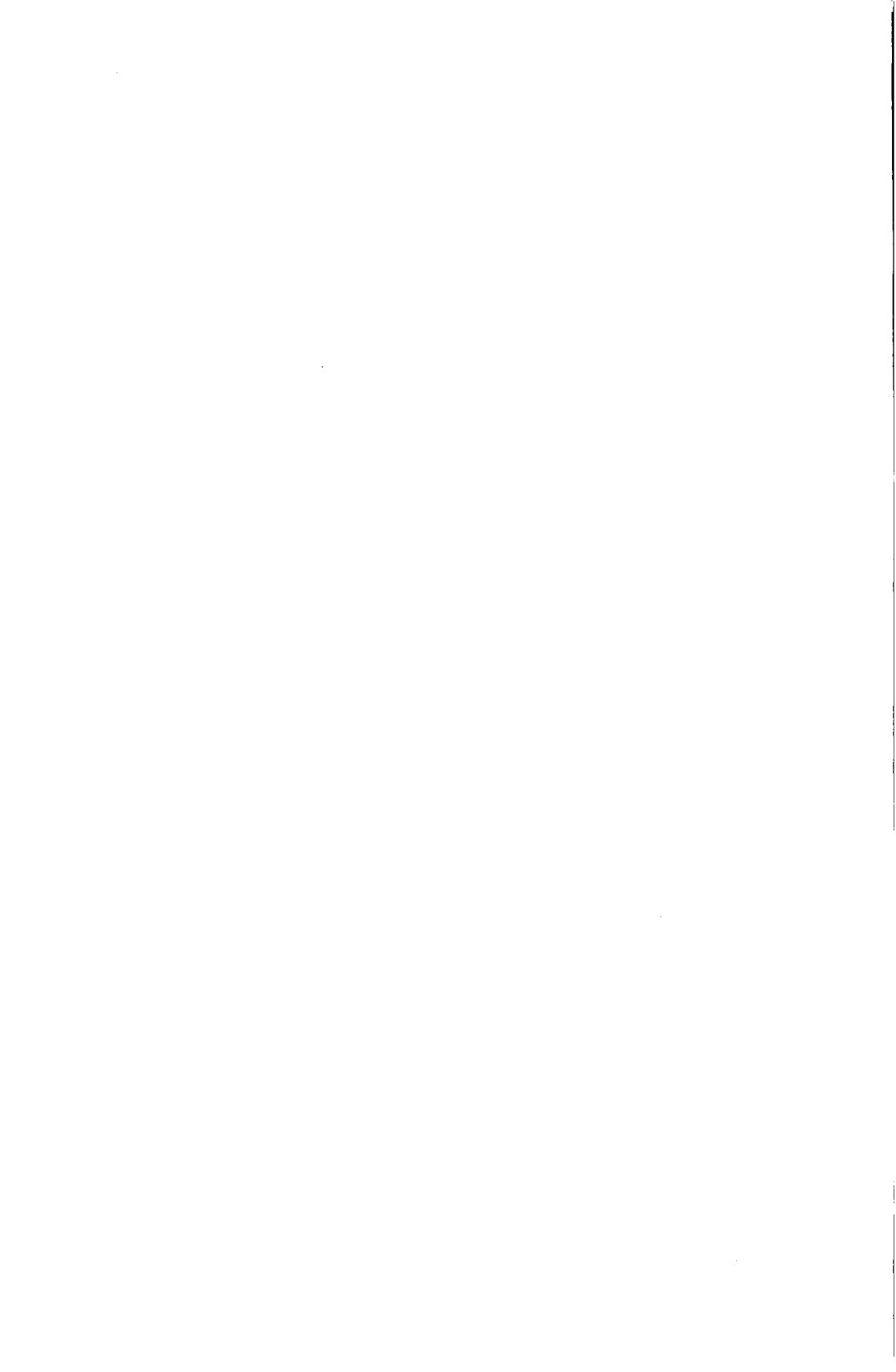
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OVERVIEW



OPPORTUNITIES FOR CONTROL OF DRACUNCULIASIS: TRANSMISSION AND EPIDEMIOLOGY

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Dracunculiasis (also known as guinea worm disease or dracontiasis) is a parasitic disease that develops in humans who drink water containing a macroscopic crustacean (Cyclops, a water flea) that has been infected by the larvae of Dracunculus medinensis. This disease is scattered throughout the rural communities of India and Pakistan,¹ the Middle East,² and parts of Africa,³⁻⁷ where it is estimated that 10-48 million cases occur annually, affecting 1-6 percent of the total rural population.⁸

The actual number of dracunculiasis cases occurring per year is unknown because official statistics grossly underestimate the extent of the problem. Dracunculiasis is not a notifiable disease in endemic areas. Because most patients are from rural areas, they are likely to have poor access to clinics and to prefer traditional treatment methods.

Diagnosis of dracunculiasis is made on the basis of a unique clinical presentation--a long, string-like worm protruding from a shallow skin ulcer, usually found on the lower leg. This condition is well known to residents of endemic areas, and information about its occurrence can be collected in retrospective surveys. Cryptic forms of the disease are less readily identified in surveys,⁹ and microscopic examination for larvae is impractical under field conditions.

In endemic areas, dracunculiasis is a major health problem because it incapacitates many farmers,³ with periods of total disability usually ranging from 6 weeks to 3 months.⁴ Because the peak case rates often coincide with the major agricultural activities of clearing land and planting or harvesting, this disease is a major cause of agricultural work loss in many areas.

Since dracunculiasis is transmitted entirely by contaminated drinking water, the disease can be completely eliminated by the provision of safe water supplies. Its control or elimination will be an indicator of progress

for the International Drinking Water Supply and Sanitation Decade of the 1980s.⁸

TRANSMISSION CYCLE AND POTENTIAL FOR ERADICATION

Humans become infected with this disease when they drink unfiltered water containing cyclops infected with D. medinensis larvae. After ingestion, the cyclops are digested and killed by gastric juices in the stomach and the larvae are freed to penetrate the intestinal wall. The male and female worms mate about 3 months after ingestion. The male worms then die at about 6 months of age and are absorbed or encysted. The gravid female worms live in the connective tissue. At about 8 months, the female worms usually move down to the lower limbs. Ten to 14 months after initial infection, the female worm, ready to emerge and reproduce, secretes a toxic substance that eventually produces a painful ulcer. When the ulcer through which the gravid female is protruding is exposed to water, the larvae are released, thus renewing the entire cycle.

Dracunculiasis occurs in areas where surface water temperatures are above 19°C, a requirement for complete development of the larvae in the cyclops. Because Dracunculus larvae do not possess a boring apparatus, only large predatory cyclops strains that can ingest larvae become infected. These types, which occur in West Africa, the Middle East, and India, propagate best in stagnant surface water. Thus, communities that depend on ponds, cisterns (Iran), and stepwells (India) for drinking water have the greatest risk of infection. Water becomes contaminated when individuals with guinea worm infections wade in to obtain water or bathe their ulcers to relieve pain.

Infection with Dracunculus does not confer immunity, and there is no effective treatment or prophylaxis.^{10,11} Residents in endemic areas are reinfected year after year. Case rates show a marked seasonal recurrence because of the availability of water with infected cyclops and because the female worm requires approximately 1 year to mature and release larvae in the water that will lead to the following year's infection.⁵

Because the transmission of dracunculiasis is well understood, the cycle may be interrupted at several points, making the disease itself potentially eradicable. Several features of the disease are helpful in its control. First, endemic foci are well demarcated and control efforts can be directed at specific geographic sites rather than a large geographic area. Second, infection of humans with contaminated drinking water often occurs

at a specific time of year, particularly during the middle or late dry season. This peak in case rates is related to a lack of alternative water sources during the dry season, consumption of large quantities of contaminated surface water, and denser concentrations of infected cyclops. Finally, because of the pain and disability caused by dracunculiasis, victims and their communities are most willing to cooperate with programs designed to eliminate this problem.

In Ghana, dracunculiasis transmission has been interrupted both by piping safe water and by treating surface ponds with the larvicide temephos (Abate). A recent history of health services in Ghana¹² describes dracunculiasis as being commonplace in Accra, the capital city, until piped water was made available in the early 1900s. By 1930, the dracunculiasis cycle had been interrupted in several rural villages because of the introduction of safe water. In northern Ghana, however, dracunculiasis remains a major public health problem. In 1955, there were an estimated 100,000 annual cases out of a population of 800,000, and in the early 1970s, dracunculiasis transmission was finally interrupted in one village when the drinking water pond was treated with Abate.⁶

CONTROL STRATEGIES

Control strategies for dracunculiasis must consider:

- o The geographical areas most affected
- o The transmission season in the different endemic areas
- o The population groups at greatest risk of acquiring dracunculiasis
- o The reliability of the available information and any means of improving baseline and monitoring (i.e., surveillance) information
- o The research needed to answer behavioral, epidemiologic, and operational questions.

Geographic Distribution

West Africa, Ethiopia, the Nile Valley, Saudi Arabia, Iran and the Middle East, and Pakistan and India are endemic areas for dracunculiasis because water supplies are poor, the appropriate cyclops species are present, and the water temperature is above 19°C. Previous foci in the West Indies and northeastern South America are no longer active because of improved economic conditions

and better water supplies.¹ In some communities where dracunculiasis had not occurred previously, travelers or immigrants from endemic areas are introducing the disease.³

Seasonality

Water sources in tropical areas vary with the season. During the rainy season, which lasts 2-3 months, surface ponds fill and overflow into small streams. Villagers collect roof water in barrels and water pots. During the dry season, however, these sources are expended and shallow surface ponds are used. By the end of the dry season, the volume of pond water becomes quite low, so that the density of cyclops is increased. Seasonal rains interrupt the transmission of dracunculiasis because the increased water volume and turbidity act to reduce the density of cyclops. Rainfall characteristics are important indicators of the likely transmission periods.⁵ In areas where wells or cisterns are used, cyclops tend to persist in larger numbers and transmission periods may be longer.

The natural or artificial ponds used as sources of drinking water in the savannah areas of Africa and in the Sind Desert area of Pakistan also provide centers for transmission. In areas with an average rainfall of less than 65 cm concentrated into 3-4 months of the year (e.g., Chad, northern Ghana, Niger, northern Nigeria, Senegal, Sudan, Uganda, Upper Volta), water is obtained from safe bored wells for most of the year when the ponds are dry. Thus the maximum incidence of infection occurs during and after the end of the rainy season, particularly when water levels become low in the ponds. Infection is markedly seasonal in these areas, and patent guinea worm disease is confined to less than 5 months of the year, peaking during the harvesting season at the end of the rains. In savannah areas of Africa with an annual rainfall of more than 150 cm, as in southern Ghana, the Ivory Coast, southern Nigeria, and Togo, ponds contain water all year round and infection may be apparent in humans for up to 8 months of the year. Even here, however, most cases of dracunculiasis occur in the latter half of the dry season and extend to the main planting season after the early rains. There are few cases during the rainy season because there is considerable surface water.

When drawwells are used as the only source of water, transmission of guinea worm is not commonly found. Stepwells, however, which provide the main source of drinking water in many rural areas of India, are ideally suited

for Dracunculus transmission. The steps that lead down into the water permit immersion of the affected limbs of those dipping a water container into the well. These areas of India have a transmission pattern similar to that found in the humid areas of West Africa. Peak transmission occurs toward the end of the dry season before the major rains in June or July.

In southern Iran where large covered cisterns are used, the water rarely dries up completely. Dracunculiasis occurs principally when the cisterns are half full, and it is absent for the 2 months before the rains begin. There is little transmission of dracunculiasis during the rainy season when the cisterns are full. While field studies should be conducted to characterize local transmission patterns,¹³ information about overall rainfall patterns and usual water sources during the dry season can be used to time drinking water treatment programs.

Population Groups at High Risk

In southern Ghana, the peak infection rates of adult male farmers probably result from their heavy seasonal farming activities and their increased consumption of contaminated water.³ In communities that use a common source of water, females are infected as often as males. Infants and toddlers are rarely infected because they are breast-fed.

Information Requirements

Available reports do not give a clear picture of the extent of dracunculiasis. A review of the reports published over the past 10 years about dracunculiasis revealed over 40 that dealt with case reports or drug trials, six special studies largely involving investigation of a specific area for just a 1-year period, and only one article that showed an effort to develop a continuing, periodic surveillance to provide accurate baseline data about dracunculiasis.¹⁴ Official statistics based on ambulatory diagnostic registers or hospitalization information markedly underreport the actual incidence of dracunculiasis. In one population survey, less than 1 percent of villagers experiencing dracunculiasis attended a clinic for treatment.³ Although dracunculiasis tends to occur in rural areas that lack protected water supplies, underreporting also persists even when numerous cases occur in communities adjacent to large cities.

Several factors may make surveillance difficult, such as a lack of established surveillance policy or procedures or inadequate resources to initiate and maintain a surveillance program.¹⁵ A standardized data base is also important to allow comparison between different regions of a country.¹⁶

The potential users of surveillance information should help plan the information requirements, which may require coordination between the various government ministries involved. A helpful classification of the level of surveillance feasible in a given setting and the appropriate activities has been described in a monograph published by the World Health Organization.¹⁵

In October 1979, a program to eradicate dracunculiasis in India was initiated with the collection of baseline data. Questionnaires were sent to directors of health services in all states and union territories to determine the extent of this infection. The first estimate tentatively identified 726 villages or hamlets comprising a population of 1.8 million. To confirm this information, paramedical survey workers then visited each village in the endemic states and union territories, where they found the disease to be more extensively distributed than the questionnaires had indicated. More than 7,500 villages or hamlets with a population of 5.9 million were revealed to be affected by dracunculiasis.

India is planning to take several steps in this program to eradicate dracunculiasis, including: (1) continued, semiannual monitoring of all affected areas; (2) surveying water sources to determine priorities for providing improvements; (3) educating communities about the hazards of unsafe water sources, mode of transmission of dracunculiasis, and personal hygiene necessary to prevent and control the disease; and (4) training health officers and distributing an operational manual on eradication of guinea worm disease. With this strategy it is hoped that this disease can be eliminated in India by December 1985.¹⁷

Research Agenda

The answers to a number of questions would allow the educational, operational, and surveillance components of a dracunculiasis control program to become more effective. At the individual or community level, research is needed to clarify the relationships among water-related behavior,¹⁸ perceptions about causation and personal susceptibility,¹⁹ and exposure risk²⁰ to dracunculiasis transmission. Such information will facilitate the design of health education programs that enable residents

to avoid water contamination or use field water treatment techniques. The current level of dracunculiasis awareness is another issue. For example, less than 5 percent of western Nigerian farmers described dracunculiasis as a problem related to contaminated drinking water.²¹ Health education activities could also be directed more effectively if it were known who is transmitting dracunculiasis (i.e., affected resident adults or children, travelers, or recent immigrants).

The popular concept of community self-help, particularly in rural areas, may be oversimplified and may divert program attention away from administrative and political realities.²² For example, information about the impact of dracunculiasis on agricultural productivity and crop losses would encourage governments to make dracunculiasis control a higher priority and would assist the responsible ministries in setting program goals.

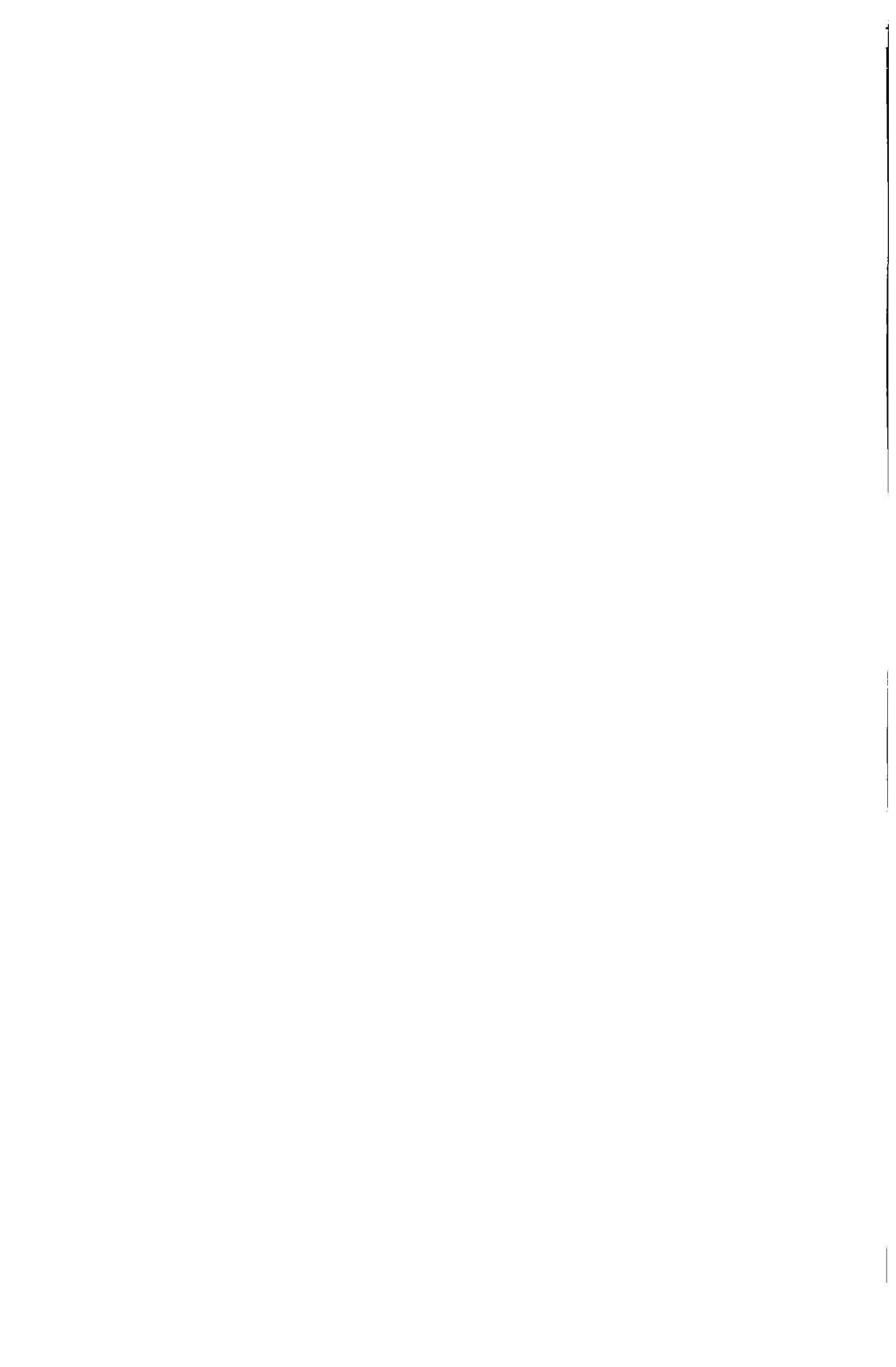
Pilot program research is needed to clarify which control approach will yield the greatest health benefits.²³ Epidemiologic information about the location of endemic foci and the seasonality of transmission are basic requirements for allocating overall program resources to achieve efficient coverage and timing objectives. For example, the addition of an organophosphorus larvicide effective against cyclops (temephos at a concentration of 0.5-1.0 mg/liter) to pond water at 4-week intervals during the transmission season can interrupt the dracunculiasis cycle.⁵ Potential disease areas (i.e., drinking water sources and water-related behavior make the community at risk) should also be identified and monitored periodically to recognize newly introduced dracunculiasis.

More effective information systems are clearly needed to provide ongoing epidemiologic information as a basis for planning and periodically monitoring the results of dracunculiasis programs. The available patient-related statistics are inaccurate because affected persons rarely seek care at clinics. Furthermore, official statistics based on passive data collection often show unexplained rate variations or missing data.²⁴ Continuing data collection to determine disease trends, outbreaks, and control program impact requires significant administrative, manpower, and other resources, as well as community cooperation in providing information. Based upon the setting and available resources, different intensities of surveillance and related resource requirements can be planned.¹⁵ The promising two-phase data collection program used in India and just described is yielding valuable information.¹⁴ If baseline data about current dracunculiasis transmission areas were available, control program resources could be applied more efficiently.

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PARASITE LIFE CYCLE AND CLINICO-PATHOLOGY



LIFE CYCLE OF DRACUNCULUS MEDINENSIS

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The seemingly rather bizarre life cycle of the guinea worm, Dracunculus medinensis, is actually very well adapted for transmission of a parasite that utilizes an aquatic intermediate host and that occurs principally in arid or semiarid environments.

The mature female worm is about 70 cm long and 0.2 cm wide and lives in the subcutaneous connective tissue of the human host. When ready to emerge, the anterior end of the worm provokes the formation of a painful burning blister in the human skin. The blister bursts, usually after immersion of the affected portion of the body in water, and the worm is exposed in a shallow ulcer. Following rupture, numerous first-stage larvae are forcibly expelled into the water in a milky stream by the contraction of the muscles of the worm and of the host. Estimates of the number of larvae contained in the uterus of a single worm range from 1.4 to 3 million. Not all of the larvae are released at once, and the anterior portion of the worm becomes flaccid and dries up after removal from the water. When the host enters water again, more larvae are released through the broken end of the worm; this process can be repeated a number of times.

Few studies have been undertaken to ascertain how many times larvae can be released and over what period of time. In a study of five patients in Nigeria, this author found that an average of 0.5 million larvae were released upon first immersion in water, and that no larvae were expelled for more than a 2-week period thereafter. In an experimental infection in a rhesus monkey, about 104,000 larvae were released upon first emergence; 26,000 three days later; 10,000 the next day; and only 1,000 a week later.

The period of release of larvae could be important in controlling transmission of the disease. For instance, various benzimidazole drugs reportedly reduce inflammation as well as the time required for complete

emergence of worms from an average of 4-6 weeks to 2-3 weeks, although these drugs do not appear to affect the viability of the contained larvae.¹ The studies described above indicate that such treatment with drugs would not significantly reduce the number of larvae reaching water.

INFECTION OF CYCLOPS SPECIES

First-stage larvae are 640 μ m long by 13.4 μ m wide and have a long pointed tail; they remain active in pond water for up to a week. Experiments have shown, however, that they are not capable of infecting cyclops for longer than 5 days at 24°C. The larvae thrash actively in the water similarly to free-living aquatic nematodes and are ingested by carnivorous species of Cyclops. While six species of Cyclops have been found naturally infected in various parts of the world,² C. leuckarti and C. hyalinus are important species in all endemic areas, particularly in many habitats in India.³ At least another 10 species, however, are potential intermediate hosts, and some have been infected experimentally.

Once inside a cyclops, the larvae penetrate head first through the gut wall to the hemocoel in 1-6 hours, depending principally on the temperature. The larvae molt twice inside the cyclops and can reach the infective third stage in 14 days with a temperature above 21°C. Below 19°C, they do not appear capable of reaching the infective stage at all (Table 1).

TABLE 1. Number of Days Required for D. medinensis Larvae to Develop in Cyclops

Authority	Species of Cyclops	Temp. (°C)	First Molt	Second Molt	Infective Stage (Presumed)
Fairley & Liston (1924) ⁴	<u>C. leuckarti</u>	24	?	?	12-15
Moorthy (1938) ⁵	<u>C. leuckarti</u>	32	5-7	8-12	14-20
Onabamiro (1954) ⁶	<u>C. nigerianus</u>	25-27	5	9	12
Muller (1971) ²	<u>C. leuckarti</u>	19	-	-	-
		21-24	8	12	14
		25	6-8	8-10	14 ^a

^a Demonstrated by experimental infections; animals could not be infected at 9 or 12 days.

Cyclops often ingest many larvae, but this results in high mortality when the larvae molt. The great majority of naturally infected cyclops contain only one third-stage infective larva (in 1951, Onabamiro⁷ found that 12 percent contained two larvae). The third-stage larva is approximately 450 μ m long and 14 μ m wide and has a short bifid tail. All stages of cyclops can be infected, but the nauplii and copepodid stages are likely to have become adult by the time they contain infective larvae, although in some cases inhibition of development has been reported.

In the laboratory, Sharma and Wattal found that uninfected female C. leuckarti lived for a maximum of 158 days,⁸ while Muller found that infected cyclops lived for less than 50 days.⁹

Cyclops that contain third-stage larvae become sluggish and sink almost to the bottom of a pond or stepwell.⁶ This is usually given as a partial explanation for increased transmission of the disease in the dry season when water levels are low in endemic areas that have a high annual rainfall.

Although there have been no studies of the level of infection necessary in cyclops to maintain transmission, Moorthy and Sweet found 5 percent infection in C. leuckarti during the height of the transmission season in a stepwell in Karnataka State, India.¹⁰ Onabamiro has reported a similar figure for C. nigerianus in a pond in southwest Nigeria.⁷ To be meaningful, however, such studies must differentiate infective larvae in cyclops, and they must be carried out over a period of time because of the sporadic nature of larval input into the water and the high mortality of recently infected cyclops.

HUMAN INGESTION

When cyclops containing infective larvae are ingested in drinking water, they are killed in the stomach of the host. The contained larvae are activated and, in experimentally infected cats, freed larvae can be found in the lumen of the duodenum 4 hours after infection. Larvae are killed in 18 hours, however, by 0.05 percent HCl (maximum stomach acidity is about 0.22 percent HCl). This can be contrasted to Trichinella, a nematode whose larvae are ingested in meat, which can withstand 0.2 percent acid pepsin for 24 hours. This may mean that Dracunculus larvae must pass through the stomach quickly. High gastric acidity has also been given as a possible explanation for the disease resistance often found in some people using a contaminated water source, although

this has not been borne out by clinical investigations.^{11,12}

In experimental animals, larvae penetrate the duodenal wall by 13 hours after infection, are found migrating along the abdominal mesenteries by up to 12 days, and are present in the abdominal and thoracic muscle planes at about 15 days. The larvae do not grow during this period,¹³ but there is probably a molt between 15 and 21 days. The developing worms then migrate to the connective tissues of the axillary and inguinal regions, and mating occurs between 80 and 100 days after infection (R. Muller, unpublished data).^{14,15} The males usually then move deeper between the muscle fasciae, die after about 6 months, become encysted, and sometimes calcify. The females move down to the extremities, usually to the lower legs, between 8 and 10 months after infection. The uterus is filled with developing eggs by 8 months and with first-stage larvae by 10 months. The gut becomes flattened and nonfunctional, and the whole worm is filled by the uterus containing larvae.

The female worms become potent between 10 and 14 months after infection (in 1971, this author reported a mean of 340 days in nine experimentally infected rhesus monkeys),² although occasionally adult female worms have been reported from young babies. A number of female worms never reach the surface, becoming encysted and eventually calcified or they are absorbed. All such worms that this author has examined from monkeys have been unfertilized. Sita Devi and colleagues found that 29 percent of supposedly uninfected villagers from an endemic area showed the presence of worms in a roentgenogram.¹² In the older literature, it has sometimes been reported that female worms can occasionally survive in the body for 2 years but there is no good evidence for this.

ROLE OF RESERVOIR HOSTS

The role of reservoir hosts in the transmission of D. medinensis has not been clearly established. Infection has been reported from a wide range of mammals from many parts of the world,² but it is not always clear whether the worms belong to the same species (for instance, the widespread parasite of wild carnivores in North America has been named D. insignis, although there is little to distinguish it from D. medinensis) or whether the occasional animal cases reported in endemic areas, usually from dogs, are just isolated accidental infections from a human source.

While there is no evidence that dracunculiasis is a zoonotic infection or has ever been transmitted from an animal to man (apart, presumably, from the occasional human cases reported from the United States), the possibility that infection could be reintroduced into an area from which it has been eliminated provides additional support for the need to provide safe water supplies as the most satisfactory method of control or eradication.

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**CLINICAL AND THERAPEUTIC ASPECTS
OF DRACUNCULUS MEDINENSIS**

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CLINICAL PICTURE

Dracunculiasis (guinea worm disease) rarely occurs in humans before the age of four, after which the incidence steadily increases, to become highest in the young adult. The incidence is seasonal in many areas, especially in India. Infection with a single worm is usual, but multiple infection is not uncommon. There is no racial or other immunity, and reinfection is frequent, even in the already infected subjects.

The mature female worm is usually present in the connective tissues of the human limbs and trunk. In 90 percent of all cases, it most commonly presents itself on the surface of the body in the feet, ankles, and lower limbs, but it may also emerge from the trunk (especially the back in water carriers) and arms--rarely the head and neck. It has also been reported in the orbit. The worm may often be visible or palpable for its whole length in the subcutaneous tissue.

The worm does not give rise to clinical signs until near the point of discharge of larvae. The active stage of the infection is accompanied by both general and local signs and symptoms. A few hours before the appearance of the worm at the surface of the skin, some local erythema and tenderness may develop over the area in which the pointing will occur. In some cases there may be general effects, sometimes severe in nature, but for the majority the local lesion tends to develop without any general reaction.

In severe cases there may be generalized pruritus, sometimes accompanied by scattered urticaria. There may also be nausea, vomiting, and watery diarrhea. In some cases dyspnea may appear and lead to attacks resembling asthma. These general reactions vary greatly in intensity and incidence from patient to patient and locality to locality. They subside as a rule by the time the local lesion has ruptured and the ejection of larvae has commenced.

The adult female worm secretes a toxic substance which causes a local inflammatory lesion infiltrated with eosinophils, monocytes, and polymorphonuclear leucocytes. The patient usually complains of deep-seated, stinging pain in the site in which the worm is reaching the surface. A papule or group of papules (which later coalesce) forms rapidly and enlarges over the course of 1 or 2 days, becoming slowly more indurated. The central region becomes raised and eventually forms a vesicle that soon ruptures, leaving a superficial ulcer large enough to admit a probe. The head of the worm is often visible within this ulcer.

If the ulcerated lesion is douched with water, a drop of milky fluid wells up in a few seconds. After an interval of about an hour, further douching will have the same effect. This fluid contains a myriad of active larvae ejected from the uterus of the worm in response to the stimulus of water.

Discharge of larvae will continue intermittently whenever the affected part is exposed to water until the worm has discharged its full load of larvae, which may take up to 3 weeks. The tissues about the presenting head of the worm become indurated, edematous, reddened, and very tender. These reactions, which may involve wide areas around the worm, are probably allergic. Even in the absence of secondary infection, walking may be very difficult and the patient is compelled to give up work.

In the case not complicated by secondary infection, the local lesion will heal completely about 4-6 weeks after its appearance. Secondary infection is, however, the rule and may lead to serious and unpleasant complications.

It is possible that the mature female never reaches the surface of the body and is absorbed without a marked reaction on the part of the host; or calcification of the worm may occur and be detected on radiological examination.¹ It is, however, often the case that a secondary infection develops and leads to abscess formation so that the first indication of the infection may be the discovery of fragments of the worm in the abscess contents. Such secondary infections may involve deep structures, including tendons, the periosteum, and bones, and may be accompanied by severe or even fatal septicemia.

In some areas, a large proportion of patients (in parts of India, over 20 percent) suffer from joint lesions perhaps caused in some instances by a toxin liberated from the worm. These lesions vary from painful reddened swellings to advanced pyogenic infections followed by fixation and deformity. The majority of such lesions occur in the ankles and knees. The aspirated fluid is usually brownish in color and contains pus cells

and fragments of the worm; in the wall of the cavity a foreign body giant cell reaction is usual. In some cases the aspirated fluid is sterile, and at arthrotomy the entire adult worm is seen in the joint.² A coiled-up worm has also been observed in an abscess cavity in the pericardium, causing constrictive pericarditis.³ Changes in joints are believed to occur occasionally without secondary infection.

An eosinophilia may occur in the early stages of infection prior to the liberation of the embryos or with damage to the parasite. Paraplegia as well as quadriplegia due to an extradural abscess have also been described,^{4,5,6} as well as scrotal, vesical, and renal lesions.

TREATMENT

The patient should rest if possible with the affected part elevated. The local lesion must be kept as clean as possible and the secondary infection treated using conventional methods. A tetanus toxoid injection should be given when indicated.

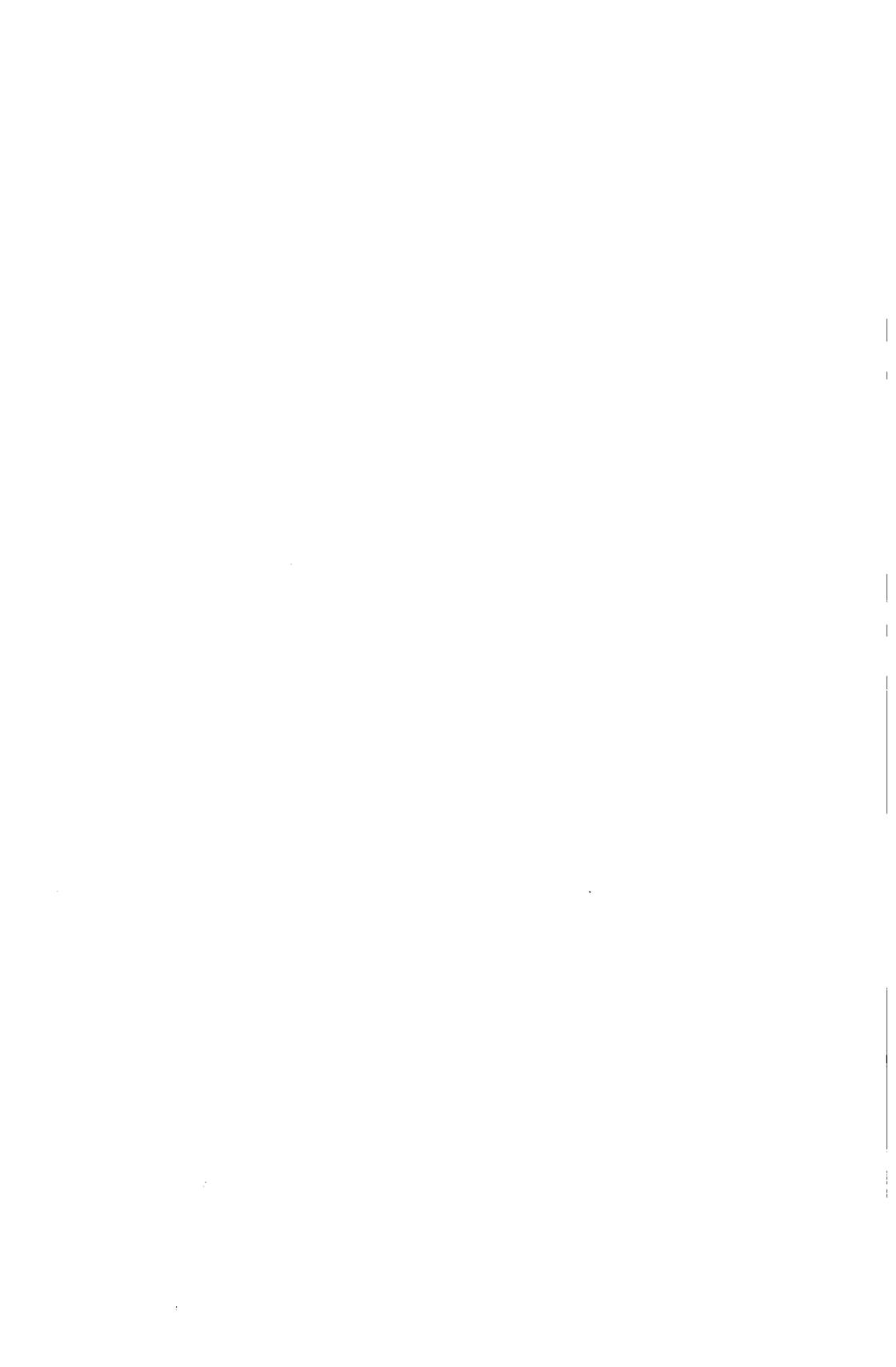
Niridazole, administered 25 mg/kg daily for 10 days, was found effective in a Nigerian study,⁷ but Kulkarni and Nagalotimath, in 160 randomly selected patients in India,⁸ and Belcher and colleagues,⁹ failed to show any beneficial effect using metronidazole or thiabendazole. Gaitonde and associates have assessed the comparative efficacy of levamisole, bitoscanate, and mebendazole.¹⁰ Unfortunately, none of the drugs seemed to have any effect on developing worms, while only mebendazole at a dosage of 100 mg twice a day for 7 days resulted in significant symptomatic improvement. The possible mode of action of a number of drugs on dracunculiasis has been reviewed by Muller.¹¹

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EPIDEMIOLOGY



EPIDEMIOLOGY OF DRACUNCULIASIS IN INDIA

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DISTRIBUTION

Dracunculiasis (guinea worm disease) has existed in India for the past several centuries. However, attention was first drawn to this disease as a public health problem by N. R. Stoll, who estimated in 1947 that 25 million people were living in endemic areas of India as opposed to 23 million in the rest of the world.¹ In 1955, based on questionnaires returned by the health services directors of each Indian state, Singh and Raghavan reported the occurrence of guinea worm disease in 11 states inhabited by about 5 million persons.² In 1967, Patnaik and Kapoor estimated, also based on reports received from the state health services directors, the existence of 12 endemic states with an average annual incidence of about 15 cases per 100,000 population.³

Recognizing that guinea worm disease could be eradicated with the existing resources, the National Institute of Communicable Diseases (NICD) set out in October 1979 to delimit the problem on the basis of questionnaires circulated to all directors of health services of the 31 states and union territories of India. These questionnaires were returned by the middle of 1980, and they revealed that seven states and one union territory had reported the presence of guinea worm cases between the years 1977 and 1979. Follow-up confirmation showed that 728 villages in 139 blocks of 47 districts in 7 states reported active guinea worm cases from 1977 onward,⁴ affecting a population of 1.8 million. All the reported cases from the Union Territory of Goa were later found to be imported from the State of Karnataka, and Goa was deleted from the list of endemic areas.

Subsequently, three active searches of every village or hamlet in the known endemic districts were organized for December 1980, May-June 1981, and October-November 1981 to estimate as accurately as possible the number of affected villages or hamlets. Each of these searches

added to the numbers. According to the latest available information, guinea worm disease is found in 80 districts spread over seven endemic states (Figure 1). The actual number of districts, villages, and population affected are given in Table 1. The states of Orissa, Uttar Pradesh, Punjab, West Bengal, and the Adaman and Nicobar Islands, which were reported endemic earlier by Patnaik and Kapoor,³ are free from the disease. These states are being reexamined, however, to exclude any guinea worm focus.

MEASUREMENT OF DISEASE FREQUENCY AND TRENDS

Measurement of the incidence of dracunculiasis remains important for its eradication. The short duration of the illness, the distribution of cases year-round, the ease of identifying cases, and a reliable history of the period of onset of the disease make incidence measurement convenient, provided that periodic visits are made to the affected communities.

Under the eradication program, two 1-week village searches for the total number of cases of guinea worm disease are planned annually. Further, all PHCs district primary health centers (PHCs) will be searched simultaneously in the same period each year.

The national estimates reported earlier¹⁻³ appear to be based on prevalence data. Special studies undertaken at different points in time to determine the annual incidence have not been evaluated to determine the degree of error. Data provided by medical institutions for this disease do not reflect its incidence as patients rarely seek treatment unless there are complications. However, these data as well as those collected through inquiries at fairs, festivals, schools, and markets can help cross-check the information collected by an active search to detect any affected village that may have been missed.

Review of the endemic areas and the extent of the population exposed to risk as reported in 1947,¹ 1955,² 1967,³ and 1979⁵ shows shrinkage in the extent of the affected areas. An analysis of reports on isolated investigations performed at different points in time also reveals a reduction in the intensity of infection.

Since the population has increased considerably during the last 30 years and the methods of collection of data vary, it is not possible to compare the earlier data with that collected later. A natural decline has been observed, however, in specific areas examined at different points in time. A study undertaken in 1964 in an endemic district revealed a reduction in the number of

TABLE 1 Guinea Worm Disease Endemicity in India as of March 31, 1982

State	Total			Affected				
	No. of Districts	No. of ^a PHCs	No. of Villages	Population (000s)	No. of Districts	No. of ^a PHCs	No. of Villages	Population (000s)
Andhra Pradesh	23	324	27,221	53,404	5	36	585	1,052
Gujarat	19	218	18,275	33,961	11	46	315	505
Karnataka	20	175	26,826	37,043	7	55	722	1,170
Madhya Pradesh	45	458	70,883	52,132	20	113	2,879	2,895
Maharashtra	26	296	35,778	62,694	11	85	932	686
Rajasthan	26	232	33,305	34,103	23	128	5,140	5,858
Tamil Nadu	15	374	15,735	48,297	3	5	9	10
TOTAL	174	2,077	228,023	321,634	80	468	10,582	12,176

^aPHCs = primary health centers.

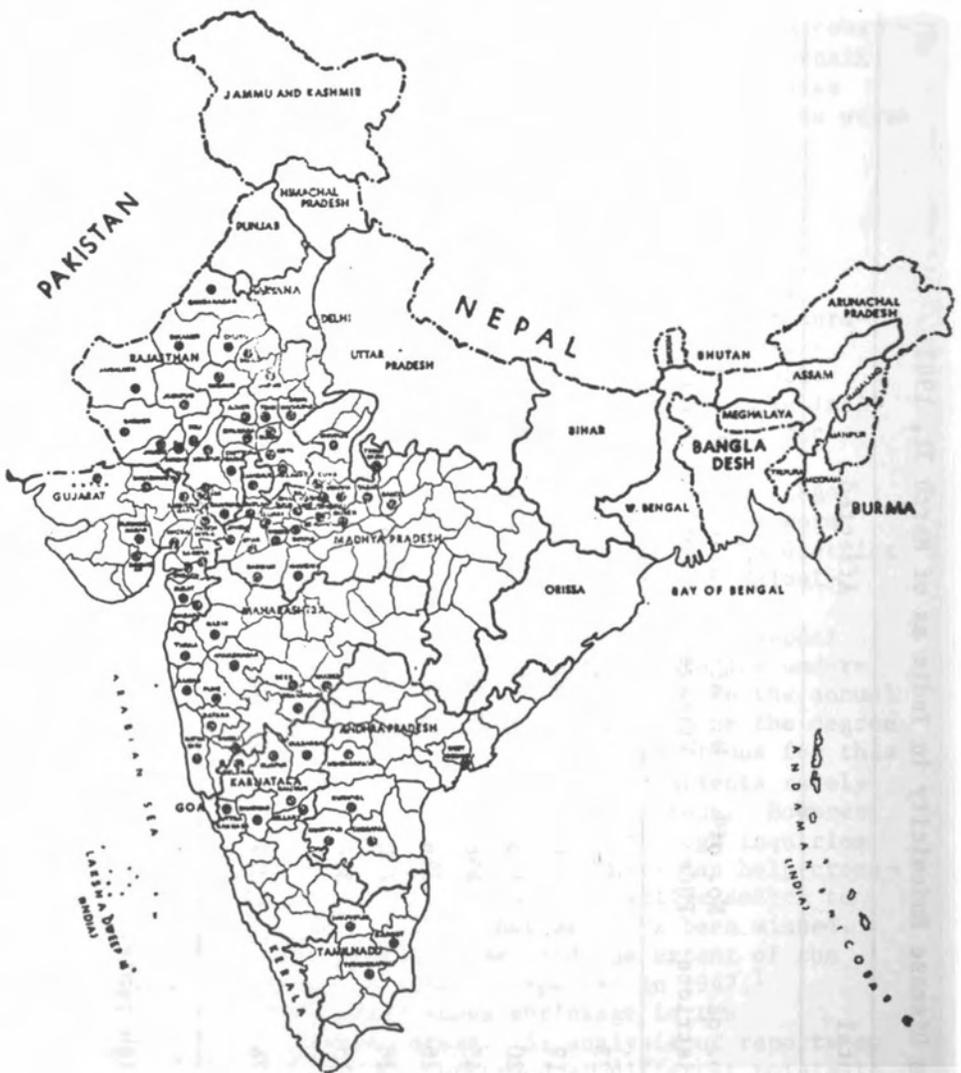


FIGURE 1 Endemicity of guinea worm disease, India, 1981.

guinea worm-affected villages when compared to earlier reports available from the district health office.⁶ Subsequent reexamination of these villages in 1978⁵ revealed a marked decline in incidence during the 15-year period, although no organized control measures were initiated and no additional safe water sources were installed. Health education on the relationship of guinea worm disease to consumption of tank water-- information passed on through the survey questionnaire-- apparently played a part. Provision of safe water through development activities during the last 35 years, and knowledge and practice of personal prophylaxis in some communities, have perhaps also contributed to the reduction in the numbers and intensities of infection.

SOURCES OF WATER SUPPLY

The consumption of drinking water from stepwells, tanks, or ponds is always associated with guinea worm disease, but the disease does not exist or spread when drawwells are the only source of water. For groups who must depend only on unsafe water sources, the incidence remains the highest.

In one NICD study, no correlation was observed between the relative proportion of available safe and unsafe water sources and incidence of the disease. In areas with both safe and unsafe water sources, it has been reported that people consuming water from safe sources also come down with the disease, although the incidence is less. Such people are exposed to unsafe water away from their homes.

In one of the searches in Madhya Pradesh, 71 villages or hamlets with only safe water sources reported cases of dracunculiasis. An epidemiological investigation of such a situation will be undertaken in the future to determine whether these cases were indigenous or imported. It is very unlikely that spread of disease occurs in villages with only safe water sources.

Marked seasonality is characteristic of this disease in all the affected areas. Areas with tanks or ponds as drinking water sources have, however, more marked seasonality, with peak transmission times in the summer months of April, May, and June.^{2,5,6,7} In areas using stepwells as water sources, cases occur year-round, although the summer peak is clearly observed. The seasonality is associated with the yearly exposure to unsafe sources because safe sources dry up, consumption of a larger quantity of water, and greater density of the crustacean cyclops (vector for this disease) per unit of water due to low water levels in tanks and shallow water in ponds.

Both sexes and all stages of cyclops (water fleas) act as the vectors for this disease. Only development—no multiplication—of the parasite occurs in cyclops. Some species of cyclops encountered in India include Mesocyclops leuckarti, Mesocyclops hyalinus, Eucyclops agilis, Tropocyclops prasinus, Ectocyclops phaleratus, and Paracyclops fimbriatus.⁸ There is no difference in the distribution of species or densities between the guinea worm endemic states and those free from guinea worm disease.

PATHOLOGY

Guinea worm disease is nonfatal except when the rare complication of tetanus occurs. Disability persists, however, from the time of blister formation until expulsion of the worm—an average of 4-6 weeks. In some instances, complete emergence of the worm takes as long as 6 months. Less than 1 percent of the cases end in permanent disability.

In 95 percent of the cases, the worm emerges around or below the ankle.⁶ Usually two to three worms emerge from an affected individual in a season, although the emergence of 7-10 worms has been reported. Worms are expelled more often consecutively than concurrently. In one study, only one out of 10 patients had a single worm in a year.⁶ The number of worms and their time of emergence are related to the intensity of infected cyclops and the duration of their presence in the water sources.

ECONOMIC LOSS FROM DRACUNCULIASIS

Dracunculiasis most frequently affects adult men of the rural poor during the summer months when intensive agricultural activities are under way. Children below age 2 remain free of the disease, and the incidence is usually very low in toddlers.⁶ Incidence increases with age and reaches a plateau beyond 35 years.^{5,6,7}

An estimated 12.2 million people live in endemic villages in India. Based on the available data, at least 4 percent of the endemic population is estimated to suffer annually from guinea worm disease. Since only 34.5 percent of the rural population is economically active⁹ and wages for about 70 days are lost due to disability every year, it is estimated that the 488,000 cases of guinea worm disease occurring annually (4 percent of 12.2 million), of which 168,360 of the affected are economically active (34.5 percent), result in the loss of about 11.7 million man-days annually in India.

RESERVOIRS

Humans appear to be the only reservoir of this infection. Natural infections in cats and dogs in the affected villages are observed occasionally, but regretably, no follow-up of these animals has been made. Experimentally, dogs and cats have been infected with Dracunculiasis medinensis. The absence of reports about the occurrence of natural infection in animals from areas where the disease has disappeared during the last 20 years and the failure of this disease to reappear in communities freed from this disease suggest that animals have no role in its spread to humans.

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EPIDEMIOLOGY OF DRACUNCULIASIS IN NIGERIA

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INTRODUCTION

This paper is based on data derived from (1) articles published in scientific journals, and (2) information extracted from a brief questionnaire posted in 1982 throughout the 19 states of the Nigerian federation.

Apart from an isolated report by Ramsay¹ in 1935 in which he conducted field trials of an intradermal test for the diagnosis of dracunculiasis (guinea worm disease) in northern Nigeria, all other epidemiological surveys reported in the medical literature have been conducted in the southwestern part of the country. This can be attributed to two factors. First, the disease appears to be more prevalent in southwestern Nigeria, which is largely in the rain forest belt, than in any other part of the country, apart from a "hyperendemic" zone in the Abakaliki district of Anambra State in eastern Nigeria. Second, systematic disease surveillance is more likely to originate from centers of higher learning staffed with scientists who have the expertise and motivation that impel them to publish their findings in scientific journals, and such higher educational institutions are concentrated in southern Nigeria. Ibadan University, from which over 90 percent of all published works have emanated, is not only the chief university but is also situated in the middle of a guinea worm disease endemic area.

The questionnaire mailed in March 1982 was designed primarily to determine the extent of dracunculiasis and its seasonality throughout the country rather than its intensity. A total of 538 questionnaires were sent to (1) all the chief health officers and heads of epidemiological units in all the ministries of health of the 19 states of the federation; (2) all doctors (post-internship) undergoing the compulsory 1-year national youth service (NYSC) and deployed to the 19 states of the federation; (3) all the residency (post-NYSC) doctors undergoing specialist training at the University College

Hospital (UCH), Ibadan; and (4) all the graduates and diplomates of the African Regional Health Education Centre of the Department of Preventive and Social Medicine, UCH, who have returned to their home states.

The response to the questionnaire has been very encouraging and many useful data on the geographical distribution of dracunculiasis have been obtained. At the time of writing this paper, returns have been received from all 19 states and completed questionnaires continue to arrive daily.

EPIDEMIOLOGY

Geographical Distribution

Dracunculiasis has been reported in 18 of Nigeria's 19 states: Anambra, Bauchi, Bendel, Benue, Borno, Cross River, Gongola, Imo, Kaduna, Kano, Kwara, Niger, Ogun, Ondo, Oyo, Plateau, Rivers, and Sokoto. The only state that is apparently free from the disease is Lagos (location of the capital city Lagos), which is tucked away in the extreme southwestern corner of Nigeria.

A more detailed breakdown of the distribution of guinea worm disease by local government areas is not possible presently, although it can be affirmed that the disease is endemic in all the 24 local government areas of Oyo State which has been extensively surveyed over the years.

Using data obtained from the questionnaire, Nigeria's 19 states can be broadly divided into the following groups on the basis of estimated prevalence: high--Anambra, Ondo, and Oyo; medium--Imo, Kaduna, Kwara, Ogun, and Sokoto; low--Bendel, Benue, Borno, Gongola, Kano, Niger, Plateau; occasional--Bauchi, Cross River, and Rivers; nonexistent--Lagos. This grouping is, however, very tentative and subject to modification that subsequent specific surveys might reveal.

Effect of Climate and Water Sources on Incidence

Climatic Factors

In considering the effect of climate on incidence, three fairly distinct but overlapping climatic belts can be recognized:

1. The rain forest belt, including the swamp forest strip, extends from the Atlantic coast to a point approximately 8°N in the west and 7°N in the

east, and embraces most or all of the Anambra, Bendel, Cross River, Imo, Lagos, Ogun, Ondo, Oyo, and Rivers states.

2. The guinea-savanna (middle) belt extends from the northern edge of the rain forest belt to a point roughly corresponding to latitude 10°N and embraces most or all of the Benue, Gongola, Kwara, Niger, and Plateau states and the southern half of Kaduna State.
3. The sudan-savanna (sub-Sahelian) belt extends from the northern edge of the guinea-savanna region to the northern border of Nigeria roughly on latitude 13.5°N, and embraces most or all of the Bauchi, Borno, northern Kaduna, Kano, and Sokoto states.

Reliable epidemiological data on the seasonal incidence of the disease are available only in connection with the rain forest zone, and Oyo State in particular, where the peak incidence is between October and March.^{2,3} This period coincides with the dry season when the water level in ponds, which are mostly perennial, is at its lowest (Figure 1). Data obtained thus far on the guinea-savanna and sudan-savanna regions from the questionnaire survey indicate that most cases of the disease are seen between the months of November and July and between May and October, respectively. These periods coincide, in the two climatic zones, with the rainy season when water is available in seasonal ponds. Almost year-round, the occurrence of infection in the middle belt zone is in keeping with the mixed or transitional nature of the climatic conditions, which is between the two extremes of the tropical rain forest and the sub-Sahelian region.

There is a close correlation between the incidence of dracunculiasis in a community in a given year and the amount of rainfall in the preceeding year. In the rain forest belt, heavy, prolonged precipitation in one year, resulting in a relative abundance of surface water, often presages a lower incidence of infection in the following season. In contrast, a prolonged period of drought is often accompanied by increased transmission and a higher incidence of infection in the following season. The same dynamics of transmission, but the other way, would be expected in the more arid savanna regions.

Water Sources

Transmission of infection is almost exclusively confined to rural populations that depend on surface water

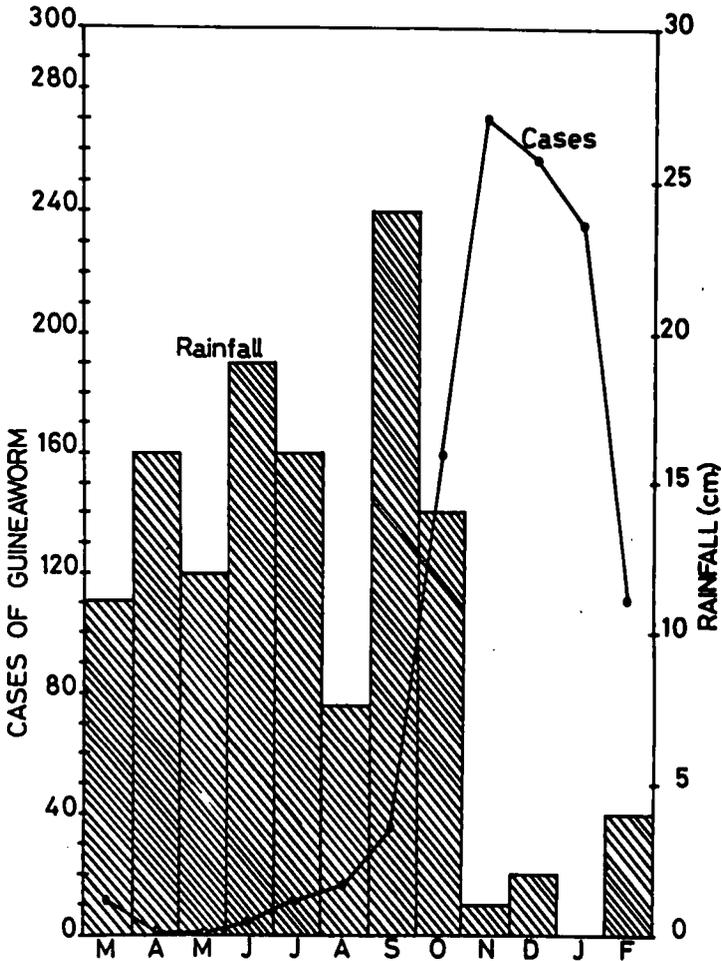


FIGURE 1 Monthly variation in the incidence of guinea worm disease in the Ibadan area (1971-1975) according to the average rainfall (1970-1974). Source: O. O. Kale.² Reproduced with the permission of the American Journal of Tropical Medicine and Hygiene.

as their main and often only source of a domestic water supply. Sources of water can take the form of hand-dug water holes, ponds, sluggish brooks, and streams that flow seasonally, as well as in a few cases sanitary open shallow wells.² All these water sources have one thing in common: to obtain water, one must wade into the water or, in the case of shallow wells, one can easily contaminate the water source. There are no stepwells or

ground-level water "tanks" for the collection of rain-water as are seen in India. Communities or households that can collect and store sufficient rainwater during the rainy season to see them through the worst part of the dry season have substantially reduced risks of exposure to infection.

Since the freshwater crustacean cyclops is an obligatory intermediate host in the life cycle of Dracunculus medinensis, it must be assumed that all bodies of water from which infection is acquired by humans contain these crustaceans. The available records show, however, that this crustacean has only been sought and examined in the southwestern parts of Nigeria.³⁻⁷

Communities that have access to a regularly treated municipal water supply, such as most urban centers, or to sanitary wells and bore holes, or that live near a large river that flows year-round are free of infection. The provision of piped water and sanitary wells to communities where the disease has been hitherto highly endemic has resulted in total interruption of transmission and eradication of the disease. It must be emphasized, however, that unless the supply of water is regular, the infection may reoccur. The following case illustrates this point.

In 1965, piped water was introduced into the Ibarapa district, including the most populous town in the district, Igboora (population about 25,000), as well as the neighboring town of Idere (population about 7,000), some 12 km east of Igboora. Within 2 years, the incidence of guinea worm disease in Igboora, which had an annual average incidence rate of 13 percent, had diminished virtually to zero. The few cases that occurred after 1967 were found among farmers who drank water from infected ponds located on their farms while at work. A few cases also resulted from consumption of infected surface water in neighboring villages.

In Idere the picture was quite different. Although communal standpipes were located throughout the town, water seldom flowed at any time of the year from those taps that were in the northern half of the town which was at a higher elevation. Thus after 1968, there was a sharp geographical delineation in the town's distribution of dracunculiasis cases; incidence in the southern half of town was virtually nil, while a high incidence (34 percent in 1975) was recorded every year in the northern half where people continued to depend on traditional sources--ponds and water holes--for drinking water.⁸

This pattern continued until 1979 when an almost total cessation in pumping piped water to the entire town

the preceding year resulted in a sharp increase in overall incidence throughout the town. It reached epidemic proportions in 1980 and 1981, with as many as 42 percent of the population being afflicted in the latter year.

The increased demand for water in Igboora, which received electricity in 1978, coupled with the grossly sporadic and less efficient pumping of water from the waterworks at Eruwa, located about 20 km south of Igboora, effectively deprived the town of Idere, further down the distribution line, of the little piped water it had been receiving. Thus the mere provision of municipal standpipes without an adequate supply of water is not a guarantee against infection. Similarly, unless the populace, particularly the farmers, can be persuaded to carry potable water obtained from the city with them to their farms, dracunculiasis will persist in the community.

In all other towns and villages in the Ibarapa district such as Igangan, Tapa, and Aiyete, to which piped water was not extended, the annual incidence of disease has remained at the pre-1965 level.

A dramatic reduction in the incidence of infection in 16 out of 17 villages in the Ibadan district of Oyo State has also been reported following periodic yearly treatment of infected cases.⁷ This reduction has been attributed to a shorter duration of infection and reduced contamination of water sources by infected persons consequent to treatment. Infective skin lesions have been bandaged and kept out of drinking water to prevent its pollution. The persistence of cyclops in water that villages draw for drinking purposes means, however, that a resurgence of transmission could occur if "imported" cases with active lesions gain direct bodily access to the pools of water. In other words, these villages are "guinea worm receptive areas," since the conditions for resumed transmission persist.

Transmission of Infection

The most extensive and detailed studies on the transmission of dracunculiasis in Nigeria were conducted in the late forties and early fifties by Onabamiro,^{3,4} who identified the various species of cyclops that acted as natural intermediate hosts of D. medinensis. Onabamiro's studies showed that in the town of Iwogye, in what is now Ogun State in the rain forest belt of Nigeria:

- o Transmission of infection occurred only in the dry season.

- o Of the eight species of "carnivorous" cyclops found to be naturally infected with D. medinensis, only the female Thermocyclops nigerianus (Keifer), the density of which was highest in the dry season, was responsible for transmission of infection to the populace.
- o No Th. nigerianus were found in pools containing waterlilies and substantial green algae.
- o The infection rate of Th. nigerianus at the height of the dry season was 5.1 percent.
- o The greatest density of infected cyclops was found in the shallow end of the pond where villagers waded in to draw water.
- o There were an average of 152 cyclops and an average of 9.5 D. medinensis larvae in every 5 liters of water at the water-drawing spot.
- o In a typical guinea worm zone in southwestern Nigeria, the average man swallows in 1 year between 72 and 200 infected cyclops with the pond water he drinks.

Reservoir of Infection

Man is the only known natural reservoir of D. medinensis infection in Nigeria. The role, if any, of vertebrate animals in the transmission of infection has not been studied in Nigeria and is not known.

Frequency of Infection in the Human Host

The overwhelming majority of the adult males in guinea worm endemic parts of Nigeria are hoe and cutlass farmers. Women participate in such varied occupations as farming, petty trading, and processing farm products into marketable forms.²

The age and sex distribution of persons infected with guinea worm among a study population of 8,200 from 17 villages north of Ibadan between 1971 and 1975² is shown in Table 1 and the age- and sex-specific attack rates are illustrated in Figure 2. The overall prevalence was 13.5 percent with a range of 4.0-32.8 percent. The highest incidence in both sexes occurred in the 40-49 age group (32.8 percent for males and 27.2 percent for females), and there is another peak as well for the 10-19 age group. In another study,⁹ the same two age-specific peaks of infection were recorded; however, that of the 10-19 age group was much higher than that of the 40-49 age group. Generally, nevertheless, the two sexes are infected about equally, a finding that coincides with those from other countries, notably India.

TABLE 1 Age and Sex Distribution of Persons Infected with Guinea Worm Disease in 17 Villages North of Ibadan, 1971-1975

Age (years)	Males Infected			Females Infected			Total Infected		
	No. in Group	No.	%	No. in Group	No.	%	No. in Group	No.	%
0-4	724	42	5.8	728	16	2.2	1,452	58	4.0
5-9	664	79	11.9	615	42	6.8	1,279	122	9.5
10-14	481	106	22.1	396	90	22.7	877	196	22.3
15-19	353	48	13.6	410	74	18.0	763	122	16.0
20-29	783	37	4.7	988	132	13.4	1,771	169	9.5
30-39	489	90	18.4	495	79	16.0	984	169	17.2
40-49	290	95	32.8	235	64	27.2	525	159	30.3
50+	318	64	20.1	231	48	20.8	549	111	20.2
TOTAL	4,102	561	13.7	4,098	545	13.3	8,200	1,106	13.5

SOURCE: O. O. Kale.² Reproduced with the permission of the American Journal of Tropical Medicine and Hygiene.

The Ibadan survey² also showed that significantly more boys than girls were affected, but that there was no difference in occurrence of the disease between children (16 years) and adults.

There is no evidence that protective immunity is acquired after infection, and repeated infections occur often among those continually exposed. The suggestion that gastric acidity plays a role in susceptibility to infection¹⁰ has not been confirmed.¹¹ Epidemiological data from Ibadan strongly indicate that exposure, through the ingestion of infected water, is the major determinant of infection.²

Clinical Aspects

As reflected in all surveys taken where dracunculiasis is endemic, in southwestern Nigeria most guinea worms emerge from the lower limbs (89.6 percent by Onabamiro,⁴ 93.4 percent by Muller,¹² and 93.6 percent by Kale²).

The average number of worms per affected person (worm burden) is a measure of the intensity of infection. Studies in southwestern Nigeria have shown that the average worm burden varies from 1.2 to 2.5.^{2,4,12,13} This parameter is important in determining the level of endemicity of infection, a subject that is discussed later in this paper.

A variety of complications arising from guinea worm infection have been reported in Nigeria.^{2,11,12,14-17} These include secondary bacterial infection leading to cellulitis, pyomyositis, and tetanus; arthritis (both septic and aseptic); tendon contractures; epididymo-orchitis; and inguinal adenopathy. Most of the arthropathic complications occur in relation to the feet and ankle joints.²

The average duration of infection (from eruption of the blister to emergence of the worm) is 5-8 weeks.² The period of incapacitation ranges from 3 weeks to 9 months, with an average of about 3 months, which often coincides with the farmer's planting season.

Using three suggested grades of disability,¹⁹ Kale's study² in the Ibadan district between 1971 and 1975 showed that out of 1,106 cases, 57 percent were mildly disabled; 31 percent, moderately disabled; and 12 percent, severely disabled. The duration of infection can be shortened, and the degree of disability reduced significantly by chemotherapy.¹⁹⁻²¹

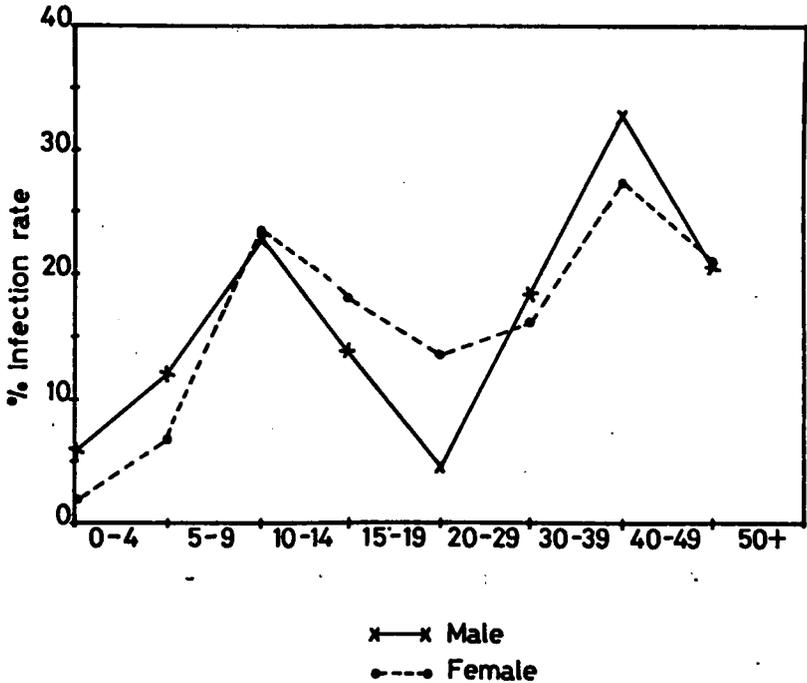


FIGURE 2 Age-specific incidence of guinea worm disease by sex in 17 villages north of Ibadan, 1971-1975. Source: O. O. Kale.² Reproduced with the permission of the American Journal of Tropical Medicine and Hygiene.

DEGREE OF ENDEMICITY OF DRACUNCULIASIS

The interaction of this parasite with man can be expressed in terms of prevalence, incidence, and intensity. These depend on a number of ecological and biological factors, most of which have been cited in this paper. In this connection, this section highlights one of the most important aspects of the epidemiology of dracunculiasis, which is of considerable relevance to the achievement of the objectives of this workshop but which has received little or no attention in the past.

One of the fundamental principles of comparative epidemiology is that there should be a set of valid parameters for assessing the impact of a health problem (in this instance a disease process) on the community under study. This would make it not only possible to make direct comparisons between different population groups, but also to monitor secular trends more accurately, irrespective of whether they evolve spontaneously or result from a specific intervention.

To the best of this author's knowledge, no attempt has been made to describe different and specific levels of endemicity of dracunculiasis, although a number of published articles have used such expressions as "hyper-endemic" or "low" or "high endemicity" with respect to dracunculiasis without a quantitative definition of what these expressions represent in terms of the epidemiological profile of the disease.

A review and analysis of data accumulated from epidemiological surveys conducted in Oyo State over the past 12 years are now being undertaken.²² Preliminary inspection of the data suggests that there are three valid parameters by which the degree of endemicity of dracunculiasis in a given community can be defined: incidence rate, worm burden, and risk of infection. These indices reflect such diverse but interrelated and relevant aspects of the epidemiology of the disease as the spread of infection in the population (i.e., the size of the human reservoir); the intensity of infection among those affected; and the probability of becoming infected.

For a disease like dracunculiasis which has such a marked seasonal variation in incidence and little carry-over of infection from one season to the other, the incidence rate is more sensitive than the prevalence rate for measuring the impact of the disease. Indeed, it has been suggested that the incidence rate is a more fundamental measure for assessing the impact of a disease on a given population and comparing this impact among two or more subpopulations with different distributions of certain characteristics of exposure.²³

The intensity of infection with dracunculiasis is reflected in the worm burden. The lower the worm burden (i.e., the average number of worms harbored by the infected person) in a community, the less the intensity, and vice versa.

The risk or probability of infection is a more complex index to estimate. It is a function of the incidence rate during the follow-up period and the length of that period.²⁴ The risk parameter is subject to such variables as the frequency of infected human contact with water sources, enabling D. medinensis larvae to be discharged into water containing cyclops; the population

density of cyclops that are capable of transmitting infection; the proportion of water sources that contain infected cyclops accessible to the population at risk; the rainfall pattern; and the volume and pattern of consumption of water by individuals in the community.

The most appropriate parameter for measuring risk in dracunculiasis is the mean age at which 50 percent of the study population was first infected. The mean age of first infection has been shown to be lower in guinea worm disease endemic areas where it was only recently introduced.^{10,25-27} The alternative of using the proportion of infected children below a given age (e.g., 10 years) in the population was rejected as being less sensitive and reliable.

The three selected parameters just described are closely related and embrace all the important variables that affect the epidemiology of the disease in a given population. When the Ibadan data are subjected to analysis using these three parameters, three distinct although overlapping levels of guinea worm endemicity can be defined:

1. A level of hyperendemicity, where the annual incidence rate is consistently above 20 percent, the average worm burden is over 1.9 per affected person, and the mean age of first infection is below 10 years.
2. A level of hypoendemicity, where the annual incidence rate is consistently below 5 percent, the average worm burden is below 1.5, and the mean age of first infection is above 15 years.
3. An intermediate level of mesoendemicity, where the annual incidence rate is between 5 and 20 percent, the average worm burden is between 1.5 and 1.9, and the average age of first infection is between 10 and 15 years.

These figures are very tentative and are subject to revision when all the data have been fully analyzed. A similar analysis of data from other countries would be valuable in determining whether the principles underlying this exercise are universally applicable and the effectiveness of the parameters proposed here.

Agreement must be reached on what criteria to use in diagnosing this disease; few published reports have given the precise criteria used for making a diagnosis. There is no doubt that surveys using strict confirmatory parasitological diagnosis cannot be compared directly with those that permit use of more subjective criteria or those based on sero-reactivity or skin sensitivity tests. Some working guidelines already exist.¹⁸

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CORRELATION BETWEEN BIO-CLIMATIC VARIATIONS AND THE TRANSMISSION OF DRACUNCULIASIS

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Dracunculiasis (guinea worm disease) is typically considered an endemic and epidemic disease that occurs around water sources in the hot and dry zones of Africa only during the rainy season. Many dry season cases, however—even a maximum frequency—have been reported by numerous investigators.

This paper examines the correlation between bio-climatic variations and incidence of dracunculiasis transmission in francophone West Africa, specifically in a number of Sahelian zones (northern Upper Volta and northern Mali), savanna zones (Upper Volta, northern Ivory Coast, and Togo), and forest zones (southern Ivory Coast). Data for this analysis were taken from reports issued by the general health departments of the Ivory Coast, Upper Volta, and Mali, and from the results of a survey conducted in the Republic of Togo by Amoussouga and reported in 1977.¹

SAHELIAN ZONE

In this zone annual rainfall is less than 600 mm. The correlation between maximum rainfall and maximum transmission frequency is quite clear. Figures 1 and 2 show that in Mali the maximum rainfall (registered in Bamako in 1977) corresponds to the maximum average number of cases reported between 1972 and 1977 in the rainy season, when ponds are filled with water. In the dry season, when the ponds dry up, particularly in northern Mali, water supplies are taken from very deep wells (20 m) which are protected because of their depth against any kind of contamination. The residual pond waters also found in Mali during the dry season result in year-round disease transmission.

Similarly, in Upper Volta maximum transmission also occurs in the rainy season (see Figures 3 and 4). This phenomenon is more striking in the northern part of the country in the region of Dori, and far less visible in the savanna zone in the south of the country.

SAVANNA ZONE

In the savanna zone, the maximum number of cases occurs between the beginning and the end of the dry season. It varies, however, according to region, the amount of rainfall, whether ponds dry up too early or too late, and the persistence of the ponds themselves. In the savanna regions, except in a few areas, the intensity of disease transmission is lowest at the end of the dry season when the ponds have completely dried up.

In the sudanian zone of Upper Volta, which has an annual rainfall of from 600 mm to 1,000 mm, maximum intensity of disease transmission shifts from the rainy season to the beginning of the dry season, and minimum intensity coincides with the end of the dry season.

In the sudano-guinean savanna zone of Upper Volta, Togo (see Figures 5 and 6), and the Ivory Coast, the annual rainfall is above 1,000 mm and, in general, there is a maximum intensity of transmission in the dry season, either at the beginning (e.g., in the region of Bobo Dioulasso in Upper Volta and the region of Korhogo in the Ivory Coast) or at the end (e.g., in the region of Odienné in the Ivory Coast and the subdivision of Bassari in Togo). In Bondoukou (eastern part of the Ivory Coast), the two peaks of maximum intensity of dracunculiasis transmission coincide with the two dry seasons.

In the savanna zone, there is maximum intensity of transmission in the dry season: at the end of the rainy season and the beginning of the dry season in the sudanian zone, and at full dry season and the end of the dry season in the sudano-guinean zones. Intensity is lowest in the rainy season and depending on the isohyets, at the end of the dry season.

FOREST ZONE

Dracunculiasis is transmitted year-round in this zone found along the south of the Ivory Coast and is related to the significant and rather regular rainfalls. Maximum transmission intensity in some regions of the Ivory Coast (Daloa, Dimbokro, and Adzopé) occurs only in the dry season, particularly when the ponds have not dried up completely and they have a high concentration of Cyclops.

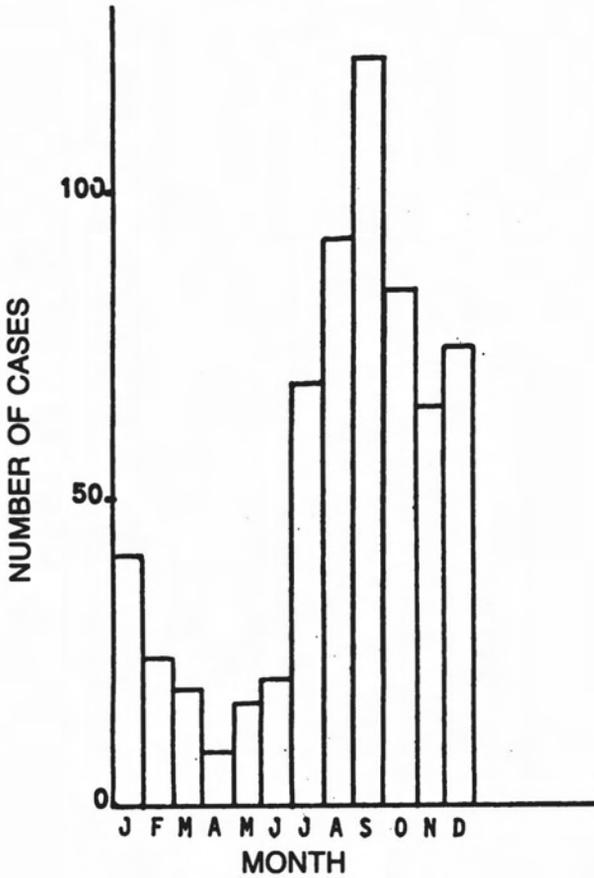


FIGURE 1 Average number of dracunculiasis cases reported monthly, Mali, 1972-1977.

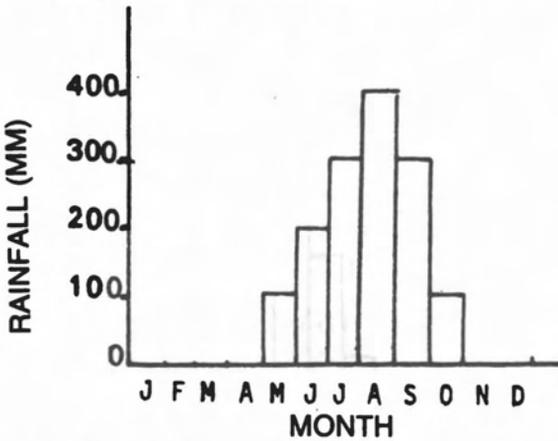


FIGURE 2 Average monthly rainfall (millimeters), Bamako, Mali, 1977.

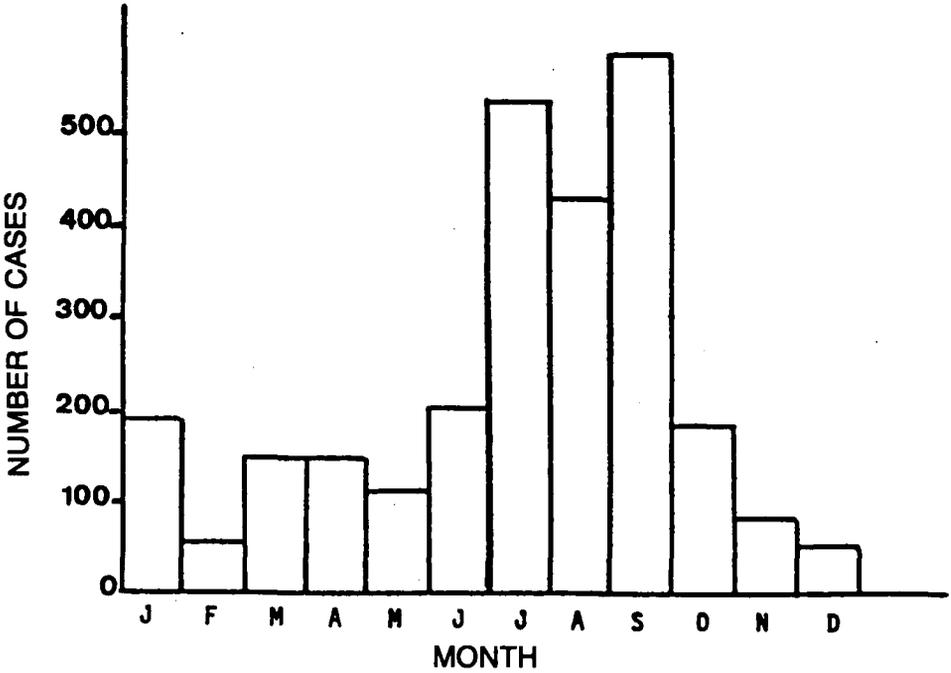


FIGURE 3 Average number of dracunculiasis cases reported monthly, Upper Volta, 1977.

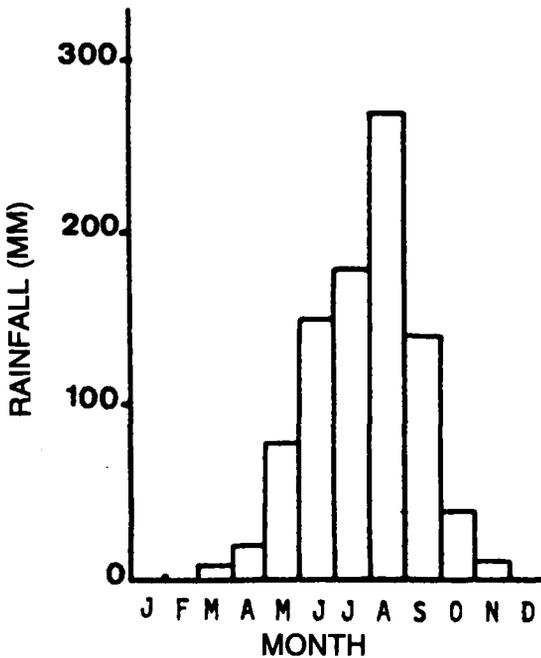


FIGURE 4 Average monthly rainfall (millimeters) over 25 years, Ouagadougou, Upper Volta

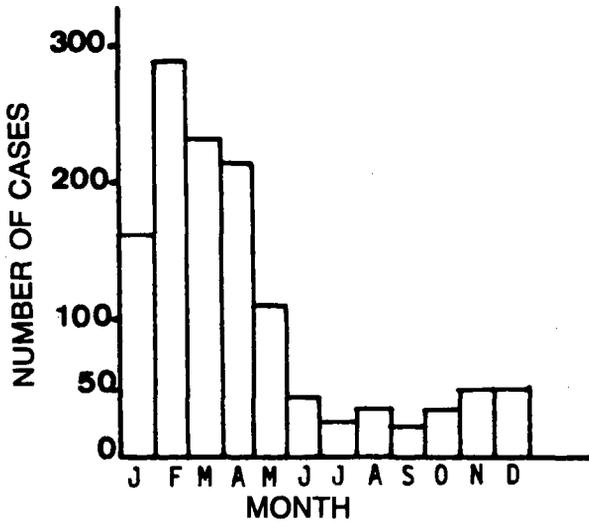


FIGURE 5 Average number of dracunculiasis cases reported monthly, Togo, 1975-1976.

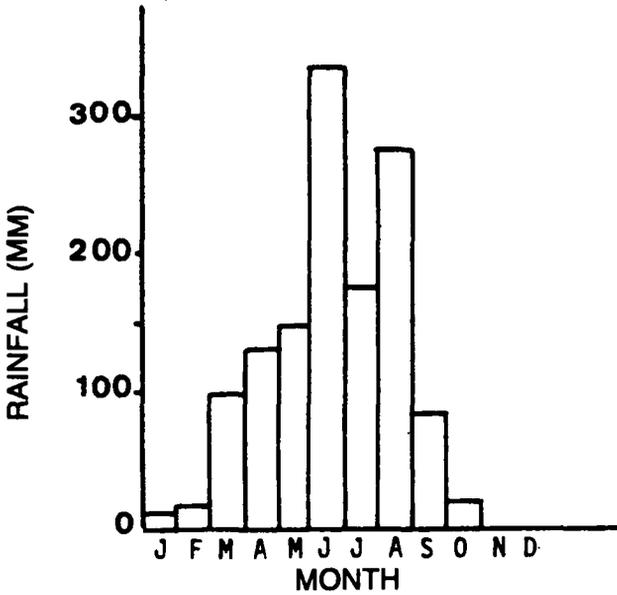


FIGURE 6 Average monthly rainfall (millimeters), region of Bassari, 1975, 1976.

The minimum number of reported cases generally appears in the rainy season.

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CONTROL METHODS



**PROTECTION OF WATER SUPPLIES
FOR THE CONTROL AND PREVENTION
OF DRACUNCULIASIS**

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Dracunculiasis (guinea worm disease) is transmitted entirely by drinking water, and thus its control and eventual elimination have been adopted as a major target of the United Nations International Drinking Water Supply and Sanitation Decade. The United Nations considers the protection of drinking water sources the best method for achieving guinea worm control. In May 1981, it specifically recommended: (1) filling stepwells, (2) providing piped water systems or other new water supplies, and (3) filtering drinking water through a double thickness cotton cloth. In addition, the U.N. System Steering Committee for the Decade has agreed that guinea worm prevention could serve as one indicator of the success of the Decade in affected areas.

PROVISION OF SAFE, ADEQUATE DRINKING WATER

Traditionally, safe, wholesome drinking water has been thought to be (1) uncontaminated (thus unable to infect the user with a water-related disease); (2) free from poisonous substances; and (3) free from excessive amounts of mineral and organic matter. Questionable water sources can be treated and protected to the degree necessary to render them safe for consumption, and this is the essence of the three U.N. recommendations just listed.

To prevent the transmission of guinea worm disease, the water source need only meet the first criteria given above. Nevertheless, using certain protection strategies, the transmission of guinea worm disease can be prevented without protecting the source against all water-related disease contamination.

Projects designed to provide safe drinking water include strategies to halt the three primary mechanisms of water-related disease transmission associated with water source quality:

- o Water-borne (the pathogen in the water is consumed resulting in infection)
- o Water-based (infection by parasitic worms that depend on aquatic host(s) to complete their life cycle)
- o Water-insect vectors (infection by insects that breed in water).

The preventive strategies for guinea worm disease, which is transmitted by the water-based mechanism, are:

- o Decrease or eliminate the need for water contact
- o Control aquatic host populations
- o Improve quality of drinking water.

It is clear that improvements based on the first two strategies would not prevent transmission of all water-based diseases. Thus, although the United Nations proposes to measure the effectiveness of the water decade by using statistical data on guinea worm infection, these data will only provide an inaccurate, partial indication of the degree to which the Decade goal of providing safe, adequate water has been met. The sensitivity of the guinea worm transmission mechanism to preventive measures may be used, however, to indicate for planning purposes those areas deserving priority for the provision of protected water supplies.

The epidemiological facts of guinea worm transmission supported by statistical data on guinea worm infection become persuasive arguments for pinpointing villages with priority needs for safe, adequate water systems. Where guinea worm disease infects 20-30 percent of the population, the water supply is certainly from unprotected sources such as surface ponds or other sources where contact with the water permits completion of the transmission cycle. In addition, statistical information on areas where guinea worm infection persists should be used to pinpoint areas and villages where existing programs are not successful. Used in conjunction with other epidemiological statistics, investigators may be able to determine whether physical protective mechanisms have failed or whether protected supplies have been bypassed because of sociological factors.

WATER SUPPLY SYSTEMS

Water supply systems can be divided into two broad categories: urban and rural. In the context used here, urban water supplies are defined as those distributed via pipes, and the raw water is treated prior to entering the

distribution system. The distribution system delivers water, under constant positive pressure, to the consumer at standpipes or house connections. A properly designed urban water supply system generally provides treatment as required by clarification, filtration, or disinfection. In addition to eliminating infectious matter from water destined for public consumption, the piping of treated water assures that the general population does not have access to the raw water source.

Slums or fringe zones of urban developments present special water supply problems that are compounded by socioeconomic conditions. Public standpipes or water vendors generally serve lower income groups in urban areas. Most progressive governments extend, as a social service, the urban water system into these areas through such standpipes. Otherwise, dwellers may seek water from unprotected sources which, in some instances, may also be the raw water source for the public water supply system. Contamination of the raw water source results.

Criteria for design of such a distribution system must insure the provision of an adequate number of standpipes and suitable drainage to serve the population properly. In the lowest income neighborhoods, the use of water vendors should be avoided, as consumers may seek alternate water sources of questionable quality when they are unable to pay for vendor-sold water or to purchase the water in adequate quantities to maintain hygiene.

Rural water supplies may be classified as either piped water, with or without prior treatment, or unpiped water. The quality of treatment as well as the reliability of distribution reflect directly on how well the community or the responsible government agency is maintaining and operating the facility.

Most improved water supplies for rural villages consist of hand-dug or bored wells using traditional lifting systems or hand- (or foot-) operated pumps. Many villages are served with dug wells primarily designed to water livestock with little or no consideration being given to protection of the water source for human consumption. Where improved water supplies do not exist, the village uses its traditional water sources which may vary from unlined dug wells to ponds filled during the rainy seasons.

PROTECTION OF WATER SUPPLIES

The protection of any water source normally found in developing countries does not present any particular technical problems, especially with regard to preventing transmission of guinea worm infection. Major constraints

to the designer are all too often socioeconomic in nature, and they may circumvent physical efforts to protect new or improved water supply systems. Researchers are now expending considerable effort to improve existing technology and to incorporate the use of economical local materials to improve and lower the costs of equipment. One major goal is to develop equipment that can be manufactured and repaired by local artisans.

The first consideration in ensuring an adequately protected water system is selecting the most appropriate water source. Surface or groundwater sources subject to a multitude of uses, such as bathing, laundry, irrigation, waste disposal, livestock watering, etc., should be avoided if at all possible. The rule is to utilize the purest or so-called most "innocent" source for drinking water. In following this rule, most planners rely on groundwater resources, since the collection, distribution, and treatment of surface waters are generally outside the technical possibilities and economic resources of most rural populations in developing countries. In this way, the movement of water through the soil and into the groundwater table provides adequate treatment. The removal of pollution as water travels through solids and water-bearing formations depends upon the mechanical removal of microorganisms and other suspended matter by filtration and sedimentation as well as the natural "die-away" of bacteria and intermediate hosts found in soils.

No improved water source can be considered fully protected, no matter how well it is constructed physically, unless steps are taken to ensure that the water supply is:

- o Technically viable, that is, the water produced by the well or source is safe and wholesome, meets the requirements of the community, and is readily available to the population it must serve.
- o Maintained and operated during its service life in a satisfactory manner.
- o The users are educated in the proper handling and use of the water.

Accordingly, protective measures for dug and bored wells include:

- o Protective linings to adequate depths
- o Protection from surface drainage using concrete aprons and covers
- o Adequate, well-designed water delivery systems
- o Proper operation and maintenance during its service life.

The economic implications of these protective measures may be considerable. For example, the addition of a reinforced concrete apron to a dug lined well designed primarily for livestock watering could increase construction material costs from 16 to 30 percent depending upon the depth of the well. Upgrading the water-lifting devices to provide adequate protection for human consumption will raise the cost even higher. The costs associated with health education and other social programs aimed at assuring the consumption of safe water are harder to pinpoint but, nevertheless, represent real drains on economic resources.

PLANNING FOR WATER SUPPLY PROTECTION

The protection of water supplies begins at the national or regional planning level. At this level, policies are established for the allocation of water resources, construction of water supplies, cooperation between resource-sharing agencies, distribution of manpower and economic resources, and determination of planning mechanisms that influence the character and nature of water supplies delivered to rural areas.

The inclusion of public health and sanitation officials in initial planning activities insures that epidemiological facts and statistical data are properly used in the decision process to determine priorities for water supply development. Planning at the national level must insure cooperation between interested agencies to realize maximum use of available resources.

Planning single-purpose water supplies in rural areas of most developing countries is not realistic given the limited resources available. For example, a well dug for livestock watering will also be used as a source of water for human consumption. For this type of well, provisions should be made to facilitate water collection for domestic purposes and eliminate problems associated with priorities of use. Otherwise, individuals seeking domestic water may become discouraged and abandon a potentially safe source to seek water from contaminated ponds or unprotected traditional sources.

Design and construction criteria should suit local conditions. For example, the adequacy of improved water supplies using hand (or foot) pumps to deliver sufficient flows to meet village needs during peak demand periods is usually not demonstrated before construction. Thus subsequently, protected wells are abandoned for traditional sources because flow is not adequate to meet demand where water collection activities are confined to specific periods of the day. Likewise, attempts to serve

two adjacent villages with a single well located midway often lead to the continued use of traditional sources by inhabitants.

The final decision on any water supply should follow an extensive local survey. In addition to information and data normally sought to support technical design, preliminary field investigations at the village level should determine:

- o The best water sources to meet present and projected multi-use demands of the village, that is, domestic, livestock, agriculture, local artisans
- o Sanitation and water use practices of the local population, taking into consideration water-related diseases and health education requirements
- o Local disease patterns, taking into consideration water-related diseases and health education requirements
- o Local possibilities for construction, maintenance, and operation of water supplies
- o The individual within the village who will be responsible for maintaining and operating the water supply to assure his early inclusion in regional and national training programs
- o Inventory of activities, both ongoing and planned, to ascertain where combined efforts are feasible
- o Experience of adjacent villages with improved supplies as well as feedback from other areas to learn from successes or avoid failures.

Although ideally one would conduct the local survey using a multidisciplinary team, this is seldom possible. Investigators should receive training and guidelines from all concerned agencies.

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CYCLOPOID COPEPODS: THEIR ROLE IN THE TRANSMISSION AND CONTROL OF DRACUNCULIASIS

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INTRODUCTION

As long ago as 1906, Leiper stated that the "practical study of dracunculiasis, one of the oldest known and, in some regions, the most prevalent of tropical diseases, has been singularly neglected."¹ Until very recently, Leiper's opinion has remained largely unchallenged in spite of the major socioeconomic advances and outstanding technological achievements of the last 50 years.

Few practical studies, with some notable exceptions, aimed at the prevention and control of dracunculiasis (guinea worm disease) have been undertaken during the present century. The main reasons for the long neglect of these studies include:

- o Globally, the distribution and public health importance of the disease does not compare with such other parasitic infections as malaria, schistosomiasis, soil-transmitted helminths, etc. At the global level, therefore, its priority is relatively low.
- o Nationally, the disease is seasonally restricted to small, often isolated communities located in impoverished areas without, to say the least, political influence, and with little chance of benefit from concerted public health activities.
- o Neither effective drugs nor a vaccine to treat or prevent the disease exist. Infected villagers have, therefore, little incentive to seek treatment at dispensaries or hospitals and tend to rely much more on traditional methods. Consequently, the true gravity of the malady is often hidden.
- o While the methods of preventing dracunculiasis are simple, their organization and effective implementation in remote rural areas are

surprisingly complex. However, recent advances in primary health care concepts give rise to more promising control prospects.

- o Prevention and control of dracunculiasis demand a multidisciplinary approach.
- o Biologists have, for obvious reasons, concentrated chiefly on medical entomology, occasionally on malacology, and hardly ever on the subclass Copepoda, probably because so few important human parasites are transmitted by the latter group.

This paper will summarize the role of cyclopid copepods in the transmission and control of dracunculiasis. Attention will be drawn to some unresolved problems, with special regard to the intermediate hosts and their preferred habitats, particularly those deserving to be more fully studied with the aim of developing more cost-effective, integrated control strategies.

FRESHWATER CYCLOPID COPEPODS

These minute, pinhead-sized crustaceans are biologically very successful, comprising many genera with diverse feeding habits. They are found worldwide and almost exclusively in standing or slowly-flowing marine, brackish, and freshwater water bodies. For example, the pelagic marine forms occur in enormous quantities and play a crucial role in the food chain of many fishes and whales. In addition, parasitic copepods are a favorite subject of study in many biology departments, as the parasitic way of life has been exploited by many different copepod families, and every stage of parasitism, between ordinary free-living forms and the most complex or degenerate parasites, is exhibited.

The free-living, freshwater cyclopid copepods (also known as cyclops), are pear-shaped organisms, comprising a cephalothorax, an abdomen, and a telson with a tail of two caudal rami. The sexes are separate and the egg hatches into a typical nauplius larva, which is then succeeded by several metanauplius stages before molting into the first of five successive copepodid stages. Almost nothing is known of the susceptibility of the different instars to the infective larvae of Dracunculus. Moreover, few publications specify confirmation of the taxonomic status or the exact age or size class of infected cyclopoids.

Taxonomy and Biology of Cyclops
Acting as Intermediate Hosts

Muller has listed 17 species of cyclops that can potentially act as intermediate hosts in different dracunculiasis endemic areas.² In addition, Cyclops vernalis americanus has proved an excellent experimental host,^{3,4} although it has not been recorded in endemic regions. More recently, Steib, working in Upper Volta, added two more species (Thermocyclops incisus and Metacyclops exsulis) to the list of potential intermediate hosts.⁵ Further species will no doubt be incriminated as more research at natural transmission sites is undertaken in the future.

Concerning the taxonomy and biology of cyclops, the following aspects are salient, but few have been studied exhaustively:

- o Only large, predatory species can readily ingest D. medinensis larvae and can thus act as potential intermediate hosts. Of these carnivorous species, the older and larger copepodid stages are more predatory than the younger and smaller ones.⁵ The smaller herbivorous species are excluded as natural intermediate hosts.
- o In each endemic zone usually only one of the local predatory species is the dominant intermediate host by virtue of its preferred habitat, its seasonal population dynamics, or both.
- o Even among carnivorous species some are more compatible with D. medinensis infection than others. While intermediate host specificity does not strictly occur, some species of predatory cyclops are more resistant to infection than others.
- o The reproductive biology, bionomics, and behavior of the dominant intermediate host species in natural transmission sites in most endemic zones (seasonal ponds, stepwells, etc.), in relation to biotic and abiotic parameters and according to cyclops and D. medinensis infection patterns, have scarcely been studied even though valid techniques to do so are now available.⁶ Obviously, data from such studies, together with information on human and water contact patterns, could help to identify and predict with reasonable certainty the most important site or sites of transmission according to geographic area.
- o For unknown reasons, some species of carnivorous cyclops are more difficult to maintain in the laboratory than others, but good experimental hosts (e.g., C. vernalis americanus) do exist.

- o Muller has already pointed out that nothing "is known of the number or density of infected cyclops necessary for continued transmission in a particular habitat."² Sound data on this subject are a prerequisite for a rational evaluation of control measures directed against the copepod hosts.

Preferred Habitats of the Cyclopoid Hosts and Season of Transmission

Transmission of *D. medinensis* is normally not associated with flowing water courses, drawwells, or impoundments such as lakes and dams which retain large volumes of water even at the climax of the dry season. Running water is, in general, incompatible with the maintenance of carnivorous copepod populations. They may occur in drawwells, but exposure to infection is minimal. While some species of potential intermediate hosts may occur in large impoundments, their population density is relatively low and thus the potential of these water bodies for transmission is low.

Both seasonally dense populations of cyclopoid hosts and high transmission potential are associated with two main types of water body:

1. Stepwells in the Indian subcontinent and cisterns ("birkehs") in Iran
2. Small, usually impermanent, man-made ponds, constructed to provide a seasonal domestic water supply and, therefore, much used during a particular time of the year.

Regarding the main seasons of transmission, it appears that:

- o Transmission is not associated with the peak of the rainy season in the endemic areas.
- o In the Sahel and dry savanna areas of West Africa, maximum transmission may take place at the onset of the rainy season, coinciding with the main planting period.
- o In the wetter savanna zone closer to the West African coast and probably to the south of Sudan, peak transmission usually coincides with the advance of the dry season prior to the drying up of village ponds.
- o In Pakistan and India, transmission is generally confined to areas of low rainfall and is maximal during the summer months.

- o In all endemic areas, peak densities of intermediate hosts and transmission of D. medinensis is confined to less than 3 months a year.
- o The incidence and prevalence rates of dracunculiasis are intimately related to local rainfall and evaporation patterns. Prediction of "good or poor dracunculiasis years" by analysis of local meteorological data has not yet been studied in depth.

Development of D. medinensis in the Cyclopid Host

The Russian biologist Aleksey Pavlovic Fedchenko (1844-1873) was the first to describe this phenomenon just over 100 years ago. Muller has noted the historical significance of this discovery for tropical medicine.²

During the last 50 years, the salient features of the development of D. medinensis larvae in the cyclopid host have been adequately described, although some minor and quantitative aspects have yet to be elucidated. Both epidemiologically and from the viewpoint of intervention, Muller's observation is pertinent: although the larvae may remain active in pond water for a week, the "percentage infection rate in cyclops fell sharply after three days of storage in pond water and was nil after six days."² Data on temperature were not given, but it can be predicted that the sensitivity to temperature, of the first-stage larvae within the cyclops host like that of later stages, is more pronounced than that of the cyclopid copepods themselves to this parameter.

When the first-stage larvae are ingested by the intermediate host, they break through the gut wall to reach the hemocoel where, at temperatures above 25°C, they molt twice to reach the infective third stage in about 2 weeks. Thereafter, they may continue to develop for 1-3 more weeks.

There is little information in the literature on the average lifespan of infected and uninfected cyclops in relation to the range of abiotic factors normally recorded in natural transmission sites.

In nature, only a single larva is found in the copepod host, and multiple infection tends to be lethal. Muller, however, mentions that "experimentally infected adult cyclops [C. vernalis americanus] may have up to five larvae."² Steib has drawn attention to observations that infection not only retards development of the cyclops host, but also that infected immature cyclopidoids do not mature.⁵ According to him, little is known of the precise status of different cyclopid species and their developmental stages in the transmission of dracunculiasis. Moreover, Steib⁵ notes that the

importance of the different instars of each cyclopoid species in acting as intermediate host of Dracunculus depends on the following conditions:

- (a) the feeding habits of the cyclopoids: whether or not the different instars of each cyclopoid species ingest Dracunculus larvae;
- (b) the potential for enduring infection with Guinea-worm larvae and the species-specific resistance of cyclopoids: whether or not the Dracunculus larvae may conclude their development in the different cyclopoid instars without being killed by the host or without lethally damaging the host;
- (c) the survival time of infected cyclopoids after the Dracunculus larvae have reached their infective stages.

Regarding the behavior of infected cyclops, Onabamiro has noted that specimens harboring third-stage infective larvae tend to remain at the bottom of the pond in contrast to uninfected specimens (C. nigerianus, Kiefer) which exhibit marked vertical diurnal migration.⁷ The role of the behavior of infected cyclops to transmission potential remains conjectural.

CYCLOPS CONTROL

Should global eradication of any pathogenic human entoparasite be anticipated, D. medinensis is probably the prime candidate despite the fact that control presently relies on preventive, rather than curative, measures.

Prevention at the community level can best be achieved by a combination of:

- o Sustained health education aimed at ensuring maximum awareness of the problem and a commitment to overcome it by self-reliant means
- o Provision of a safe and enduring domestic water supply using, if possible, appropriate technology
- o Control of infected cyclops by chemical or biological methods or by, for example, simply ensuring that drinking water from potential transmission sites is sieved during the period that Dracunculus is patent. A research study on the latter topic, based on appropriate technology

and community participation concepts, is presently being carried out by K. Steib in Upper Volta, supported by the Director's Initiative Fund of the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases.

Inevitably, dracunculiasis prevention must be multidisciplinary, and good coordination of the different elements involved is mandatory. Control of Dracunculus at the village level lends itself to primary health care principles. At the national level, marked reduction, if not elimination, of the infection is attainable where enthusiasm and support by all concerned are assured.

The possible need to control cyclops should not be omitted from the above preventive measures. Rural dwellers, in general, are conservative and prefer traditional water sources, or they may be forced to resort to them if the improved water supply fails to function adequately. In the upper region of Ghana, for example, more than half of over 2,000 water pumps had ceased to function within 2 years of installation.

Chemical Control of Cyclops

Compounds used for control of cyclops should be:

- o Highly toxic to all developmental stages of cyclops
- o Low in cost
- o Of insignificant toxicity to mammals and fish
- o Tasteless at effective concentrations
- o Readily available
- o Easily applied
- o Effective residually for at least 4, but preferably 12, weeks
- o Stable in storage.

Many chemicals have been tested,⁸ though few under field conditions. The organophosphorous temephos (Abate, used primarily as an insecticide⁹) in sand granule formulation, is presently considered the compound of choice. This formulation is commercially available (1 percent active ingredients), and at the recommended dose of 1.0 mg/liter, cyclops should be eliminated from the water body within 5-7 weeks. Muller has observed that the sand granule formulation of temephos "provides a very convenient method of adding the compound to ponds as it has limited solubility and the quantities do not have to be dispensed with any great accuracy."¹⁰ Since

issuance of the WHO/FAO Data Sheets on temephos in 1975,⁹ 2-year feeding studies of rats have been completed and no significant difference between the incidence of tumors in exposed rats (10 mg/kg, 100 mg/kg, and 300 mg/kg of temephos in the diet) and control animals was found. Moreover, during large-scale field trials and operational use of temephos in the drinking water at a target concentration of 1 mg/liter in Thailand and Indonesia, no complaints have been reported.

The timing and frequency of applications will vary according to the local epidemiological conditions. The timing of the first application will depend on local rainfall and evaporation patterns. It should also coincide as closely as possible with first evidence of patent infection in the community, bearing in mind that larvae in the intermediate host require about 2 weeks to develop to the infective third stage. Thereafter, applications may be repeated at monthly intervals until the end of the transmission season. Rarely more than four applications during the transmission period in any endemic area are likely to be necessary. An operational manual recently published in India⁶ gives very clear, practical details for the use, properties, formulation, dosage, and frequency of application of temephos. This document should provide an excellent model for the preparation of other national manuals on dracunculiasis control.

The need cannot be stressed too strongly for both small-scale and large-scale field testing of the efficacy of temephos for D. medinensis control in different endemic areas representative of the range of epidemiological conditions. After the methodology for applying temephos has been clearly defined, the feasibility of its use under the supervision of community leaders should be emphasized. Similarly, studies to identify improved residual formulations, permitting reduction in the frequency of application, are desirable.

Biological Control of Cyclops

Two field investigations on the biological control of cyclops were recorded some 40 years ago in India,^{11,12} but apparently in recent years no biocontrol studies have been carried out. Certain species of fish predators have been advocated on the basis that, apart from efficacy, they may be cheaper and more permanent than repeated chemical control. Gidgeon has recommended the use of Rasbora doniconius for permanent stepwells,¹¹ while Moorthy and Sweet reported encouraging results in 35 endemic villages using fish as biocontrol agents of cyclops.¹² Transmission of dracunculiasis

was eliminated in six villages and significantly reduced in four others. The maintenance of fish in the transmission sites posed certain problems, but they were not insurmountable.

The first measure in routine control of D. medinensis transmission by small predatory fish should be the establishment of hatcheries for regular supply purposes. A successfully controlled stepwell could, of course, function as a hatchery. In India, the custom of keeping fish in the drinking water supply is widespread.

In spite of these encouraging results, the new manual on dracunculiasis eradication in India⁶ makes no mention of biological control. In Africa, where many transmission sites dry up each year, the only fish that can be considered for biocontrol are the so-called annual species. The efficacy of certain invertebrate competitors or predators of cyclops should be explored.

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HEALTH EDUCATION STRATEGIES FOR THE CONTROL OF DRACUNCULIASIS

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INTRODUCTION

Behavioral factors contributing to the transmission of dracunculiasis (guinea worm disease) have been clearly documented.¹ Behaviorists generally agree that the transmission cycle involves two clearly distinguishable and preventable behaviors of man:²

1. An affected person, and thus that part of the body from which the adult female worm is emerging, comes in contact with water. This enables the anterior end of the worm to rupture, liberating thousands of larvae which are ingested by cyclops (the intermediate host).
2. A susceptible person fetches and drinks water containing infected cyclops. His gastric juices kill the cyclops, but the larvae develop into adult worms and the cycle continues.

Although these associated behaviors appear obvious and simple, it is paradoxical that their clear identification has not been used to advantage in planning control measures. Control of dracunculiasis presents two challenges to behavioral scientists, especially health educators, who have designed control strategies around human behaviors associated with the disease. The first challenge is the inability to find a solution to a situation in which humans pollute their own source of drinking water and then consume the water without taking any measures to protect themselves from the possible effects of their actions. The second challenge is that preventive measures against dracunculiasis are much cheaper, more effective, and more adaptable than curative measures which are costly, inconvenient, and relatively ineffective. Yet health educators have not succeeded in helping affected populations take sufficient advantage of the benefits of preventive measures.

OVERVIEW OF HEALTH EDUCATION ACTIVITIES
FOR CONTROL OF DRACUNCULIASIS

A review of health education activities that have been carried out for control of dracunculiasis suggests that they have stemmed from three assumptions which are rationalistic in concept. First, if a man sees his contact with water as a source of pollution, he will not deliberately pollute his water. Second, if a man associates pollution as a causal factor in transmission of the disease and perceives himself at risk, he will not want to pollute his source of water. Third, if affected populations have faith in or are sufficiently convinced about the effectiveness of preventive measures, they will embark on them. Health educators have, therefore, directed their efforts toward three broad areas of educational intervention:

1. Community awareness and perception of the disease, in particular its causation and transmission
2. Provision of improved water supplies for affected populations
3. Acceptance of disease control measures through community participation and acquisition of skills needed for surveillance of introduced control measures.

With respect to the first area, research evidence continues to show a marked shift from the traditional, regionalized, and unscientific notions of causation and prevention to the more proven, scientific, and sophisticated ones. For example, studies carried out on some rural populations in Nigeria where dracunculiasis is endemic show that more and more people over time are associating the cause of the disease with polluted water.³ Investigations during a 1980 epidemic of dracunculiasis in Idere in Oyo State of Nigeria revealed that the population was attributing the disease more to the god Sonponna (god of smallpox) than the scientific notion of causation (association with water pollution). This had also been recorded in a previous study in the same population.⁴ These findings imply that a scientific explanation of causation is acceptable only when the infection rate is not out of proportion.

This type of behavior is not peculiar to just one culture. In any culture a new explanation to any abnormal situation is expected as people are always more satisfied with the invention or suggestion of a new reason for the unusual. Experience in areas with high endemicity in Nigeria also shows that a certain low rate

of incidence every year is considered "normal" by the affected population. From this experience, it may be suggested that since dracunculiasis is to a large extent linked with people's environment and life-style, it should be expected that the affected population will develop a minimum level of tolerance for the disease, especially when an effective remedy is not available.

The danger of this attitude from an intervention point of view is that remedies sought for the disease may be geared more toward coping, which probably partly explains the lack of commitment to control programs on a long-term basis by affected populations. This phenomenon has a strategic implication for timing an intervention to coincide with abnormal situations in which people are likely to be more receptive to new information and willing to accept new measures hitherto considered extraordinary. The extent to which the interventionist can take advantage of the panic measure in the case of dracunculiasis, however, is limited in that an effect cannot be immediately demonstrated.

The second area of focus in the control of dracunculiasis is bridging the "application gap" in the acceptance of available control measures. It is well known that technology for the prevention of dracunculiasis has been more perfected than that for curative measures.

Improved water supplies that break the contact between the infected person and the vector in the form of protected wells and springs or pipe-borne water have been responsible for dramatic reductions in prevalence rates in many areas of the world. Although there have been instances of rejection of water-improved measures, these have been sporadic and largely attributable to lack of community participation and involvement in the planning and execution of the projects.⁵

With respect to curative measures for the disease, however, the available technology is far from perfected. For example, the criteria for early diagnosis are not yet well defined, and procedures for removal of the adult worm are not as dramatic as the infected person might want. At best, curative medicine has succeeded only in preventing such complications as tetanus and treatment of ulcers.

The educational implication is that the replacement of traditional approaches (considered to be ineffective) with modern ones (considered to be more effective) is bound to face major problems of acceptance unless the efficacy of modern technology is proven to be far superior to traditional measures. The level of perfection of preventive measures is hindered, of course, by a "delayed" demonstrated effect.

The third area of control measures relates to the importance of community participation with the ultimate goal of self-reliance in the surveillance of control measures once developed. The sign of success of most intervention programs has always been a marked short-term reduction in the prevalence and incidence of the disease. The most important evaluation criteria for successful intervention, however, should be the extent to which the affected population has accepted responsibility for carrying out established control measures on a permanent basis. This results from the fact that there has not been a major breakthrough in chemotherapy. Even when this is achieved, its usefulness is limited because reinfection is so easily possible. Furthermore, the maintenance of preventive control measures and their surveillance have not received adequate attention by the target population.

NEW METHODOLOGICAL OPTIONS

For analytical purposes, four behavioral change models could be used in designing health education strategies for the control of dracunculiasis:³

1. Behavioral control intervention matrix model
2. Replacement model
3. Application gap model
4. Primary health care model.

These models, although distinctive, are interrelated, and there may be an overlapping application of two or more of them.

Behavioral Control Intervention Matrix Model

Developed by William Brieger⁶ in the course of his fieldwork on dracunculiasis control in the Ibarapa District of Oyo State, Nigeria, where dracunculiasis is endemic, this model provides a clearer understanding of the human behaviors that contribute to the disease. It includes four steps for identifying behavioral control action levels for guinea worm disease (see Table 1):

- o Step One: Based on epidemiological information, identify the levels of prevention possibly applicable to dracunculiasis. Levels identified for dracunculiasis from an epidemiological point of view are: health promotion, specific protection, early detection, limitation of disability, and rehabilitation.⁷

TABLE 1 The Behavioral Control Intervention Matrix Model Applied to Dracunculiasis

Levels of Prevention	Levels of Prevention Applicable to Dracunculiasis (Behavioral Action Levels)	Behavioral Factors Operating at Each Behavioral Control Action Level	Health Education Strategies That May Be Used
1. Health promotion	Use of clean potable water	Unprotected sources; pollution and contamination of water sources during collection, inadequate water supply	Mass communication organization; Primary health care services
2. Specific protection	Not applicable (no immunization or chemoprophylaxis)	---	---
3. Early detection	Not applicable (long incubation period)	---	---
4. Limitation of disability	Treatment of blisters to prevent ulceration and tetanus infection, leading to reduction of physical handicap	Delay in seeking; unhygienic traditional methods of treatment	Training in self-care; primary health care services
5. Rehabilitation	Social rehabilitation for physical handicap; economic rehabilitation due to unemployment	Neglect; dependency	Social support resource linkages

- o Step Two: Determine which of the five levels of prevention are specifically applicable to dracunculiasis. For example, the prevention level "health promotion" is applicable, since use of clean potable water can prevent transmission of dracunculiasis. The levels "specific protection" and "early detection" are not, however, very applicable to the control of dracunculiasis as immunization or chemoprophylactic measures for specific protection against the disease have yet to be developed, and early detection is difficult because the incubation period ranges from 6 to 12 months on the average. The level "limitation of disability" is restricted more or less to the prevention of secondary and tetanus infections. The "rehabilitation" level is also applicable and takes the form of social and economic adjustments necessitated by deformities as well as loss of income from lost working days and temporary unemployment. Each applicable level of control now constitutes an action level.

- o Step Three: Determine the behavioral factors operating at each level of prevention applicable to the disease.

- o Step Four: Tailor behavioral interventions to the characteristics of each level of prevention. For example, "health promotion" will require health information and community development strategies, whereas "limitation of disability" will revolve around strategies aimed at using modern health services for removal of worms, treatment of ulcers, and antitetanus immunization. Strategies applicable to "rehabilitation" might include health insurance, unemployment benefits, and social welfare services.

A level of behavioral control action may be defined, more simply, as any distinctive point or stage in the transmission of the disease at which an individual or community could engage in behaviors or actions capable of preventing the disease, reducing its severity and associated disabilities, and disallowing its transmission to healthy individuals. The control of dracunculiasis is made more difficult as no measures can be taken at the "specific protection" and "early detection" levels.

Replacement Model

The theoretical basis of this model developed by Adeniyi⁸ for the control of dracunculiasis is that the choice of health service and the subsequent prescribed remedy for a disease are, to a large extent, predetermined by how the individual perceives the cause of the disease (Table 2).

	Traditional approach ^a	Modern (Western) Approach
Notion of causation	SUPERSTITION An enemy has used supernatural means to affect the sufferer by charming the worm to appear in his leg.	GERM THEORY A person is infected by drinking water containing infected cyclops.
Diagnosis	DIVINATION Use of oracles by traditional diviners to know the enemy in order to appease him	PHYSICAL EXAMINATION Physical examination; trace source of water supply for examination of cyclops
Remedy or treatment	TRADITIONAL MEDICINE Folk medicine (herbs), sacrifice to the god, charms and amulets	DRUGS Drugs (ambilhar) for worm removal; antibiotics in form of tablets and injection for accompanying ulcer and antitetanus immunization
Prevention	Charms and amulets, medicinal scarifications, taboos	Alternative source of water supply (protected wells), purification of water, health education

^aBased on the Yoruba Belief System in Nigeria.

This model shows a marked but consistent and logical difference between the traditional and modern approaches to the control of dracunculiasis. When a change from traditional to modern is contemplated, it is helpful to have adequate information on the notion of causation, diagnostic criteria, type of remedy, and type of prevention practiced in both approaches. To ensure compliance with modern treatment regimens for the control of dracunculiasis, health educators must consider the following factors:

- o The existing level of social, economic, and cultural development in the community as well as the degree of compatibility of the traditional and modern approaches being contemplated. The more compatible they are, the greater the chance of success.
- o The relative strengths of the traditional over the modern methods being contemplated should be identified to determine whether there are any good aspects of the old that can be integrated into modern methods to help them gain acceptance in the affected population.

Application Gap Model

Also developed by Adeniyi,⁸ the application gap model (Table 3) assumes that:

- o The technologies available for various types of health problems are at different stages of development or levels of sophistication.
- o There is wide variation in the level of acceptance of these technologies in different communities.

Indices for measuring level of sophistication of a health technology with respect to a given disease include potency of drugs, cost effectiveness of treatment or preventive measures, ease of administration of drugs, duration of treatment, presence or absence of side effects, and the extent to which the technology is designed to fit man.

The design of any technology should take into consideration the whole range of the consumers' characteristics. For example, a drug for children may be preferred in liquid form instead of tablets in a culture where traditional drugs for children are usually in liquid forms. Although a high level of technological sophistication should logically bring about a high level of

TABLE 3 The Application Gap Model Applied to Selected Tropical Diseases

<u>Level of Acceptance</u>	<u>Level of Technological Sophistication</u>	
	<u>Perfected</u>	<u>Not Perfected</u>
High	Smallpox	Cancer, diabetes
Low	Yaws	Malaria
	Tetanus	Schistosomiasis
	Tuberculosis	Onchocerciasis
		Dracunculiasis

acceptance, this is not always the case. For diseases like tuberculosis, tetanus, and yaws, the technology has been perfected but acceptance is low, probably because morbidity and mortality indices for these diseases are less severe and less dramatic.

As to treatment efforts using this analogy, control efforts for dracunculiasis are already severely limited in that technologies in use are not yet perfected. The available drugs are expensive, do not produce dramatic effects for worm removal, have serious side effects, and are difficult to use. There is also great room for improvement in the design of workable and acceptable alternatives in the form of improved water supply schemes. It is hoped that because of the physical, economic, and social costs of dracunculiasis to the victim a more perfected technology will have a high level of appeal.

The application gap model makes the health educator aware of the limitations of the technology for which he is trying to gain acceptance--the less perfected and accepted a technology, the greater the task of health education. This model also makes it possible to determine the relative progress that has been made in the control of other tropical diseases, as shown in Table 3.

Primary Health Care Model

According to a 1977 report of a UNICEF-WHO Joint Committee on Health Policy,⁹ the characteristics of a primary health care input to a health program may be summarized as follows:

- o A government policy to encourage community participation and the inclusion of primary health care at all levels of regional and decentralized planning
- o Tapping of external resources to supplement limited local resources
- o Establishment of an association or ties with other rural and urban development programs
- o Mobilization of local resources—human, financial, and material—as well as training, supervision, and use of primary-level workers who are selected by the community and whose orientation is not necessarily restricted to health
- o Use of existing traditional systems such as local government cooperatives, ceremonial events, and cultural practices and beliefs as one basis for expanding community participation efforts
- o Determination and use of community-felt needs, degree of readiness for change, and capacity to undertake projects based on estimates of available infrastructure for the purpose of setting priorities and strategies for intervention
- o Use as entry points of other programs in non-health sectors and programs in which children are beneficiaries
- o Use of nongovernmental organizations as channels for community participation
- o Engaging in activities that are acceptable and adaptable to local situations.

These characteristics of the primary health care model provide a sufficient framework for integrated team efforts for dracunculiasis control with sectors that are not medically oriented. The primary health care resources are found largely in the community itself. This allows participation of the target population in the planning and implementation of educational intervention strategies as dictated by the realities of their environment.

Self-reliance, which is fundamental to long-term control measures, will also be promoted by application of the primary health care model. Primary health care has already been introduced by Akpovi¹⁰ in Idere, in the Ibarapa District of Oyo State, Nigeria, to bring health services within the reach of the people for control of dracunculiasis.

Akpovi's research and its culmination at the intervention phase show that the change was focused on three factors:

1. The existing behaviors that are associated with the diseases

2. The situational realities under which these behaviors occur, and particularly the barriers to desired behaviors needed for control of the disease, of which economic and geographic factors are the most important. The main occupation in Idere is subsistence farming, and water is scarce because of rocky topography and low rainfall.
3. The organized systems and institutions to which people belong (social, cultural, religious, technological, political, etc.), which impose rules and codes of conduct that sometimes conflict with desired actions and behaviors required for the control of dracunculiasis. Because most of the people in Idere had enjoyed pipe-borne water which is no longer available, they have become overly dependent on the government to come to their aid. The self-help spirit which died down must be rekindled as a first step toward community participation in new control measures.

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CONTROL PROGRAMS



DRACUNCULIASIS ERADICATION IN INDIA

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INTRODUCTION

Eradication of smallpox from all countries, as declared by the World Health Organization in December 1979, has been an unprecedented achievement.

The achievement of smallpox-free status in India in the brief period of about 2 years beginning July 1973, clearly demonstrated the sound basis of the intensified campaign against the disease. Besides bestowing invaluable benefits on humanity at large, this miraculous achievement has generated confidence in the leadership of the country, technical and nontechnical administrators, health organizations, the community and its leaders, and health workers, and has spread the belief that such successes against other diseases are possible and well within their reach with all the consequent benefits.

It is well known that operations against smallpox mainly consisted of searching for cases and implementing containment measures to liquidate the foci that were found. It was thought that for a country like India the same approach could be used successfully to eradicate dracunculiasis (guinea worm disease). Experienced epidemiologists elsewhere have also been thinking along the same lines and are confident that with the implementation of a well-planned, fool-proof strategy--keeping eradication of the disease as the firm ultimate objective--success can be achieved within a few years.^{1,2,3} (D. R. Hopkins, 1974, personal communication; G. Weisfeld, 1979, personal communication).

Dracunculiasis, one of the oldest tropical diseases, has existed in India from very early times.⁴ In 1947, it was estimated that out of 48 million persons residing in endemic areas worldwide, 25 million were in India.⁵

The latest information on dracunculiasis has been obtained through visits by paramedical personnel to all villages in the known affected or suspected districts

who inquired about the occurrence of cases from the year 1977 onward. It was found that seven states--Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu--have endemic areas of the disease. A total of 10,582 villages in 80 districts with a population of 12.2 million are affected by the disease⁶ (C. K. Rao, 1982, personal communication).

DRACUNCULIASIS AS A HEALTH PROBLEM

A program to eradicate dracunculiasis, beyond eliminating suffering from the disease, may also have demonstrable secondary effects on agricultural output (in some areas, up to 30 percent of the work force is incapacitated during the period of maximum agricultural activities). Furthermore, it is very likely to have tertiary effects on the nutrition of young children in affected villages. Although infection by itself does not cause mortality, it does result in prolonged suffering and disability of its sufferers for about 3 months. A number of patients suffer from complications as a result of the disease, and at least 0.5 percent of them may be permanently disabled³ (D. R. Hopkins, 1974, personal communication). The preventable economic loss is, therefore, enormous.^{7,8}

It is sometimes argued that the population under risk is so small that the disease as such is not a major health problem. This is a fallacious assertion from the point of view of the affected community, however, and of health planners who always stress that programs should cater to the felt needs of the people. Moreover, a program to eradicate dracunculiasis is more than justified on economic considerations alone.

The epidemiological features of dracunculiasis are such that it cannot spread to nonendemic areas. It is transmitted only from a specific water source. In fact, there is little chance of a known water source's infecting other water sources. It is also a disease of remote and under-developed areas where the movement of persons remains extremely limited. These are, indeed, the reasons that the disease is easily eradicable in practice.

PLAN OF OPERATIONS FOR DISEASE ERADICATION

The Government of India, based on the recommendations of the task force on "Eradication of Guinea-worm Disease in India," agreed to undertake eradication of this disease. The National Institute of Communicable Diseases is the focal point for planning, guiding, and monitoring

operational activities and their impact on disease incidence in the endemic states. In this connection, an operational manual on guinea worm eradication has been prepared, and it details the strategy, calendar of activities, job descriptions of the staff, and methods of assessing of activities and results.⁹

DISEASE ERADICATION PROGRAM

Identification of Endemic Areas and Infective Water Sources

The first essential step in this program is to identify those villages in which dracunculiasis cases have occurred since 1977. This is being achieved by means of case search operations carried out by paramedical personnel. In endemic areas, the disease is well recognized and thus information can be easily elicited from a few prominent persons. Similarly, infective water sources are identified with the help of the cases and community leaders. Three case search operations have already been carried out, and two similar operations are planned for the coming years. Areas in which no cases are detected for 2 consecutive years will be declared free of the disease.⁹

The lists of the endemic villages have been given to the concerned public health environmental engineering organizations so that they can arrange to supply safe water in these places on a priority basis. The current International Drinking Water Supply and Sanitation Decade has provided additional stimulus and impetus to such an activity.¹⁰ The infective water sources will be closed when an alternative safe water supply is available. In places where this is not possible, these sources may be made safe by, for example, converting them to drawwells.

Use of Temephos as a Cyclospicidal Agent

The provision of a safe water supply in all the disease endemic areas will take time, and, when available, the supply may be intermittent or it may break down at times. For these reasons, people may continue to use water from infective sources, which must, therefore, be treated periodically with a cyclospicidal agent.

Temephos is considered the most suitable because of its effectiveness and very low mammalian toxicity (G. Weisfeld, 1979, personal communication; G. C. Joshi, 1980, personal communication). Sand granules containing

2 percent temephos have been found to be a suitable formulation, and this is applied at the rate of 1 g/20 liters of water (50 g/m³) resulting in a dosage of one part temephos per million parts of water. A premeasured quantity of granules in a sprinkler should be applied uniformly. Usually temephos is applied every 6 weeks or so as indicated by the density of cyclops during the transmission season. The first application should be made immediately before the transmission season. The effectiveness of temephos for different types of water collections may vary. A new device for determining densities of cyclops--the recently designed "funnel net"--could be adopted.¹¹

Personal Prophylaxis

For individual protection the simple measure of sieving water through a double-folded muslin cloth to filter out the cyclops is advocated.⁴ Boiling infected water, although effective, is neither practical nor economical.

Treatment

Treatment of cases is undertaken as a medical relief measure. Patients are encouraged to visit the nearest primary health center or dispensary where they can receive the necessary health education. The age-old treatment of laboriously rolling out each emerging worm a few centimeters each day is no longer necessary, since drugs such as niridazole, thiabendazole, and metronidazole can be given to the patient for more rapid expulsion of the worm. Other measures can also be taken for the prevention or treatment of complications.^{2,12}

Health Education

Health education is a vital component of the disease eradication program, and all staff and the available media will be used for this purpose. They will tell how this disease is transmitted, what methods of personal prophylaxis exist, and what kinds of activities are being undertaken toward eradication of the disease. The affected communities, and particularly the active cases with blisters, are instructed about the imperative necessity of their not coming into contact with sources of drinking water.

Evaluation of the Program

Officers responsible for the implementation of the program at the central, state, and peripheral levels will undertake a concurrent evaluation. This evaluation will cover achievements related to the main operational activities (e.g., quality and thoroughness of case search operations), progress in the provision of safe water supplies in disease endemic areas, and chemical treatment of infective water sources. The evaluation exercise will also include the impact of operational activities, which is measured in terms of reductions in the number of affected areas and incidence of cases until no affected village or new case is recorded in any of the endemic states for 2 consecutive years.

If a new endemic area is found during any of the case search operations, proper epidemiological investigations will be carried out as to how and from where the person(s) acquired the infection. The necessary remedial action will then be instituted accordingly.

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DRACUNCULIASIS: ITS HISTORY AND ERADICATION IN THE USSR

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HISTORY OF DRACUNCULIASIS RESEARCH

Dracunculiasis is one of the oldest parasitic diseases of man. The parasite itself and the symptoms of the disease were known quite long ago.

The first information on dracunculiasis was found in the writings of Egyptian, Roman, and Greek physicians, and much attention was paid to this helminthosis by such Eastern doctors as Abu Ali al-Husain ibn Abdallah ibn Sina (Avicenna), Bagadur, and Hodzendi. Avicenna (980-1037) was the first to give a detailed clinical picture of the disease. He noted the animal origin of the pathogen and recommended various treatment procedures and drugs.

Interest in the structure of the parasite dates from the seventeenth and eighteenth centuries. In 1674, Velschius described the parasite and discussed various theories concerning its existence. In 1758, Linnaeus published his Systema Naturae, in which names were given to all the then-known helminths, including the dracunculiasis pathogen, which thereafter bore the name Dracunculus medinensis (L. 1758). Until the nineteenth century, scholars knew nothing about the biology of the parasite, nor about the epidemiology and prophylaxis of dracunculiasis.

In 1868, Russian researcher Aleksej Pavlovic Fedchenko (1844-1873) organized an expedition to the area that is now Soviet Central Asia. During his travels, he noted the great harm caused by dracunculiasis to the health of the populations of Samarkhand, Bukhara, Dzhizak, and Karshi, and in 1869, he began to study the disease.

Until the middle of the last century there were four points of view as to how humans contracted dracunculiasis. The parasite larvae either: (1) were carried by insects; (2) were dispersed in the air and entered the human body when infected air was breathed; (3) entered

the human body with food and drinking water; or (4) were present in ponds and the soil and entered the human body through uncovered parts. Fedchenko's discovery of the intermediate host provided information on the life cycle of the helminth and explained how dracunculiasis was contracted.

In 1869, Fedchenko discovered D. medinensis larvae in the body cavity of copepods (Cyclops), successfully infected Cyclops with the larval parasites in a number of experiments, and traced their development in Cyclops. On the basis of his knowledge of the biology of the parasite, Fedchenko put forward the epidemiological formula of dracunculiasis: man is the definitive host of the parasite; Cyclops is the intermediate host; Cyclops are infected with larval parasites that enter water from a person with the disease; and man becomes infected when he drinks unboiled water that contains Cyclops with mature larvae in their bodies.¹

Fedchenko established the epidemiological features of dracunculiasis in the areas of Central Asia that he visited. He noted the importance of the small storage ponds ("hauzy"), which literally teemed with Cyclops, as well as the way in which they were used as sources of water for washing clothes, bathing, etc. Furthermore, he compared foci in Bukhara, Dzhizak, and Karshi, where the storage ponds were never cleaned, where their water was hardly ever changed, and where dracunculiasis morbidity was extremely high, with those in Tashkent,* where the water in the storage ponds was frequently changed and invasion was not noticed. Fedchenko also outlined prophylactic measures: "What needs to be done to avoid becoming infected is to drink boiled or filtered water, or, at the very least, running water from irrigation channels. . . ."¹ Fedchenko published his experimental results and observations in five papers that appeared from 1870 to 1875.

The years 1923-1932 were mainly a period in which the epidemiology of dracunculiasis was studied and systems of measures were devised for eradication of the disease in the city of Bukhara and in eight adjacent permanent settlements--the only remaining foci of invasion in the USSR by that time. (Other known foci--Samarkhand, Dzhizak, Karshi, Khiva, Gergana, Katta-Kurgan, and Merv--had, for various reasons, become extinct by this time.) This task was carried out by the Tropical Institute, founded in Bukhara in 1924 and headed by Leonid Mihajlovic Isaev. Isaev demonstrated that D. medinensis

*A number of authors have mistakenly reported the existence of dracunculiasis in Tashkent, (e.g., R. Muller² and others).

embryos did not find their way into the body of Cyclops by boring through the integument but through ingestion, and he made a detailed study of larval development in Cyclops to the invasive stage. He also succeeded in reproducing dracunculiasis experimentally in dogs.

ERADICATION OF DRACUNCULIASIS

All this work made it possible to define approaches to control of the disease: the timely detection and recording of sufferers from dracunculiasis, measures to render them harmless as sources of invasion, the destruction of Cyclops in storage ponds, and health education. Control was based on the principle of breaking the epidemic link between the definitive and intermediate hosts.

To prevent larvae from entering storage ponds, corrosive sublimate (in a dilution of 1:1,000) was administered to worms already in human tissues, resulting in death of the larvae, and mechanical stimulation of the helminth leading to expulsion of embryos from the uterus was sometimes carried out. Well covers were also fitted. Action taken against the definitive host also included a campaign in Bukhara against dogs with dracunculiasis, which played an important role in the epidemiology of the invasion in Bukhara. Finally, health education was widely carried out using a film produced for the purpose.

In the campaign against the intermediate host, stagnant storage ponds were periodically drained and cleaned, keeping in mind the development periods of Cyclops and the larvae. In addition, water levels in storage ponds were lowered at certain times to make conditions less favorable for resident Cyclops, and cracks in lined storage ponds inhabited by Cyclops were cemented. Finally, the clay-lined storage facilities ("humby") in which people stored water were cleaned periodically.

All foci had been rendered healthy by 1932. Before initiation of this effort, dracunculiasis infestation had reached 20 percent (some 10,000 sufferers).* New cases recorded in the years 1926-1932 were 148, 207, 95, 59, 39, 1, and 0, respectively. Defeat of the helminth was assisted by the construction of a water supply system in Bukhara in 1929.

The period from 1932 to the present has been mainly one of epidemiological monitoring and carrying out prophylactic measures to prevent reestablishment of the disease in settlements. During this period, the dracunculiasis pathogen has been found in various districts in

*In 1947, N. R. Stoll inaccurately estimated the number of dracunculiasis sufferers in the USSR, namely, 3.3 million instead of 10,000.

the republics of Soviet Central Asia and Transcaucasia in a number of carnivorous animals (badger, jackal, common fox, cat, dog). No human cases have, however, been found during this period. Consequently, dracunculiasis has not occurred as a human disease in the USSR for half a century* despite the presence of the pathogen under natural conditions.

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*The 1940s are mistakenly given in the literature as the time when dracunculiasis was eradicated in the USSR.

**PROPOSED WHO/AFRO PROGRAM FOR CONTROL OF
DRACUNCULIASIS IN THE AFRICAN REGION**

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As improvements are made to water supply systems, the incidence of dracunculiasis (guinea worm disease) will no doubt continue to decline in areas where it still persists, but additional control measures will probably be required. For example, India has recently embarked on a national effort that combines intensified surveillance, provision of safe drinking water, provisional chemical treatment of unsafe water sources, and health organization. This effort is intended to eradicate dracunculiasis from India by December 1985. Although the control and eventual elimination of dracunculiasis are feasible, this disease has not received enough attention in national health programs in the African Region.

PROPOSED PROGRAM

Objectives

The specific objectives proposed by the World Health Organization (WHO) for the control of dracunculiasis in the African Region include:

- o Creating awareness of this disease and its socio-economic impact, and the benefits of eliminating it
- o Strengthening international recognition of the problem and attracting bilateral and multilateral resources
- o Demonstrating the role of safe drinking water in eliminating dracunculiasis.

The proposed program would, during the International Drinking Water Supply and Sanitation Decade (IDWSSD), give priority to the provision of safe drinking water for all identified villages and areas affected by dracunculiasis and currently having cases of the disease.

Areas with a past history of cases should have second priority.

International awareness and recognition of dracunculiasis have been essentially accomplished by the May 1981 resolution of the World Health Assembly, the advent of the IDWSSD whose steering committee endorsed the idea of using dracunculiasis control as an indicator of the Decade's impact on health, and the initiation of a national program for the eradication of dracunculiasis in India.

Planned Activities

Although the planned activities deal with dracunculiasis in the whole African Region, immediate efforts will focus on West Africa. AFRO, the WHO regional office located in Brazzaville, Congo Republic, is cooperating with affected member states in this subregion to initiate and implement their national programs for dracunculiasis eradication in conjunction with their primary health care services and water and sanitation projects.

The plan of operation includes three principal phases. In Phase I, current knowledge of dracunculiasis will be reviewed and accurate baseline data established. During Phase II, suitable control measures will be developed, while Phase III will include evaluation and monitoring.

Phase I

During this phase, heavily infected villages and areas at risk will be identified. As a first step, AFRO has asked all concerned member states in West Africa to intensify their epidemiological surveillance of dracunculiasis, to identify areas of high prevalence, to select sample villages or areas for frequency observation, to measure the extent of infection in selected communities, and to measure the economic impact. All these activities will pave the way for follow-up studies to monitor progress in the reduction of this disease and its final elimination.

The current distribution of dracunculiasis in the African Region includes much of the savanna belt of West Africa and some parts of eastern Africa. The disease apparently exists in Benin, Cameroon, Chad, Ethiopia, Ghana, Guinea, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sudan, Togo, Uganda, and Upper Volta. The number of cases given in Table 1 were obtained from official data and from published reports related to the areas of operation.

TABLE 1 Reported Cases of Dracunculiasis, Africa

Country	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Benin	1,480	-	820	-	-	-	-	-	-	-
Atakora	90	-	90	-	-	-	-	-	-	-
Atlantic	100	-	90	-	-	-	-	-	-	-
Borgou	130	-	50	-	-	-	-	-	-	-
Mono	70	-	30	-	-	-	-	-	-	-
Quesse	90	-	50	-	-	-	-	-	-	-
Zou	1,000	-	510	-	-	-	-	-	-	-
Cameroon	-	-	-	251	-	-	-	-	-	-
Chad	-	-	-	-	-	-	172	-	-	-
Ghana	693	1,606	1,226	4,052	1,421	1,617	1,676	-	-	-
Accra	6	30	15	49	3	65	22	-	-	-
Ashanti	35	-	-	1,536	229	19	88	-	-	-
Brong.										
Ahafo.	290	453	90	194	225	362	619	-	-	-
Central	18	95	-	267	62	143	146	-	-	-
Eastern	624	48	261	600	335	319	89	-	-	-
Northern	127	910	748	1,031	454	231	432	-	-	-
Upper	348	9	56	185	86	347	75	-	-	-
Volta	45	27	39	127	62	71	148	-	-	-
Western	200	34	15	63	15	60	57	-	-	-
Ivory Coast	4,891	4,654	6,283	4,971	4,656	5,207	6,993	-	-	-
Mali	668	786	737	542	760	1,084	-	-	-	-
Mauritania	-	-	-	-	-	127	-	-	-	-
Niger	-	-	-	-	2,600	3,000	5,560	-	-	-
Nigeria	98	-	-	1,007	-	-	-	-	-	1,693
Senegal	-	334	208	65	137	-	-	-	-	-
Togo	-	-	-	3,261	1,648	-	2,617	2,673	-	-
Upper Volta	5,822	4,404	4,008	6,227	1,557	-	2,885	2,694	2,565	-

The surveillance data obtained are useful only as a broad indication of the general geographic areas known or reported recently to be affected. They reflect only superficially the numerical extent of the problem, since this disease occurs in areas where reporting and surveillance systems tend to be rudimentary or nonexistent. The disease has, in general, been neglected, and affected communities realize that hospital visits can do little, apart from controlling secondary infection, to modify the course of the disease. Thus patients tend to accept this health problem with resignation.

In one study in Togo in 1977, less than 4 percent of observed dracunculiasis cases had been reported to public health authorities. A recent study in Benin, in 1981, showed dracunculiasis to be present in almost all regions of the country. Out of 513 villages surveyed, the infection exists in 192 villages, and it is estimated that 600,000 persons are affected. Another survey to study the socioeconomic impact on these affected areas is under way, and the final results are expected to be available by May 1983.

When public health workers conducted a special village-by-village search for dracunculiasis in India in January-February 1981, they found an estimated 5.9 million persons to be at risk in 7,533 affected villages of seven states, whereas in response to a written inquiry 15 months earlier, the same areas had reported 1.8 million persons in 728 villages to be at risk of this disease. That is, therefore, a need to investigate further the present incidence and prevalence of dracunculiasis, particularly since it is established that only a third of the cases are seen in health centers and hospitals in West Africa. It is hoped that as more attention is paid to this disease, surveillance will improve.

In West Africa, a survey of dracunculiasis in Upper Volta is now being carried out by the Organisation Centrale Contre les Grandes Endémies (OCCGE), which has its headquarters in Bobo Dioulasso, with the participation of a U.S. Centers for Disease Control (CDC) staff member. Discussions are now under way on the initiation of similar studies in other countries, namely, Mali, Benin, Togo, and Ivory Coast. There is an understanding that the CDC staff member on EPI projects carried out under the auspices of the U.S. Agency for International Development (AID) will be available if additional studies are carried out.

As a further step toward accelerating the dracunculiasis survey, the project, Strengthening Health Delivery Systems (SHDS), based in West Africa under AID auspices, has agreed to provide a consulting epidemiologist for 3 years to cooperate with interested governments

in carrying out surveys to clarify the extent of the disease and its impact on affected areas. During his mission, the consultant will study further the most suitable methods of case-finding to determine the prevalence of infection in selected areas and the peak season.

Phase II

In Phase II, a feasibility study will be carried out to determine the most suitable methods and strategies for controlling dracunculiasis, with an emphasis on cost-effectiveness in the African environment. This study is intended to support AFRO's initiation and encouragement of national efforts in West Africa to intensify surveillance, provision of safe drinking water, provisional chemical treatment of unsafe water resources, and health education with the intention of eradicating dracunculiasis.

The use of all available media and various approaches to health education to convey the necessary knowledge about the disease is the backbone of the eradication program. Special training and hygiene instruction will be particularly directed to paramedicals, primary health care workers, village elders, religious leaders, teachers, and all voluntary agencies. In the absence of a safe drinking water source, the salient methods of prevention are: boiling water before drinking, sieving it through a double-folded cloth, or treating it with chemicals. Wide publicity will encourage communities to only use safe drinking water and, more important, will discourage infected persons from coming into contact with water in ponds, wells, tanks, etc. Full participation by members of the community in planning and operating the campaign will encourage proprietary pride and ensure the success of the eradication program through their own efforts.

Phase III

Indices of economic and social activities must be identified and developed to measure the impact of dracunculiasis control. These parameters must be based on the local social and economic situation, e.g., industrial or agricultural enterprises, school attendance and absenteeism, etc.

Guidelines for evaluating control achievements and to act as a suitable basis for assuring that elimination has been achieved will be established. The prevalence

of dracunculiasis before and after intervention to interrupt transmission will be measured. A 2-year follow-up after safe water is provided and used will be needed.

WHO/AFRO INVOLVEMENT

Resolutions by the May 1981 World Health Assembly and by the IDWSSD Steering Committee emphasized the importance of the Decade to health worldwide, efforts expected from member states, and the support to be given by WHO, the U.N. Development Program (UNDP), and other organizations and donor agencies. Following resolution WHA 34.25 of the thirty-fourth World Health Assembly, AFRO strengthened its communication and technical cooperation with member states in order to start and consolidate their national campaigns for eradication of dracunculiasis based on a primary health care system.

The activities of the program have thus far consisted chiefly of joint multidisciplinary consulting missions involving health engineers, epidemiologists, health educators, financial analysts, etc. Interested international, intergovernmental, nongovernmental, and bilateral agencies have also been contacted for technical and financial cooperation. As part of its regional program for the Decade, WHO is collaborating with member states in formulating national drinking water supply and sanitation programs, including dracunculiasis eradication, and in identifying external funds. In this connection, operational linkages are being developed with CDC, SHDS, and OCCGE.

EHE/HQ has proposed that a WHO sanitary engineer be attached to the mission that is presently carrying out a dracunculiasis survey in Upper Volta with a view toward relating the mission more effectively to actual government programs for the improvement of water supply and sanitation. Funds had been earmarked for this offer.

A variety of international, bilateral, and multilateral agencies are currently cooperating with WHO in providing technical or financial support for the African Region:

- o The interregional WHO/SIDA (Swedish International Development Agency) cooperative project is providing two permanent professional staff members-- a health engineer and a financial analyst.
- o The interregional WHO/GTZ (Agency for Technical Cooperation of the Federal Republic of Germany) cooperative project is providing a health engineer to be based permanently at Ouagadougou, Upper Volta. A decision has also been made to

assign a second full-time health engineer to be based at Lome, Togo. The project has been particularly active in organizing and running national workshops which have provided excellent media for gaining national support for ongoing activities.

- o The joint WHO/World Bank program is under way in many countries in the region.
- o At the country level and frequently on a bilateral basis, several multilateral, bilateral, and nongovernmental agencies are currently cooperating or are willing to do so, including the European Development Fund, West African Economic Community, Fonds d'Aide et de Coopération, Norwegian Agency for International Development, Danish International Development Agency, Saudi Fund, CARE, etc. For all these activities, coordination and follow-up are provided at the WHO/AFRO Regional Office in Brazzaville, Congo.

WHO intends to coordinate its program with the planned or yet unplanned water sanitation programs carried out in dracunculiasis-infected areas and supported by UNICEF; the International Labor Organization's Special Public Works Program; the World Bank's Technical Advisory Group and Population, Nutrition, and Health Project, and the European Development; GTZ, and WHO's own programs carried out in connection with the water and sanitation decade.

A comprehensive operations manual on the eradication of dracunculiasis in Africa will also be developed. Persons working in the field will find such guidelines and methods of national surveillance useful in carrying out their day-to-day work.

Training of nationals at all levels will have top priority in order to improve managerial skills, provide manpower training, establish information systems, and allow the operation and maintenance of existing facilities. Such task forces are needed to carry out a well-planned strategy for the eradication of dracunculiasis in West Africa.

IMPLEMENTATION OF CONTROL ACTIVITIES IN GHANA

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Dracunculiasis (guinea worm disease) is posing a serious health problem in Africa, Asia, and the Middle East. In Ghana, the records indicate that it occurs in almost all the poor rural areas of the country.

Information on water-borne diseases is needed to plan water supplies and health measures for their control. In this regard, attempts have been made to compile information for Ghana on the occurrence of dracunculiasis and on how the disease relates to sources of water supply. The resulting report provides an organized presentation of existing records of observed incidence of water-borne diseases and where those diseases occur in Ghana.

To make the report as useful as possible for planning purposes, information was provided by district, that is, each of Ghana's nine regions was divided into survey areas. Medical statistics, hospital records, and other information on the number of recorded cases of water-borne diseases in each survey area depict how these diseases relate to sources of water supply. Where no figures were provided for given disease, it only meant that no cases had been recorded and not that the survey area was necessarily free of disease.

An analysis of the compiled information supported the initiation of a government policy on water supplies and sanitation programs. From the data, it was observed that where treated pipe-borne water was provided, as in towns and urban communities, dracunculiasis was virtually eliminated. Furthermore, the district surveys indicated that dracunculiasis was prevalent in almost all rural communities where there were no safe water supplies.

In southern Ghana, guinea worm disease was found in villages that depend on pond water during the dry season. The recent occurrence of the disease in the survey area indicates that the disease is spreading. This is attributable to the fact that almost half of the 159 villages surveyed use pond water, and residents frequently travel to endemic areas.

These observations led to the conclusion that dracunculiasis can be completely eliminated by the provision of safe water supplies. Ghana must now develop the information available about the incidence of infection--geographically and numerically--and institute continuous surveillance and documentation of the benefits of disease control.

Guinea worm disease incapacitates farmers, school children, and other villagers, thus affecting a community's agricultural productivity. In southern Ghana, the survey established that male farmers are at the greatest risk of infection.

The disease has had particular effect on cocoa production in Ghana. Cocoa farms are normally located in remote areas where water sources are grossly polluted and farmers have no alternative but to use the sources for drinking purposes. Because these areas do not have access to health posts, clinics, or hospitals, cases of the disease are not reported. Thus health agencies must attempt to study the prevalence of guinea worm disease particularly in remote farming areas. In the meantime, public health educators must inform Ghanaians about the preventive measures of boiling and filtering water.

CONTROL OF DRACUNCULIASIS

The most effective preventive measure for control of dracunculiasis is the provision of safe water supplies, and attempts are being made to provide low-cost systems to the affected communities. The type of water supply system selected will vary from one community to the next. Those under consideration are:

- o Wells and springs, protected to avoid contamination
- o Rain harvesting
- o Wells fitted with hand pumps
- o Deep mechanized bore holes (i.e., fitted with submersible pumps)
- o Conventional treatment (i.e., surface water, preferably selecting water treatment systems that incorporate slow sand filtration).

Water Source Selection

The process of choosing the most suitable water source for a public water supply largely depends on local conditions. Where springs are not available, the best

option is exploring groundwater--digging wells and drilling a tube well. If groundwater is not available, it will be necessary to consider surface water from sources such as rivers, streams, or lakes, which will almost always require treatment to make it safe for human consumption. Where the rainfall pattern permits, rainwater harvesting and storage for dry periods can be provided. This may be sufficient only for household and small community supplies, however.

All control measures should be directed toward freeing domestic water supplies from Cyclops and preventing infected people from contaminating water supplies. Boiling unsafe drinking water is a good control measure since cyclops are killed when water is heated to 65°C. Simple filtration will remove cyclops and excess lime will kill them, but they are resistant even to comparatively large doses of chlorine. Public education is also a vital control ingredient.

Control in the Context of the IDWSSD

Since guinea worm disease prevention is an official target of the International Drinking Water Supply and Sanitation Decade (IDWSSD), provision of safe drinking water in rural communities continues to receive the support of the Ghanaian government so that the disease can be eliminated in the early part of the Decade.

According to the present sector status and policy for a water supply, the Ghana Water and Sewerage Corporation (GWSC) is responsible for supplying water in both urban and rural communities. Urban communities are always provided with pipe-borne water. House-to-house connections are encouraged, and public standpipes are provided wherever necessary. In rural areas, pipe-borne water through standpipes is provided for communities of between 2,000 and 5,000 people. For those with less than 2,000 population, water is provided from drilled wells fitted with hand pumps. In 1975, 92.49 percent of the urban population had access to a potable water supply, while only 16.6 percent of the rural population enjoyed this benefit. Consequently, the emphasis has now greatly shifted to the rural areas.

The Ghanaian government's concern with protecting public health is reflected in the increasing resources it has been devoting to this area over the past years. For example, from 1975 to 1980, the percent of total population enjoying a potable water supply increased from 38.2 to 48.3. The percentage of urban and rural populations served with potable water in 1980 was 94.1 and 29.9, respectively. This represents, over the 5-year

period, increases of 1.61 percent for the urban population and 13.3 percent for the rural population.

National Sector Plan for the Decade

The Decade target is to:

- o Provide pipe-borne water to 71 communities with over 2,000 inhabitants and 250 communities with between 500 and 1,999 inhabitants which are en route or close to pipelines.
- o Provide water from drilled wells fitted with hand pumps for 790 communities in the 500-1,999 population range.
- o Upgrade and extend existing water supply systems to the urban fringes.

It is expected that this target will make it possible for 72 percent of the total population to enjoy potable water supplies by the end of the Decade in 1990, including 61 percent of the rural population. Although the target for providing everyone in the country with access to a safe supply of drinking water will not have been achieved, the occurrence of guinea worm disease in the rural areas will be reduced considerably.

The largest rural water supply scheme, which is located in the upper region of Ghana, presently has a public education component aimed at creating an awareness of the value of hand pump-fitted systems. This program will encourage the population to ignore their polluted water sources and appreciate the value of good drinking water. A similar program will be incorporated in a rural water supply program currently under way in central and southern Ghana.

Two major ongoing projects in Ghana that will have a tremendous impact on the health of rural dwellers by eliminating dracunculiasis are concerned with drilling wells and fitting them with hand pumps. With the help of bilateral assistance from the Federal Republic of Germany and the Canadian International Development Agency, these projects will cover 3,000 wells in central and southern Ghana (2,000 have already been completed under Phase 1 of the program), and 1,500 wells in upper Ghana, all of which are in operation. These projects are scheduled for completion by early 1983.

Close cooperation between the Ghana Water and Sewerage Corporation and the Ministry of Health will be required so that high priority is given to the construction of safe water supply schemes in areas where guinea worm disease occurs. It is expected that this disease

will be reduced drastically in most areas of Ghana during IDWSSD, although some difficulties remain in implementing Decade programs:

- o There is a shortage of GWSC professional staff to carry out efficiently the planning, design, and supervision of development projects and the operation and maintenance of the system.
- o Government financing and foreign exchange for the importation of plant and equipment are inadequate.
- o The supply of construction materials (i.e., reinforced steel, cement, etc.) is inadequate.
- o Local pipe manufacturers are unable to supply pipes on schedule due to a shortage of imported raw materials.



DRACUNCULIASIS IN TOGO

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INTRODUCTION

The population of Togo is estimated at 3 million, 85 percent of whom live in rural areas, grouped in 2,579 population centers. More than 49 percent of the total rural population is clustered in villages of between 100 and 500 inhabitants.

The climate of Togo is one of moderate rainfall with intense evaporation and fixed dry seasons every 3-5 months, especially in the northern part of the country. The geologic conditions in Togo make it difficult to excavate wells by hand. The shallow bedrock composing much of the country is made up of crystalline rocks.

Because of these conditions, most of the population must use the traditional polluted sources of water supply: small rivers or lakes, ponds, catchments, poorly constructed and badly protected wells, etc. Sanitation statistics show that diseases directly or indirectly connected to water are prevalent in Togolese pathology, and that dracunculiasis (guinea worm disease) is one of these water-borne diseases.

SOME EPIDEMIOLOGIC CONSIDERATIONS

Table 1 shows the reported cases of dracunculiasis in Togo in 1979. Transmission of the disease is linked to the environment and poor hygiene. A long dry season promotes the population's use of scarce water sites heavily infested with infected Cyclops, particularly in the regions of Tsévié, Notse, Bassari, Niamtougou, and Dapaong.

Both the intake of nonfiltered or unboiled water and exposure of the diseased part of the human body to water, allowing the female worm to discharge embryos that are ingested by Cyclops, assure perpetuation of the disease.

TABLE 1 Number of Reported Cases of Dracunculiasis, Togo, 1979

Location	Number of Cases
Lomé	27
Anécho	3
Vo	--
Tsévié	204
Tabligbo	12
Kloto	62
Notse	87
Atakpamé	18
Anlame	--
Badou	--
Sotouboua	--
Tchaoudjo	19
Bafilo	4
Tchamba	--
Bassari	98
Lama-Kara	25
Niamtougou	412*
Kandé	--

*Dracunculiasis and onchocerciasis.

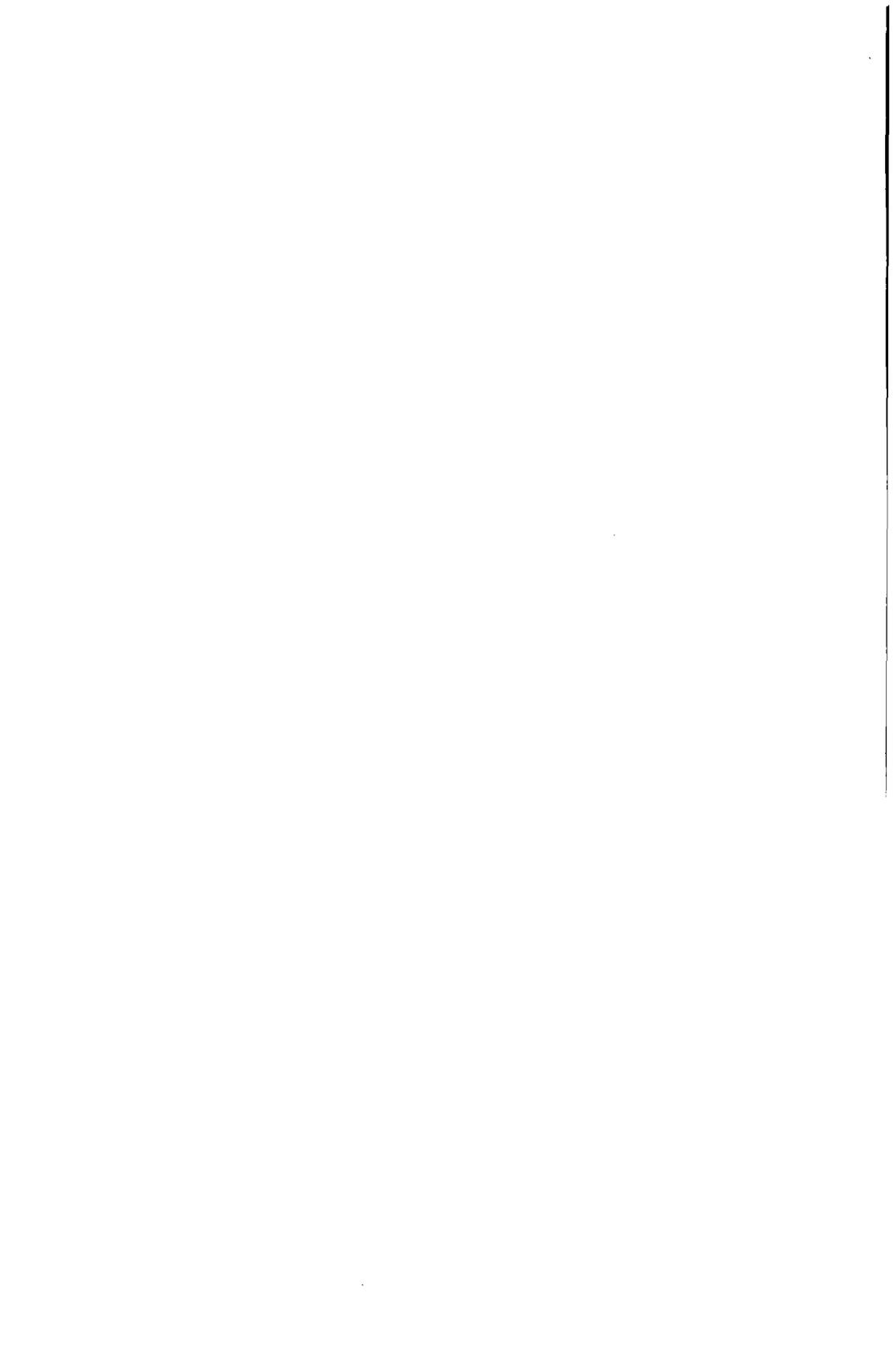
CONTROL STRATEGIES

General control strategies include managing wells and other water sources, furnishing safe potable water, and impeding the users' direct contact with sources of water. Some preventive measures include treating the water before consumption by boiling it or at least filtering it through finely meshed material. Ponds that provide drinking water could be disinfected using lime or chlorine. Some fish that eat Cyclops, such as Gambusia affinis and the Poecilia "guppy" which is being tested in Togo, could be introduced into pools.

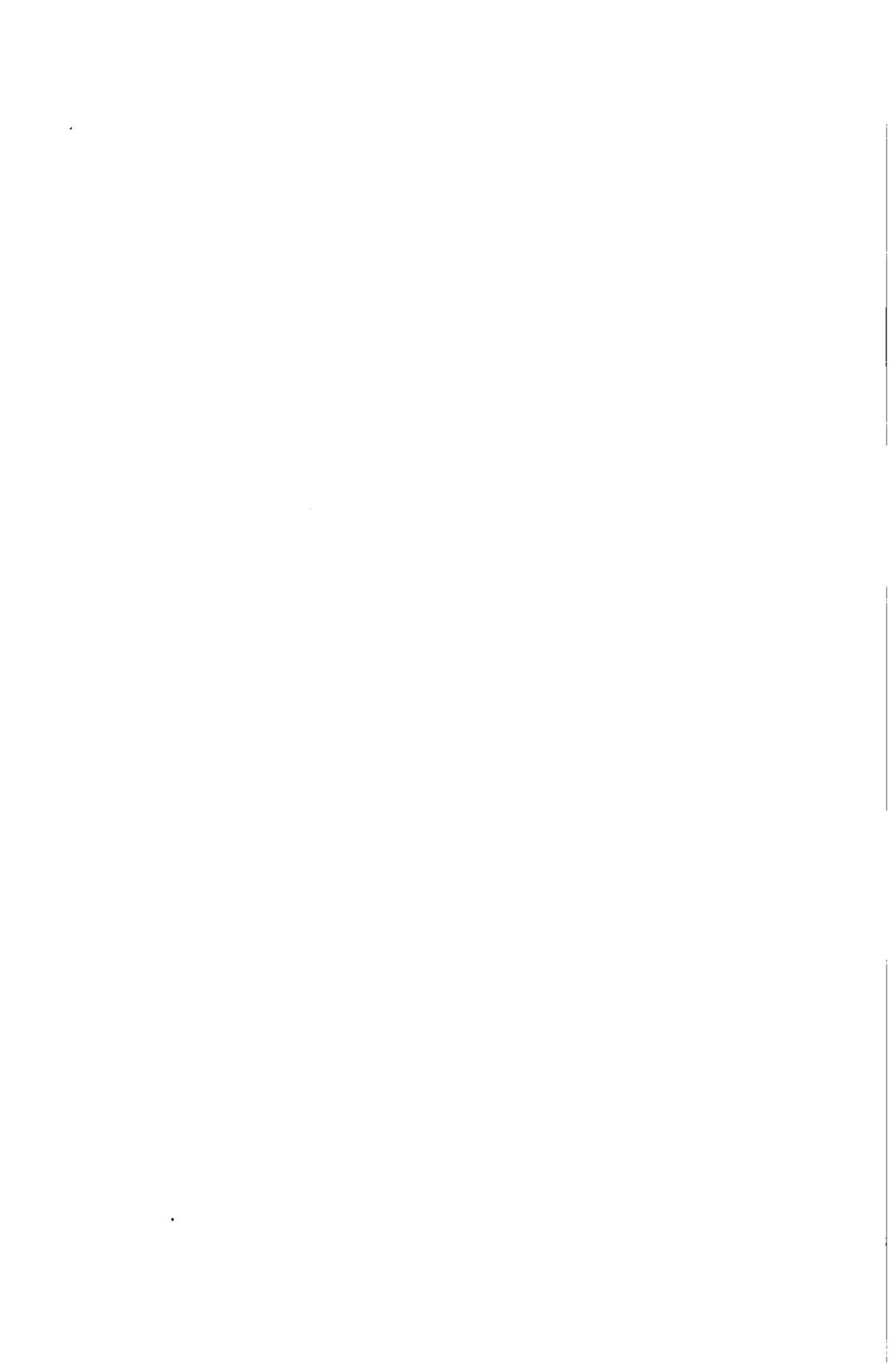
In the strategy for Togo's 3-year plan, the provision of safe water to Togo's population is number one priority, and all other government programs are more or less dedicated to achieving this goal. Justification of this policy does not reside solely in the aims of providing proper sanitation and improved water supplies; economic factors are also important. This policy is being accomplished by supplying potable water to all urban population centers and establishing village waterworks, including a certain number of projects of which the principal objective is to manage a water site for 500 inhabitants.

The success of this policy should result in a better quality of life for the Togolese in general, and better health. The success of the village waterworks program will unquestionably result in the reduction, and perhaps even the elimination, of dracunculiasis, which has long been a cause of absenteeism from work by many of Togolese who live in heavily infested areas.

The principal bottleneck of such a village waterworks program is insufficient financial resources. Outside bilateral or multinational sources of funding are needed to bring about the desired effect and to complement the effort being made by the Togolese government. To measure the level of reduction or elimination of guinea worm disease resulting from the village waterworks program, a number of population centers in heavily infected areas should serve as the subject of epidemiological studies to be carried out, during, and after the program.



SOCIAL AND ECONOMIC ASPECTS



**THE IMPACT OF DRACUNCULIASIS ON THE HOUSEHOLD:
THE CHALLENGE OF MEASUREMENT**

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The annual worldwide incidence of dracunculiasis (guinea worm disease) is a matter of widely varying speculation, and estimates range from 10 to 48 million cases.^{1,2} One scholar, however, has indicated that nearly 20 years have elapsed since these estimates were made. The doubling of the world's population without a reduction in mitigating factors could have resulted in an increase over these figures.³ Other studies suggest these figures may be overestimates.⁴

A review of the literature on dracunculiasis provides only limited estimates of the number of households or percentage of productive members (defined here as ages 15-44) represented among the affected. A considerable number of studies fail to provide simple community demographic information organized according to the same age and sex breakdowns used in counting cases. Others only cite experience with clinical cases.⁵⁻⁷ For other disease entities, however, the pattern of reporting may include:

- o Actual community maps showing geographic incidence and prevalence by household^{8,9}
- o Information on the percentage of a given age group afflicted⁹⁻¹²
- o Household attack rates.¹³

In the epidemiologic literature on guinea worm disease, therefore, the incomplete data on the individual, household, and community severely hamper attempts to estimate the extent of the problem.¹⁴ Needed are (1) an understanding of the variability in attack rates by community and household, (2) a unified scaling system for estimating individual case severity, and (3) a consensus on which of the many existing systems is adopted for estimating the physical, economic, and social impacts of the disease.

Until that consensus is reached, however, it is necessary to examine what is currently provided about variations in levels of infection, the extent of possible disability, and the possible range of duration of such disability. Dean et al.¹⁵ have posed the following formula for calculating the impact of morbidity:

$$\text{Impact of Morbidity} = \frac{\text{duration of illness} \times \text{degree of disability}}{\text{population (in 100,000's)}}$$

This formula will provide a measure of disability per 100,000 people per year. To estimate lost working potential, it is necessary to have an idea of the average lifespan of the worker in each geographic area under investigation.

Existing studies provide a wide range of qualitative and quantitative measures of degree and duration of disability.^{2,12,16,17} Based on the availability of this information, rough attempts can be made to estimate annual days of work lost.

FACTORS IN TRANSMISSION

Transmission of guinea worm disease is limited to specific and identifiable times of the year^{12,18} (usually the driest season), when water use needs are greatest because of higher temperatures¹⁹ and heavy labor is required to prepare the fields for planting or harvesting.¹⁰

The agent, the adult Dracunculus medinensis whose life cycle has been described elsewhere,¹⁷ has a propitious (for the worm) sense of timing. The larva reaches the water source at the time of year when ponds have begun to dry up. At this time, the intermediate host Cyclops is in greatest concentration and is most likely to ingest the larva. Furthermore, the probability of humans completing the infection cycle is greatest.¹⁸

Differential infection rates may occur among those communities that rely on a variety of water sources. Similarly, the extent to which there is selective access to a water site can influence infection and contamination. Migration of individuals to endemic areas and their periodic return can lead to recurring contamination of a local water source after a period of abatement.²⁰

Most water sources are used for a wide variety of purposes in addition to water fetching, the most prominent being, swimming, bathing, and drinking¹⁹—activities that increase the potential for direct transmission of infection. Although efforts to provide barriers to

direct access to the water site, most notably for step-wells, have led to rapid reductions in Dracunculus infection, many sites do not lend themselves to such barriers. Furthermore, even if feasible, the use of pumps or pulleys generally requires a greater expenditure of energy and may reduce the social aspects of drawing water. In establishing such a system, all communities with standing water drinking sources must be identified. Moreover, migration patterns to and from such communities should be noted.

Table 1 summarizes the relationship between the agricultural season in a given area and the season of highest disease impact. Although these data provide only a rough sketch, there is apparently a considerable overlap between major agricultural activity and time of high incidence and prevalence of disease onset. This suggests that the potential impact of guinea worm disease on the economy is greater than that of diseases that lack such a highly defined seasonal relationship to peak productivity periods.

India's effort to develop a continual surveillance system²³ is a major step forward in the eventual elimination of this dread disease. Identifying those villages without existing cases but with the necessary environmental characteristics must be a part of this effort.

IMPACT OF GUINEA WORM DISEASE ON THE INDIVIDUAL, HOUSEHOLD, AND COMMUNITY

Any attempt to eradicate dracunculiasis must include consideration of: (1) the environmental factors affecting transmission, (2) aspects of the intensity of disease impact, (3) high-risk factors that lead to variation in susceptibility, and (4) social and health implications.

The chief impact of guinea worm disease, outside of physical pain and anguish, is socioeconomic. This fact and the immediate problem of severe morbidity suggest that eradication programs must emphasize not only prevention but also have an aggressive primary care component. This suggestion springs from growing evidence in the literature that the period of disability can be reduced considerably through timely medical intervention.^{16,24} Further, emergency programs must be developed to assist those communities where attack rates deplete the ability of households to come to each other's aid during planting and harvesting activities.

TABLE 1 Summary of Studies Documenting the Relationship Between Peak Transmission Periods of Guinea Worm Disease and the Rainy Season

Study	Relation of Peak Transmission Period to the Rainy Seasons			
	During Rains	Beginning of Rains	1-3 Months Before	4 or More Months Before
Muller ¹⁷	3	2	9	2
Sahba et al. ²⁰ (South Iran)				1
Saxena ²¹ (Madhya Pradesh)			1	
Belcher et al. ¹⁰ (South Ghana)			1	
Kale ¹² (West Nigeria)			1	
Johri and Saxena ²² (Madhya Pradesh)			1	
Edungbola ¹⁹ (Kwara State, Nigeria)			1	
Carne ⁵ (Mali)	1			

The Individual

Two factors appear to be highly related to the impact of dracunculiasis on the individual and, as a result, on his or her productivity: (1) duration of the disability, and (2) its severity. Table 2 lists a number of categorizations used to estimate severity. Definitions of severity revolve around the extent to which the individual is unable to farm or participate in other economic and important household activities. Although only limited evidence exists, according to the definition above, it appears that the estimate that approximately 40 percent of those afflicted are completely disabled is reasonable.²⁵

TABLE 2 Categorization of Severity

Kothari et al.¹⁶

- (i) Severe: acute edema, erythema, ulcer, and swelling accompanied by severe pain and marked disability
- (ii) Moderate: local swelling and ulcer with some pain and disability
- (iii) Mild: local swelling, ulcer, or both but no disability

Pardanani et al.²

Grade I: visible and palpable subcutaneous worm but no acute inflammation, preemergent stage

Grade II: ulceration with or without a protruding worm; inflammation, but not so severe as to cause disability

Grade III: abscess, ulcer, edema, and cellulitis, with or without malaise; secondary bacterial infection resulting in disability

Grade IV: more severe manifestations with acute deformities and marked disability

Kale¹²

Grade I (mild): with minimal or no discomfort

Grade II (moderate): with severe discomfort but mobile--usually with a limp (31 percent)

Grade III (severe): with severe discomfort and immobile

Packer²⁶

- 1--Minor disability
 - 2--Restricted activity
 - 3--Limited activity
 - 4--Limited mobility
 - 5--Confined
 - 6--Death
-

There is obviously no correlation between village attack rate and average individual duration of disability, but a high correlation does exist between (1) degree and disability and location of the worm in the foot and (2) length of disability and greater number of worms.

The Household

Although there is limited information on attack rates by household, where information does exist the household attack rate averaged 5.4 times that of the village. In cases where the household attack rate was lower than 5.4 times that of the village, it could be assumed that a number of households in the village were sharing unequally in the burden of affliction.*

The extent to which a household has a high household dependency ratio, little opportunity for alternate cash income, greater consumption demands than potential for productivity, and multiple members afflicted with dracunculiasis, identifies those households at high risk of further eroding their socioeconomic and health base. In short, a high rate of guinea worm suggests a possible vicious cycle of problems with a potential for actual economic destruction. Fortunately, this sequence is a worst-case scenario. While it is drawn from studies of the impact of other diseases on rural productivity as well as the general literature of rural development, the important point is that the existing literature on the impact of guinea worm disease provides a very limited basis for actually estimating disease impact.

The household dependency ratio is an heuristic statistic that attempts to estimate the extent to which household consumption demand is balanced with productivity.^{27,28} Most household productivity results from the efforts of members aged 15-44. Since this age group also consumes a higher level of household productivity than those who are younger, the value in having a high percentage of productive workers in the household is marginal rather than absolute.²⁹

Other factors such as availability of land and the potential for obtaining high cash wages are important considerations,³⁰ and the specific mix of cash and farming income is significant in estimating socioeconomic status. For example, to increase yields, a household may need to purchase advanced technology (machinery, pesticides, etc.).³¹ Families that have both adequate

*A more reliable figure is needed than that presented here. It was obtained from data on only six villages or village clusters (the standard deviation was +2.25).

material resources and local wage labor are likely to be the most successful, but at the same time, outside work in a cash cropping economy, unless only seasonal, reduces the pool of farm workers, and it can accelerate village and household member outmigration.^{27,32} The hypothesis that there is considerable labor flexibility in rural areas as a result of constantly available underemployment has not been well demonstrated.³³ Furthermore, during times of peak activity such as planting or harvesting, any flexibility that might have existed in rural areas disappears as the marginal farm workers are conscripted to help.^{29,32}

There is growing evidence that increasing demographic pressure on the household is important since the result is the "financing" of increased total food through reduced savings and nonfood consumption.³⁴ The additional demand for productivity also reduces leisure time and the expenditures of resources on equally critical activities such as child care.²⁸

The following formula is one means of estimating demographic pressure on a household, or region, but actual quantification of the variables would be difficult:

$$\text{Demographic pressure} = \frac{\text{productive adults} + \text{nonproductive adults} + \text{seniors} + \text{children}}{\text{productive adults (cash + farming income)}}$$

In this formula, demographic pressure is defined as the total of all household members divided by the number who are productive. Thus loss of a single productive member can seriously increase the demographic pressure on a household. The member point made by this formulation is that it is much more a function of social units for coping with the surrounding environment than a measure of people per square mile.²⁸

The states of the life cycle through which a household passes may also determine its ability to cope with disability. Additional children have an initial impact on household socioeconomic status because of child care demands, but make only modest demands on consumption.³⁵ As they grow, consumption demand also grows until the age they become productive.²⁹

Socioeconomic status can be represented in several ways. Household income has been found to be significantly related to "a child surviving to age 3."³⁶ Other socioeconomic factors found related to child mortality are: (1) the mother's educational level, (2) her health, (3) household use of toilet facilities, and

(4) type and availability of medical facilities.³⁶ In addition, an obvious and recurring theme in the literature is the relationship between health and the extent of disease prevalence in the area.³⁶

Community

Studies of an Asian influenza epidemic among developing country farm workers and of malarial attacks in Thailand and Sri Lanka have shown that a mere week of disability, on the average, can have a major effect on productivity.³⁷⁻³⁹ Assuming that 40 percent of those afflicted are completely disabled for an average of 43.4 days, an examination of village attack rates, primarily those of men and women in the most productive periods of their lives (ages 15-44), will give a rough estimate of days of productivity lost annually by the village:^{26,31}

$$\text{Total days lost} = \frac{\% \text{ ages 15-44 affected} \times 40\% \text{ complete disability}}{\text{annually} \times \text{average affliction of 43.4 days}}$$

Thus for every 6 percent of the population ages 15-44 affected, it may be assumed that approximately one day of productivity per worker is lost annually. An attack rate of around 35 percent would represent a week's work lost for each member of the productive population. Among the studies reviewed, this attack rate was not uncommon. In general, there appears to be high correlation between village and household attack rates.

In summary, factors that seem to identify villages at highest risk of serious economic loss from dracunculiasis through lost productivity are:

- o Attack occurs during peak agricultural effort.
- o A high attack rate occurs in the 15-44 age group.
- o A high average worm count per individual.
- o A long average period of disability.

CONCLUSION

Dracunculiasis has a major impact on community and household productivity because of its frequent occurrence at times of peak farming activities and its ability to disable severely those afflicted. Attempts made here to

estimate its impact are based on sketchy information. The existing literature, however, permits an assessment of its impact which may justify establishing a comprehensive surveillance system and a balanced approach that includes preventive and curative services. There is also a need to establish more complete data bases, comparing those attacked to the remainder of the village population in order to identify high-risk communities and households.

To build a case for a comprehensive intervention program, it must be determined to what extent the disease is responsible for the following sequence of events:

- o Increased disability
- o Reduced manpower
- o Increase in the effective dependency ratio (due to disabled adults)
- o Reduced leisure time
- o Reduced productivity
- o Increased market dependency
- o Reduced savings
- o Reduced consumption
- o Reduced nutrition
- o Decline in general health parameters.

Development of studies to assess this impact should have a high priority, but should not divert resources away from efforts to eliminate guinea worm disease as a health threat. Rather, studies that provide field workers with clear guidelines in deciding where to focus scarce resources should be assigned the highest priority, and they should include:

- o Refined comprehensive surveillance schemes
- o Systems for identifying communities and households at high risk of serious socioeconomic and health repercussions from infection
- o Careful estimates of variables influencing loss of productivity as a result of disease
- o Studies that provide criteria for allocating limited resources in a balanced fashion to preventive primary disease care and social welfare efforts for those most affected.

Programs to deal with dracunculiasis should not, however, wait until this information is available. Its impact has already been demonstrated in numerous studies worldwide.

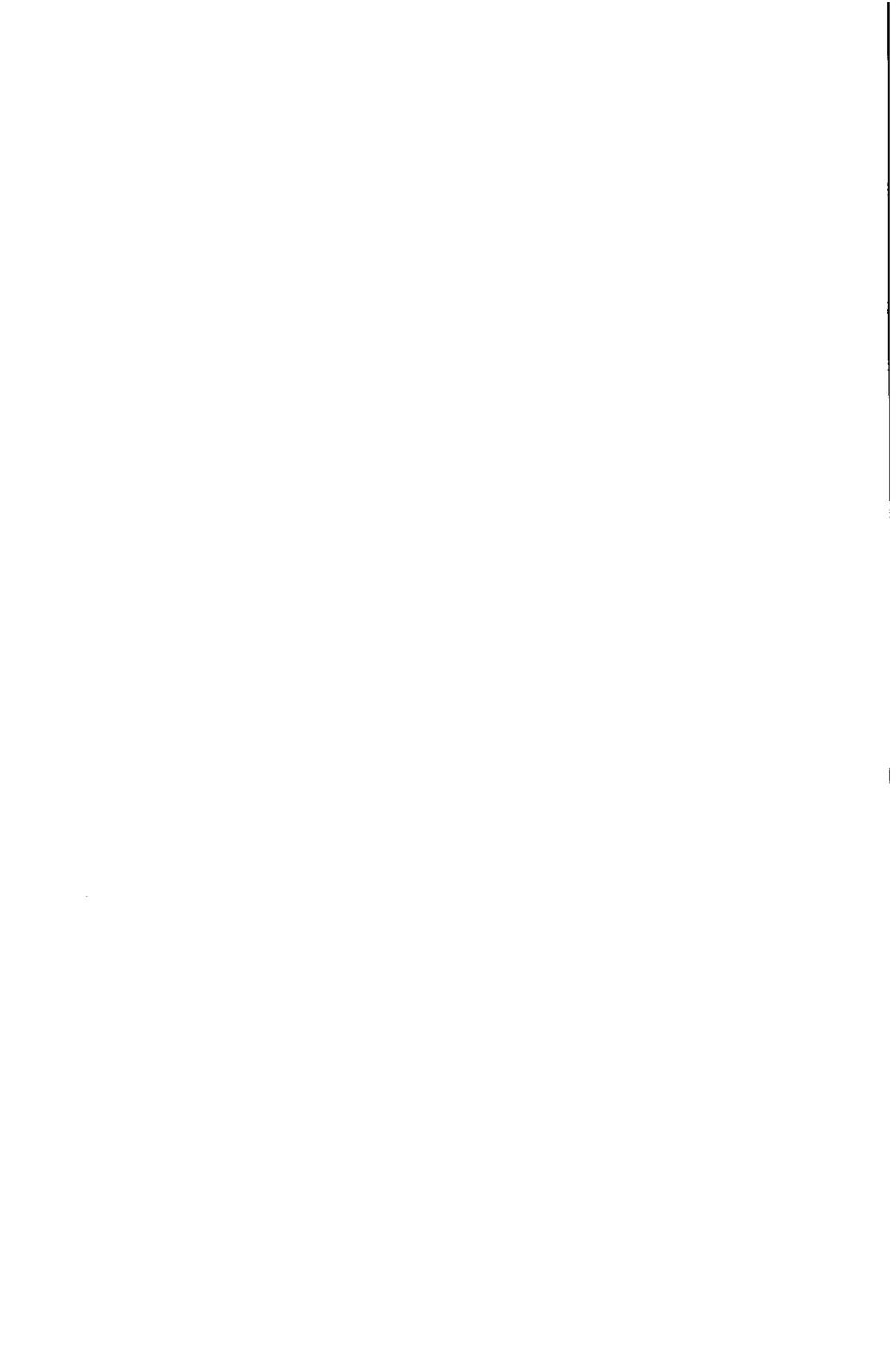
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ON CORRELATIONS BETWEEN DRACUNCULIASIS AND MALNUTRITION IN WEST AFRICA

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Unlike previous regional health efforts in Africa to control diseases with high mortality rates (such as smallpox), the prospect of curtailing dracunculiasis (guinea worm disease) promises increased agricultural production, and thus a better nourished population, without placing additional burdens on the environment due to direct increases in population. Reduced incidence of dracunculiasis will not only relieve severe and recurring suffering, but--as important--would remove a significant constraint (shortage of labor) at the most critical points during the short monsoon-linked agricultural cycle in affected areas. Availability of this manpower resource should produce sizable increases in crop yields, even without the addition of scarce capital inputs such as agro-chemicals or mechanization.

REVIEW OF PREVIOUS STUDIES ON THE SOCIOECONOMIC AND NUTRITIONAL EFFECTS

There has been little research on the measurable economic effects of dracunculiasis and no research on potential nutritional effects on afflicted populations. Most research has been limited to clinical, epidemiological, and therapeutic investigations.

Prior to the 1978 Conference on Seasonal Dimensions of Rural Poverty, conducted by the Institute for Development Studies (IDS), University of Sussex, economic considerations of dracunculiasis were limited to remarks by Bildhaiya et al.,¹ Raffier,² and Lamontellerie³ and to the epidemiological perspective of Belcher, et al.⁴ of the infection's impact on agricultural productivity.

The investigation by Bildhaiya et al.¹ in India demonstrated an average labor loss of 60-90 days per victim. Although they made no further calculations of their own, Bildhaiya et al. reported that the director of health services estimated in 1956 that the nominal

value of lost labor per farmer was Rs. 2 per day. They note that "the effects are so incapacitating that the (Division's) agricultural operations may be interfered with owing to the scarcity of labor."¹

Raffier's 1969 report on the "Activity of Niridazole" estimated anecdotally that the Ivory Coast alone had up to 50,000 victims annually, with agricultural operations in 35-50 percent of the villages "immobilized."² Lamontellerie's 1972 analysis of filarial infections near Banfora, Upper Volta, concluded that of the human filariases, dracunculiasis plays a more important role economically, as it can render an important fraction of the population temporarily inactive.³

The most significant work, however, is the 1975 study by Belcher et al., which quantitatively confirms the pattern suggested by Bildhaya, Raffier, and Lamontellerie. After explaining how afflicted farmers coped with illness to minimize its impact, Belcher et al. conclude that, despite efforts to substitute family or hired labor

because guinea worm is seasonal, coinciding with peak agricultural activities, and few alternative (uninfected) labor sources are available for the incapacitated farmers, marked reduction in agricultural output occurs.⁴

Although crop losses were not reported in cash or harvest yield equivalents, and no comparison was made between yield or nutritional status in infected versus non-infected villages, the correlational links between the seasonality of dracunculiasis, labor constraints, and agricultural production were unequivocally established. Some dracunculiasis studies since then have looked more closely at a demographic analysis of incidence rates and labor incapacitation, but to date no systematic analysis has done more than point out these correlations.

By the 1978 IDS conference, the linkages made by Belcher et al.,⁴ in terms of the seasonality of dracunculiasis and its effect through incapacitation on crop production, had been broadened considerably. Data from a variety of disciplines suggested a wide range of correlations between disease, cultural practices, the agricultural crop cycle, nutrition, and the onset of the seasonal rains.

Chambers⁵ provides a holistic view of the linkages between health, agriculture, and rural poverty and the onset of the rainy season, arguing that

for agriculturalists in the tropics, the worst times of the year are the wet seasons,

typically marked by a concurrence of food shortages, high demands for agricultural work, high exposure to infection . . . , loss of body weight, low birth weights, high neo-natal mortality, poor child care, malnutrition, sickness and indebtedness. In this season, poor and weak people, especially women, are vulnerable to deprivation and to becoming poorer and weaker. . . .

Although much of Chamber's work extends beyond the scope of immediate concern, the salient point is the relationship between the nutritional shortfall during the pre-harvest season and the occurrence of dracunculiasis (particularly acute among rural farmers), which coincides annually with the onset of the monsoonal rains at the most critical labor input points of the crop cycle. B. B. Waddy⁶ has also emphasized the synergistic, negative impact of several infections, including dracunculiasis, and shortages of food during the same important period of the agricultural year in Ghana.

EVIDENCE OF INTERACTION AMONG DRACUNCULIASIS, NUTRITIONAL STATUS, AND AGRICULTURE

The absence of any paradigm by which to measure the impact of guinea worm disease on Sahelian pastoral populations restricts one to looking mainly at sedentary farmers. However, the marked need of pastoralists for grain (usually millet) in their traditional diets makes them, despite their transhumance, also nutritionally dependent on how successfully sedentary farmers produce surplus stocks. Swift⁷ has demonstrated that pastoralists represent a significant reservoir of demand for grain.

Millet production studies conducted by Nigeria's National Accelerated Food Production Project (NAFPP) in 1975-1976, and analyzed by Knipscheer, Menz, and Khadr⁸ of the International Institute of Tropical Agriculture (IITA), estimated a gross per capita yield of 202.9 kg--an indication of the nutritional marginality in the savanna zone studied. According to U.N. Food and Agriculture Organization (FAO) figures quoted by the government of Upper Volta, this yield would assure 2,150 calories per day. As 94 percent of the millet farmers studied by NAFPP also grew some sorghum, groundnuts, and or cowpeas, and 78 percent engaged in at least some other part-time employment during the year, their basic nutritional needs were met. However, the gross per capita

yield ignores postharvest storage losses caused by pests or bacteria, the traditional barter of grain for services with pastoral populations, and payments-in-kind of grain to cover credit and other expenses.

Ideally, one would like to be able to compare longitudinal agricultural and general nutritional data on similar ethnic groupings within the same ecological/agro-
nomic zone--the only variable being the presence or absence of dracunculiasis. If such data existed one might be able to postulate nutritional relationships with some confidence. In the absence of such direct data from the sub-Saharan zone, however, indirect indicators must be used. The NAFPP/IITA survey of millet farming in northern Nigeria provides as accurate a description of the time allocated to the various production tasks of the crop cycle as currently exists. Fortunately, additional data on monthly weaning distribution, live birth distribution, and hospitalizations for pediatric malnutrition are also available from other sources for the same region. Unfortunately, however, although dracunculiasis is endemic in this area, a literature search revealed no epidemiological studies of the disease in the same area. A 1972 study* by Lyons⁹ in northwestern Ghana near the Upper Volta frontier correlates monthly data on guinea worm disease incidence and prevalence to rainfall distribution. A long-term comparison of monthly rainfall figures in northern Nigeria and northwestern Ghana suggests, if not environmental similarity, at least parallel patterns of rainfall and distribution of agricultural tasks. Upon examining the relationship between rainfall, the millet crop cycle, and selected statistics, it is apparent that increased requirements occur at the onset of the rainy season to support the activities of males, although northern Nigeria is a Moslem society where women are frequently confined to household compounds. This

*Lyons reports that average annual precipitation in the Wa district of northwestern Ghana is 1,105 mm, based on observations from 1917-1957. He provided no monthly rainfall distribution figures, however. The nearest location for which longitudinal monthly precipitation figures were available was the Bobo Dioulasso reporting station, approximately 100 air miles northwest of WA. Average annual precipitation, based on 10 years' observation during the pre-drought period of the late 1950s to 1960s, was 1,179 mm (converted from English measurement at 1" = 25.4 mm). As the ecological zone, ethnic composition, and crop mixture on both sides of the Voltaic-Ghanaian frontier are similar, the Bobo Dioulasso monthly precipitation table is considered regionally accurate.

sudden reallocation of labor is associated with a 400 percent increase in the weaning rate. In fact, 40 percent of the preceding year's live births are weaned within 2 months of the onset of monsoonal rains. By the time the heaviest rains arrive 6-8 weeks later, local hospital admissions for pediatric malnutrition have jumped by almost 75 percent. It is believed that this is due to the combination of (1) premature weaning of infants and women's increased labor requirements, both of which preclude time to prepare adequate meals for toddlers; and (2) changes in food allocation practices during times of high adult energy demands when children eat last and least.

Figure 1 shows the relationship of the monthly totals of self-reported guinea worm from Lyons'⁹ most heavily infected villages in northwestern Ghana over 3 years (1968-1971) and the area's average monthly rainfall, calculated on a 10-year base. As mentioned earlier, the monthly distribution of precipitation between northern Nigeria and northwestern Ghana is quite similar, especially at the onset of the rainy season. This figure also indicates when specific tasks related to millet production are conducted in northern Nigeria. Although there are undoubtedly some differences in the crop mix and agricultural labor cycles between northern Nigeria and northwestern Ghana, the need for field preparation in the 2 months prior to the rains, planting at the onset of the rains, and initial weeding shortly thereafter is the same. Crippling of affected populations by dracunculiasis thus reaches its peak in this geographic zone just at the time of highest demand for agricultural labor.

The reported interaction of dracunculiasis, seasonal precipitation, and food production in the savannah areas of West Africa may then be summarized as follows:

1. Agricultural cycle. The period of highest labor input demand in the study area runs from April (when field preparation and early planting begin in earnest) to July (when the second weeding and fertilization have been completed), at which point crops should be adequately established.
2. Dracunculiasis cycle. The period of highest self-reporting of the onset of the patent stage of dracunculiasis runs from April to July. This period accounted for 75 percent of the cases annually reported in the study area.
3. Precipitation cycle. Almost 85 percent of the annual rainfall in the study area occurred

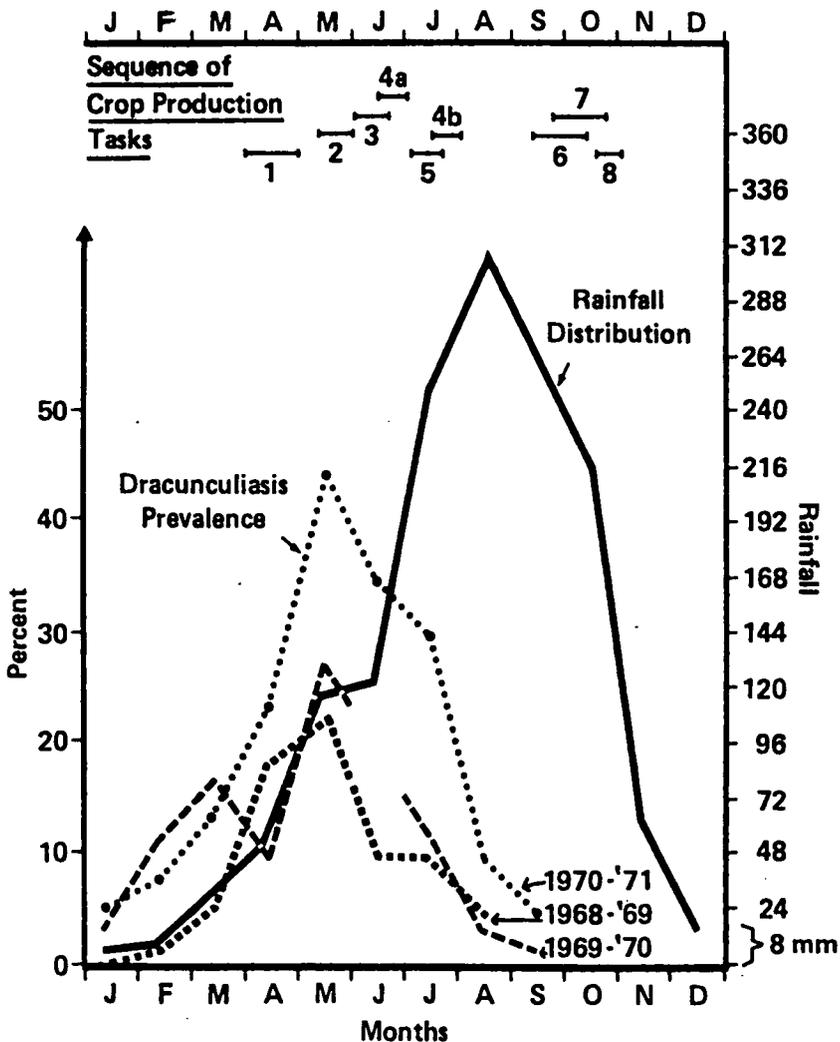


FIGURE 1 Interaction of dracunculiasis prevalence, seasonal rainfall, and crop production tasks. The indicated crop (millet) production tasks are: (1) land clearing/preparation, (2) planting, (3) thinning/transplanting, (4) weeding, (5) fertilizing, (6) harvesting, (7) threshing, (8) storage. (Dracunculiasis and rainfall data on Ghana from Lyons; data on millet production tasks in similar Nigerian zone from Knipscheer et al.; rainfall distribution from U.S. Department of Commerce.¹⁰

between May and September. Not only does the onset of monsoon rains govern the crop cycle, but a positive correlation may exist between any year-to-year fluctuations in precipitation distribution and the onset of dracunculiasis. Although the reported average length of physical incapacitation suffered by guinea worm victims is variable--according to whether one uses lower (about 30 days) or higher (about 90 days) estimates--the impact of such labor losses on crop production and, therefore, on carry-over grain stores is staggering.

DISCUSSION

Although no direct causal link between dracunculiasis and chronic seasonal malnutrition has been documented, the preceding data suggests a causal relationship between labor losses resulting from dracunculiasis-related physical incapacitation, production of inadequate staple food supplies, and seasonal chronic malnutrition. The evidence cited above includes seasonal fluctuations in weaning rates, seasonal variations in food consumption patterns affecting the adequacy of child nutrition, and seasonal variations in hospitalizations for pediatric malnutrition.

This is not to suggest that the eradication or significant abatement of dracunculiasis will result in the elimination of chronic seasonal malnutrition among afflicted populations. (Note that if improvement of water supply sources is the intervention chosen, this would also be expected to reduce the prevalence of gastroenteritis, another condition that may be associated with malnutrition.)

It may be expected, however, that increased availability of labor in the agricultural sector due to suppression of dracunculiasis will result in improved crop yields which will be reflected, over time, in improved nutritional status. Thus any dracunculiasis abatement program should include indicators of community nutrition status among its evaluation criteria. Considering the complex interaction of physical, social, economic, and health variables affecting a population's crop yields, and subsequent nutrition status, of the populations concerned, studies of the impact of anti-dracunculiasis efforts should include the following indicators:

1. Epidemiologic indicators--using standard pre- and post-intervention epidemiological survey data.

2. Socioeconomic indicators—including not only longitudinal shifts in crop yields, but also pre- and post-intervention patterns of male and female labor allocation and incapacitation.
3. Quality of life indicators—general health levels, family food consumption, nutritional status, education, shelter, life expectancy.

As chronic malnutrition is most easily recognized in, and has its greatest impact on, young children, it may be more productive to avoid the problems associated with collecting data about adult nutritional status by focusing on measurement of age, weight, and height of children under 5 years.

Dracunculiasis programs may seek to "capture" existing data collected by other agencies conducting ongoing maternal and child health programs in target areas, or they may assess nutritional status as part of their own annual household and village-level monitoring and evaluation samples. An effective place to begin, therefore, is to determine what nutritional data are already being collected and whether such data are amenable to reexamination for the purposes desired. Potential problems with this approach include variability in different agencies' data collection methodologies; variability in the accuracy and reliability of anthropometric measurements, as well as recording, transcribing, and maintenance of data among agencies; and variability in clinic outreach effectiveness.

Changes in the nutritional status of children from weaning to age 5 appear to be the best proxy indicator not only of the nutritional status of the population at large, but also the clearest indicator of changes in the overall quality of life of the target population. As existing data suggest that children in the Sahelian zone are at greatest nutritional risk during the 3-month period following the onset of the rainy season, annual age-based, cross-sectional analyses of their nutritional status should be collected during this period based on age, height, and weight. Regardless of the area to be served or the technical intervention(s) selected to combat dracunculiasis, longitudinal cross-sectional examination of children's nutritional status may be expected to reflect success in the elimination of or significant reduction in dracunculiasis transmission.

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SOCIAL AND CULTURAL ASPECTS OF GUINEA WORM ERADICATION

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INTRODUCTION

Most attention to guinea worm disease (dracunculosis, dracontiasis, dracunculiasis, Medina worm, la filariose de Médina) has focused on the biology of the worm and hosts, supplies of safe water, chemical treatment of water, and medical treatment of infected individuals. All too neglected are the cultural beliefs and practices surrounding guinea worm disease; patterns of social structure that determine water use, contact, and consumption; and the often considerable variation in these dimensions among even neighboring ethnic groups. While it is theoretically simple to eradicate this disease--to interrupt its cycle at any of several points--it has proven more complex to actually do so. Lack of attention to practical social or cultural factors has resulted repeatedly in the reappearance of the disease where it was once eradicated, or resurgence where it was once under control.

Several researchers involved in the study and reduction of dracunculiasis have noted that the difficulties in controlling and eventually eradicating this disease require an interdisciplinary, integrated campaign, which includes attention to local beliefs, attitudes, social structure, and patterns of water use and migration. Akpovi's comments on Idere, Nigeria, also apply to much of West Africa, the Middle East, and India:¹

Since engineering and medical approaches have not produced lasting benefit to the people of Idere, the challenge became obvious to try a health education approach. Hopefully better results would come from emphasizing citizen participation, self-help and careful attention to the social and behavioral aspects of the problem.

As the operational manual from the Indian Division of Helminthology states, "the social customs of the inhabitants and unsanitary conditions of the area determine the extent of disease transmission."² An example from francophone West Africa makes the point dramatically:³

It's clear that the dracunculosis is a real sociological disease. The curative action (in our present knowledge), the chemical fight against the vector, the piped-water buildings are certainly indispensable, but they can only be considered as a substitute meant to palliate the total lack of health education. In fact, the villages often prefer the Cyclops-infested pond-water to the protected and safer well-water because of its taste. We even discovered, to our amazement, that in a village in the North of Mali, the villagers filled up a well with whatever they could find, simply because they would not give up drinking the pond-water.

Understanding the social and cultural context of guinea worm disease does not require accumulating anthropological esoterica for its own sake, but the use of facts directly and indirectly helpful in hastening eradication of the disease. This paper describes a member of the social and cultural aspects of dracunculiasis, culled from articles on Dracunculus medinensis listed in Index Medicus over the last 15 years and from papers presented at this workshop, to emphasize the variety of factors that must be considered in a comprehensive war against this disease. These examples are, however, by no means exhaustive.

BELIEFS, ATTITUDES, AND VALUES

In locations of high endemicity, inhabitants tend to be fatalistic about the disease, accepting incapacitation as an unavoidable part of life. Where the incidence of disease is moderate, infection is considered normal and acceptable provided it does not "go out of proportions."⁴ As Adeniyi hypothesizes, "since dracunculiasis is to a large extent linked with people's environment and life-style, it should be expected that the affected population will develop a minimum level of tolerance for the disease, especially when an effective remedy is not available."⁴ Although a sense of hope could arise when the level of infection is reduced, any modern scientific understanding of the disease may yield to supernaturalistic explanations in the face of an epidemic of guinea

worm disease.⁴ In Ghana, Ward and colleagues found that 67-90 percent of the respondents in two ethnic groups believed that dracunculiasis could not be prevented.⁵ They also discovered in the same culture that while the disease had major economic and health impacts, it was not a topic of conversation, for "to discuss the disease might increase a person's chance of getting it."⁵

The source of the disease may be understood in terms of modern materialistic germ theory or in terms of traditional animistic concepts. For example, some Ghanaian villagers believed that inherited characteristics caused the disease.⁵ In Nigeria, beliefs emphasize its generational links.⁶ Illustrating the ways in which traditional beliefs can be combined with modern approaches, Akpovi and colleagues,¹ also working in Nigeria, described how

in one village the chief related that while the caretaker said guinea worm was spread through water, he personally believed the god of smallpox was at fault. By neither challenging traditional belief and alienating the chief nor undercutting the role of the caretaker, the lecturer suggested that possibly the god of smallpox might trick people into contaminating and drinking the water, thereby spreading guinea worm. This explanation was acceptable to all.

Traditional beliefs have consequences, of course, for the use of modern curative opportunities. In Ghana, for example, it was found that although all the villages were within 32 km of a hospital, patients did not seek, nor were they taken for, medical treatment. This attitude is not surprising, particularly when modern medicines are not especially helpful, except against secondary infections. In Wawa village of Kwara State, Nigeria, attitudes were similar. "Few patients went to the hospital . . . or to the Dispensary in the village . . . because they believed that traditional treatment is more effective than modern medicine."⁸ Some may have been reluctant to go for help because the worms emerged in their genital areas.⁸

To what extent villagers associate guinea worm disease with contaminated water is an important question for health educators working in rural areas. In general, a considerable proportion of people link the disease with unclean water, and have done so, in some areas at least, for centuries. Ward and colleagues found that one-third of both ethnic groups studied in Ghana made this connection.⁵

Writing in 1768 and referring to practices in West Africa, James Lind reported how containers of pond water were sealed until the cyclops were dead:⁹

And thus supposing the guinea-worm to be generated from animalcula or their ova, contained in the waters of the country, their production in the human body may probably be afterwards prevented by drinking those waters only that have been rendered perfectly sweet by undergoing a previous putrefaction.

Describing dracunculiasis at Ormus in 1584, the Dutch navigator Linschoten wrote: "There is in Ormus a sickness or common plague of worms, which growe in their legges, it is thought that they proceede of the water that they drink."¹⁰ According to British Secretary Sir James Tennent who worked there from 1845 to 1850, "in Ceylon, as elsewhere, the natives attribute its occurrence to drinking the waters of particular wells."¹⁰

Preventive and Treatment Measures

Even when people engage in the most desirable public health practices, they may not understand the reasons for doing so. If this is the case, they may still run a risk of infection. In the Kurnool District of India, "even those who boil or filter the water in their own houses may contract the infection by drinking untreated water in neighboring houses."¹¹ In Banaskantha District, Gujarat, India, "practically all the affected families did filter water with a piece of cloth merely as a cultural habit as only 23.50 percent of families thought it as a measure of avoiding infection."¹²

The application of herbs and oils, and the eventual extraction of the worm by incision or winding it around a stick are widespread. In one area of Ghana, Ward's group reports the use of local herbs to stimulate swelling at the pre-blister stage, followed by palm oil to soften the skin. Then the ulcer may be incised or, following eruption of the worm, other herbs will be placed on the wound and the limb soaked to hasten the exit of the worm, as it is wound around a stick. A string may be tied around the infected limb to keep the worm from migrating should it break.⁵ Similarly, in Idere, Nigeria, "traditional treatment includes application of palm oil (of no obvious therapeutic value) or certain leaves (called "ewe imin" in the local language) on the ulcer."¹ Describing the situation in West Nemar District, Holkar State, India, Bildhaiya and colleagues

found neither modern nor traditional methods effective for guinea worms:¹³

The villagers applied locally indigenous preparations and leaves like neem, ipomoea, nirgud, tameshwar, hing (asafoetida), lime, camphor, and akao. The local quacks practised extraction of the worm in a single piece by suction with an animal horn. This procedure worked well especially if the worm was superficial and the ulcer was large. Marking nuts were also administered orally by some of the villagers.

And Linschoten's 1584 description¹⁰ was unsurpassed:

These wormes are like unto lute strings, and about two or three fathomes longe, which they must plucke out and winde them aboute a straw or a feather, everie day some part thereof, so longe as they feele them creepe; and when they hold still, letting it rest in that sort till the next daye, they bind it fast and amongst the hole, and the swelling from whence it commeth forth, with fresh butter, and so in ten or twelve dayes, they winde them without any let, in the meanetime they must sit still with their legges, for if it should break, they should not without great paine get it out of their legges, as I have seen some men doe.

Social Structure and Water-Use Patterns

Social structure and water-use patterns are often intimately related. Which groups are involved in water collection and where and when they collect it, can influence rates of infection or reinfection. If water-use patterns must be changed, it can be essential to identify and work through the influential decision makers in a village or community.

The intimate and varied association of humans with water has been detailed for studies of schistosomiasis and other water-borne diseases,¹⁴ and these should not be neglected in the efforts to extingulsh guinea worm disease. Edungbola lists 14 ways in which humans use water in Ilorin, Nigeria, any of which might be significant for perpetuating dracunculiasis: swimming, drinking, clothes washing, car washing, animal washing, food washing, bathing, farming, refuse disposal, defecation, fishing, recreation, building, and religion.¹⁵ Contaminated water consumed spontaneously while filling water vessels, or drunk by farmers on the way to their fields, are primary occasions for infection.^{8,16}

Sources of Water

When piped, treated water is not available, several sources of contaminated water may pose problems. Stepwells, but not drawwells or rapidly flowing water, are notorious sources of infection, as are water holes excavated in dry river beds. In northern Nigeria, "cattle dams" constructed for use by Fulani pastoralists were sites of transmission.⁸ Where most villagers depended on cement-lined cisterns (berkehs) in Iran, a high density of cyclops in the dry season resulted in high rates of guinea worm infection.¹⁷ Even when modern wells are installed, they may remain unused and weed-covered if inappropriate locations are used. "The residents [of Idere, Nigeria] did not participate in the design and location of the well. The engineers' inadvertent choice of a politically unpopular site doomed that effort to failure."¹

Caste is a factor in southern India. In one case where the lower caste people were not allowed to use the well, they used the river water and were free of infection. Most of the others used the stepwell and acquired guinea worms.¹¹

Good wells may be available and there may be no social structural constraints, yet people will persist in using contaminated sources for making palm wine or drinking for the simple reason that it tastes better. Pond water is preferred in Benin because well water "does not quench their thirst."³ Water from tubewells and drawwells may not compare to pond water in "palatability and satiety."¹² All of these factors must be considered by health educators and somehow resolved before guinea worm disease can be totally eliminated.

Migration Patterns

Migration of workers, pastoralists, and refugees can have a bearing on patterns of infection and reinfection. Kale found that workers in the city who returned to their homes in rural areas on weekends to help with their gardens had much less chance of infection because of less exposure to contaminated water.¹⁸ Examples of reinfection in areas once free of guinea worm disease--Pakistan,⁷ Iran,¹⁷ and Sri Lanka¹⁰--emphasize the need to reinspect remote villages from time to time until the disease has been eradicated. In Paris, 50 cases of dracunculiasis were found recently among workers who had come from West Africa.¹⁹ The first report of guinea worm disease in Kenya is associated with nomadic Turkana pastoralists who may have acquired it while trading and

raiding cattle in affected areas of the Sudan.²⁰ The problems of the Fulani pastoralists in Nigeria have already been mentioned.⁸

Although this list of social and cultural aspects of guinea worm disease could be longer, and despite the potential value these factors might have in the work against dracunculiasis, relatively little attention has been paid to these aspects of the problem. It is extremely important that the value of the social and cultural dimensions of this disease not be lost in the rush to carry out biomedical research and water sanitation engineering.

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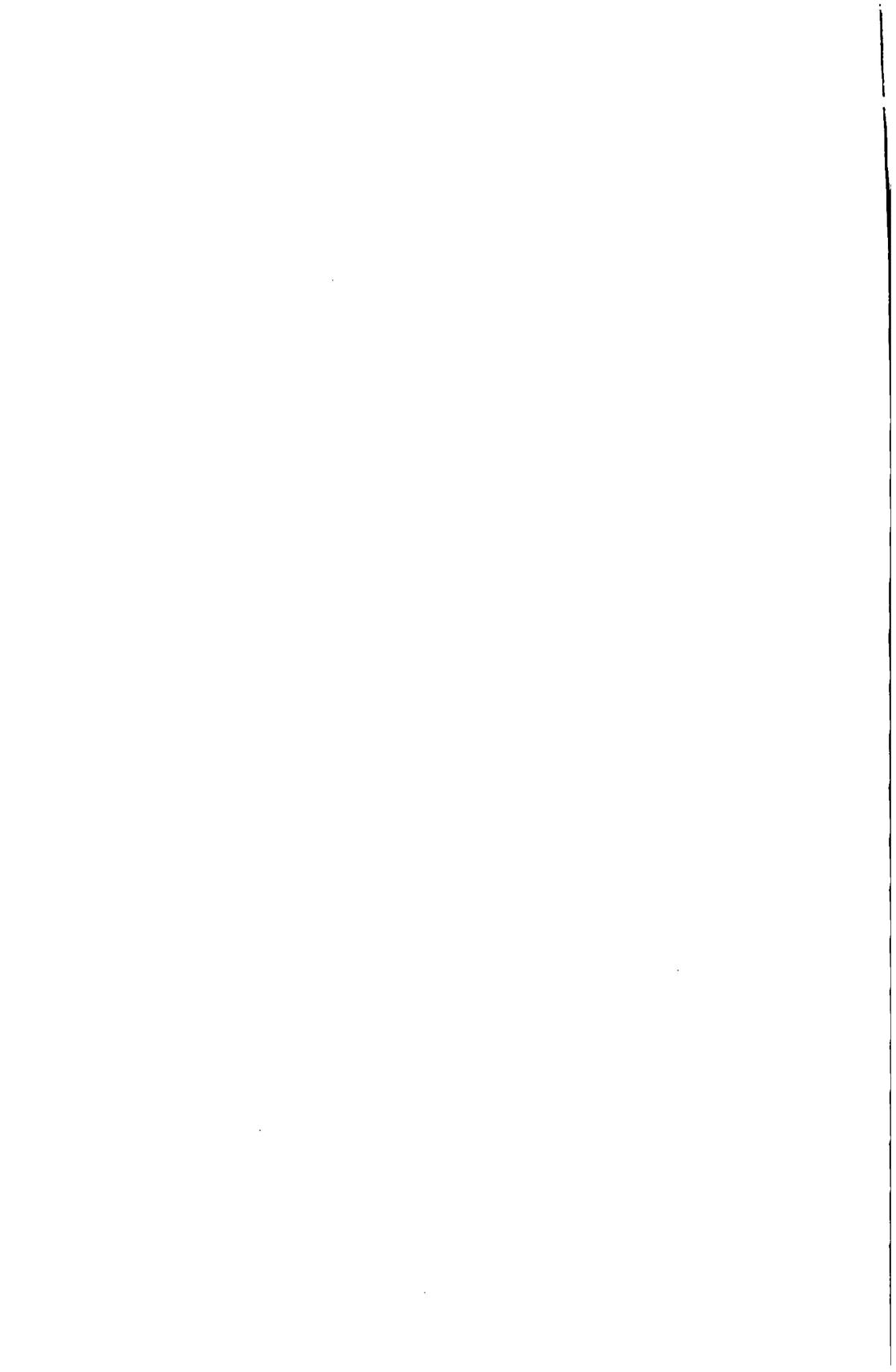
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Bibliography of Dracunculus

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All titles have been translated into English but the first three letters of the original language are given at the end of all non-English citations.

Historical references were obtained principally from Bartet (1909), Bremser (1819), Davaine (1860), Hirsch (1885), Hoeppli (1959), Huber (1894), Inglis & Leiper (1912) and, most important of all, the Index Catalogue of Medical and Veterinary Zoology by C.W. Stiles and A. Hassall (1920-1952).

The writings of Classical and 'Arabian' authors are given in editions or translations available in libraries today and no attempt has been made to indicate their probable original date of publication; e.g. a 1735 edition of the work by Aretaeus of Cappodocia (who lived ca 200 AD) is cited and reference is also made to an English translation of 1856.

More doubtful allusions in ancient literature are not included directly: these include the oft-quoted passage in the Old Testament (Numbers XXI, 6) - see Bartholinus (1672), Bloch (1899), Kuechenmeister (1857) and Velschius (1674); the Ebers Papyrus - see Ebbel (1937); the Rg Veda (p360 of the 5th edition of the 1889 translation by R. Griffith) - see Kavan (1977); the connection with the Caduceus Motif - see Kintzen (1968), Markell (1968), Menk (1974) and Velschius (1674).

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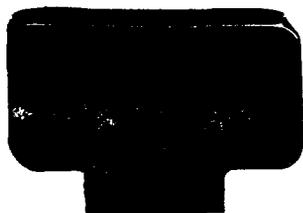
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