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# Cost-Benefit Analysis of the Global Dracunculiasis Eradication Campaign

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The Global Dracunculiasis Eradication Campaign has brought about a remarkable decline in the incidence of dracunculiasis, or Guinea worm disease, in the countries in which it was endemic. Under conservative assumptions about the average incapacitation caused by Guinea worm infection (five weeks), the campaign has shown an estimated economic rate of return of 29 percent.

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## Summary findings

Dracunculiasis (or Guinea worm disease) was endemic in several African countries as well as in India, Pakistan, and Yemen. The past decade, however, has seen a remarkable decline in the incidence of dracunculiasis as a result of the Global Dracunculiasis Eradication Campaign.

Kim, Tandon, and Ruiz-Tiben compare spending on the eradication campaign with estimates of increased agricultural production resulting from reductions in infection-related morbidity as a result of the program.

Using a project horizon of 1987–98, they calculate the economic rate of return as 29 percent, under conservative assumptions about the average incapacitation caused by Guinea worm infection (five weeks).

After 1998, Sudan is projected to be the only country in which the disease will remain endemic. The authors' results indicate that for economic returns in Sudan to be consistent with those in other countries where the disease was endemic, eradication must be completed in Sudan at the very latest by 2001.

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This paper — a product of the Africa Human Development Department — is part of a larger effort in the department to use economic analysis to improve the quality of health projects. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Aehyung Kim, room J10-046, telephone 202-473-5029, fax 202-522-3157, Internet address [akim@worldbank.org](mailto:akim@worldbank.org). October 1997. (16 pages)

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**COST-BENEFIT ANALYSIS  
OF THE  
GLOBAL DRACUNCULIASIS ERADICATION CAMPAIGN (GDEC)**

*by*

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<sup>1</sup> We would like to thank Pedro Belli, Jeffrey Hammer, Donald Hopkins and the participants of the consultation meeting at the Carter Center/Global 2000 for valuable comments.

## Introduction

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In 1986, there were over 2.25 million cases of dracunculiasis (Guinea worm disease) worldwide.<sup>2</sup> Ten years later, in 1996, the estimated worldwide incidence of dracunculiasis was close to 330,000 cases.<sup>3</sup> This remarkable decline in the incidence of dracunculiasis has been the result of the Global Dracunculiasis Eradication Campaign (GDEC). GDEC is spearheaded by national eradication programs and is supported by a coalition of agencies, institutions, organizations, and bilateral donors. As the numbers attest, as a result of GDEC, dracunculiasis has been virtually eliminated as a major public health problem and an impediment to socioeconomic development in several African countries as well as in India, Pakistan, and Yemen.<sup>4</sup> Dracunculiasis was eradicated from Pakistan in 1994.<sup>5</sup> In 1996, an overwhelming majority (78%) of a provisional total of 152,185 reported cases of dracunculiasis occurred in Sudan, where civil strife has complicated the successful operation of its national Guinea worm eradication program.

Dracunculiasis is caused by the nematode parasite *Dracunculus medinensis*. An individual becomes infected by drinking water containing tiny crustaceans (copepods) which harbor infective larvae and act as an intermediate host. After about one year, the mature female worm approaches the skin, eventually causing a blister to form. The blister ruptures (within 24–48 hours) causing the head of the worm to become exposed to the external environment. When the affected person enters a body of water the worm releases myriads of larvae which are then ingested by copepods (water fleas). Upon release of the larvae, the worm dies and must be extracted manually, usually by rolling a few centimeters of the worm each day on a stick. The extraction of the worm is a slow and intensely painful process incapacitating individuals for weeks, and often longer. In addition to the blisters and skin lesions, secondary bacterial infections exacerbate local inflammation, and often lead to sepsis, abscesses, arthritis, contracture of joints, or even tetanus. In a small number of instances, infection may be associated with permanent crippling similar to polio. There is no cure for the disease, but it is amenable to prevention through educating people about the origin of the disease and what they can do to prevent it: filtering their drinking water through a piece of cloth to remove copepods, and never entering a source of drinking water (or allowing someone else to do it) when a Guinea worm is emerging. The disease can also be prevented by providing safe sources of

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<sup>2</sup> Watts (1987) estimated the worldwide incidence of dracunculiasis to be 3.3 million cases. Review of the available data, while preparing this paper, warranted that we revise that 1986 benchmark to 2.25 million cases.

<sup>3</sup> This differs from the provisional number of cases reported to the World Health Organization (WHO) of 152,185. This discrepancy is largely caused by incomplete knowledge of the full extent of dracunculiasis and incomplete reporting of cases in Sudan.

<sup>4</sup> The entire list of countries covered is: Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Ethiopia, Ghana, India, Kenya, Mali, Mauritania, Niger, Nigeria, Pakistan, Senegal, Sudan, Togo, Uganda, and Yemen.

<sup>5</sup> See Hopkins *et al.* (1995).

drinking water to affected communities and by the application of the insecticide Abate (temephos) to selected unsafe sources of drinking water.

The objective of this paper is to report on a cost-benefit analysis of GDEC: expenditure on GDEC activities is compared with the economic benefit resulting from the campaign. The emergence of the Guinea worm is a painful and debilitating process causing serious disability in infected individuals for weeks -- thereby seriously constraining their income-generating capacity. Therefore, the major benefit of GDEC is considered to be the prevention of this period of infection-related economic incapacitation.<sup>6</sup> Based upon the resulting augmentation of agricultural production, this economic benefit is accorded a monetary value and then compared with the costs of the campaign. This "human capital" approach enables an assessment of the economic viability of large-scale public health programs such as GDEC which are demonstrably successful in controlling and/or eradicating disease incidence.

The economic assessment of GDEC entails the following. First, we examine the strategies for eradication under the auspices of GDEC and the associated costs of the campaign. Second, we elaborate the projected benefits from the eradication program, focusing specifically on the prevention of economic incapacitation resulting from incidence decline. Finally, we contrast the costs with the projected economic benefits in order to estimate the economic returns of the campaign.

## **Dracunculiasis Eradication: Strategies and Costs**

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There are several characteristics of dracunculiasis transmission that make the disease amenable to eradication<sup>7</sup>: there is no human carrier state beyond the one-year incubation period; there is no known animal reservoir; transmission is seasonal; active detection of individuals with worms protruding from skin lesions is a sensitive means of assessing the presence of the disease in villages; and the methods for controlling transmission (as subsequently elaborated) are relatively simple. Beginning in 1986, 1987, and 1988, the Global 2000 Project of the Carter Presidential Center, in collaboration with the Center for Disease Control (CDC), assisted national Guinea worm eradication campaigns in Pakistan, Ghana, and Nigeria, respectively.<sup>8</sup> The strategies for eradication in these three

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<sup>6</sup> Other benefits -- difficult to quantify in economic terms -- include the alleviation of suffering and social stigmatization, improved school attendance, better child care, and elimination of infection-related expenditures.

<sup>7</sup> It is important to note that GDEC is an *eradication* -- and not a *control* -- campaign. Consequently, some of the operational requirements reflect the fact that the goal of an eradication campaign is to reduce the incidence of disease to zero in all affected communities by a certain target date. In contrast, the goal of a control campaign is usually the reduction of disease incidence in selected communities (e.g., those with the highest disease incidence) over a period of time to a level that is considered "tolerable" by public health authorities.

<sup>8</sup> India independently initiated its national Guinea worm eradication program in 1983.

countries later formed a model for Guinea worm eradication campaigns in other affected countries.

### ***Strategies for Dracunculiasis Eradication***

As elaborated in Hopkins and Ruiz-Tiben (1991), key activities of dracunculiasis eradication can be grouped into three operational phases. *Phase I* includes: the establishment of a national campaign coordinator, office/secretariat; completion of national baseline village-by-village surveys for case-detection and prevalence statistics; and preparation or revision of a national plan of action. *Phase II* incorporates implementation of interventions and includes activities such as: the identification and training of village-based workers for each endemic village; implementation of village-based surveillance using case registries; initiation of a comprehensive health education/mobilization strategy; provision of cloth filters (and training in their usage); provision of safe sources of drinking water (such as bore-hole wells) and control of copepod populations using Abate (temephos); and monitoring the coverage as well as quality of surveillance/interventions. *Phase III* involves implementation of case-containment strategies: as the expected case load of the village-based health worker becomes one (or below) case per worker per day, increasingly stringent surveillance and control measures are initiated -- shifting the focus from the village or community-level to the individual case-level. In addition, after Phase III, post-eradication activities include the maintenance of adequate surveillance for 3 years after the last case and a request to WHO to evaluate and certify the attainment of eradication.<sup>9</sup>

### ***Target Population Coverage***

GDEC eradication activities progressively reached larger sections of the target population. The initiation of control interventions reached *all* target countries only in 1995. Table 2 reports the years in which there were increments in target population coverage, i.e. the years in which the various countries initiated intervention activities associated with the campaign.

**Table 2. Target Population Coverage.**

Year	Countries Where Control Activities Initiated
1983	India
1987	Pakistan
1989	Ghana, Nigeria
1991	Cameroon
1992	Burkina Faso, Senegal, Togo, Uganda
1993	Benin, Cote d'Ivoire, Mali, Mauritania, Niger
1994	Chad, Ethiopia, Kenya, Sudan
1995	Yemen

<sup>9</sup> See Hopkins and Ruiz-Tiben (1991) for additional details regarding strategies for dracunculiasis eradication.

## Measuring the Costs of Eradication

The estimated expenditures of GDEC for the above-mentioned eradication activities include costs incurred by Global 2000, UNICEF, as well as WHO in the time horizon 1987-1996.<sup>10</sup> Table 1 reports the annualized expenditure figures. In nominal terms, actual and projected GDEC expenditures in the time horizon 1987-1998 equal US\$87.46 million in nominal terms and US\$68.46 in 1987 constant dollars.

Table 1. GDEC Expenditures (1987-1998<sup>a</sup>) in US\$ millions

Year	Global 2000 <sup>b</sup>	Other Sources <sup>b</sup>	Total <sup>b</sup>	Total Constant <sup>c</sup>
1987	1.26	0.23	1.49	1.49
1988	2.81	0.26	3.07	2.96
1989	3.12	0.30	3.42	3.16
1990	3.60	2.77	6.36	5.66
1991	5.84	2.12	7.95	6.80
1992	2.50	2.93	5.43	4.46
1993	7.68	8.95	16.63	13.15
1994	6.63	3.27	9.90	7.52
1995	8.66	3.39	12.06	8.81
1996	6.67	4.20	10.87	7.64
1997	5.60		5.60	3.78
1998	4.67		4.67	3.03
Total	59.04		87.46	68.46

a. Expenditures for 1997 and 1998 are projected estimates.

b. In nominal terms.

c. In 1987 constant US\$.

## Methodology for Estimating Economic Benefits

Through the prevention and elimination of infection-related incapacitation and debility among productive members of the population, the consequent additional output produced is assumed to be the primary benefit of GDEC.<sup>11</sup> Several studies have underscored the adverse economic impact of dracunculiasis. For instance, Belcher *et al.* (1975) estimated that, in southern Ghana, adult male farmers were at greatest risk of contracting the disease and, on average, untreated adults lost 5 weeks of work time. A review of twelve published studies yielded an average duration of disability caused by Guinea worm disease to be about 8 weeks (estimates ranging from 2 to 16 weeks). Furthermore, the economic impact of dracunculiasis is aggravated by the seasonality of infection -- coinciding with peak agricultural activities -- when few alternatives exist to alleviate

<sup>10</sup> Expenditures borne by national governments for campaign implementation and control activities are not considered in this analysis. Information regarding national campaign expenditures is difficult to obtain and, in any case, expected to be modest (in dollar terms) in comparison to total annual expenditures of GDEC from other sources such as Global 2000, UNICEF, and WHO.

<sup>11</sup> This is proposed as a *lower-bound* estimate of the economic returns accruing from GDEC. We are ignoring, for instance, the benefits in terms of reduced infection-related expenditures among cases as well as positive effects on savings and income in the long run.

labor shortages caused by infection, especially so in endemic communities.<sup>12</sup> Since GDEC activities have been typically prevalent in rural areas, the marginal product of labor is estimated as the additional output gained in the agricultural sector through increasing the supply of productive labor input.<sup>13</sup> In order to estimate the additional output of labor accrued through prevention of Guinea worm infection, methods based on the Cobb-Douglas production function were used.<sup>14</sup>

The following parameters are considered relevant in estimating the additional output of labor in the agricultural sector: the number of cases of Guinea worm infection prevented by GDEC (the difference between the number of cases of Guinea worm without GDEC and with GDEC) in the productive age group, the productivity loss -- in terms of percent of work-year lost -- per case of dracunculiasis, the output elasticity of labor in the agricultural sector, and the length of the effective project horizon. As in the analysis of costs, output figures are measured in 1987 constant dollars for consistency of comparison between costs and benefits. The following subsections describe how each of these parameters was estimated.

### *Cases of Guinea Worm without GDEC*

Global 2000 estimates that in 1986 (i.e., prior to the initiation of GDEC activities) the annual worldwide incidence of dracunculiasis was in the vicinity of 2.2 million cases. For the benchmark case we assume that in the absence of GDEC, in the very least, the annual incidence would have remained at this level.<sup>15</sup>

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<sup>12</sup> See Shulman (1985) for additional details regarding the coincidence of peak labor input demand with the dracunculiasis cycle and the precipitation cycle. In our paper we assume a work year of 40 weeks.

<sup>13</sup> We are assuming unemployment is *not* a major factor in the analysis. Several surveys of labor markets in Sub-Saharan Africa have indicated that unemployment is largely an urban phenomenon. In fact, as Vandemoortele (1991) indicates, unemployment in the region *increases* with educational and skill level. The rural labor sector (on which this study exclusively focuses) primarily comprises unskilled workers (with relatively low levels of education) as well as subsistence farmers. Therefore, increases in productive labor time *are* expected to result in the augmentation of agricultural output.

<sup>14</sup> This methodology follows that in Kim and Benton (1995) and Kim *et al.* (1997). The Cobb-Douglas function relates output  $Y$  to inputs  $E$  (effective labor input in efficiency units) and  $K$  (land/capital) in the following manner:  $Y = AE^aK^b$ , where  $A$  is a technology parameter. The parameters  $a$  and  $b$  represent the elasticity of output with respect to inputs:  $a$ , for example, is the percentage increase in output caused by a unit percentage increase in labor input. Also,  $a$  represents the labor share of output. Similarly for  $b$ . Constant returns to scale can be represented by the assumption  $a+b = 1$ , which means that if both land and labor inputs increased by a certain proportion, then output would also increase by that same proportion: for example, a doubling of both labor and land inputs would yield double the output.

<sup>15</sup> In a subsequent section, we assess the sensitivity of our analysis to increases as well as decreases in the projected annual incidence of dracunculiasis over time in the absence of GDEC.



### *Number of Cases of Guinea Worm Prevented in Productive Age Group*

Based upon epidemiological studies, the estimated total number of cases of Guinea worm in the period 1986-1996 is known. A sharp reduction in the number of cases of Guinea worm infection as a result of GDEC activities has been observed. By 1996, only 329,521 cases (including those in Sudan) were estimated to have occurred.<sup>16</sup> Global 2000 projections indicate that, by 1998, it is likely that dracunculiasis could be eradicated from all countries except for Sudan. The total number of cases of Guinea worm infection prevented as a result of GDEC in any given year is computed as the difference between the projected number of cases of Guinea worm *without* GDEC and the number of cases *with* GDEC. We make the following assumptions regarding the number of cases of Guinea worm infection: (a) in the absence of GDEC, the total annual number of cases of Guinea worm would have remained at 1986 levels (around 2.2 million every year in the entire region), (b) two-thirds of all cases reported (or estimated) represent those among the "economically productive" age group of 15-44, and, as mentioned in a previous subsection. Table 3 reports the total number of cases of Guinea worm infection prevented in a given year, based upon the above-mentioned information and assumptions.

Table 3. Number of Cases of Dracunculiasis (1986-1998).

Year	Total Cases of Dracunculiasis (with GDEC)	Total Cases of Dracunculiasis Prevented <sup>a</sup>	Cases Prevented In Productive Age Group <sup>b</sup>
1987	2,178,272	0	0
1988	2,118,368	59,904	39,936
1989	2,061,543	116,729	77,819
1990	1,523,540	654,732	436,488
1991	1,202,351	975,921	650,614
1992	997,016	1,181,256	787,504
1993	1,118,829	1,059,443	706,295
1994	521,365	1,656,907	1,104,605
1995	408,742	1,769,530	1,179,687
1996	329,521	1,848,751	1,232,501
1997	315,000	1,863,272	1,242,181
1998	300,000	1,878,272	1,252,181

a. Assuming the annual incidence without GDEC in the productive age group is 1,452,181 out of 2,178,272 for all age groups.

b. Assuming cases in productive age group represent two-thirds of total cases.

As can be seen from Table 3, by 1998, as a result of GDEC, an estimated total of almost 13 and 9 million cases of dracunculiasis would have been prevented in total and in the productive age group, respectively. This implies a unit cost of about \$5 and \$8 per case prevented in 1997 constant dollars for all age group and in productive group, respectively over the life of the program.

<sup>16</sup> This is a Global 2000 estimate.

### *Productivity Loss Per Case*

It is important to note that the benefits accruing from the availability of more productive labor days (as a result of reduction in the number of cases of Guinea worm) is not easily estimated. Since transmission occurs seasonally, usually coinciding with the period of peak agricultural labor demand, there is a significant adverse impact on agricultural productivity. The methodology for computing the enhanced productivity of labor as a result of GDEC is as follows. We assume that production of agricultural output is represented in the form of a Cobb-Douglas production function:  $Y = AE^a K^b$ .<sup>17</sup> Denote  $E$  as the effective labor force (in efficiency units<sup>18</sup>) without GDEC. One non-infected worker is assumed to supply one year of productive labor in any given year. An infected worker, due to disease-related incapacitation, is assumed to provide *less than* one year of productive labor in any given year.<sup>19</sup> The prevention of the loss in productive labor time due to Guinea worm infection is the estimated benefit accruing from GDEC.

Every case of dracunculiasis prevented is projected to add  $k$  worker-years of productive labor input time in a given year. This degree of incapacitation  $k$  may be expressed in terms of the percentage of labor days per year not worked as a result of infection. As mentioned earlier, a review of twelve published studies yielded an average duration of disability from infection of about 8 weeks, with estimates ranging from 2 to 16 weeks. This implies that over 20% of annual work-time is lost per case of infection.<sup>20</sup> In order to be conservative, we assume that on average 5 weeks of production time is lost per case of Guinea worm: a loss of 12.5% of annual work time. We elect a conservative estimate as a benchmark to allow for the possibility that other members belonging to the households of infected individuals may pick up some of the slack in income generation during the period of disability. Furthermore, there may be attempts at long-term

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<sup>17</sup> See footnote 13 for additional details.

<sup>18</sup> We are measuring the labor force  $E$  in terms of the labor service inputs (i.e., time worked) instead of in terms of natural units (i.e., number of workers).

<sup>19</sup> The framework is similar to that in Cuddington (1993). The effective labor force, in the absence of GDEC, may therefore be decomposed as the sum of the labor input supplied by infected and non-infected individuals in any given year. If  $z$  is the proportion of the labor force  $L$  that is infected in any given year then the effective labor force  $E$  may be characterized as:  $E = (1-z)L + z(1-k)L$ , where  $(1-z)L$  is the labor supplied by non-infected workers and  $z(1-k)L$  is the labor supply of infected workers;  $k$  (taking a value between 0 and 1) represents the fraction of work year *lost* per Guinea worm-stricken worker. In the presence of GDEC, the effective labor force  $E_G$  is similarly given by:  $E_G = (1-z_G)L + z_G(1-k)L$ , where  $z_G$  is the fraction of the labor force infected with dracunculiasis in a given year. With GDEC,  $z_G$  is progressively lower than  $z$ . The incremental labor input available as a result of GDEC is given by  $(E_G - E)$  or  $k(z - z_G)L$ , where  $(z - z_G)L$  is simply the number of cases of Guinea worm prevented due to GDEC in the productive segment of the population. Therefore,  $(z - z_G)L$  times  $k$  gives us the additional productive labor input available as a result of reducing the incidence of dracunculiasis.

<sup>20</sup> This is assuming a 40 week work-year, given the seasonality of agricultural production and its coincidence with disease transmission.

intertemporal coping such that infected individuals are later able to make up (to some extent) for lost production time. In a later section, we assess the sensitivity of our results to variations in this parameter. In order to estimate the additional output produced, the percentage increase in the labor force for a given year due to GDEC is then estimated by dividing the incremental productive labor input time available by the rural labor force in the GDEC area.

### *Output Elasticity of Labor*

The percentage increase in agricultural output available as a result of increased labor input time stemming from reduced infection-related incapacitation is calculated assuming an output elasticity of 0.66 in GDEC countries. This means a 1% increase in labor input will increase output by 0.66%.<sup>21</sup> Output is measured as the agricultural value-added in GDEC countries. To estimate the value of the additional output attributable to the increased labor input available as a result of GDEC, the agricultural value-added is multiplied by the computed percentage increase in output (i.e., benefits equal 0.66 times the percentage increase in labor input times the agricultural value-added).

### *Project Horizon*

We assume, for the benchmark case, that the campaign has a 12 year project horizon: from 1987 through 1998.<sup>22</sup> In a later section, we assess the sensitivity of our results to changes in the project horizon concerning operations in Sudan.<sup>23</sup>

## **Economic Returns from Dracunculiasis Eradication**

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Based upon the above-mentioned methodology, a cost-benefit analysis was conducted. Table 4 reports the Net Present Value (NPV)<sup>24</sup> and Economic Rate of Return (ERR)<sup>25</sup> for GDEC.

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<sup>21</sup> This follows from Kim and Benton (1995) and Over (1992). Cuddington (1993) assumes a value of 0.7 in his study of Tanzania.

<sup>22</sup> Benefits beyond the project horizon are not considered in this analysis (benefits in later years, in any case, are progressively smaller due to discounting). Hence, our results may be taken to represent a lower bound to the projected economic returns accruing from the eradication campaign.

<sup>23</sup> The major unknown remains the length of time (beyond 1998) required to eradicate the disease in Sudan, where civil strife has precluded the successful operation of control activities.

<sup>24</sup> The Net Present Value (NPV) is the present value of the stream of net returns (benefits minus costs) of a project during its economic life. The present value is determined by discounting expected future net returns at a rate which reflects opportunity costs and/or time preferences. A relatively high positive NPV is taken as an indication of the economic viability of a project.

**Table 4. Net Present Value (NPV) and Economic Rates of Return (ERR) of GDEC.**  
**Project Horizon: 1987-1998.**  
**Percent of Work-Year Lost Per Case of Dracunculiasis: 12.5% (5 weeks out of 40).**

Discount Rate	Net Present Value (NPV)
3%	\$7,235,744
10%	\$6,257,928
<i>Economic Rate of Return (ERR):</i>	29%

As can be seen from Table 4, even under relatively conservative assumptions of infection-related disability and limiting the calculation of benefits to the productive age group, GDEC appears to represent an efficacious use of resources. The ERR is very respectable at 29% and the NPV at a 10% discount rate is almost US\$6.3 million in constant dollars. These economic returns compare very favorably with those from other health-sector projects. Typically, institutions such as the World Bank consider ERRs in excess of 10% to represent sound economic investments in "productive" sectors such as transport, energy, and agriculture.<sup>26</sup>

### *Switching Value*

We calculate the switching value ( $V$ ) which is the value of a case prevented that would make the ERR equal 10%. In other terms,  $V$  times the present value (at 10% discount) of prevented cases equals the present value of cost (also at a 10% discount). Using this formulation, we find  $V$  to equal about US\$10 in constant dollars. Therefore, if the value of a case prevented is at least US\$10 in the productive age group, then the intervention can be viewed as being sound in economic terms with an ERR of 10%.

### **Sensitivity Analysis**

The above analysis is based upon several crucial assumptions regarding: (a) the average degree of incapacitation caused by Guinea worm infection (*5 weeks*), (b) the projected annual incidence of Guinea worm in the absence of GDEC (*2.2 million every year*), and (c) the project horizon (*1987-1998*). In this section, we determine the sensitivity of our results to variances in these estimates.

<sup>25</sup> The Economic Rate of Return (ERR) is that discount rate which makes the present value of the stream of net returns (benefits minus costs) equal to zero. If the ERR is greater than the cost of borrowing funds, the project is usually considered to be worth undertaking from an economic point of view.

<sup>26</sup> Social sectors such as health and education are evaluated against lower "social" discount rates, reflecting the difficulties in quantifying the broader economy-wide benefits (such as benefits to future generations from disease eradication) accruing from investments in such sectors.

### *Productivity Loss Per Case*

We assume a range of values against the benchmark assumption of 5 weeks loss per case in order to assess the sensitivity of our results. As mentioned earlier, the average degree of incapacitation caused by Guinea worm infection -- as chronicled several studies -- is about 8 weeks. Thus, our benchmark assumption of 5 weeks of work-time loss is quite conservative in that it is more representative of the lower bound estimate of the dracunculiasis-related duration of disability reported in most studies. Table 5 reports the results of a sensitivity analysis with regard to changes in this parameter. As can be seen, the results are quite sensitive. In any case, even at a relatively low estimate of a 4 week loss of productivity per case of infection, the NPVs are substantial.

**Table 5. Sensitivity of NPV and ERR: Productivity Loss Per Case**  
Project Horizon: 1987-1998.

Productivity Loss			
4 weeks	NPV	@3%	\$4,927,370
		@10%	\$4,233,999
	ERR		11%
5 weeks	NPV	@3%	\$7,235,744
		@10%	\$6,257,928
	ERR		29%
6 weeks	NPV	@3%	\$9,544,119
		@10%	\$8,281,857
	ERR		44%

### *Annual Incidence without GDEC*

For our benchmark analysis, we have assumed that in the absence of GDEC the annual incidence of Guinea worm would remain at the level of approximately 2.2 million over the course of the time horizon in our study. We now assess the sensitivity of our results to this assumption. We assume growth rates of -1.5% and 1.5% -- in addition to the benchmark of 0% -- in the annual incidence of dracunculiasis in the absence of GDEC.<sup>27</sup> Values of other parameters are the same as in the benchmark. Table 6 reports the results. As can be seen, the ERRs again are quite sensitive to this parameter. Not surprisingly, any projected increases in dracunculiasis infection (due to population growth, for instance) significantly augment the economic returns from the program.

<sup>27</sup> A negative growth in annual incidence growth is also assumed since, arguably, general socio-economic development can sometimes lead to incidence declines even in the absence of any intervention.

**Table 6. Sensitivity of NPV and ERR: Annual Incidence without GDEC**  
**Project Horizon: 1987-1998.**  
**Percent of Work-Year Lost Per Case: 12.5% (5 weeks out of 40).**

Growth in Annual Incidence			
-1.5%	NPV	@3%	\$5,185,570
		@10%	\$4,460,382
	ERR		15%
0%	NPV	@3%	\$7,235,744
		@10%	\$6,257,928
	ERR		29%
1.5%	NPV	@3%	\$9,617,654
		@10%	\$8,346,331
	ERR		43%

### ***Project Horizon: The Case of Sudan***

So far in our analysis we have assumed the project horizon to be 1987 through 1998. However, by the end of 1998, the disease is projected to be eradicated from all countries *except* for Sudan, given the precarious political situation there. In this subsection, we focus specifically on the eradication program in Sudan. Assuming it takes anywhere from 3 to 5 to 7 years to ensure eradication there *beyond* 1998, we derive the economic returns specifically for that country. Table 7 summarizes the results.<sup>28</sup>

**Table 7. Sensitivity of NPV and ERR: Project Horizon**  
**Percent of Work-Year Lost Per Case: 12.5% (5 weeks out of 40).**

Project Horizon for Eradication in Sudan			
3 years (1999-2001)	NPV	@3%	\$999,971
		@10%	\$696,083
	ERR		30%
5 years (1999-2003)	NPV	@3%	\$83,245
		@10%	-\$107,681
	ERR		10%
7 years (1999-2005)	NPV	@3%	-\$716,339
		@10%	-\$808,738
	ERR		0%

According to Table 7, the economic returns from eradication in Sudan are consistent with the returns from the campaign for other countries as long as eradication is achieved within 3 years beyond 1998 (i.e., by the year 2001). The longer it takes for eradication efforts to be successful, the lower are the projected economic returns – going down to 0% by 2005, and negative thereafter.

<sup>28</sup> Annual costs for eradication in Sudan were assumed to be between 3 to 3.5 million in real terms.

## Conclusions

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This study has assessed the economic efficacy of GDEC in terms of comparing the costs of the campaign to the benefits that have resulted from the decline in the incidence of dracunculiasis. We have developed a methodology by which we are able to estimate the extent to which additional output is produced as a result of the prevention of infection-related economic incapacitation. It has been widely reported in the literature that a case of dracunculiasis results in some degree of work time lost. As a result of GDEC, this loss in productive potential is prevented. The additional output produced as a result – derived using techniques that involve the use of the Cobb-Douglas production function – represent the quantifiable economic benefits of the campaign. Based upon this methodology, we determine that the economic returns of GDEC are sensitive to assumptions regarding the average degree of economic incapacitation, in terms of percent of work year lost, caused by a case of dracunculiasis. Nevertheless, even under conservative assumptions we find highly respectable ERRs that range from 11% to 44%, depending upon whether an average case leads to 4 weeks or 6 weeks of economic incapacitation. A sensitivity analysis was also conducted to assess the variance caused by changes in key parameters. One key implication of the analysis is that eradication efforts in Sudan must be completed as soon as feasible in order for the economic returns there to be consistent with those obtained in other GDEC countries.

## Appendix

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This appendix elaborates on the methodology utilized for the estimation of the additional output produced as a result of an augmentation of productive labor time available from dracunculiasis eradication. Basically, we are interested in estimating the marginal product of labor, or how much additional agricultural output ( $Y$ ) is available from additional labor time ( $E$ ), where labor input is measured in efficiency units. Assuming agricultural production may be characterized by a Cobb-Douglas production function of the form:

$$Y = A E^a K^b$$

where  $Y$  is agricultural value-added;  $A$  is a technology parameter;  $E$  is labor input in time (equals total working population for a healthy labor force);  $K$  is land/capital; and  $a$  and  $b$  are the elasticities of output with respect to the two inputs. Hence, we have:

$$a = (dY/Y)/(dE/E)$$

or,

$$dY = a (dE/E) Y$$

The additional output ( $dY$ ) available from disease control in any given year can be approximated by the output elasticity of labor  $a$  (assumed equal to 0.66) times the percentage increase in labor time ( $dE/E$ ) times the agricultural value-added ( $Y$ ).



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