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Dracunculiasis eradication - Finishing the job before surprises arise

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ABSTRACT

Dracunculiasis (Guinea worm disease) is a preventable waterborne parasitic disease that affects the poorest people living in remote rural areas in sub-Saharan African countries, who do not have access to safe drinking water. The Guinea Worm Eradication Program, a 25-year old campaign to rid the world of Guinea Worm disease has now reached its final stage accelerating to zero cases in all endemic countries. During the 19th and 20th centuries, dracunculiasis was common in much of Southern Asia and the African continent. The overall number of cases has been reduced tremendously by ⩾99%, from the 3.32 million cases estimated to have occurred in 1986 in Africa to only 1 797 cases reported in 2010 reported in only five countries (Sudan, Mali, Ethiopia, Chad and Ghana) and Asia free of the disease. This achievement is unique in its kind - the only previously eradicated disease is smallpox, a viral infection for which vaccination was possible - and it has been achieved through primary community-based prevention and health education programs. Most efforts need to be taken in two countries, South Sudan (comprising 94% or 1 698 out of 1 797 of the cases reported world-wide in 2010) and Mali because of frequent movements of nomads in a vast area inside and outside Mali's borders. All factors favourable to dracunculiasis eradication are available including adequate financial resources, community and political support and high levels of advocacy. Thus there is no reason that this disabling parasitic disease cannot be eradicated soon before surprises arise such as new civil conflicts in currently endemic countries.

1. Introduction

Dracunculiasis [Guinea worm disease(GWD)] is a parasitic disease caused by the nematode (roundworm) *Dracunculus medinensis*. This worm is known to parasite on human since at least ancient Egypt, where it has been identified in 3 000-year-old Egyptian mummies[1]. The disease affects the poorest populations, often in remote rural areas, who do not have access to safe drinking water. Most endemic areas now are conflict zones or is insecure; this constitute a major challange to roll out full interventions to interrupt transmission of dracunculiasis.

Therefore, dracunculiasis is both a disease of poverty and a cause of poverty. With sometimes more than half of a village population being affected, it significantly affects agricultural productivity, school attendance and maternal and child health[2]. Although this neglected tropical disease has a low mortality, morbidity is considerably high causing huge disabilities which are physically and economically devastating[3,4]. Since the start of the Dracunculiasis Eradication Program -25 years ago- conducted by several organizations such as the Carter Center, Centers for Disease Control and Prevention, UNICEF, World Health Organization, Ministries of Health of affected countries, and numerous other non-governmental organizations, enormous progress has been made[5]. The overall number of cases has been reduced tremendously by more than 99% from the 3.5 million cases estimated to have occurred in 1986 in 20 different countries in Africa and Asia, to 1797 cases reported in only 5 African countries in 2010, with most cases (94%) reported in Southern Sudan[6,7] (Figure 1). In addition, cases have been reported in Chad which was considered as disease-free for the last decade. The target dates for eradication have been postponed several times and were usually over-optimistic and difficult to achieve.

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This is due to the fact that target dates were mainly set up for political reasons as it can strengthen the advocacy efforts of the eradication program in endemic countries, rather than choosing a realistic evidence-based target date guided by estimates of the impact of interventions. This however, has demonstrated to be difficult, because of the scarce number of impact evaluations of control and surveillance programs[8].

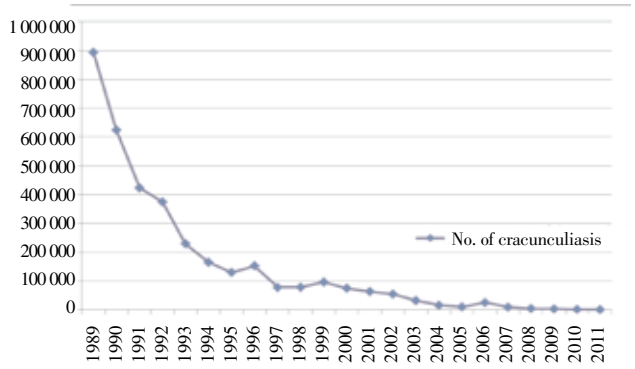


Figure 1. Annual number of cases reported worldwide, 1989-2011. *2011: Provisional: The 804 cases reported worldwide as of June 2011.

2. Life cycle and clinical impact

People become infected by drinking unfiltered water from stagnant ponds or open shallow wells contaminated with copepods (small water fleas) containing infective larvae. In the stomach, the copepods are killed by the digestive juices and consequently the larvae are released and then penetrate their way through the digestive wall into the body cavity. The ovoviviparous female grows up to 1 meter (3 feet) length, but only 1 to 2 mm thickness in the subcutaneous tissue, and can live up to 12 to 14 months, while the male worm dies within a few months[9]. No symptoms manifest until a year or so after the infection by which time the female worm has produced millions of eggs in its uterus, and is predominantly localized in the lower extremities (80%-90%). A sudden release of larvae causes a hot, painful sensation under the skin, creating a painful blister (1 to 6 cm diameter). The person may develop a slight fever, local redness, swelling and severe pruritus around the blister. Also diarrhoea, nausea, vomiting and dizziness may be present. The blister will burst within 1 to 3 days. When one or more female worms (1.8 worms per person on average, with as many as 14 worms documented to emerge from a given person in a season) slowly come out of the blister (Figure 2), an excruciating burning sensation and pain is felt[10]. Immersing or pouring water over the blister helps to relieve the pain, but also for sloughing-off the skin over the blister, allowing exposure of the worm to the outside environment[2]. This is the moment that the female worm releases a milky white liquid into the water that contains millions of immature larvae. When released in water, the larvae are ingested by copepods where they moult twice and become infective larvae within two weeks[11]. This contaminates the drinking water source and the cycle begins anew[12].

Figure 2. Several Guinea worms emerging from a leg of a patient from Ghana, photo by Dr. A. Tayeh.

3. Treatment

There is no available curative drug or vaccine against dracunculiasis. Infected persons do not develop immunity. There is only the "traditional treatment"-gradually pulling the worm out manually-, usually by winding a few inches/centimetres of the worm each day on a small wooden stick, which is a very painful process[12]. Thus, it can take weeks to months for the entire worm to be removed, during which time the patient is often severely incapacitated. Moreover, nearly every infected person will be a victim of secondary bacterial infection. If not treated with antibiotics, these lesions can cause several complications such as erysipelas/cellulitis, abscesses, sepsis, septic arthritis and even trismus (lock jaw caused by tetanus infection)[11]. Patients ought to be careful not to break the worm during manual extraction, because if the worm breaks it can cause intense inflammation as the remaining part of the dead worm disintegrates in the affected limb.

4. Epidemiology and economic impact

Dracunculiasis affects people that depend on contaminated drinking water sources, usually stored in unprotected stagnant water source such as ponds. Villages that depend upon such water for drinking can have 15% to 70% of their

population infected. It threatens economic development[13], because it mainly affects the most productive people (12–50 year old), sustaining the disease–poverty–disease cycle. Variation in incidence between age, gender and occupation is mainly determined by the type of water source from where the people drink. GWD transmission has a seasonal pattern and is closely related to rainfall. In arid areas, people get infected during the rainy season, when surface water is available. In wet regions, people generally get infected during the dry season, when sources of drinking water are scarce and becoming stagnant. The seasonal pattern of clinical manifestations of the disease, which occurs one year after transmission, often coincides with harvest or planting seasons and significantly affects agricultural productivity. In Nigeria for example, GWD was responsible for an approximate 11.6% decrease in the total rice crop production. It is estimated that infected people lose 100 days of work per year. Furthermore, it affects school attendance because of inability to walk to school, with children being absent for at least 25% of the school year. The World Bank has estimated that the economic rate of return on the investment in GWEP will be about 29% per year once the disease is eradicated[3].

5. Main strategies

The main strategies of the GWEP are preceded by setting up national surveillance programs, to identify cases and consequently establish an appropriate policy and national plan for eradication[14]. After that, interventions are implemented. Main strategies are early case detection (within 24 hours of worm emergence) to interrupt transmission immediately, community mobilizations and awareness campaigns including health education such as village–by–village health education by village–based volunteers about the origin of the infection, mode of transmission and methods of prevention. Another important factor remains vector control by temephos application (a chemical copecide which is not harmful to animals and humans)in contaminated drinking water sources to kill the intermediate host. Filtering all unsafe water before drinking could be achieved by millions of cloth filters (*e.g.* personal special filter straws), hence preventing ingestion of the water fleas containing infective larvae. Provision of safe water sources such as bore–hole wells and deep dug wells were proposed as the major contributor in combating GWD, but appeared to be an extremely expensive option not affordable by most endemic countries[15]. One of the most effective strategies, whatever the prevalence or incidence or setting is so called "case containment"; unfortunately this is very costly and is now only used in areas where the prevalence is low. Case containment programs are preventing infected people to enter drinking water sources in order to interrupt transmission completely. Case–containment centres have been set up, where patients can be kept for about a week and receive free medical treatment and food. To maintain intensive surveillance, nationwide in–kind reward systems for informing on cases exists. Rewards vary from U.S. $ 10 to 100. All these grassroots public health initiatives have been demonstrated to be extremely effective and suitable to be used in remote and less developed communities in the poorest countries on earth[12].

6. The road to eradication

Shortly after the WHO declared the world free of smallpox in 1977, the first disease ever eradicated, dracunculiasis was posed to be the ideal next candidate for eradication[16]. It was stated that dracunculiasis, a disease only transmitted via drinking water, would be an ideal indicator to measure the success of the United Nations declaration of the International Drinking Water Supply and Sanitation Decade (IDWSSD) 1981–1990. In 1981 the possibility of elimination of GWD by improving the quality of human drinking water was adopted by the IDWSSD as a sub–goal of their endeavours. An international campaign led by the Carter Center launched the battle against GWD in 1986. In addition, other international partners including the United Nations Development Program and UNICEF, together with countries endemic for GWD, joined the global effort. The WHO has been deeply involved from the start of the campaign; The World Health Assembly (WHA) accepted a resolution (WHA 34.25, 1981) linking drinking safe water supply to the prevalence of dracunculiasis, which could serve as a unique visible and measurable indicator of the progress of the IDWSSD. In 1986 the WHA accepted a resolution (39.21) calling for the elimination of dracunculiasis. As the campaign gained support, the World Health Assembly in 1991 accepted a resolution calling for the eradication of the disease by 1995. In addition, national programs for dracunculiasis eradication in Asia started from 1983. Since then, the number of newly reported cases declined tremendously (Figure 1), eliminating the disease in Asia (Pakistan 1993, India 1996) and several African countries (Cameroon, Senegal and Yemen 1997[17–19]. It is estimated that one million cases each year are prevented due to the campaign. The global success of the GWEP is unprecedented because it is mainly achieved by involving thousands of village volunteers who disseminate health education for this disease, which has no drug based or vaccine therapies[17].

7. Current status of the campaign

GWD remained endemic during 2010 in 5 African countries, Sudan (1 698 cases), Mali (57 cases), Ethiopia (21 cases) and Ghana (8 cases). In addition Niger, which reported interruption of dracunculiasis in 2008, reported 3 cases in 2010 all imported from Mali. Chad confirmed that 10 indigenous cases were detected in 2010.

Sudan currently reports most cases. Within Sudan, the northern states already eradicated GWD, which is not surprising since the civil war was being fought mostly in the southern part of the country. Southern Sudan, where it has been proved to be difficult to implement an eradication program, reported 94% (1 698/1 797) of global cases in 2010. This continuing transmission is not only a concern for South Sudan, but also for neighbouring states such as Uganda, because of cross-border travelling of indigenous nomads. A 4-month cease-fire in 1995, negotiated by former US president Jimmy Carter, allowed health workers to establish health education programs and distribution of cloth filters[17]. Currently, the eradication program in South Sudan is the last program that needs to be fully scaled up after the signing of the Comprehensive Peace Agreement in 2005, ending the longest-running, bloodiest and most neglected civil war in Africa. It was acknowledged that this long-awaited peace agreement to bring peace in Southern Sudan removed the most important obstacle for eradication dracunculiasis[20]. Nevertheless, even after the peace agreement and the gain of independence of South Sudan on July 9th 2011, the GWEP is still not running at full speed. It will be a quite challenge to maintain a high priority for this eradication program on the political agenda in a newly formed nation with many other challenges ahead. Humanitarian agencies are now still unable to freely access the civilian population, despite improvements in the security situation. Besides this, ongoing fighting and inter-communal clashes displaced thousands of people, making it difficult to reach them[21]. It is hoped that after a short period of the independence of South Sudan, political stability and peace will prevail at last, which is of vital importance to the success in the eradication of dracunculiasis in the region[14].

The situation of dracunculiasis in Ethiopia is tied to that of South Sudan, as the endemic areas in both countries are adjacent to each other. Twenty one cases from a small endemic zone, Gog District, have been reported nearer to the border with South Sudan in 2010. Members of the main community frequently move across the Ethiopian-Sudanese border transmitting the disease from one side to another and thus the disease transmission will be easier to interrupt if the number of cases in South Sudan is further reduced.

Mali reported 57 cases in 2010, that is a reduction of 69% compared with the number of cases in 2009. Although the number of cases is not high, the situation in Mali is considered an obstacle to GWEP due to the movement of nomadic populations in a vast area not only in Mali but also to neighbouring formerly endemic countries including Burkina Faso, Mauritania and Niger. It is no surprise that the 3 cases reported in Niger in 2010 were imported from Mali.

After more than ten years of stagnation in the number of Guinea worm cases in Ghana that reported between 4 000 to 8 000 cases annually before 2008, there was a dramatic decrease in the number of detected cases during 2008-2009 and only 8 cases were reported in 2010. All of these 8 cases were contained. As the last case was reported in May 2010 and no more were reported to the end of July 2011 (14 months with no cases) it is likely that the disease has been interrupted in the country[22].

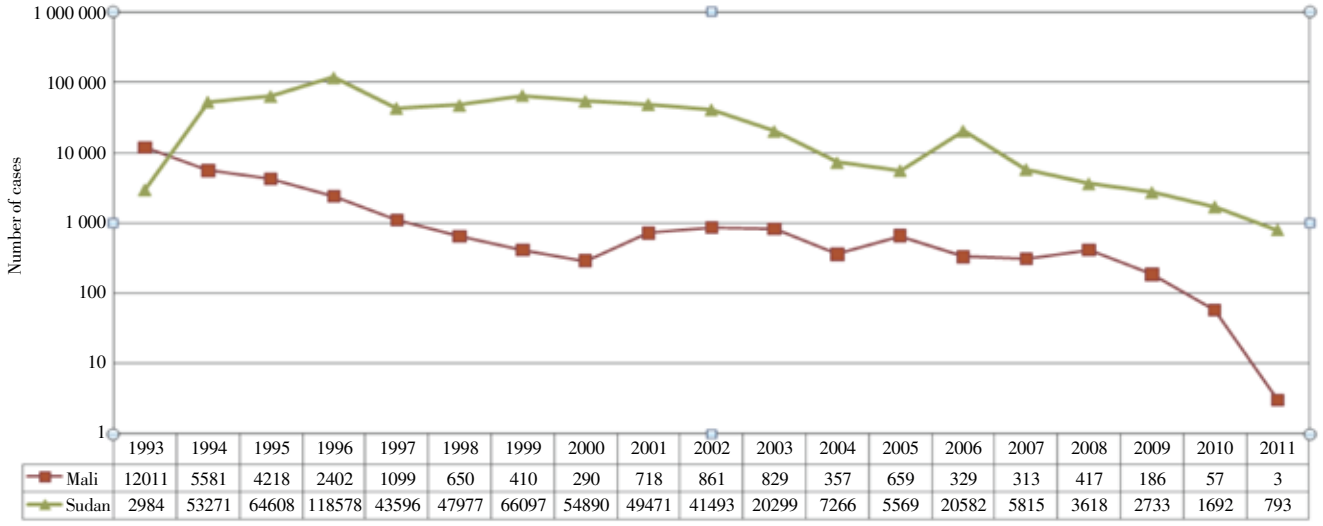
The recent re-emergence of cases in the southern part of Chad, a decade after transmission was halted, is of concerned to all persons involved in GWEP. It is not possible to ascertain whether this resurgence is a result of continuing undetected low-level indigenous transmission over the past 10 years or if it has originated from a recently imported case that was not detected[6]. It can also be considered a consequence of the delay in interrupting the disease in countries that are neighbouring Chad including Niger, Nigeria, Cameroon and Sudan.

8. Conclusion

With no more than 1 797 Guinea worm cases reported in 2010 from only 4 Sub-Saharan African countries endemic for GWD, there are indications that the number of endemic countries and the number of cases will be reduced further in 2011. Ghana may have interrupted disease transmission as discussed earlier. The number of reported cases in Ethiopia was low (6 cases) during the first half of 2011, which is half the number of the cases reported during the same period in 2010[22]. As of June 2011, provisional data show a further decline in GWD with a total of 804 cases; South Sudan reported 99% (793/804) of all cases of GWD in the world.

Thus, only two endemic countries will determine the future of GWEP, Mali and South Sudan. Figure 3 shows the status of dracunculiasis cases during 1989 to 2011 for Mali and Sudan. There has been stagnation in the number of cases for Sudan and Mali for 1993 to 2008. But there is a sign of decrease in the number of cases during 2009 to 2010 which is promising if continues.

With $\geqslant$94% of the global cases concentrated in South Sudan, focused efforts of GWEP will be required in this newly born country that has been devastated after many



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mali	12011	5581	4218	2402	1099	650	410	290	718	861	829	357	659	329	313	417	186	57	3
Sudan	2984	53271	64608	118578	43596	47977	66097	54890	49471	41493	20299	7266	5569	20582	5815	3618	2733	1692	793

Figure 3. Annual cases of GWD in Mali and Sudan.

* Provisional. Data as of June 2011; South Sudan reported 99% of all cases of Guinea Worm disease in the world.

Box 1 – Key papers in the field of Guinea worm eradication.

•Cairncross S, Muller R, Zagaria N. Dracunculiasis (Guinea worm disease) and the eradication initiative. *Clin Microbiol Rev* 2002; **15**(2): 223–246.

•Greenaway C. Dracunculiasis (guinea worm disease). *CMAJ* 2004; **170**(4): 495–500.

•Ruiz-Tiben E, Hopkins DR. Dracunculiasis (Guinea worm disease) eradication. *Adv Parasitol* 2006; **61**: 275–309.

•Tayeh A, Cairncross S. Editorial: Dracunculiasis eradication by 2009: will endemic countries meet the target? *Trop Med Int Health* 2007; **12**(12): 1403–1408.

•Muller R. Guinea worm disease--the final chapter? *Trends Parasitol* 2005; **21**(11): 521–524.

Box 2 – Learning points of this review.

•Dracunculiasis (Guinea worm disease) is a preventable waterborne parasitic disease which caused a enormous public health problem, however, the disease has now reached its final stage accelerating to zero cases in all endemic countries.

•The Global Guinea Worm Eradication Program (GWEP) has reduced the overall number of cases by ⩾ 99%, from the 3.32 million cases estimated to have occurred in 1986 in Africa to only 1 797 cases reported in 2010. From 1 January to 30 June 2011 there have been only 814 confirmed cases of dracunculiasis. The majority of cases come from South Sudan (801), Mali (3), Ethiopia (8) and Chad (2).

•The success of the GWEP will be determined by only two endemic countries; Mali and South Sudan; The eradication program in South Sudan is the program that needs to be fully scaled up because a long civil war impeded effective implantation of national public health initiatives. Mali is considered an obstacle to GWEP mainly due to the high degree of movement of nomadic populations in vast areas bordering several countries. If surprises arise, such as a new conflict in South Sudan or in Mali, interruption of dracunculiasis will be difficult and the disease may spread. The utmost challenge for the next few years will be to increase and sustain the current eradication efforts using all the existing tools.

years of civil wars, which will now gradually and slowly rebuild itself. In South Sudan, there may be as many as 732 villages endemic for dracunculiasis. As in other countries, eradication requires implementing a village-based program in each endemic village, which is easier said than done with the hundreds of villages in Southern Sudan with restricted access to particularly during the rainy season. South Sudan, though it is now very rich in oil, remains one of the least developed regions on earth, with ethnic tensions, mass movements of displaced people, troubled relations with the north, few roads or other infrastructure, and limited communication possibilities[2]. Additional difficulties caused by upheavals are disruptions in activities and loss of personnel, and increased costs because of the need to airlift supplies.

Mali can prove that it is as crucial as South Sudan in determining the fate of success of GWEP with a high degree of movement of nomadic populations in vast areas bordering several countries. Mali has for long been exporting cases to other endemic countries such as Burkina Faso and Niger and to non-endemic countries, namely Algeria[23]. The recent re-introduction of dracunculiasis in Chad, which was free from the disease since the year 2000, is a strong reminder of the significance of maintaining surveillance in areas that are considered to be free from the disease. It also can be considered a consequence of the delay in interrupting the disease in countries that are neighbouring Chad including Niger, Nigeria, Cameroon and Sudan.

If surprises arise, such as a new conflict in South Sudan or in Mali, interruption of dracunculiasis will be difficult and the disease may spread. The utmost challenge for the next few years will be to increase and sustain the current

eradication efforts using all the existing tools[8]. Effective surveillance and case containment followed by reliable reporting will be crucial at this stage to ensure that disease transmission can be interrupted soon. Special attention should also be given to cross-border spread of the disease particularly to northern Uganda which has already been certified in 2009 as disease free; the zones where nomads travel may pose a risk for re-introduction of the disease in former endemic countries. Surveillance strategies focusing on zones of transmission that cut across such boundaries need to be implemented. Yet, given adequate resources and high level advocacy by national and international leaders in an environment of political stability and peace, there is no reason that this disabling parasitic disease, which has plagued mankind since ancient times, cannot be eradicated soon.

Conflict of interest statement

We declare that we have no conflict of interest.

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References

[1] Richards FO, Ruiz-Tiben E, Hopkins DR. Dracunculiasis eradication and the legacy of the smallpox campaign: What's new and innovative? What's old and principled? Symposium on smallpox eradication: lessons, legacies & innovations. *Vaccine* 2011 (Epub ahead of print).

[2] Ruiz-Tiben E, Hopkins DR. Dracunculiasis (Guinea worm disease) eradication. *Adv Parasitol* 2006; **61**: 275-309.

[3] Ramakrishna J, Brieger WR, Adeniyi JD, Kale OO. Illness behavior in guineaworm disease. 1985-86. *Int Q Community Health Educ* 2006-2007; **26**(2): 127-140.

[4] Feasey N, Wansbrough-Jones M, Mabey DC, Solomon AW. Neglected tropical diseases. *Br Med Bull* 2010; **93**: 179-200.

[5] Barry M. The tail end of guinea worm - global eradication without a drug or a vaccine. *N Engl J Med* 2007; **356**(25): 2561-2564.

[6] WHO. Dracunculiasis eradication - global surveillance summary, 2010. *Weekly Epidemiological Record* 2011; **86** (20): 189-204.

[7] Lodge M. And then there were four: more countries beat guinea worm disease. *BMJ* 2010; **340**: c496.

[8] Tayeh A, Cairncross S. Editorial: Dracunculiasis eradication by 2009: will endemic countries meet the target? *Trop Med Int Health* 2007; **12**(12): 1403-1408.

[9] Greenaway C. Dracunculiasis (guinea worm disease). *CMAJ* 2004; **170**(4): 495-500.

[10] Müllner A, Helfer A, Kotlyar D, Oswald J, Efferth T. Chemistry and pharmacology of neglected helminthic diseases. *Curr Med Chem* 2011; **18**(5): 767-789.

[11] Iriemenam NC, Oyibo WA, Fagbenro-Beyioku AF. Dracunculiasis--the saddle is virtually ended. *Parasitol Res* 2008; **102**(3): 343-347.

[12] Hopkins DR, Ruiz-Tiben E, Downs P, Withers PC Jr, Roy S. Dracunculiasis eradication: neglected no longer. *Am J Trop Med Hyg* 2008; **79**(4): 474-479.

[13] Ojo TB, Ojo KK. Nigeria's dracunculiasis eradication triumph and the need for caution. *J Infect Dev Ctries* 2011; **5**(12): 901-902.

[14] Breman JG, Arita I. The certification of smallpox eradication and implications for guinea worm, poliomyelitis, and other diseases: Confirming and maintaining a negative. *Vaccine* 2011 (Epub ahead of print).

[15] Muller R. Guinea worm disease--the final chapter? *Trends Parasitol* 2005; **21**(11): 521-524.

[16] Hopkins DR, Foege WH. Guinea worm disease. *Science* 1981; **212**(4494): 495.

[17] Aronson SM. Dracunculiasis: a candidate for eradication. *Med Health R I* 2010; **93**(3): 67.

[18] Wakabi W. Africa sees obstacles to Guinea worm disease eradication. *Lancet* 2009; **373**(9670): 1159.

[19] Fabiansen C, Harboe ZB, Christensen V. Dracunculiasis in South Sudan. *Am J Trop Med Hyg* 2010; **82**(5): 757.

[20] Aylward B, Hennessey KA, Zagaria N, Olive JM, Cochi S. When is a disease eradicable? 100 years of lessons learned. *Am J Public Health* 2000; **90**(10): 1515-1520.

[21] United Nations Office of Humanitarian Affairs (OCHA). *Weekly humanitarian bulletin*. Sudan: OCHA; 2011.

[22] CDC. Guinea Worm Wrap-up 15 July 2011, No 206. Atlanta, USA: CDC; 2011, p. 4.

[23] Harrat Z, Halimi R. La dracunculose d'importation: quatre cas confirmés dans le sud algérien, *Bull Soc Pathol Exot* 2009; **102**(2): 119-122.