P562

XIX. The clinical and laboratory tolerance of high dose ivermectin. *Trop. Med. Parasitol.* 46, 131–137
36 Calcoen, D. and Mabor, M. (1997) Onchocerciasis monitoring and mass treatment with ivermectin under unstable war conditions in south-western Sudan. *Bull. Trop. Med. Int. Health* 5, 1 & 4
37 Chaves, C. (1997) Ocular onchocerciasis in Brazil. *Bull. Trop. Med. Int. Health* 5, 6

Note added in proof

Finally, the most recent information on onchocerciasis describes monitoring and ivermectin treatment in the war conditions of South Sudan[36] and in the same publication a brief note describes the endemicity and prevalence of ocular lesions amongst the Yanomami Indians of the Brazil–Venezuela border[37].

Twenty-two Years of Blackfly Control in the Onchocerciasis Control Programme in West Africa

J-M. Hougard, L. Yaméogo, A. Sékétéli, B. Boatin and K.Y. Dadzie

Twenty-two years after the launch of the Onchocerciasis Control Programme in West Africa (OCP), Jean-Marc Hougard and colleagues critically review the vector-control strategy adopted. They go on to identify the few hydrological basins where transmission of the infection remains difficult to control, to analyse the causes and to propose appropriate corrective measures on a case-by-case basis. Most of these measures, which are mainly based on ivermectin chemotherapy, will continue to be applied after the end of the OCP in 2002, under the control of the countries concerned.

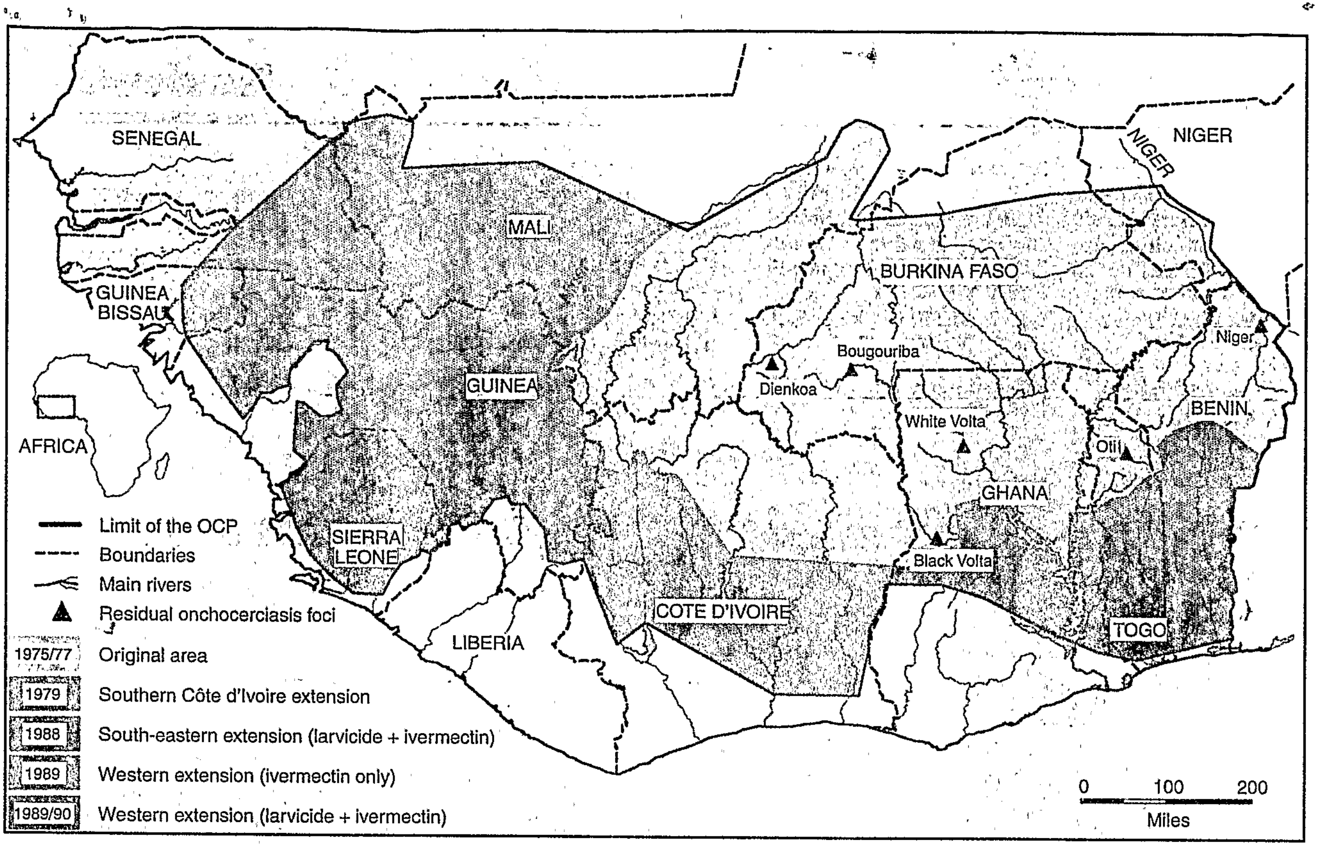
Onchocerciasis, a dermal filariasis caused by *Onchocerca volvulus*, is a disease transmitted to humans by a blood-sucking dipterous insect, the blackfly (*Simulium*). The most serious manifestations are blindness and debilitating skin lesions. This disease is found in 37 countries, 30 in Africa, six in America and one in the Arabian peninsula[1]. Africa is by far the most affected continent in terms of the severity of the clinical manifestations of the disease and the extent of its distribution. Hence, as early as 1968, representatives of the Organisation de Coopération et de Coordination pour la Lutte contre les Grandes Endémies, WHO, Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) and United States Agency for International Development, encouraged by the results of the pilot campaigns for the control of blackflies in the savanna zone of West Africa[2], laid down the foundations of an ambitious regional onchocerciasis control project at a meeting in Tunis (1–8 July 1968).

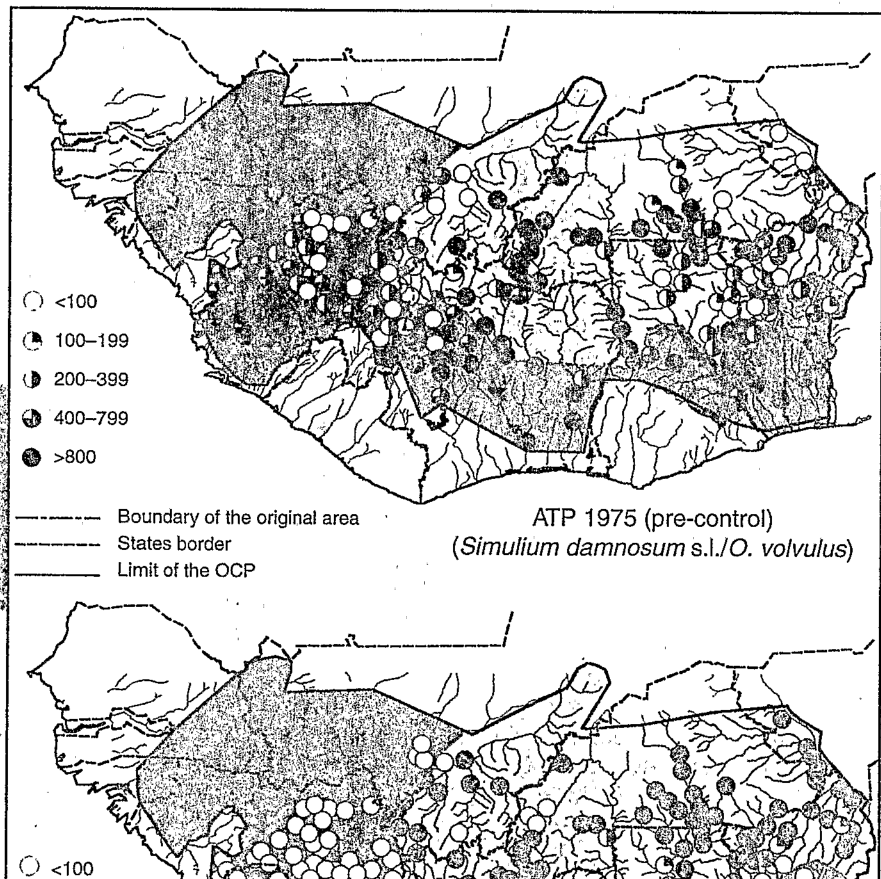
The Onchocerciasis Control Programme in West Africa (OCP)[3] began its activities in January 1974. Its objective was to eliminate onchocerciasis as a disease of public health importance and as an obstacle to socio-economic development. The basic strategy was to interrupt the transmission of the blinding strain of *O. volvulus* for a period longer than the longevity of the adult worm in its human host (about 14 years)[4]. The interruption of transmission is achieved by destroying the larval stages of the vector, *Simulium damnosum* s.l., through the aerial application of selective insecticides to infested rivers (Fig. 1). Each week, the OCP selects the most appropriate insecticide (out of seven, which are used in rotation) for application in each river stretch to be treated (Fig. 1). This decision allows the optimization of larviciding in terms of cost-effectiveness, management of resistance and environmental protection[5,6]; several criteria need to be considered, not only relating to the insecticides, but also to the hydrological conditions and blackfly populations involved. One of the seven insecticides is a liquid concentrate of a biological control agent, *Bacillus thuringiensis* H-14 (Ref. 7). Of the six chemicals, formulated as emulsified concentrates, three are organophosphates (temephos, phoxim and pyraclofos), two are synthetic pyrethroids (permethrin and etofenprox) and one is a carbamate (carbosulfan).

The first aerial insecticide treatments began in February 1975, in areas where the incidence of blinding onchocerciasis was highest. Later, the area covered was gradually extended to 654000 km², spread over seven countries (Burkina Faso, south-eastern Mali, south-western Niger, the northern parts of Côte d'Ivoire, Benin, Ghana and Togo) by the end of 1977. However, it soon became apparent that the border of this area was infiltrated by infective blackflies originating from regions outside the OCP area[8]. To give permanent protection in the original OCP area and to control the vector in the basins where the re-invading *Simulium* originated, the hyperendemic regions were identified and larvicidal treatment was given[9]. This resulted in two extensions to the original OCP area, one to the west, comprising the basins of south-eastern Guinea and northern Sierra Leone (western extension), and a second to the south and east, comprising the southern basins of Côte d'Ivoire, Benin, Ghana and Togo (south-eastern extension) (Fig. 1).

Jean-Marc Hougard is at the Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) and is seconded to the World Health Organization, currently based at the Vector Control Unit of the Onchocerciasis Control Programme in West Africa (OCP), PO Box 549, Ouagadougou, Burkina Faso. Laurent Yaméogo, Azodoga Sékétéli, Boakye Boatin and Kofi Yankum Dadzie are at the OCP. A. Sékétéli is also the Programme Manager for the African Programme for Onchocerciasis (APOC). **Tel: +226 34 22 57, Fax: +226 30 21 47, e-mail: hougard@oncho.orstom.bf**

ed 0169-4758/97/$17.00 S0169-4758(97)01145-9


SENEGAL
MALI
NIGER
NIGER
BURKINA FASO
GUINEA BISSAU
GUINEA
AFRICA
SIERRA LEONE
LIBERIA
COTE D'IVOIRE
GHANA
TOGO
BENIN
Dienkoa
Bougouriba
White Volta
Black Volta
Oti
Niger
Limit of the OCP
Boundaries
Main rivers
Residual onchocerciasis foci
1975/77 Original area
1979 Southern Côte d'Ivoire extension
1988 South-eastern extension (larvicide + ivermectin)
1989 Western extension (ivermectin only)
1989/90 Western extension (larvicide + ivermectin)
0 100 200
Miles


<100
100–199
200–399
400–799
>800
Boundary of the original area
States border
Limit of the OCP
ATP 1975 (pre-control)
(Simulium damnosum s.l./O. volvulus)
<100
100–199
200–399
400–799
>800
Entomological evaluation ceased as from 1992. Results were excellent: ATP = 0
0 150 300
Miles
ATP 1996
(Simulium damnosum s.l./O. volvulus)

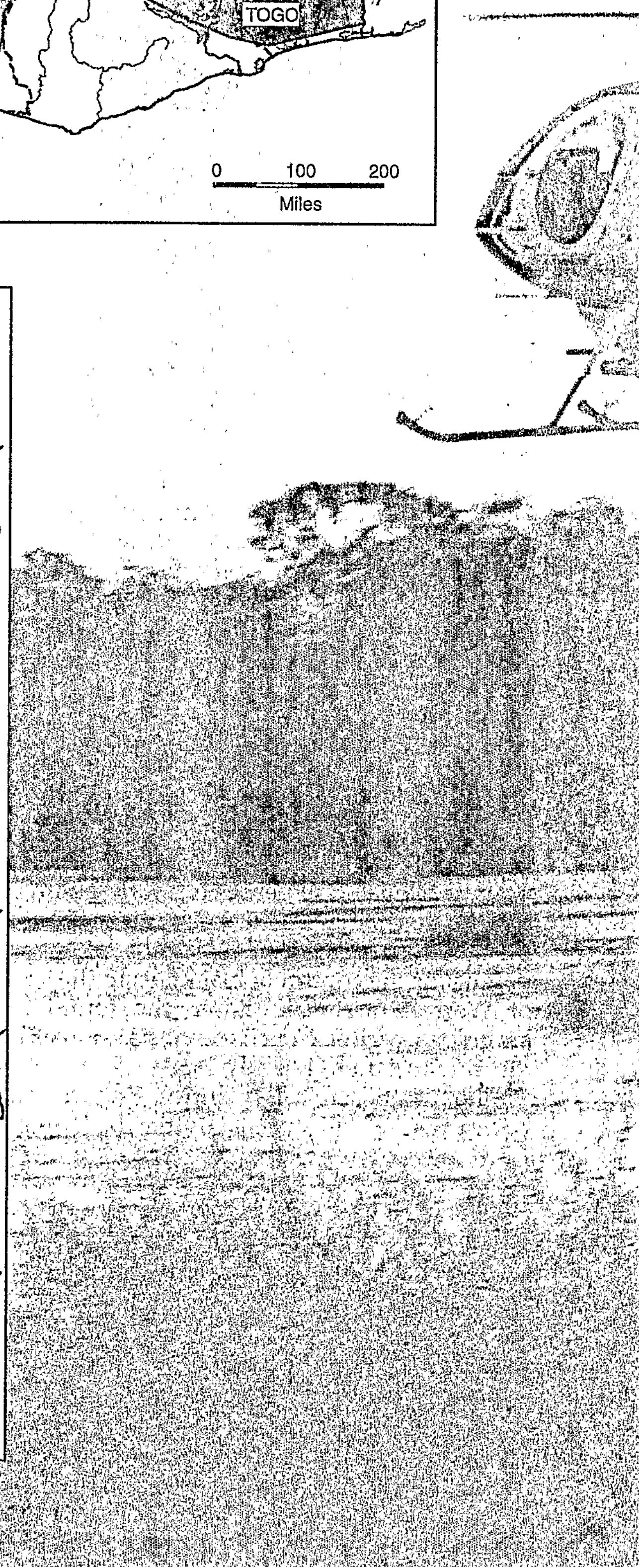
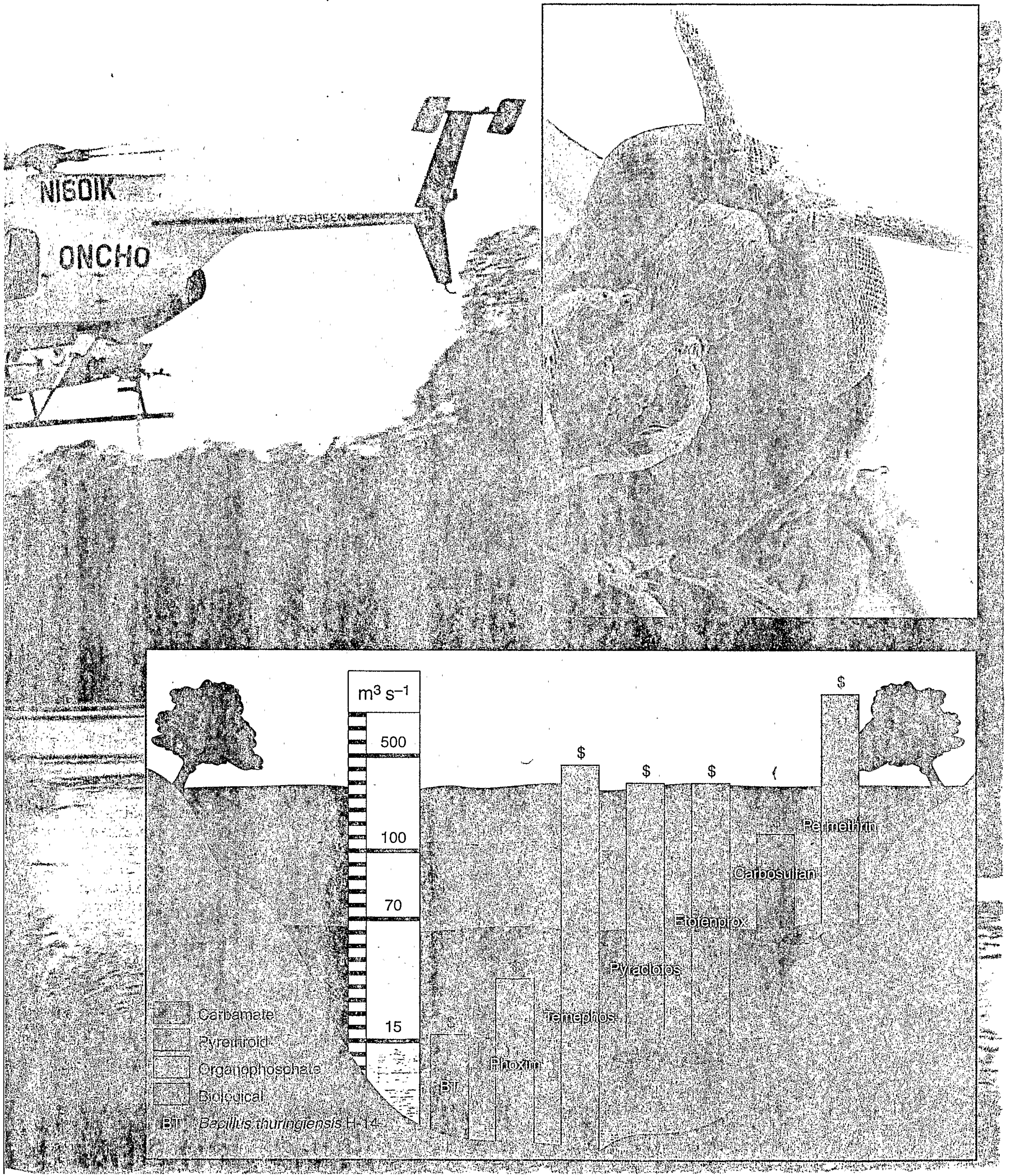


Fig. 1. An overview of the vector-control activities in the Onchocerciasis Control Programme in West Africa (OCP). The map (top left) shows the different operational phases of the OCP and identifies the residual foci in the original OCP area. The photograph below (kindly supplied by the Institut Français de Recherche Scientifique pour le Développement en Coopération) shows an adult of *Simulium damnosum* s.l. complex species, which is responsible for the transmission of onchocerciasis. The background shows a helicopter (photograph kindly supplied by OCP) spraying one of seven larvicides selected according to their operational range (bottom right). In this figure, the position of the fish represents the minimum level of water discharge with respect to the water gauge at which the product is authorized to be used because of the risk of impact on the environment. The dollar sign ($) represents the level above which the cost of use of the product is no longer acceptable. The entomological evaluation is also shown (bottom left). The entomological index most frequently used to quantify transmission is the annual transmission potential (ATP): the theoretical number of infective onchocerca larvae that a person at a catching point would receive if highly exposed to blackfly biting 12 hours a day for 12 months a year. In the savanna area, transmission of onchocerciasis at a level <100 infective parasite larvae per person per year is considered to give no risk of developing severe ocular lesions.



The installation of vector-control operations in the extension areas was completed towards the end of the 1980s, while all the basins of the original area were still being treated. The larviciding coverage then reached its peak with >40000 km of river being treated over an area of 10^6 km^2, over nine countries of the OCP. The satisfactory results achieved mean that larviciding operations have now stopped in almost all the basins of the original area. In the extension areas, larviciding is proceeding, and is combined with the distribution of the microfilaricide ivermectin, the only drug available so far which is suitable for the mass treatment of onchocerciasis[10]. By pursuing this combined drug and vector-control strategy, the whole of the basins treated should be free from onchocerciasis by 2002 at the latest, which is the end point of the OCP operations[11]. A few residual foci of infection will remain, however, after the conclusion of the OCP, both in the controlled areas and in the extension areas.

Residual foci in the original area

The control strategy. The original OCP area is a savanna zone and is relatively homogeneous in its blackfly species and parasite strains. Before the OCP was launched, the area was plagued mainly with the most severe form of onchocerciasis, the savanna type, which is characterized by high blindness rates, and is transmitted by the group of savanna species of the *S. damnosum* complex (Fig. 1)[12–14]. In principle, the vector-control strategy was simple to implement, as it consisted of arresting transmission of the parasite regardless of its pathogenicity, through the indiscriminate elimination of vector species[15]. Although the blackflies could carry animal filariae, some of which could not be differentiated from *O. volvulus*, evaluation of the treatments posed no particular problem. Indeed, the savanna blackflies were largely anthropophilic, and the annual transmission potential (ATP; Fig. 1) reflected the intensity of the blinding form of human onchocerciasis[16].

The implementation of this control strategy made it possible to interrupt transmission of the blinding strain of the parasite. From 1990, the first decisions to stop larviciding were made for the basins in which the situation was deemed satisfactory from both the epidemiological and entomological points of view[17,18]. Subsequently, vector-control operations ceased in other basins that had received at least 14 years of larviciding and where the trends of the epidemiological data indicated depletion of the parasite reservoir. However, because of contamination by infective blackflies, some rivers at the edge of the original area continued to be treated beyond the theoretical period of 14 years, and up to the time the extension areas were set up. Onchocerciasis is no longer a public health problem in the whole of the original area, that is, clinical signs of the disease have totally disappeared. WHO forecast in 1991 (Ref. 19) that the whole of the original area would be free from onchocerciasis by 1997; however, a few basins remain slightly endemic[20].

The residual foci. The persistence of some residual foci is a cause for concern. While the risk of contamination of the adjacent basins remains, there is no guarantee that an alternative control strategy would succeed fully where the current strategy has only been a partial success. The OCP and the participating countries are therefore paying particular attention to these foci in an attempt to identify the factors that have hindered success. To our knowledge, six residual foci of onchocerciasis remain in the original area; a succinct analysis of these foci follows.

(1) In the north-eastern part of Benin, a few villages located near two tributaries on the east side of the river Niger are still hypoendemic despite 18 years of uninterrupted vector control. The persistence of this focus is due to a seasonal contamination by infective blackflies carried by harmattan winds from untreated hyperendemic areas of Nigeria.

(2) The problem of the Lower Black Volta focus in Ghana is partly caused by demographic factors. A recent sociological study[21] has shown that this area attracted large numbers of migrants in search of new farmlands; the migrants mainly originated from areas to the east of Lake Volta, which were still endemic.

(3) The control programme in the White Volta focus in Ghana was hampered for many years by serious logistical problems related to the inaccessibility of two of its tributaries during the rainy season. Some larval breeding sites thus escaped larviciding, allowing an unsuspected transmission to continue as a result of the inappropriate location of one blackfly-catching point.

(4) In the Dienkoa focus in Burkina Faso, onchocerciasis remains mainly because of the premature decision to stop vector-control operations in the 1980s. This was partly a consequence of continuing undetected transmission as a result of an inappropriate reduction in the evaluation network.

(5) The decision to stop larviciding in the basin of the Bougouriba, Burkina Faso in 1989 might also have been premature. Indeed, although transmission had been successfully controlled for more than 14 consecutive years, focal entomological, epidemiological or demographic signs suggested that larviciding should have been continued or, at least, some back-up measures (entomological and/or epidemiological monitoring or ivermectin distribution) instituted.

(6) Lastly, the causes of the persistence of high transmission levels and poor epidemiological results on three of the tributaries within the Oti focus are difficult to determine, but could result from interactions between climatic, demographic and logistical factors. Aerial larviciding, in combination with ivermectin treatment, is being continued pending further investigations.

The corrective measures. The identification of the characteristic features of these foci has made it possible to take corrective actions, in particular, treatment with ivermectin and, to a lesser extent, larviciding. In the White Volta focus, considering the delay in controlling transmission and the fact that transmission is localized, the large-scale ivermectin treatment that was instituted in 1995, soon after larviciding was stopped, might accomplish more than a simple control of morbidity through more focal treatment. The relatively isolated nature of this focus and its low endemicity level, combined with the treatment regime employed (150 $\mu g\ kg^{-1}$ twice a year), permits hope that a significant impact on transmission might be achieved, as occurred in the savanna zone of northern Cameroon[22]. In the Dienkoa focus, satisfactory larvicidal treatments, combined with ivermectin distribution, were achieved (ATPs <100 infective larvae per person per year, and no new infections in humans) only from 1990. The ground larviciding by health service technicians in Burkina Faso should end in 2001, after a period of 12 years of successful control, which is long enough to reduce the risk of recrudescence to <1%. In the Oti focus, where vector control is planned only until 2002, and in the other remaining foci, the long-term control of morbidity through community-directed treatment with ivermectin is probably the only remaining solution in the absence of a macrofilaricide suitable for mass treatment. Community-directed ivermectin treatment, which is used by the African Programme for Onchocerciasis Control, directly involves the exposed communities[23], which is probably the best way to ensure optimal and sustainable protection of the populations after the conclusion of OCP, in the current socio-economic context.

Potential residual foci in the extension areas

History of onchocerciasis control. Larviciding of the river basins that were the initial sources of invasion by infective savanna blackflies commenced as early as 1979 in southern Côte d'Ivoire[9]. Year-round larviciding was started in 1987 in the southern parts of Ghana, Togo and Benin, which were the sources of invasion to the southern borders of the original area[24,25]. In 1989, insecticide treatment of the basins of eastern Guinea and then, in 1990, those of northern Sierra Leone was started[26,27]. With the registration of ivermectin in 1987, these basins also benefited from large-scale ivermectin treatment from 1989. This strategy led to a rapid reduction in ocular morbidity[28] from the effects of ivermectin, as well as a longer-term reduction in transmission from the combined effects of ivermectin treatment and larviciding[29]. At the same time, the foci of Guinea Bissau, western Mali, Senegal and southern Sierra Leone were treated with ivermectin only, because they were isolated, had low-level endemicity and were not a source of invasion into the original area. Thus, at the beginning of the 1990s, vector control and/or ivermectin treatment had brought blinding onchocerciasis under control over the entire area of almost 1300000 km^2 of the 11 countries of the OCP (Fig. 1).

The control strategy. In the extension zones undergoing larviciding, the nature of the soil, the altitude, latitude, rainfall or human activities determine the different types of vegetation, which range from the savanna in Sudan and Guinea to the degraded forests. This diversity is reflected in the habitats of different cytospecies of the *S. damnosum* complex, from the savanna to the forest vectors[30]. When larvicidal treatments were initiated, a selective strategy exclusively targeted at the savanna blackflies was considered. However, the transmission dynamics of different parasite strains was unknown, and it was difficult to identify the infected adult females accurately. This option was therefore discarded in favour of a less targeted strategy, which took into account the seasonal abundance of the savanna blackflies in their larval habitat based on the cytotaxonomic tools available[31]. Species identification by cytotaxonomy is based on the analysis of the banding sequence on the polytene chromosomes from the larval salivary glands[12]. Among the nine sibling species of the *S. damnosum* complex found in the area covered by the OCP[13], six are the primary vectors for *O. volvulus* in West Africa. *Simulium sirbanum* and *S. damnosum* s.s. are the primary vectors in the savanna, while *S. squamosum* and *S. yahense* are the primary vectors in the rain forest. The remaining two vector species, *S. leonense* and *S. sanctipauli*, have a restricted distribution, which is mostly limited to the large coastal rivers of Sierra Leone and Côte d'Ivoire, respectively[30].

Morphological identification of adult blackflies has now improved, allowing the differentiation of the savanna species from the others at the same blackfly-catching point[30]. DNA probes can differentiate between the savanna strain and the forest strain of the parasite[32], and a technique involving mitochondrial DNA sequences is being developed, which allows the identification of the adult flies of the six main vector species[33]. These methods are providing insights into the mechanisms of transmission under natural conditions and, hence, into vector-control strategies. Toé and colleagues[34] have shown that the relation between savanna vectors and the blinding strain of the parasite is not as clear as was suggested by earlier experimental xenodiagnostic studies. The consequent overemphasis on the role of savanna species in transmission, when planning control activities, might favour the transmission of blinding onchocerciasis by the forest blackflies. This hypothesis is supported in that the vectorial capacity of forest species is higher than that of savanna species[35]. However, other observations made in several basins of the extension areas suggest that the current strategy can be maintained without jeopardizing the achievements of vector control. For example, at the Benin village of Kaboua in the degraded forest zone (Fig. 1), transmission of the savanna parasite strain is relatively high (an ATP of 421 infective larvae per person per year in 1996), although the transmission is mainly due to forest blackflies originating from the untreated basins of Nigeria (*S. soubrense* Beffa type)[36]. This level of transmission, in the savanna zone, would have been associated with clinical signs.

These different observations underline the uncertainties regarding the threat posed by the blinding strain of the parasite in the extension areas. Research is now under way to improve molecular tools (heteroduplex, DNA microsatellites) to facilitate the identification of the vector and parasite populations[33,37]. The heteroduplex technique permits the identification of individuals on the basis of hybridization with mitochondrial DNA fragments. Microsatellite DNA provides useful polymorphic markers for populations and even for individuals. The application of immunodiagnostic techniques to determine whether different levels of pathogenicity exist in the parasite or whether individuals can be predisposed to develop blinding onchocercal lesions is also being planned. Pending the results of these studies, with five years to go to the end of larvicide treatments, the current vector-control strategy – a realistic compromise between a selective option and a more global option – should be pursued without major changes until the conclusion of the OCP.

The potential residual foci. Vector control, combined with ivermectin distribution, is being continued in almost all the basins of the extension areas. Larviciding is planned to stop at the end of 1998 in the Côte d'Ivoire basins, and between 2001 and 2002 in the western and south-eastern extensions[38,39]. However, in a few river basins where the blinding strain of the parasite predominates, transmission sometimes remains difficult to control despite continued larviciding and the distribution of ivermectin (eg. the Lower Tinkisso, Guinea, in the western extension, and the Pru, Ghana, in the south-eastern extension). Therefore, as observed in the original area, it is possible that a few residual foci of savanna onchocerciasis will persist after the end of the OCP. After 2002, when vector-control measures will have ceased, in the absence of a macrofilaricide suitable for mass treatment, ivermectin will be the only means of control for these residual foci. The research mentioned previously, if successful, will help to assess the threat represented by these foci, allowing the appropriate adjustment in ivermectin-treatment strategies on a case-by-case basis. Meanwhile, work on modelling onchocerciasis transmission and its control might help to determine precisely how long ivermectin distribution needs to be continued to make the recrudescence of blinding onchocerciasis unlikely[40].

Transfer of residual activities

By 2002, the responsibility for maintaining the residual activities of the OCP will be transferred to the participating countries. A few residual foci will remain in both the original and the extension areas; however, their total size will be fairly small compared with the 25 million hectares of fertile land that will be disease free by the end of the OCP; furthermore, the disease will no longer be a public health problem. Although the studies conducted so far in the disease-freed zones have given encouraging results, it is possible that new onchocerciasis foci will emerge after 2002 in the areas currently considered to have been freed. In the basins of the White Volta in the south-east of Burkina Faso, for example, onchocerciasis has been reduced from hyperendemic to almost absent after 14 years of vector control alone. The latest parasitological surveys still show excellent results six years after larviciding was stopped.

The health services of the countries involved must be given the means to detect an onchocerciasis focus early enough that control is feasible. The necessary tools and know-how for entomological surveillance will be made available by the OCP to the national health services to enable them to detect a resurgence of transmission. A simple and cheap method for the detection of infective larvae of the parasite in blackflies is in the process of being tested for use in the field[41]. This method will provide an early warning of potential recrudescence, enabling the health services of the affected area to apply the various techniques currently available or in development[42] before the infection becomes difficult to control. In the southern areas of the OCP, especially south-eastern Côte d'Ivoire, south-eastern Guinea and south-western Ghana, the national health services will also have to monitor closely the consequences of deforestation on vectorial dynamics and, hence, on the epidemiology of onchocerciasis. For the time being, to avoid any deterioration of the situation, OCP will provide the countries with logistical and technical support for the distribution of ivermectin to control onchocercal morbidity, regardless of pathogenicity.

All vector-control activities will probably have ceased by the end of 2002, as sustained vector-control action to arrest transmission in each residual focus would be beyond the budgets of the participating countries. However, the use of ground larviciding with non-toxic and non-persistent insecticides to control blackfly nuisance might increase, at least in socio-economically important sites, where the efficient and sustainable management of such treatments is possible[43].

Acknowledgements

The authors dedicate this article to the late Daniel Quillévéré, Chief of the Vector Control Unit at OCP 1989–1994. They thank most sincerely B. Philippon, former Chief of the Vector Control Unit and Head of the Health Department of ORSTOM in Paris, David Molyneux, Chairman of the Expert Advisory Committee of OCP and Director of the Liverpool School of Tropical Medicine, UK, and A.W. Soumbey from the OCP, who participated in the revision of this paper and encouraged its publication. Sincere thanks are also extended to the entire technical and administrative staff of the OCP, especially in the Vector Control Unit and in the entomological, hydrological and hydrobiological national teams, who have contributed to the success of the OCP from 1974 to the present.

References

1 WHO (1995) Onchocerciasis and its control. Report of a WHO Expert Committee on Onchocerciasis Control. *WHO Tech. Rep. Ser.* 852, 25–30
2 Le Berre, R. (1968) Bilan sommaire pour 1967 de lutte contre le vecteur de l'onchocercose. *Médecine d'Afrique Noire* 15, 71–72 (in French)
3 Samba, E.M. (1994) *The Onchocerciasis Control Programme in West Africa: an Example of Effective Public Health Management* (WHO, ed.), Public Health in Action
4 Plaisier, A.P. *et al.* (1991) The reproductive lifespan of *Onchocerca volvulus* in West African savanna. *Acta Trop.* 48, 271–284
5 Hougard, J-M. *et al.* (1993) Criteria for the selection of larvicides by the Onchocerciasis Control Programme in West Africa. *Ann. Trop. Med. Parasitol.* 87, 435–442
6 Guillet, P. (1991) *Resistance and Rotational Use of Insecticides in the Onchocerciasis Control Programme in West Africa (OCP)*, CTD/OPR/EC/91.45, WHO
7 Hougard, J-M. and Back, C. (1992) Perspectives on the bacterial control of insects in the tropics. *Parasitol. Today* 8, 364–366
8 Garms, R., Walsh, J.F. and Davies, J.B. (1979) Studies on the reinvasion of the Onchocerciasis Control Programme in the Volta River Basin by *Simulium damnosum* s.l. with emphasis on the south-western areas. *Trop. Med. Parasitol.* 30, 345–362
9 Walsh, J.F., Davies, J.B. and Garms, R. (1981) Further studies on the reinvasion of the Onchocerciasis Control Programme by *Simulium damnosum* s.l.: the effects of an extension of control activities into southern Ivory Coast during 1979. *Trop. Med. Parasitol.* 32, 269–273
10 Chippaux, J-P., Boussinesq, M. and Prod'hon, J. (1995). Apport de l'ivermectine dans le contrôle de l'onchocercose. *Cah. Santé* 5, 149–158 (in French)
11 Molyneux, D.H. (1995) Onchocerciasis Control Programme in West Africa: current status and future of the Onchocerciasis Control Programme. *Parasitol. Today* 11, 399–402
12 Quillévéré, D. (1975) Etude du complexe *Simulium damnosum* en Afrique de l'Ouest. I. Techniques d'étude. Identification des cytotypes. Cah. ORSTOM *Sér. Ent. Méd. Parasitol.* 13, 87–100 (in French)
13 Boakye, D.A. (1993) A pictorial guide to the chromosomal identification of members of the *Simulium damnosum* Theobald complex in West Africa with particular reference to the Onchocerciasis Control Programme area. *Trop. Med. Parasitol.* 44, 223–244
14 Vajime, C.G. and Dunbar, R.W. (1975) Chromosomal identification of eight species of the subgenus *Edwardsellum* near and including *Simulium (Edwardsellum) damnosum* Theobald (Diptera: Simuliidae). *Trop. Med. Parasitol.* 26, 111–138
15 Le Berre, R. *et al.* (1979) Displacements of *Simulium* and strategy of control against onchocerciasis. *Philos. Trans. R. Soc. London Ser. B* 287, 277–288
16 Philippon, B. (1977) Etude de la transmission d'*Onchocerca volvulus* (Leuckart, 1883) par *Simulium damnosum* Theobald 1903, en Afrique tropicale. *Travaux et Documents no. 63* (Institut

Français de Recherche Scientifique pour le Développement en Coopération, ed.), p. 308 (in French)
17 Remme, J.H.F., Alley, E.S. and Plaisier, A.P. (1995) in *Estimation and Prediction in Tropical Disease Control* (Mollison, D., ed.), pp 377–399, Cambridge University Press
18 Agoua, H. *et al.* (1995) Etudes entomologiques de post-traitement dans le programme de lutte contre l'onchocercose en Afrique de l'Ouest. *Parasite* 2, 281–288 (in French)
19 WHO (1991) *Plan of Operations for the Fourth Phase (1992–1997)*, WHO
20 Boatin, B. *et al.* (1997) Patterns of epidemiology and control of onchocerciasis in West Africa. *J. Helminthol.* 71, 91–101
21 Awedoba, A.K. (1996) *Socio-demographic Study of Oncho-endemic Communities in the Basins of the Lower Black Volta and Southwest Ghana*, 412/7/96/PET, WHO/Onchocerciasis Control Programme
22 Boussinesq, M., Prod'hon, J. and Chippaux, J-P. (1997) *Onchocerca volvulus*: striking decrease in transmission in the Vina valley (Cameroon) after eight annual large scale ivermectin treatments. *Trans. R. Soc. Trop. Med. Hyg.* 91, 82–86
23 Dadzie, K.Y. (1997) Onchocerciasis control: the APOC strategy. *Africa Health*, 13–15
24 Cheke, R.A. and Garms, R. (1983) Reinfestation of the southern flank of the Onchocerciasis Control Programme area by wind-borne vectors. *Philos. Trans. R. Soc. London Ser. B* 302, 471–484
25 Walsh, J.F., Philippon, B., Henderickx, J.E.E. and Kurtak, D.C. (1987) Entomological aspects and results of the Onchocerciasis Control Programme. *Trop. Med. Parasitol.* 38, 57–60
26 Sékétéli, A. *et al.* (1993) Equipes nationales entomologiques de la zone d'extension ouest du programme de lutte contre l'onchocercose en Afrique de l'Ouest (OCP) de 1986 à 1990. Partie I. Structures opérationnelles, fonctionnement et avenir. *Bull. WHO* 71, 737–753 (in French)
27 Baker, R.H.A. *et al.* (1990) Progress in controlling the re-invasion of wind-borne vectors into the western area of the Onchocerciasis Control Programme in West Africa. *Philos. Trans. R. Soc. London Ser. B* 728, 731–750
28 Remme, J. *et al.* (1989) A community trial of ivermectin in the onchocerciasis focus in Asubende. I. Effect on the microfilarial reservoir and the transmission of *Onchocerca volvulus*. *Trop. Med. Parasitol. Ser B.* 40, 367–374
29 Guillet, P. *et al.* (1995) Impact of combined large-scale ivermectin distribution and vector control on transmission of *Onchocerca volvulus* in the Niger basin, Guinea. *Bull. WHO* 73, 199–205
30 Wilson, M.D., Post, R.J. and Gomulski, L.M. (1993) Multivariate morphotaxonomy in the identification of adult females of the *Simulium damnosum* Theobald complex (Diptera: Simuliidae) in the Onchocerciasis Control Programme area of West Africa. *Ann. Trop. Med. Parasitol.* 87, 65–82
31 Crosskey, R.W. (1987) A taxa summary for the *Simulium damnosum* complex, with special reference to distribution outside the control areas of West Africa. *Ann. Trop. Med. Parasitol.* 81, 181–192
32 Zimmerman, P.A., Toé, L. and Unnasch, T.R. (1993) Design of *Onchocerca* DNA probes based upon analysis of a repeated sequence family. *Mol. Biochem. Parasitol.* 58, 259–268
33 Tang, J. *et al.* (1995) The *Simulium damnosum* species complex: phylogenetic analysis and molecular identification based upon mitochondrially encoded gene sequences. *Insect Mol. Biol.* 4, 79–88
34 Toé, L. *et al.* (1997) Vector–parasite transmission complexes for onchocerciasis in West Africa. *Lancet* 349, 163–166
35 Quillévéré, D. *et al.* (1978) Etude du complexe *Simulium damnosum* en Afrique de l'Ouest. VIII. Etude de la bioécologie et du pouvoir vecteur des femelles de savane. Comparaison avec les femelles de forêt. *Cah. ORSTOM Sér. Ent. Méd. Parasitol.* 16, 151–164 (in French)
36 Meredith, S.E.O., Cheke, R.A. and Garms, R. (1983) Variation and distribution of forms of *Simulium damnosum* complex from West Africa. *Ann. Trop. Med. Parasitol.* 77, 627–640
37 Herder, S. (1996) Variabilité génétique d'*Onchocerca volvulus* (Leuckart, 1893). Relations avec le faciès épidémiologique de l'onchocercose. *Thèses et Documents Microfichés no. 145* (Institut Français de Recherche Scientifique pour le Développement en Coopération, ed.), p. 115 (in French)
38 WHO (1996) *Plan of Operations for the Fifth Phase (1998–2002)*, WHO
39 Hougard, J-M. *et al.* (1994) De la nécessité de mener à terme les activités de lutte antivectorielle du programme de lutte contre l'onchocercose en Afrique de l'Ouest: rappel des enjeux et proposition d'un budget a minima pour la période 1998–2002. *Parasite* 1, 295–303 (in French)
40 Plaisier, A.P. *et al.* (1997) The required duration of combined annual ivermectin treatment and vector control in the Onchocerciasis Control Programme in West Africa. *Bull. WHO* 75, 237–245
41 Katholi, C.R. *et al.* (1995) Determining the prevalence of *Onchocerca volvulus* infection in vector populations by polymerase chain reaction screening of pools of black flies. *J. Infect. Dis.* 172, 1414–1417
42 WHO (1996) *Meeting on Operational Research and Strategies. Report of the Expert Advisory Committee*, OCP/EAC 17.2, WHO
43 Hougard, J-M. *et al.* La lutte contre la nuisance simulidienne, une conséquence de l'arrêt des activités de lutte contre le vecteur de l'onchocercose en Afrique de l'Ouest. *Forum Mondial de la Santé* (in French) (in press)

Global Eradication of Guinea Worm

H. Periès and S. Cairncross

Little more than a decade ago, it was estimated that over three million cases of dracunculiasis occurred worldwide. Since then, the numbers have fallen dramatically, thanks to the water supply initiatives of the 1980s and, more recently, the national guinea worm eradication programmes implemented in a score of endemic countries. Hervé Periès and Sandy Cairncross discuss how eradication will require the containment of cases in the remaining endemic areas, together with the simultaneous strengthening of surveillance to permit the certification of eradication. This aim requires existing strategies to be adapted to maintain their efficacy and also to improve their sustainability and cost-effectiveness. Sudan with its civil war, and more than a hundred thousand reported cases, remains a major obstacle to rapid achievement of the goal.

Hervé Periès is at the UNICEF Regional Office for West and Central Africa, 04 BP 443, Abidjan 04, Ivory Coast, West Africa. **Sandy Cairncross** is at the London School of Hygiene and Tropical Medicine, Keppel Street, London, UK WC1E 7HT. **Tel: +44 171 927 2211, Fax: +44 171 636 7843, e-mail: scairncr@lshtm.ac.uk**

Dracunculiasis, or guinea worm disease, is a painful and debilitating human condition, caused when an adult female of the nematode *Dracunculus medinensis* emerges gradually from the subcutaneous tissue, usually on the legs. The disease is endemic in rural, poor and usually water-short communities of sub-Saharan Africa (mostly in the Sahel Belt and Gulf of Guinea), and vestigial foci remain in parts of the Arabian peninsula and the Indian subcontinent. It is the only disease that is transmitted exclusively in drinking water. Although dracunculiasis kills few people, it causes frequent complications and long-lasting disabilities, and also has far-reaching socio-economic effects in affected communities.

This ancient scourge has caught many people's imagination because of its striking clinical manifestation, the age-old treatment of winding the worm

November 1997 Vol. 13 No. 11 ISSN 0169-4758

PARASITOLOGY today

This Wormy World – Then and Now

- Fifty years of intestinal nematode infections
- Helminth control and child development
- Eradication of the guinea worm

POSTER inside this issue