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The WHO Onchocerciasis Control Programme: Retrospect and Prospects

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The history of onchocerciasis control in Africa and the genesis of the WHO Onchocerciasis Control Programme in West Africa (OCP) are briefly reviewed. The importance of experience gained in anti-locust campaigns in helping to plan the OCP is stressed. Members of the *Simulium damnosum* species complex are the vectors of onchocerciasis, which OCP is controlling with insecticide treatments on the stretches of rivers where the *Simulium* breed. Migrations of flies have been responsible for reinfestations of controlled areas and the spread of insecticide resistance. The management of these problems and related research are described, but it is emphasized that despite setbacks OCP is achieving its aims. A strategy for the future is outlined: vector control supplemented by chemotherapy is expected to continue until the year 2004.

1. Introduction

Onchocerciasis, or 'river blindness', is caused by a nematode worm (*Onchocerca volvulus* (Leuckart)), which is transmitted from person to person by its blackfly vector, *Simulium damnosum* Theobald. The World Health Organization (WHO) Onchocerciasis Control Programme (OCP) in West Africa is interrupting disease transmission by killing the fly's larvae, which inhabit fast-flowing sections of rivers.

At the first meeting on Migrant Pests (1977) several of the present authors (Le Berre *et al.* 1979) of this article described the Onchocerciasis Control Programme executed by WHO, its structure, its first results after three years and its problems, especially the reinvasion of treated areas. Twelve years later, we feel it is timely to present the results obtained so far, the problems faced, with the exception of the reinvasion, which will be discussed by Baker *et al.* (1990), and the way they were solved. We will also elaborate on the future of what can be considered as a successful venture.

2. The pre-OCP era

Before the late 1950s, onchocerciasis and its control were not considered as priorities. Several reasons accounted for this: onchocerciasis was a discrete disease at the 'end of the track' and other diseases (sleeping-sickness, leprosy) still had higher priority; there was no drug, and vector control seemed to be difficult to achieve despite the eradication of *Simulium*

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neavei obtained by McMahon *et al.* (1958), in Kenya; WHO as a whole was deeply engaged in the 'Malaria Eradication Programme'; more simply, there were very few scientists interested in the problem, with the noticeable exceptions, on the vector side, of D. J. Lewis, M. Ovazza and R. W. Crosskey.

This initial period was followed by an era of intense research carried out by two complementary groups of scientists, one British (Medical Research Council, MRC) and the other French (Office de la Recherche Scientifique et Technique Outre-Mer, ORSTOM). The MRC group based in Kumba (Cameroun) dealt mainly with different patterns of transmission of the parasite, *Onchocerca volvulus*, epidemiology of the disease and drug trials (Duke 1957; Duke *et al.* 1975). The ORSTOM group, based in Bobo Dioulasso (then Upper Volta, now Burkina Faso), covered successively many aspects of the biology of *Simulium damnosum*, which was identified as a complex of species by Vajime and Dunbar (1975): its bionomics, behaviour, ecology in relation to disease transmission, and vector control (Ovazza *et al.* 1965; Le Berre 1966; Philippon 1977; Quillévéré 1979).

It was the huge increase in knowledge gained by these groups and other more isolated, scientists (Walsh 1970) that allowed the planning and implementation of *S. damnosum* control operations in small areas during limited periods of time (1–6 years). Two of these campaigns were successively carried out inside the present OCP area. The first (1962–1964) was sponsored by French Cooperation. It concerned a small area at the border of Upper Volta and Mali, including the Farako Valley in Mali. The second, financed by the European Communities, began in 1965. It covered successively the Farako area of Mali, the southwest zone of Burkina Faso and the Northern Bandama in Côte d'Ivoire.

As already stated by Le Berre *et al.* (1979) 'earlier campaigns all had the effect of being too limited in time and space; with perhaps one exception (Farako), the inadequate extent of the treated areas has resulted in transmission, by immigrant female flies, being maintained at too high a level to be acceptable for resettlement of the deserted valleys'.

Although showing limited success, these campaigns, often considered as experimental by the scientists involved, permitted the collection of a bulk of additional information on the vector, the *S. damnosum* species complex, the control strategies, methods and techniques. Last but not least, note was taken of earlier mistakes, not to be repeated, about the size and duration of such operations.

In 1968, aware of the progress made towards the control of what they considered as a major health and socio-economic problem, Ansari (WHO) and Richet (Organisation pour la Collaboration et la Coopération pour la lutte contre les Grandes Endémies (OCCGE)) organized a meeting in Tunis (Chairman: Janssens, Antwerp) to discuss the following questions. Is Onchocerciasis a major problem? Can it be controlled? Where, when, how, for how long, how much will it cost? Except for the very last question, all were answered positively. The Tunis meeting was really the start of the OCP.

In 1972, at the official request of seven Heads of States of West Africa, WHO organized a mission of 'preparatory assistance to Government' (the PAG mission, 1973) in charge of planning and costing a campaign now known as the OCP.

3. The OCP

Throughout its 15 years' existence, the OCP has faced many problems. Two major ones relevant to vector control have been the reinvasion by immigrating flies, sometimes infected, and resistance to insecticides. The first problem will be dealt with by Baker in his presentation to this meeting (Baker *et al.* 1990).

The second, resistance to insecticides, was detected in 1980 (Guillet *et al.* 1980) on the lower part of the Bandama river, Côte d'Ivoire. This resistance of the 'forest' species (*S. sanctipauli* and *S. soubrense*) of the *S. damnosum* complex to the initial insecticide, temephos (Abate (R)) spread rapidly, mainly in Côte d'Ivoire and Ghana. In 1983, the 'savanna' species (*S. damnosum sensu stricto* and *S. sirbanum*), those responsible for severe, blinding, onchocerciasis, also became resistant to temephos (Kurtak & Ouédraogo 1984). Resistance of these 'savannah' species also spread quickly, to reach a large part of their area of distribution, including the non-treated area located next to the OCP, i.e. the western extension area. These species also became resistant, intermittently or permanently, to another organo-phosphate insecticide, chlorphoxim. These resistances necessitated the use, under certain circumstances (low river discharge), of an insecticide of biological origin, *Bacillus thuringiensis* serotype H 14, highly selective for *Simulium* and certain mosquitoes. At present, the OCP is implementing a highly sophisticated strategy of vector control, by using alternatively five different insecticides, depending on river profiles and discharges: temephos, chlorphoxim, *B. thuringiensis* H 14, carbosulfan and permethrin. The rotational use of these insecticides, a real burden to the Vector Control Unit (VCU) of the OCP, represents the only major exercise of resistance management in the world.

The effect of insecticides on the environment has been closely monitored by independent groups under the authority of an Ecological Committee: the results have always been considered to be satisfactory.

4. Results

Despite these problems, the OCP has shown outstanding results regarding vector control, reduction of transmission and, eventually, disease and blindness. After 15 years of control, 20 million people have been protected against infection; seven million children, born within the area, have not been at risk of blindness due to onchocerciasis; 100000 people have been protected from going blind.

The socio-economic benefits have not been evaluated as completely as they should have been. However, many river valleys deserted by people are now repopulated, the density of people in some areas being so high, and the onchocerciasis prevalence so low, that vector control has been, or could have been, interrupted. To give an example, all Burkina Faso, apart from 10 km of river, has not been treated at all since 1987.

5. Research

The OCP is still regarded by the authors as an experimental operation, constantly adapting its tactics, and sometimes its strategy, to deal with forecast or unforeseen events and, last but not least, to discover new tools.

Like similar operations (i.e. locust control), one of the reasons for its success is that the OCP has produced, and provoked, a huge amount of research. The main areas of research have been, and still are: insecticides and formulations; this has always been *the* priority of the OCP. In addition to the five compounds already mentioned, several chemical insecticides of different classes (pyrethroids, organophosphates) and new formulations, both chemical and biological (*B.t.* H 14), are being tested presently. Resistance to insecticides is now being monitored through methods developed by the OCP and collaborative institutions. For operational use of insecticides, diagrams have been produced by the OCP to allow optimization procedures for dosage of each insecticide and treatment interval. Teletransmission of hydrological information, to allow precise dosages of insecticides; this method, developed by ORSTOM, has now become operational in all OCP river basins, including the extension areas. Experiments in disease transmission continue. Identification of *O. volvulus* larvae in their respective vectors is considered a priority, as it will allow a more precise delimitation of the programme boundaries. Modelling: a model has been quantified and tested by OCP in collaboration with the University of Rotterdam. Simulations of the impact of the vector control imply that 14 years of interruption of transmission will reduce the local parasite reservoir to such a low level that recrudescence of the infection is extremely unlikely if larviciding is stopped and the vector is allowed to return. Thirteen years appears to be the breakpoint and recrudescence is certain after 12 years of control. Chemotherapy: temephos, the initial insecticide had been found, not searched for. The same applies to Ivermectin, an anti-helminthic compound developed for veterinary purposes. Tested on onchocerciasis patients (collaborations between OCP, the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) and many research Institutes), Ivermectin has shown to be an excellent micro-filaricide without major side-effects. This drug has been given, progressively, with extreme precautions to more than 100000 patients, with great success. It has the following advantages: very low dosage, oral, once a year to selected patients; exclusive criteria are related to pregnancy, lactation, weight and/or age. The discovery of this drug will obviously influence the strategy of onchocerciasis control inside the OCP area, especially the extension zones and outside, in those many countries that have not benefitted, and will never benefit, from another OCP.

6. Training

As expected, the OCP has trained over 200 nationals in many disciplines, including entomology, hydrology, parasitology, ophthalmology, computer sciences and administration.

7. The OCP extensions

Success calls for success. In 1977, countries located to the west of the seven 'OCP countries' asked to be included in a larger OCP. The western extension, including Guinea, Guinea Bissau, Senegal and Sierra Leone, plus the remaining part of Mali, is now under progressive treatment with the following effects: countries are protected for themselves; the reinvasion is now restricted, and will be more so.

Similar benefits arise from the southeastern extension in Benin, Togo and Ghana.

8. The future of the OCP

The central area of the initial zone (mainly Burkina Faso) is not treated any more, which concurs with the modelling results, mentioned above, concerning the period needed for protection. The regions located east and west of this core area will still be treated until they also meet the criteria required to permit a cessation of control measures.

As regards the future strategy, the last report of the OCP Expert Advisory Committee provides a good summary:

> Since the inception in 1974 of the Onchocerciasis Control Programme (OCP), the control strategy has been based on larviciding aiming at virtual interruption of the transmission of the parasite and resulting eventually in the elimination of the human reservoir of the onchocercal worm within the Programme area.
>
> When Ivermectin became available in 1987 for use in human populations, the possibility was raised that large-scale distribution of the drug could contribute to reducing transmission, and might eventually replace larviciding as a control agent. However, recent extensive field trials and epidemiological model projections demonstrate that Ivermectin is unlikely to contribute substantially to transmission control.
>
> Consequently, the Expert Advisory Committee (EAC) recommends that the Programme should continue to rely on larviciding for the control of transmission with the use of Ivermectin to reduce morbidity in individuals, in particular to rapidly reduce high microfilarial loads and thereby avert impending blindness in heavily infected communities. Thus, in the extension areas the drug would be used widely for the treatment of infected cases.
>
> *The Original Programme area*
>
> When the original plan for the Programme was prepared, the Donors and the Participating Countries agreed in principle that OCP would operate for twenty years in the seven countries in order to reach its objective i.e., to eliminate onchocerciasis as a disease of public health and socioeconomic importance throughout the Programme area, and to ensure that there be no recrudescence of the disease thereafter.
>
> This objective will be attained in the Original OCP area as originally scheduled, by 1994. Full control has been virtually secured throughout that seven country area. Larviciding came to an end in the northern one third of the area in 1986 and will have ceased in most of the remaining zones in the Original area by 1990.
>
> After that date entomological surveillance will continue for another two years and larviciding will be confined to limited operations in two circumscribed zones where transmission had only been partly controlled due to operational difficulties. It is expected that such limited vector control will be completed in 1994 by which time the Programme will have withdrawn entirely from an area considerably larger than the Original area as defined in 1974. The remaining reinvaded regions in the southeast and in the west will have become operationally integrated into the Extension areas.
>
> *The Extension areas*
>
> The OCP operations planned for the Southern and Western Extension areas involving four additional countries could be seen as a consecutive programme which is distinct operationally and in its timeframe from the programme carried out in the Original OCP area, but which is, nevertheless, necessary to protect the achievements in the Original area.
>
> In view of the fact that Ivermectin did not appear to be effective in interrupting the transmission of onchocerciasis, the Committee recommends that as larviciding was the proven method of onchocerciasis control, resulting in immediate interruption of transmission, the Programme should embark upon full-scale larviciding operations in the Extension areas.
>
> However, recent epidemiological investigations in areas where larviciding has been conducted since 1974, supported by predictions of the epidemiological model, have now established that up to 14 years of vector control is required to eliminate the human reservoir of the onchocercal parasite as against the eleven years estimated.
>
> Given the delay in the commencement of vector control operations in the Extension areas, and

the limitations of Ivermectin in controlling transmission, OCP will need to continue vector control operations in parts of the Extension areas beyond 1997 (2004). However, by then the Programme's objective of eliminating onchocerciasis as a disease of public health and socioeconomic importance will have been achieved in more than two thirds of the eleven-country Programme area, and OCP will be actively phasing out its operations.'

9. Conclusions

The design of the OCP during the early 1970s was facilitated by the example given by the locust control operations carried out in West and East Africa: aerial treatments, radio-communication networks, and wide distributions of control and evaluation units in the field are still considered as keys to the success of the OCP, as was seen for locust control.

Locust control organizations declined after the mid 1960s, when the plague had given way to recession and international and national support progressively vanished. It has often been said that the OCP would finish the same way: what will come after? The authors strongly believe that all the information gained by the OCP regarding onchocerciasis guarantees that the 'after' will be clear and serene: vector control is efficient in almost suppressing transmission, if carried out for 14 years; vector control in extension areas will considerably reduce reinvasion; research is always considered as a vital part of the Programme; last but not least, a good and safe drug is now available for controlling the disease.

Even inside WHO, the OCP has often been regarded as a monolithic, vertical, expensive programme. A recent study by the World Bank, one of the supporting agencies of the OCP, has shown that the protection of an individual per year amounts to U.S. $0.45, compared with the miserable U.S. $1 available at the Ministry of Health 'for all other diseases'. What the World Bank's report does not say is that, for once, these U.S. $0.45 are going directly to the poorest of the poor, those living at the end of the track.

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Discussion

J. F. Walsh (*WHO/OCP, Kara, Togo*). Dr Le Berre has summarized the vast and long-running Onchocerciasis Control Programme (OCP) operations and has shown the considerable degree of success attained. Dr Baker will discuss the achievements in the Western Extension Area. Since the beginning of 1988, larviciding activities have also been extended into an area of 115000 km^2 in southern Togo, Benin and southern Ghana east of Lake Volta, which is referred to in the OCP as the Southern Extension Area. In this area we have moved from an all-out attack to a more selective approach, both temporally and spatially, in fact, from vector control to vector management. This has become feasible with our increasing knowledge of the biology of the different members of the vector complex, and is partly a necessary response to operating in an area where one of the vectors, *S. squamosum*, which is fortunately a rather inefficient vector there, breeds in small, heavily wooded montane streams. In February 1988 all known breeding sites of *S. damnosum s. str.*, *S. sirbanum*, *S. sanctipauli* (Djodji form) and *S. soubrense* (Beffa form) in the area were brought under larviciding operations. No attempt was made to cover all breeding sites of *S. squamosum*, and *S. yahense* was not considered as a target. Both the Beffa and Djodji forms have very limited dry season distributions in the OCP area and control was intended to eradicate these species, at least temporarily (Walsh *et al.* 1987).

Within eight weeks of commencing larviciding, the Djodji form disappeared from the area east of Lake Volta and no form of *S. sanctipauli* has been taken there since that time, though larviciding has been interrupted for lengthy periods. *Simulium sanctipauli*, including the Djodji form, which typically inhabits larger forest streams and rivers, was not thought to be a long distance migrant (Garms & Walsh 1987), although it is capable of considerable extension of range northwards during the rainy season (Garms *et al.* 1990). Large uncontrolled populations of *S. sanctipauli* breed to the southwest of the Southern Extension, 250 km away. This distance, which includes a 20–30 km crossing of Lake Volta, appears to be too great for recolonization to occur readily.

The elimination of the Djodji form has resulted in a reduction of the biting fly population in its original distribution area, even when control is interrupted for lengthy periods. Although *S. squamosum* rapidly recolonizes rivers that are taken off the larviciding schedule, its larval populations under these circumstances are scattered, and the high larval densities typical of the Djodji form are not reached. In addition, *S. squamosum* is a much less efficient vector than was the Djodji form (Cheke & Denke 1988), so that transmission rates have declined even more than biting rates. As against these beneficial effects of the larviciding, *S. yahense* has shown a tendency to spread into the treated rivers, once larviciding is interrupted, and though it has not yet become a serious problem it is an excellent vector in the area.

The Beffa form of *S. soubrense* was also temporarily eliminated from Benin and Togo (it did not occur in Ghana) in the 1987–1988 dry season, though uncontrolled populations breed in the Ogun and Oshun Basins of southwest Nigeria (Post 1986). Breeding sites in the Ogun River lie 120 km to the southeast of the reaches of the Okpara River, Benin, which were invaded at the start of the 1988 and 1989 wet seasons by small numbers of parous flies. This elimination of, and repopulation by, the Beffa form, is among the first, suggesting long distance movement by *S. damnosum s.l.* against the direction of the prevailing winds.

The situation following the 'intermittent eradication' of the Beffa form is epidemiologically

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complex: in the huge rapids of the Ouémé River, where it was invariably associated with *S. damnosum s. str.*, there is no evidence to suggest that man-biting populations remained lower after control measures were relaxed. However, in the main tributary rivers, the Okpara and the Zou, man-biting populations are slow to recover in the absence of the Beffa form, except at the end of the rainy season when there is a major influx of *S. damnosum s. str.*, probably from the east, into the Okpara valley. Also, in the lower Mono Basin in Togo where the Beffa form was certainly a major vector (Garms & Cheke 1985), control has proved extremely easy, with larviciding interrupted 50% of the time. Unfortunately, the building of a hydro-electric dam has drastically altered the hydrological situation, and though this apparently favours greater *Simulium* production, it makes comparison of the pre- and post-control entomological data impossible.

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J. B. Davies (*Medical Research Council and School of Tropical Medicine, Liverpool, U.K.*). I congratulate Dr Le Berre for his summary of what is a vast, complicated and long-term control exercise. The World Health Organization and the staff of the Onchocerciasis Control Programme (OCP), past and present, deserve recognition for managing to keep the Programme going for 15 years in the face of a constant onslaught of problems, both fiscal, logistic and biological. As I know from my 6-year involvement in the Vector Control Unit, one lives from day to day, never knowing what surprises and set-backs the next day will reveal. In this respect, the controllers of locusts and grasshoppers are to be envied. *Simulium* is there all the year round. There are no periods of aestivation, and no years of recession during which one can relax and take stock.

I would like to highlight some of the evidence for less dramatic movements by members of the *S. damnosum* complex than those long-distance migrations of the 'savanna' cytospecies (usually called reinvasion) that have been touched on by Dr Le Berre, and about which we will hear more from Dr Baker.

These smaller movements appear to be most evident in the forest zones adjacent to and south of the OCP which are inhabited by the 'forest' cytospecies of the *S. sanctipauli* subcomplex. Examples include: (i) In 1966 Dr Le Berre (1966) recorded what he described as 'radial dispersal' of blackflies for distances of up to 41 km westwards from the Bandama River in Côte d'Ivoire. (ii) In Sierra Leone, we have observed *S. damnosum s.l.* biting at villages in the coastal swamp grasslands only 10 km from the sea and 25–30 km south of the nearest breeding sites.

These flies only appear in December when the dry 'harmattan' wind is blowing from the north, and it seems that flies from the inland breeding sites are thus being carried southwards by these winds. *S. soubrense* 'B' is probably the species involved. Hypo–meso endemic onchocerciasis exists in these areas, and we have recorded biting rates of 70 flies per day and a Monthly Transmission Potential of over 300. Dr Walsh has just referred to a westward movement of forest flies of the 'Beffa' form from Nigeria to Benin. No doubt there are many other examples. The overall impression is one of small-scale movements of flies in all directions. Most probably wind patterns are the main vehicle for this dispersal.

It is possible that the cumulative effect of such movements over several years was responsible for the eastwards spread of temephos-resistant flies from the Bandama River in Côte d'Ivoire to the untreated rivers in Ghana between 1980 and 1983 (Meredith *et al.* 1986). The distance involved in this case was about 300 km.

I would like to remind ourselves not to be too complacent over the future of the OCP. The fact that Burkina Faso has not been treated with insecticides since 1987 is good news indeed, and we all hope that this condition will continue. However, even if all sources of 'savanna' cytospecies are eliminated, what are the risks of repopulation of areas like the headwaters of the Black Volta near Bobo Dioulasso by 'forest' species from the south (such as *S. squamosum*, which was present in the area before OCP)? We must now ask our epidemiological modellers what might happen if some of these new arrivals were to be infected. Could they start up new foci of the disease, and how would we detect such an introduction in its early stages?

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R. Le Berre. Regarding Dr Davies's question about modelling, I can say that Dr Remme and colleagues have shown that with 14 years of treatments, the microfilarial rates will return to pre-treatment levels after five or six years and the disease prevalence rates will follow. However, the population will not show any ocular lesions, and hence no blindness, until 30 or 40 years after the end of treatments.

L. G. Goodwin, F.R.S. (*Shepperlands Farm, Park Lane, Finchampstead, Wokingham, U.K.*). Dr Le Berre mentioned Ivermectin and its use against the microfilariae. Is it administered once a year or more frequently?

R. Le Berre. The drug, Invermectin, donated by M.S.D. for Onchocerciasis control was developed as a cattle anti-helminthic and after extensive trials it can now be used as a microfilaricide for people: but it does not kill the adult worms, which may live for as long as 12 years. It has to be given at least once a year, preferably before the start of the transmission season, for instance, every February. Under some circumstances, in severe foci for instance, it may need to be given at six-monthly intervals. The effects of mass treatments with Ivermectin on onchocerciasis transmission have not been as good as were expected; partly, perhaps, because there are always some people in a community who don't get treated.