Bull. Org. mond. Santé } 1973, 48, 299-307
Bull. Wld Hlth Org. }

Molluscicide for the control of schistosomiasis in irrigation schemes

A study in Southern Rhodesia

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The development of large areas of irrigation farming in the south-eastern lowveld of Southern Rhodesia has produced the risk of severe transmission of schistosomiasis over an extent of some 30 000 ha. Control measures instituted by the Ministry of Health were primarily directed against the large and widely distributed snail populations by using molluscicides. The chemical was applied to the irrigation water by drip-feed methods once every 6–8 months. The drains, however, were treated routinely by pairs of rangers searching for snails and applying chemical where they were found. The efficacy of control operations has been assessed by longitudinal studies in children free from infection to determine the incidence of infection. The results indicate that transmission of both Schistosoma haematobium *and* S. mansoni *has been reduced to a level below that measured in areas of the country where irrigation is not practised. The total annual cost for this work was US$ 54 800–55 500.*

The improvement of agricultural productivity in many parts of the developing world is dependent on irrigation. However, where schistosomiasis is endemic, the establishment of irrigation systems invariably leads to an increase in the transmission of the disease. This can be attributed to several factors, the most important of which are the increase in extent and permanence of snail habitat provided by the irrigation canals, reservoirs, and drains, and the concentration of large human populations with a consequent increase in man-water contacts. Surveys in long-established irrigation systems have shown the extent to which schistosome infections can increase (Clarke, 1966). It is therefore advisable that those responsible for the design and development of irrigation systems in Africa and elsewhere should consider the hazards of this disease and plan accordingly.

The irrigation potential of the south-eastern lowveld of Southern Rhodesia has been described (Sabi-Limpopo Authority, 1969, 1970). The area involved is at an altitude of 300–400 m and extends over some 280 000 ha. Water is supplied from large catchment dams on rivers draining the main plateau of the country. The project area system, which derives water from the Lake Kyle complex, was developed between 1963 and 1971 and covers an area of about 30 000 ha. As there was a potential risk of intense transmission of schistosomiasis in this region, it was decided by the Ministry of Health to attempt area control of snails to limit transmission and prevent the disease from becoming a serious public health problem. Control of the disease was the main goal; there was no thought of eradication of either snails or parasites.

During the formative period, various molluscicides were tried and techniques of application were perfected. Once satisfactory procedures were evolved and put into practice, an assessment of the efficacy and cost of the programme was undertaken. It was anticipated that once the system had been proved to be successful, its implementation would be passed on to the community, which would then be responsible for raising the necessary finance and employing the staff to do the work. The Ministry of Health would only retain the functions of advice, assessment, and research.

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PROJECT AREA

The project area consists of 2 large farming complexes, the Triangle Estate and the Hippo Valley Estate, together with a number of contiguous private farms, most of which are functionally a part of the Hippo Valley irrigation system. The primary source of water is a series of 3 reservoirs on the Mtilikwe River. In the third of these is the main offtake point for a large concrete canal carrying water at 19 820 l/s and extending for 56.4 km. The canal passes through Triangle Estate feeding 20 offtakes that lead into various sections of the estate. Each of these offtakes is controlled by self-regulating gates that are let into the side of the main canal and interfere only slightly with the water movement in it. The main canal then enters Hippo Valley Estate and divides into two. Below this point water levels are maintained at the offtakes by long weirs that impede water flow. Maximum flow into the Hippo Valley irrigation system is 9 500 l/s.

IRRIGATION PROCEDURES

Triangle Estate

The estate covers about 8 000 ha of irrigated land and is divided into 31 sections and 8 farms. Two-thirds of the area is watered by overhead sprinklers. The spray sections are served by 7 large reservoirs of between 55 507 m^3 and 185 000 m^3 in capacity. The reservoirs are filled by gravity from the main canal, and from them water is reticulated under pressure into the sprinkler systems. There are 12 sections using flood irrigation, which requires more storage reservoirs, usually 1 for each field. There are 140 reservoirs in the flood sections and there is a considerable amount of man-water contact, not only because of the nature of the farming activities, but also because there is more surface water available. This increased snail habitat contributes to the potentially high risk of schistosome transmission in these sections.

Throughout the estate and on all associated farms the drainage and effluent water system is well designed and developed. To prevent salination of the soil by capillary action from the subsoil, all fields are crossed by drains cut to a depth of 1.0–1.5 m. Regenerated and excess water collects in these drains and is led from the fields into the main drains. These discharge into the natural swales and thus create small perennial waterways, leading finally along natural drainage systems into the rivers. The water is eutrophic and encourages both luxuriant plant growth and large snail populations.

Hippo Valley Complex

This region consists of an estate of some 10 000 ha of irrigated land that includes 45 individually owned farms, each of approximately 150 ha. Almost all the area is under flood irrigation. There are 154 reservoirs storing approximately 2 800 000 m^3 of water and, as there is so much surface water, man-water contacts are high. All fields are drained by a system similar to that used on the Triangle Estate, with similar ecological consequences.

POPULATION

The population in the area numbers about 70 000, of which some 25 000 are employed, the rest being dependants. The population is centred in the local towns—Triangle and Chiredzi—and in the villages and compounds scattered through the estates. Although good terms of employment are offered by the farmers, there is still a substantial turnover of population. In addition, wives and families of employees are continually moving between the estates and farms and their domiciles in the tribal areas.

The entire population is to some extent at risk of schistosomiasis. The men come into contact with water at work, the women and children spend a good deal of time watering small gardens and playing and washing clothes in the rivulets and drains, and all fish and swim in the night storage reservoirs. As the drains are frequently used as latrines, and the products of this pollution are likely to affect entire water systems downstream, the problem of infection is serious. Efforts are being made to curtail this unhygienic practice as improved water supplies and latrines are provided.

SNAIL DISTRIBUTION

The project area, with its networks of canals, drains, and storage reservoirs, provides numerous habitats suitable for aquatic snails; *Biomphalaria pfeifferi* and *Bulinus* (*Physopsis*) *globosus* are both widespread. The latter is found mostly in the canals, drains, and natural watercourses, while the former predominates in the night storage reservoirs and in regenerated water channels. Certain features of the irrigation system encourage snail populations; these will be considered below.

Canals

The main feeder canal and all secondary and tertiary canals are of concrete. Apart from those in the fields, few canals are unlined; nevertheless, in nearly all instances they either harbour or convey host snails. The presence and density of snail populations is influenced by the rate of water flow and snails are generally found in large numbers only where the rate is low. The flow rate is reduced by various structures in the canal system, such as gates, long weirs with offtake gates housed in recesses, and any abrupt decrease in gradient.

The long weirs, which are used to maintain a constant level of water in the canal regardless of flow, are longitudinal dams within the canals, with spillways into adjoining sections of the canal. The damming effect reduces the flow and allows snails to colonize these parts of the canal. Offtake gates in the vicinity of long weirs are recessed into the walls and afford temporary refuge for the snails, but since the gates are used frequently, the snails soon become dislodged and are swept into other parts of the system. Snails also occur in inverted siphons and in sumps into which the water wells before flowing down the canal or into the fields. Water in the sumps is usually quiet, even in those associated with spray pumps, and when the canals are not flowing the siphons and sumps hold water that may remain undisturbed for several days. Snails thrive under these conditions.

Unlined canals where the water does not flow rapidly provide ideal habitats for both species of snails, except that the unlined canals that serve field furrows are normally dry, and it is unusual to find snails in them.

Night storage reservoirs

These are seldom dry and are ideal habitats for snails, particularly *B. pfeifferi*, which prefers stable conditions. The water level in the reservoirs fluctuates according to irrigation demands; normally water is drawn off during the day and replenished at night, hence the name. Occasionally this sequence is interrupted and the reservoirs may remain low for several weeks. This often alters the structure of the snail population, the dominant species changing from *Biomphalaria pfeifferi* to *Bulinus globosus*. Whatever catastrophies may occur to the snail populations, repopulation soon takes place.

Drains

The drainage system removes excess water from the fields and prevents excessive mineralization of the soil through control of the water table. Water flows into the field drains only during and shortly after irrigation, but as several field drains join to form large main drains, the latter are seldom dry. The main drains discharge into watercourses that maintain a perennial flow of 100 l/s or more. They are often obstructed by rocky outcrops, beds of aquatic vegetation, and masses of debris from the fields and villages. These small impoundments are heavily infested with snails, many of which become infected.

APPLICATION OF MOLLUSCICIDE

In irrigation schemes such as those considered here, it is important to distinguish between the inflow system carrying the irrigation water, which includes the night storage reservoirs, and the effluent system of drains carrying overflow and regenerated water. The former can be treated with chemicals by means of a drip-feed because the water first enters the area along a single main canal and is then dispersed into the complex of feeder canals and night storage reservoirs before finally reaching the fields. Any chemical fed into the main canal will thus flow through all the regulatory devices, over the weirs and the distribution sumps, etc., to the reservoirs. The treatment of the drainage system with chemicals is more complicated. Here numerous small drains coalesce to form a decreasing number of larger drains that finally lead into natural watercourses, usually making chemical treatment from a limited number of points impossible. Accordingly, the entire drainage complex is treated by snail surveillance and focal control (Shiff & Clarke, 1967).

Inflow system

The chemical of choice for this work has been niclosamide, either as a 70% water-dispersible powder (WDP) or as a 25% emulsion concentrate (EC). Each application is conducted according to a careful plan. No chemical is applied to the primary canal, but the various offtakes and the entire system downstream of each are treated in a systematic manner to complete the whole irrigation system in less than 1 month. If the water management procedures are carried out satisfactorily, so that the molluscicide penetrates into all parts of the system, the next major application is not usually required for 6–8 months.

All reservoirs fed from the offtake to be treated are lowered to approximately one-third of their capacity by zero hour (usually 06.00 h on a Saturday). Water is then allowed into the offtake at a rate that will permit all the reservoirs to fill in 24 h. This is an important phase of the operation because it ensures an accurate apportionment of the water containing the molluscicide into all the reservoirs.

The amount of chemical required is calculated to assure an overall concentration of 0.3 mg of active ingredient per litre in the stored water of the system under treatment. For every 1 000 m^3 of water stored, 300 g of active ingredient or 430 g of 70% WDP formulation is required. However, an additional 10% is added to cover contingencies. The necessary amount of chemical is then released at the offtake at a constant rate for a period of 12 h. During this period all water gates in the system are opened slightly to allow a trickle of treated water to escape along such bypass canals that would not be involved in the main flow of treated water. At the end of 12 h, all the chemical required has been applied to the canals and distributed to the night storage reservoirs, although at a concentration in excess of 0.3 mg/l. Untreated water then flows into the system for a further 12 h in order to fill the reservoirs where it mixes and dilutes the chemical. Chemical analyses have shown that there is a fairly adequate distribution of the molluscicide. The reservoirs are then held full for a further 24 h to allow adequate contact with the snail population. By 06.00 h on the following Monday, the system is ready for normal irrigation. If niclosamide 25% EC is used, the final concentration in the night storage reservoirs can be reduced to 0.2 mg/l owing to the greater efficacy of this formulation.

Drainage system

Application of molluscicide to the field drainage system presents a major problem as there is no simple method of dispersion. Access to the field drains is possible only after crops have been reaped or in the early stages of crop growth. Otherwise chemical can be applied only to the outlets from the fields. Various slow-release chemical briquettes have been tried in the drains but the most successful technique of controlling snail populations has been found to be a system of snail surveillance and focal control. The drains, watercourses, and rivulets are examined by rangers working in pairs on a 4-week cycle. The rangers are trained to search for host snails and to apply chemical by means of stirrup pumps or knapsack sprayers to all foci of snails they find. No attempt is made to estimate the volume of water to be treated; the molluscicide is applied by " rule of thumb ". Approximately 30 g of niclosamide 70% WDP is added to a sprayer, which is then filled with 9 litres of water. This is sufficient to spray some 50 m of drain. A pair of rangers would be expected to cover 15–20 km of drains and streams per week and to survey all reservoirs in their region. A report is given to the supervisor at the end of each week. At this time the supervisor allocates the programme for the following week. The efficacy of this method depends very much on the quality of the supervision —i.e., the supervisor's knowledge of the area and his ability to organize the work. No attempt is made to eradicate the snails, the aim being merely to ensure that numbers are kept to a minimum. However, when surveillance is carried out properly the host snails become extremely scarce after a few cycles.

EQUIPMENT

Drip-feed

For the application of niclosamide 70% WDP into the affluent canal system, it is necessary to use a constant flow device that can dispense fairly large quantities of chemical (up to 100 kg in 12 h) and will allow agitation of the suspension while it is being dispensed. A constant flow dispenser [1] has been found to be practical and inexpensive. This consists of an open 200-litre metal drum containing a floating siphon, the base of which remains on the surface of the molluscicide suspension. As the siphon has a constant head the rate of discharge depends on the diameter of the outflow orifice. It has been found practical to allow the drum to discharge in 30 min and to use 2 dispensers at each dispensing point, operating alternatively.

Surveillance

The most satisfactory apparatus for treating snail foci in drains and riverine watercourses is a 9-litre portable pressure sprayer equipped with a fine jet nozzle, approximately 2.0 mm in diameter, or a similarly equipped stirrup pump. Rangers carry the molluscicide powder preweighed in 30 g lots; one such packet is used to charge the sprayer, which is then filled with water. The mixture is sprayed liberally into the water where snails are seen, with no attempt to regulate the rate of application other than by the experience of the spraymen.

ASSESSMENT

Malacology

Normal methods of malacologic assessment involve regular systematic sampling of snail populations at various localities within the area under control.

[1] Barrett, unpublished data.

Table 1. Malacologic information from treated and untreated night storage dams on Hippo Valley and Triangle Estates *

Date of survey	No. of snails found in untreated dams [a]									No. of snails found in treated dams [b]																				
	Bondo/6 (4 934 m^3)			Farm 30/4 (3 672 m^3)			Makari/4A (12 335 m^3)			Section 1/9 (18 503 m^3)			Section 11/13 (12 240 m^3)			Farm 30/1 (4 284 m^3)			Farm 17/1 (9 992 m^3)			Orange (9 792 m^3)			Daisy (28 152 m^3)			Mill (7 401 m^3)		
	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O	B	P	O
1970																														
Nov.																82	40	5												
Dec.											treated			treated			treated													
1971																														
Jan.										0	0	0	0	0	0	0	0	0												
Feb.										0	0	0	0	0	0	0	0	0												
Mar.	22	80	0	131	434	0				0	0	0	0	0	0	0	1	0												
Apr.	0	0	0	47	220	0				0	0	0	0	0	0	0	1	0												
May	3	19	0	194	229	0				4	0	0	3	0	0	0	5	3					treated			treated				
June				72	266	0																								
July	25	3	2	109	88	0																0	0	0	0	0	0	0	0	0
Aug.				50	44	0				87	0	0	584	0	0				81	9	0				0	0	0			
Sep.	67	11	3	6	7	0	0	72	9		treated			treated						treated		0	0	7	0	0	0	51	63	22
Oct.							0	79	31										0	0	0								treated	
Nov.	38	0	24	11	11	0	0	228	7	0	0		0	0	0				0	0	0				0	0	10	0	0	0
Dec.	91	18	10	9	47	0	0	147	4	0	0	0							22	19	6									
1972																														
Jan.				23	42	0	0	309	30	0	0	0										0	0	246	192	0	140	0	0	0
Feb.				130	207	0	0	193	34	0	0	0							195	39	9		treated					0	0	0
Mar.	119	262	13	144	177	0	0	282	35	0	0	0										0	0	0				0	0	0
Apr.	116	375	15	1010	747	0	0	346	50	0	0	0	2	4	0							0	0	0	1537	0	460	0	0	0
May	205	666	54	681	832	0	0	672	7	9	7	0										0	0	2		treated				

* Throughout the table: B = *Biomphalaria pfeifferi*, P = *Bulinus (Physopsis) globosus*, and 0 = other species.
[a] Number of snails collected in 15 dredge samples and 1 man-hour of searching.
[b] Number of snails collected in 4 dredge samples and 1 man-hour of searching. Treated with niclosamide WDP at 0.3 mg/l.

This system is satisfactory as long as the area is fairly small and it is feasible to deploy staff to carry out time-consuming sampling procedures. When routine control is being undertaken over a large area, the approach must be simpler. One way is for a small research team to undertake comprehensive surveys from a fixed number of localities. The data in Table 1 were obtained by such a team using scoops and a bottom dredge. The effects of mollusc101ciding on these reservoirs is clear; however, they represent a small proportion of waterbodies treated. For the rest, surveillance teams are instructed to search for host snails and to apply molluscicide where these are found. They detect snails visually or by scooping, and report the presence of foci to the supervisor. The latter carries out random checks to ensure the reliability of the rangers' reports.

Parasitology

Urine and stool surveys were carried out annually in the project area prior to the implementation of snail control and for several years afterwards. The object of these examinations was to assess the age-specific prevalence of both schistosome species within the population to see if there was any change in this factor as a result of snail control. However, it was discovered subsequently that there was a large annual turnover of the resident population so that each successive survey measured the infection in a predominantly immigrant population.

Prevalence surveys were discontinued in favour of longitudinal studies among known resident children in order to assess the incidence of schistosomiasis in certain parts of the project area. These data, collected from 1968 to 1971, are given in Tables 2 and 3.

Table 2. Data from controlled areas on Triangle Estate showing incidence of *S. mansoni* and *S. haematobium* in cohorts of children under 6 years of age *

Date of survey	*S. mansoni*				*S. haematobium*			
	spray irrigation		flood irrigation		spray irrigation		flood irrigation	
	no. negative	incidence (%)	no. negative	incidence (%)	no. negative	incidence (%)	no. negative	incidence (%)
Apr. 1968– Oct. 1968	54 52	3.40	65 63	2.77	64 63	1.14	55 51	5.24
Oct. 1968– Apr. 1969	96 92	3.65	77 64	16.03	112 110	1.24	83 78	4.46
Apr. 1969– Aug. 1969	103 101	2.39	63 59	7.25	115 112	1.34	70 69	0.70

* Results have been corrected where necessary for rate of loss of infection. Incidence has been extrapolated to 120-day intervals.

Table 3. Data from controlled areas on Hippo Valley Estate (flood irrigation only) showing incidence of *S. mansoni* and *S. haematobium* in cohorts of children under 6 years of age *

Months of survey	*S. mansoni*				*S. haematobium*			
	1969–70		1970–71		1969–70		1970–71	
	no. negative	incidence (%)	no. negative	incidence (%)	no. negative	incidence (%)	no. negative	incidence (%)
Feb.–June	130 121	8.72	154 133	17.19	192 187	2.61	220 210	4.55
June–Oct.	144 141	2.63	111 99	13.24	203 200	1.48	158 151	4.43
Oct.–Feb.	105 102	3.60	151 141	8.35	149 147	1.35	212 204	3.37

* Results have been corrected where necessary for rate of loss of infection. Incidence has been extrapolated to 120-day intervals.

Table 4. Incidence of schistosomiasis in children under 6 years of age in areas where no control measures are carried out *

Area	Date of survey	Incidence of *S. mansoni* (%)	Incidence of *S. haematobium* (%)
Barwick I.C.A. dryland farming, no irrigation, highveld (1 500 m)	1971–72		
	Mar.–June	17.29	8.06
	June–Sep.	16.97	11.33
	Sep.–Dec.	12.00	8.93
	Dec.–Mar.	10.77	9.84
Chipoli Estate [a] irrigation farming, high transmission area, lowveld (approx. 900 m)	1971		
	Feb.–June		16.62
	May–Sep.		29.03
	Oct.–Dec.		22.91

* Incidence has been calculated for 4-month periods, corrected where appropriate for rate of loss of infection, and expressed as a percentage.

[a] Children who showed no live ova in the urine for 2 months after drug treatment were regarded as negative and included in the study cohorts in the third month.

A distinction has been made between incidence in children living in areas where flood irrigation or spray irrigation is practised, and also between the 2 estates. On Triangle Estate, the incidence of *S. haematobium* remained consistently low in spray irrigation sections and showed a decline in the flood sections. On Hippo Valley Estate, the situation was similar in 1969 and early 1970, but a breakdown in control in part of the system was reflected by an increase in incidence during the period February–June 1970 that continued into 1971. The data concerning *S. mansoni* show its importance in flood as opposed to spray irrigation sections. Again the breakdown in effective control in the Hippo Valley system is evident, as was a lapse on Triangle Estate from October 1968 to April 1969.

Unfortunately incidence data were not collected prior to the control programme but data collected from other parts of the country are incorporated here for comparison (see Table 4). Barwick Intensive Conservation Area is a farming area in the northern highveld of Southern Rhodesia (about 1 500 m altitude); the region is well watered with perennial streams and many reservoirs, but irrigation is not normally practised. Chipoli is an old-established irrigation farm in the north-eastern lowveld of the country (about 900 m altitude). Transmission of schistosomiasis in this area is high and no control is currently practised. The data in Tables 3 and 4 show that the incidence of both parasites in the project area has been maintained at a level below that observed in a dryland farming area, and far below that which could be expected to occur in warm areas under irrigation as at Chipoli.

COSTS

A variety of items and personnel are involved in a large-scale control scheme, and costs vary from year to year, depending not only on the equipment and the chemicals used, but also on salaries. Costs for control work in the project area have been measured for 2 consecutive years and are presented in Table 5. The categories used in this table require some explanation. The supervisors are trained personnel who are responsible for determining work programmes, arranging and coordinating drip-feeds, assessing snail survey work, and supervising spraying operations. The spraymen are unskilled labourers who are trained to search for snails, to mix molluscicide, and to spray it into appropriate snail habitats. Allowances are paid to spraymen for bicycles used during work. In the transport category the main charges are for the light vehicles (500-kg trucks) used by supervisors during work. These cost 9.20 US cents per km. The remainder of the items detailed are self-explanatory.

Table 5. Itemized expenditure for snail control operations on Triangle and Hippo Valley Estates for 2 consecutive years: July 1968 to June 1969 and July 1969 to June 1970

Item	Costs in US $ 1968–69	1969–70
Personnel costs		
3 supervisors	12 570	14 844
30 spraymen	15 564	16 216
allowances	2 042	2 802
Transport		
light vehicles and caravans	3 318	3 565
heavy vehicle (3 tons)	435	553
Equipment		
protective clothing, spray pumps, scoops	3 255	2 452
Molluscicide	17 113	15 204
Total	54 297	55 636

The mean annual cost of schistosomiasis control operations was about US$ 55 000, giving an average cost of just over US$ 3.00 per ha per year.

DISCUSSION

The evidence presented in this paper indicates that control of schistosomiasis in a large system of irrigation farms, such as in the south-eastern lowveld of Southern Rhodesia, is not only feasible but, when compared with the productivity of the area, is economical. In the absence of control measures transmission of schistosomiasis would be expected to approach levels seen at Chipoli with the incumbent disease and presumed loss of labour efficiency. The local public health authorities feel that such a situation must be prevented.

In order to maintain a system of control that is viable and effective, it is necessary to develop an infrastructure including personnel with the power to coordinate the work, and with the knowledge and ability to carry it out. The key personnel are those involved with coordination and supervision. The overall responsibility for the control should be vested in a local authority, usually the authority responsible for the general health problems of the district, that should have a Health Officer and appropriate staff to carry out periodic assessment and reporting of the control measures. The authority should have the power to prosecute miscreants and to tax the community, providing schistosomiasis control as a service. It may, however, delegate responsibility to the water users and the farmers themselves, as is the case in the project area described. Here the management of each estate appoints the coordinators, supervisors, and spraymen. Costs are apportioned among the sections of the estates and private farms according to their water consumption, since this is directly proportional to the area of land under cultivation and thus protected.

Staff of the Ministry of Health provide an overall assessment of the work, maintaining a 10% check on the actual surveillance work and undertaking incidence studies among parts of the community to monitor transmission rates in the area. If and when the situation is seen to be deteriorating, this is reported to the appropriate personnel. If the matter is not rectified, the situation is reported to the Rural Health Authority, which will require the estate responsible to correct the problem in accordance with current legislation.

ACKNOWLEDGEMENTS

The authors thank the Secretary for Health for permission to publish this work. The data for Table 5 were kindly supplied by Mr D. M. Millar, Clerical Officer.

RÉSUMÉ

LES MOLLUSCICIDES DANS LA LUTTE CONTRE LA SCHISTOSOMIASE DANS LES ZONES D'IRRIGATION: ÉTUDE EFFECTUÉE EN RHODÉSIE DU SUD

Dans beaucoup de régions des pays en développement, la productivité de l'agriculture ne peut être améliorée qu'en recourant à l'irrigation, ce qui va invariablement de pair avec une augmentation de la transmission de la schistosomiase dans les endroits où cette affection est endémique. Ce risque existait dans une région du sud-

est de la Rhodésie du Sud, d'une superficie de 30 000 hectares, où la mise en valeur des terres a nécessité la création d'un vaste système d'irrigation. La population vivant et travaillant sur ce territoire est de quelque 70 000 personnes, en majorité exposées à contracter l'infection.

On a mis au point une technique d'application des molluscicides qui permet de traiter l'ensemble du réseau d'irrigation en peu de temps. Le système d'arrivée d'eau est traité par la niclosamide tous les 6–8 mois, grâce à l'utilisation de distributeurs à débit constant. Quant aux canaux, ils sont surveillés une fois par mois par des équipes de travailleurs chargés de rechercher les mollusques et d'appliquer le molluscicide dans les endroits infestés.

L'efficacité de ces mesures a été évaluée par des enquêtes longitudinales visant à déterminer l'incidence de la schistosomiase parmi les enfants initialement non infectés résidant dans le territoire ainsi que par l'étude des populations de vecteurs. Les résultats indiquent que l'emploi des molluscicides permet de maintenir la densité des populations de mollusques à un niveau minimal et que le taux de transmission de la schistosomiase est inférieur à ceux enregistrés dans d'autres régions du pays où l'irrigation n'est pas pratiquée. Le coût annuel des opérations de lutte est de l'ordre de $55 000.

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