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Preliminary Results of the Project for Controlling and Preventing Schistosomiasis in the Lower Mangoky (Malagasy Republic)

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Contents

I. Introduction

The following were the aims of the Project for controlling and preventing schistosomiasis in the Lower Mangoky, which was initiated as a result of the Swiss/Malagasy Agreement signed on 19th November 1966 and given the name "Mangoky Project":

- to impose as severe a check as possible on the endemic schistosomiasis in the irrigated Samangoky area by simultaneously combining all the methods of schistosomiasis control:

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* Doctor in charge of the Mangoky Project.
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*** Assistant Biologist to the Mangoky Project.

  - chemotherapy of all the infected persons, using niridazole (Ambilhar®),
  - chemical treatment, using N-tritylmorpholine (Frescon®), of all the water in the area where intermediate hosts of schistosomiasis were to be found,
  - health education of the population,
  - supervision of the installation of irrigation and development of new areas.
- to try to define the methods of controlling and preventing schistosomiasis over an irrigated area which is being developed, to calculate the profitability of such a project and to plan its organisation.

This project has been carried out with the participation of:
- the Ministry of Public Health and Population of the Government of the Malagasy Republic and its Department for the Control of Endemic Diseases,
- the Swiss Federal Political Department (Technical Co-operation) and the Swiss Tropical Institute in Basle,
- and the firms CIBA-GEIGY Ltd. for Ambilhar® and SHELL INTERNATIONAL CHEMICAL Co. for Frescon®.

The people involved in the project, who worked from a base at the Tanandava Epidemiological Centre, consisted of:
- a Swiss team:
  - the Doctor in charge of the Mangoky Project,
  - a Biologist, acting as assistant to the Doctor in charge,
  - two Laboratory Assistants,
- and a Malagasy team:
  - the Doctor in charge of the Epidemiological Centre,
  - three Hygiene Assistants,
  - a secretary, a driver and six unskilled workers.

It was intended that during the initial 3-year period:
- all the inhabitants of the area, i.e. about 10,000 persons, should be examined and then all those found to be infected should undergo mass treatment with Ambilhar,
- the distribution and ecology of the molluscs in all the water in the area should be examined, and then all those habitats harbouring intermediate hosts should be treated with Frescon.

This period of attack was to be followed by a 2-year control period during which the intention was solely to check the efficiency of the mass chemotherapy and of the chemical anti-mollusc campaign.

The aims of this programme have finally been achieved, but the control period was reduced to one year only.

II. Organisation of the work during the attack and control phases

II.1. Situation and organisation of the zone chosen

II.1.1. Geographical, economic and demographic situation of the Project

The zone chosen corresponds to that part of the lower valley of the Mangoky which is being developed.

The source of the river Mangoky is in the High Plateaux and the river traverses the South-West part of Madagascar. It flows into the sea in a wide delta on the boundaries of the "sous-préfectures" of Morombé and Manja.

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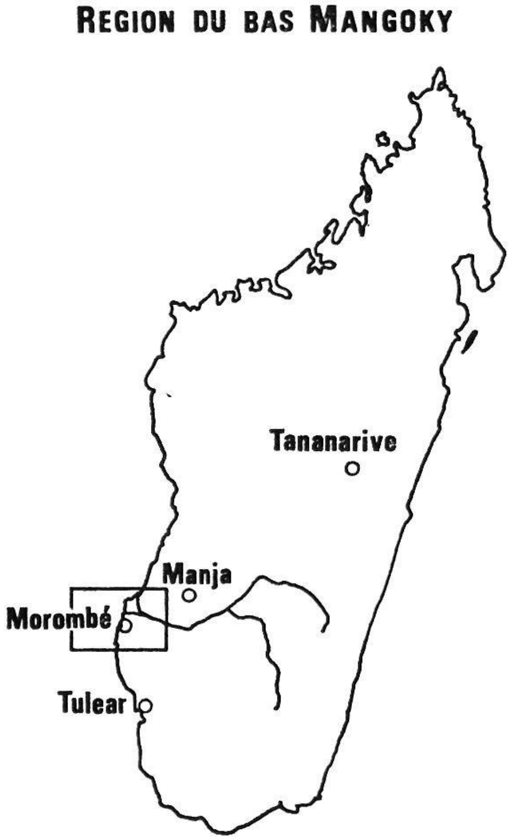

Fig. 1. Madagascar, Lower Mangoky Region.

It is expected that the agricultural conditions of the land in this area will enable 100,000 hectares to be cultivated once irrigation has been carried out.

About 2,500 ha of irrigated land have at present been developed and are used for the cultivation of rice and cotton (Fig. 2). The irrigation system operates solely by gravity. All the irrigation channels, from the main canal to the individual channels in each plot, have been constructed from concrete using the most modern techniques. The main canal, which takes water from the Mangoky at Bevoay, is designed to irrigate 10,000 ha on the left bank of the river. It consists of a feeder canal which is about 20 km in length (Bevoay–Tanandava), and a main irrigation canal, 16 km long (Tanandava–Ambahikily). The 8 secondary canals, which each irrigate 300 to 500 ha, take their water from this latter section. The land is drained by means of a network of drains, the largest of which, i.e. the five main drains, empty into the Mangoky or into its dead branch, the Kitombo.

All the development work is financed by the European Development Fund. A Mixed Management Company, the SAMANGOKY, has been responsible, since 1961, for developing the land and for supervising the agricultural work carried out by the tenant farmers.

This area, which has a semi-desert climate, consisted previously of forest and xerophilous bush. Its population was fairly homogeneous, consisting mainly of Vezo and Masikoro ethnic groups, both of which belong to the Sakalava group. These populations made their living from agriculture – highland crops, consisting of maize, sweet potato and cassava, and beans grown in the main river bed after subsidence of the waters – and from zebu cattle.

Now the cultivation of rice, cotton and forage crops on a rotation basis has meant that the traditional crops have been pushed out to the edge of the irrigated area.

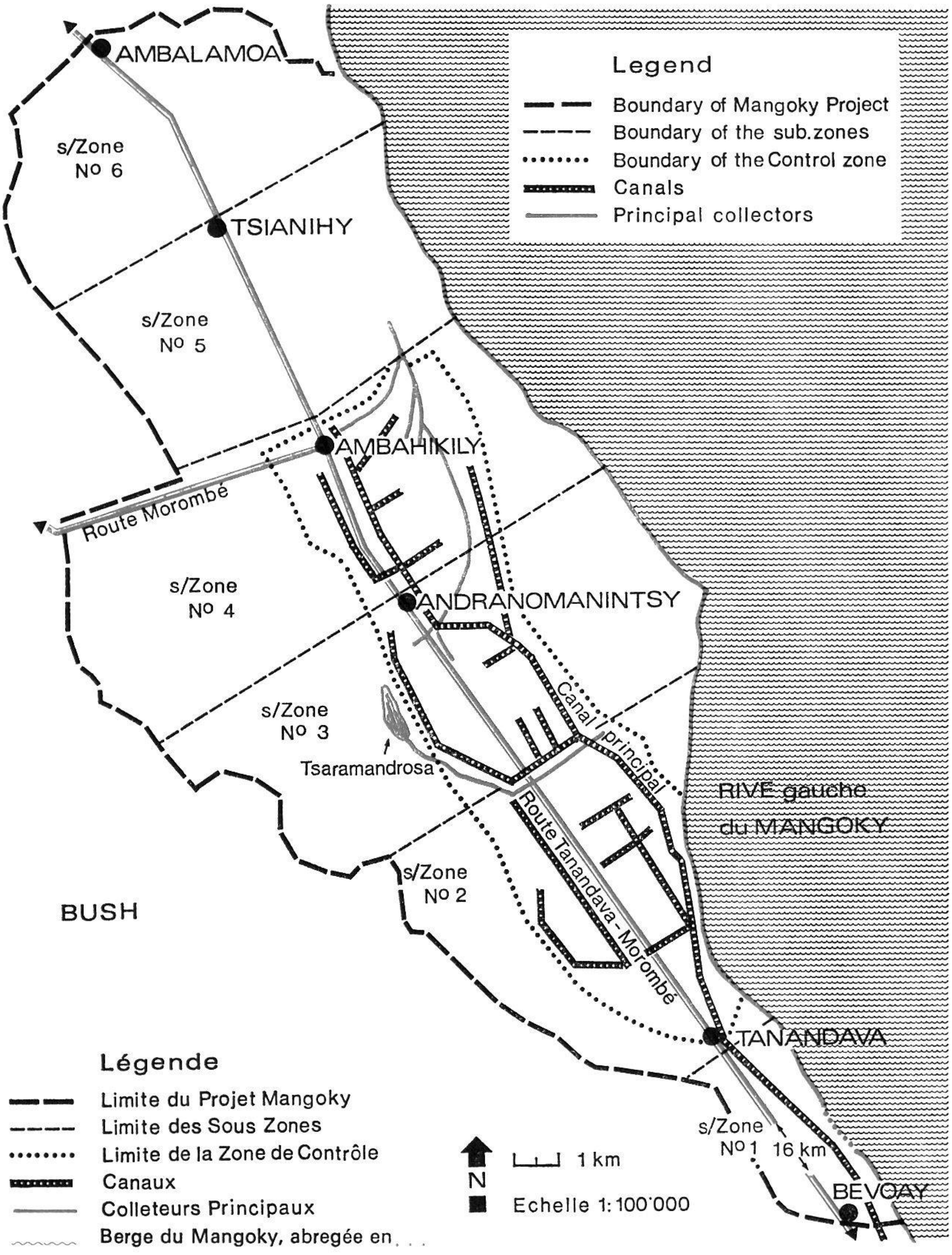

Fig. 2. Diagram of the area of the Mangoky Project.

S/Zone	=	sub-zone
Route Tanandava–Morombé	=	Tanandava–Morombé road
Rive gauche du Mangoky	=	Left bank of the Mangoky
Légende	=	Legend
Limite du Projet Mangoky	=	Boundaries of the Mangoky Project
Limite des Sous-Zones	=	Boundaries of the sub-zones
Limite de la Zone de Contrôle	=	Boundaries of the control area
Canaux	=	canals
Drains (collecteurs principaux)	=	main drains
Echelle	=	Scale

As the local population is small and somewhat scattered, it has been, and will continue to be, necessary to bring in a large number of workers to develop the area. These workers have come from the populations of the neighbouring areas, but the main contingents consist of emigrants coming principally from the High Plateaux: Betsileo, from the South: Antandroy, Mahafaly, and from the South-East coast of Madagascar: Antaisaka, Antanosy.

II.1.2. Boundaries of the Mangoky Project zone (see Fig. 2)

Because of its geographical position, the area can easily be divided up into a treatment zone consisting of:

II.1.2a. A Control zone proper, corresponding to the 2,500 hectares at present being cultivated. This runs from the village of Tanandava to that of Ambahikily and consists of a strip of land 16 kilometres long and between 2 and 3 kilometres wide. Its population consists of the personnel of the Samangoky Mixed Management Company and the tenant farmers.

For practical reasons, this Control zone has been divided up into three sub-zones:

- Sub-zone No. 2, Tanandava, consisting of the first 1,000 ha of the Pilot Unit (U.P.B.M.).
- Sub-zone No. 3, Andranomanintsy, corresponding to the South Andranomanintsy sector (800 ha).
- Sub-zone No. 4, Ambahikily, corresponding to the North Andranomanintsy sector (700 ha).

A fifth sub-zone, that of Tsianihy, had been planned, but as a result of the Mangoky floods in 1969 and 1970 and the ensuing protection work, development of this area was delayed.

II.1.2b. A so-called Protection zone which covers the whole of the Control zone and has as its natural boundaries:

- in the North East, the Mangoky, which is an effective barrier to population movement, apart from the Bevoay ferry. Moreover, its right bank does not seem to be very much affected by schistosomiasis;
- in the South West, the Kitombo, the dead branch of the Mangoky, and the Tuléar-Morombé road, beyond which there is a xerophilous bush which is particularly inhospitable and difficult to penetrate;
- in the South, the village of Bevoay, where it is possible to keep a check of the population movements from Manja via the ferry and from Southern Madagascar by road;
- in the North, the village of Ambalamoa, beyond which the soil and water are too salty to permit of cultivation and do not favour the establishment of the intermediate hosts of schistosomiasis.

As the population movements mainly take place along the Tuléar–Morombé road which passes through the Mangoky Project zone from South-East to North-West, an attempt was made to create a buffer effect by setting up three Protection sub-zones:

- in the South, sub-zone No. 1, which stretches from Bevoay to Tanandava over a distance of 16 kilometres;
- in the North, sub-zones No. 5 (Tsianihy) and No. 6 (Ambalamoa), which also cover a distance of 16 kilometres.

II.1.3. Medical infrastructures

In spite of some improvement, the Medical centres were and still are inadequate for a population of 10,000:

- an inter-company medical service in sub-zone No. 2,
- a Civic Department hospital in sub-zone No. 3,
- a surgery and a 40-bed hospital in sub-zone No. 2.

On the other hand, the Tanandava Epidemiological Centre for the Control of Endemic Diseases had the facilities for carrying out an effective campaign in its own field. The Mangoky Project team worked from there from 1967 to 1971, and this Centre has now taken over responsibility for the continuation of the anti-schistosomiasis campaign. The disproportion between the facilities for Medical Care and the Department for control of schistosomiasis, together with the lack of integration and standardisation between these services, hampered the task of the Mangoky Project and made it impossible to reap the maximum benefit from the systematic examination of the population.

II.1.4. Epidemiological situation with regard to schistosomiasis before the Mangoky Project

The epidemiological investigations carried out by the Mobile Hygiene Groups (MHG) in 1952 and 1956–1958 on the left bank of the Mangoky gave very varied rates of infection oscillating between 6 and 55 % (Brygoo, 1968). Apart from this, there is no information about whether or not *Schistosoma haematobium* was being transmitted in this area before 1967. On the other hand, the Basibasy focus of infection has existed for a long time, and this is situated about 60 km from Tanandava and is a place often visited by the populations of the Lower Mangoky. There is every reason to suppose that in 1966 the prevalence of vesical schistosomiasis in the Samangoky varied between 10 and 15 % (consisting mainly of imported cases), apart from the Ambahikily area (20 to 25 % 1958 Faidherbe MHG 3) where there was possibly an intermittent focus of transmission of the disease.

With regard to intestinal schistosomiasis caused by *S. mansoni,* we have no information prior to the Mangoky Project. The nearest endemic focus of infection is Manja, which is about 100 kilometres to the North-East of the Samangoky area.

Thus, the Mangoky Project has been carried out in an area relatively little affected by schistosomiasis until it was developed for agricultural purposes; however, all the conditions – irrigation and population migration – were right for transmission of the endemic disease to become explosive.

II.2. Organisation of the systematic examination of the population

Initially, a systematic census of the population had to be carried out (the huts had to be numbered and the total number of inhabitants had to be recorded hut by hut), and then these figures had to be brought up to date every three months in the newly settled villages and every six months in the traditional villages. These censuses necessitated a tremendous amount of work, but they were essential, because is was never possible to find all the inhabitants together at one time in their village and on each occasion when our teams visited a village, 10 to 30 % of the population had temporarily or permanently moved.

In drawing up our programmes for tracking down infected people, we had always to take into account the state of the roads and the agricultural traditions of the inhabitants of each village. For example, the farmers' villages are more or less deserted at the time when the rice is transplanted and when the cotton is harvested; on the other hand, the traditional villages are deserted when beans are being sown and harvested.

The systematic examination of the population involved:

- making a record of the individual on a card (name, age, address, occupation, etc.);

- taking urine and faecal samples for parasitological examinations;
- and handing out a health card giving details of name, address and file number when the parasitological examinations had proved negative.

Until 1968, these case-finding operations took place during the daytime, either at the Tanandava Epidemiological Centre or in the villages themselves. Our initial programme had been to track down infected persons from among all the inhabitants of the villages, one by one, starting with those in sub-zone No. 2, and spreading out radially from there. The first balance-sheets drawn up demonstrated the complete failure of this method:

- less than 60 % of the population of those villages in which infected persons were thought to have been diagnosed had in fact been examined. The rest, having left the village at sunrise and not returning till evening for their meal, had not been seen by our teams;
- 10 to 25 % of the population of those villages in which infected persons were thought to have been diagnosed had moved three months after the end of the case-finding operation;
- finally, while we were concerned with sub-zones Nos. 1, 2 and 3, a focus of vesical schistosomiasis appeared and developed very rapidly in sub-zone No. 4.

As a result of a considerable increase in the numbers of our staff and as a result of a pilot zone decree regulating movement within the Samangoky area, we were able to reorganise the case-finding programme in 1969 in the following way:

- we set up two mobile teams which systematically crossed and recrossed the area taking a census of the inhabitants and tracking down infected persons;
- a fixed diagnostic team was maintained at the Tanandava Epidemiological Centre;
- the health cards in the villages were checked, particularly when the company employees were paid. This method enabled us to examine nearly 3,000 people in 3 months;
- health education in the villages was stepped up by means of instructive or amusing films. This procedure was astonishingly successful and enabled us to complete the case-finding operations in the villages, even though urine samples collected in the evening are less favourable for diagnosing vesical schistosomiasis. However, we are sure that, had it not been for these film sessions, over 15 % of the population would never have been examined and the urine examinations would have been a complete failure.

The methods of parasitological examination used were deliberately made extremely simple:

- Sediment in the urine was allowed to settle in separating funnels; the sediment was then examined in a Petri dish lid using magnifying glasses. One or two additional urine examinations were carried out on individuals when haematuria was found without *Schistosoma* eggs, and then in some cases a rectal biopsy was performed. In view of the nature of our work, as all the positive cases had to be treated until they were negative, the counting of *Schistosoma* eggs was only carried out in the case of those post-treatment examinations which were positive, and this was then in conjunction with a hatching test.
- Successive sedimentation in water containing 0.5 % glycerine was used in order to examine the stools, and then two or three drops of the final sediment were examined under the microscope.

Because of the time taken and because of the difficulties in organising the systematic examination of the population, we were obliged to re-examine the urine of all the inhabitants before starting mass treatment with Ambilhar. This examination was carried out village by village, in conjunction with the mass treatment, from 1st July 1969 to 30th September 1970. A second systematic urine examination was organised along the same lines from 1st October 1970 to 30th September 1971, the aim in this case being to investigate the efficacy of our methods of controlling schistosomiasis.

At the same time, case-finding and treatment of the positives amongst newcomers to the area and any latecomers were carried out continuously until 30th September 1971.

II.3. Organisation of the clinical examination and treatment of infected people

In principle, infected people had to go through the following procedures:

- a Polaroid identity photograph was taken and immediately stapled to their identification card,
- they underwent a brief clinical examination by one of the Doctors at the Epidemiological Centre. This examination was designed to give a brief assessment of the extent to which the patient was affected by the disease and of the treatment to be given; a fresh medical file was drawn up for each patient,
- Ambilhar treatment was administered either at the Epidemiological Centre or directly in the villages.

In order to test the susceptibility of the inhabitants of the area to Ambilhar, about 400 patients were treated in 1968 either at the Epidemiological Centre or at Tanandava hospital.

Mass treatment started in October 1969 and was only really completed in September 1970, apart from the Tsaramandroso focus of infection. All the patients were treated without hospitalisation at the dosage rate of 25 mg/kg/day. The Ambilhar tablets were distributed twice a day for seven days, morning and evening, and a check was made that they were taken.

A special card was filled in for each treatment and for each patient. In order to offset the side effects of Ambilhar, various adjuvants were used: antispasmodics, antihistamines, barbiturates, tranquillisers and vitamins:

- apart from epileptics, children under 16 years of age never received adjuvants;
- adults between the ages of 16 and 40 were divided up into five groups by drawing lots, and one of the groups received no adjuvants;
- adults over the age of 40 were divided into four groups by drawing lots and these all systematically received one or two adjuvants.

Apart from the severe cases of hepatosplenomegaly, all the patients underwent the same mass treatment procedure. They were never, at any stage of the treatment, warned of the side effects of the chemotherapy. When such effects were observed, they were merely mentioned on the treatment card, no details being given other than the information supplied by the patient.

Carrying out the Ambilhar treatment was one of the most difficult stages in the Mangoky Project, not because of the side effects, but because of the extreme mobility of the population. The degree of participation in treatment which was achieved was only possible as a result of a real hunt for infected people throughout the area. However, we should mention in this respect how valuable we found the organisation of cinema sessions and the arrangements made for checking health cards; information was recorded on these cards about the various stages of the examination of infected people.

II.4. Organisation of the post-treatment examinations

Initially the following programme of post-treatment examinations was carried out:

- parasitological examination of urine and stools one year and two years after mass treatment,
- hatching test on all urine found to be positive,
- brief clinical examination of patients and questions asked of them in order to assess what improvement there was, if any, in their condition.

Very satisfactory examinations were carried out on the 400 patients treated in 1968, most of them being carried out every 3 months for a year, and then annually until 1971. But, as was the case also with the systematic examinations and treatment, we encountered a great many difficulties when trying to apply the same programme to the patients treated during the mass treatments. Their participation in the various examinations varied from one sub-zone to another and from one village to another, and as there were not enough personnel, the hatching tests and the clinical examinations were not always carried out.

II.5. Organisation of the health education of the population

Since all serious attempts at health education were doomed in advance to failure because of the constant movement of the population within and outside the area, our work in this field consisted of:

- putting up a number of notices recommending the inhabitants to come to the Epidemiological Centre to be examined and treated, and advising them to avoid any contact with water prohibited by other notices,
- showing a film about schistosomiasis and the Mangoky Project which was shot by CIBA-GEIGY on the spot,
- holding educational sessions in the villages, schools and various Samangoky departments using pictures explaining the cycle and the damage caused by schistosomiasis and also explaining the methods used to combat it.

II.6. Organisation of the malacological surveys and investigations

The hydrology of the area is dominated by the river Mangoky, its dead branch, the Kitombo, and the Samangoky irrigation network.

The Mangoky floods each year submerge the North-Eastern part of the Mangoky Project zone which consists of floodplain, called baiboho, where tracts of water are continually being created or filled up.

The irrigation system consists of:

- a main feeder, and then a complete network of concrete irrigation canals running through secondary canals down to quaternary canals or individual plot canals. These canals cross the tracks by means of siphons which constitute very good habitats for certain *Bulinus* species;
- a drainage system from the individual or quaternary drains to the primary drains which run into the Mangoky or the Kitombo, thus creating enormous reservoirs.

The areas of stagnant or semi-stagnant water consist of:

- ponds or reservoirs formed by the overflows from the irrigation canals;
- artificial borrow-pits formed when dikes or roads were constructed;

- natural pools, mainly in the so-called Protection zone;
- and some more or less temporary marshes, also in the Protection zone.

Our first task was to index and map all these areas of water, and then to keep our distribution maps up to date as planning and development work was carried out in the area.

Where to survey was determined according to the different types of habitat and the extent to which they were frequented.

The malacological surveys proper involved:
- making a topographical survey of the habitat: dimensions, speed of current, vegetation, etc.;
- taking a sample of water in order to make physical and chemical measurements: turbidity, conductivity, amount of anions and cations, pH;
- a trained worker carrying out a 10 to 30 minute survey. Using a special net at different levels, he would dredge an area of about 100 m^2, placing what he had dredged in a plastic tank.

The Hygiene Assistant responsible for the malacological surveys then had to sort, count, identify and, where necessary, test all the molluscs found, either on the spot or in the laboratory. At the same time he assessed the number of eggs laid and the number of very young snails.

In view of the fact that it was our aim to check as completely as possible all the populations of intermediate hosts of schistosomiasis, our programme and methods were selected so as to give us information about:
- all the habitats of intermediate hosts, attempting not to miss a single one, even if its epidemiological role were negligible;
- the dates of aestivation and egg laying, to help to assess the best time for molluscicide treatment.

This precluded any serious study of the density of the mollusc populations and the variations in it.

A check was made each year on whether or not the infection was being transmitted in the areas of water which were much frequented, by the method of exposing two mice to infection over a period of one day and then dissecting them 8 weeks later.

The malacological surveys carried out over these five years were concerned mainly with:
- identifying the *Bulinus obtusispira* and *Bulinus liratus,* which, from a morphological point of view, is very difficult to do, but which is of great interest, because only the former is to date considered to be an intermediate host of *S. haematobium,*
- studying the susceptibility of the various *Bulinus obtusispira – liratus – bavayi* – and *forskalii* to infestation by the *S. haematobium* miracidia,
- assessing the possible colonisation by *Biomphalaria pfeifferi* of the irrigation system,
- and studying the various factors governing the distribution and multiplication of *B. obtusispira* and *B. liratus:* temperature, pH, salinity, microflora and microfauna.

II.7. Organisation of the anti-mollusc campaigns

After checking that Frescon was not toxic to the various plants cultivated by irrigation (rice, cotton) and after finding out what was the optimum concentration of Frescon to destroy the various *Bulinus*, the anti-mollusc campaign was carried out during two campaigns of mulluscicide treatment.

The first campaign (1969–1970) was aimed merely at controlling the *B. obtusispira* populations in the areas where vesical schistosomiasis was transmitted; water harbouring non-infected *B. obtusispira* was merely placed under observation. When the Tsaramandroso focus of vesical schistosomiasis appeared, thus proving that this campaign had failed, a new anti-mollusc campaign on a large scale was planned for 1970–1971, involving:

- molluscicide treatment of all the water harbouring *B. obtusispira*, including the rice fields,
- and also treatment of water harbouring *B. liratus*, since it had been proved that this snail could occasionally be an intermediate host of *S. haematobium*.

For the application of Frescon we used:

- aerial spraying for the rice fields and the large expanses of water,
- manual spraying for the small areas of stagnant or semi-stagnant water,
- and drip feeding for the running water.

Before carrying out these applications, the land was first carefully cleared of bush and weeds so that the whole of the area of water being treated was accessible.

III. Preliminary results of the attack and control phases

III.1. Censuses

We give below the main results of the complete population censuses carried out during the 4th quarter of 1969 and the 3rd quarter of 1971.

		1969	1971
Population counted since 1967			22,224
Population counted, according to sub-zones			
sub-zone No. 1 (9 villages)		647	905
sub-zone No. 2 (18 villages)		4,195	6,010
sub-zone No. 3 (7 villages)		1,658	1,951
sub-zone No. 4 (10 villages)		1,222	1,849
sub-zone No. 5 (4 villages)		620	765
sub-zone No. 6 (4 villages)		650	793
	Total	8,992	12,273
Total number of huts occupied			4,124
Total number of huts unoccupied			679
Average number of inhabitants per hut			2.97
Annual migrations within the area		2,262	
Annual immigrations		2,362	
Annual emigrations		2,022	
Total number of emigrations since 1967			10,551
annual average			2,111
Number of tenant farmers (Samangoky)		2,800	3,100

The population of the zone should be estimated at about 10,000 persons, because in 1971 we included in our censuses the workers of two large public works companies temporarily working in the region, and their families.

These figures demonstrate clearly the extent of population migrations both within and outside the Samangoky area.

III.2. Results of the systematic examinations of the population

The clinical, parasitological and therapeutic data from our medical files are still being processed by the computer. The results mentioned here come from a preliminary partial processing. They are therefore neither complete nor final:

- Total number of people examined: 19,450.
  - Percentage of participation: 85 %.
  - Percentage of persons not examined in 1971: 14 %.

The number of people not examined includes babies of under 3 months and blind or impotent old men whose role in the epidemiology of schistosomiasis is negligible. The other people not examined usually comprise recent immigrants or temporary visitors. True recalcitrants in the case-finding operations are in fact exceptional and we estimate that the participation in these systematic examinations should really be put at nearly 95 %.

- Total number of medical files which can be processed: *18,788.*
  - 1967: 1,076, 1968: 5,951, 1969: 6,815, 1970: 2,690, 1971: 2,256.
- Number of *S. mansoni* cases diagnosed during the systematic examinations: 698 (3.7 %). As *S. mansoni* is not transmitted in the Samangoky area, the majority of the cases diagnosed come from sub-zones Nos. 2 and 3 (669 cases) where there is a concentration of the immigrants coming from the endemic zones of the High Plateaux or the South and East of Madagascar.
- Number of *S. haematobium* cases diagnosed during the various stages of the Mangoky Project:
  - Initial systematic examination of the population (case-finding): *1,847* (10 %).
  - Urine examination carried out when haematuria was present, without there being any *Schistosoma* eggs: *116* (9 %) (1,341 people examined; rate of participation of those persons undergoing this examination: 71 %).
  - Rectal biopsy carried out when haematuria was present, without there being any *Schistosoma* eggs: *13* (11 %) (155 persons examined; rate of participation of those persons undergoing this examination: 12.6 %).
  - First systematic urine examination (1969–1970): *612* (9 %)

(6,836 persons examined; rate of participation of those persons undergoing this examination: 92 %).

- Second systematic urine examination (1970–1971): *256* (6 %) (4,057 persons examined; rate of participation of those persons undergoing this examination: 81%).
- Total number of cases of vesical schistosomiasis diagnosed from 1967 to 1971: *2,844* (15,1%).

– Prevalence of vesical schistosomiasis in the Samangoky area before the mass chemotherapy: *13.7* %.

– Breakdown of cases of vesical schistosomiasis:

· by sex:	males	1,622 (15.8 %)
	females	1,222 (14.3 %)
· by age:	0–1 year	32 (3.2 %)
	1–5 years	251 (11.7 %)
	6–15 years	947 (26.1 %)
	16–30 years	1,156 (14.5 %)
	over 30 years	458 (11.3 %)

- by ethnic group: the main ethnic group, the Masikoro (36 %), has the highest infection rate: 22.2 %. The other main ethnic groups, Antandroy, Vezo, Mahafaly and Antaisaka in order of importance, have infection rates varying between 8.6 % (Vezo) and 14.9 % (Antandroy). The minority ethnic groups have infection rates varying between 1.5 % (Antaimoro) and 17.2 % (Antaifasy).
- By sub-zone:

Sub-zone No. 1	108 (9.8 %)	
Sub-zone No. 2	1,420 (13.3 %)	
Tanandava-Angarazy		395 (11.8 %)
Mahampanarivo		101 (26.6 %)
Béreniala		58 (24.7 %)
Sub-zone No. 3	705 (23.3 %)	
Tsaramandroso		456 (27.2 %)
Mahavory		27 (15.1 %)
Civic Department		48 (11.8 %)
Sub-zone No. 4	749 (35.3 %)	
Ambahikily		538 (34.6 %)
Betakona-Ambahikily		100 (40.6 %)
Sub-zone No. 5	185 (22.2 %)	
Tsianihy		147 (23.5 %)
Sub-zone No. 6	158 (16.2 %)	

N.B.: In these statistics, which have been obtained from a computer, the infected persons are classified according to the address where they were originally examined. This means that people examined in Tanandava-Angarazy, for example, who have come to live in Ambahikily and been infected there, are classified in their village of origin. When processing these statistics manually, we took the address of diagnosis into account and this explains the differences in rates of infection given in the analysis following these results.

· By year of being diagnosed:

1967: 144 (13.4 %)
1968: 758 (12.7 %)
1969: 663 (10.0 %)
1970: 231 (8.6 %)
1971: 160 (7.1 %)

– Analysis of the breakdown of those with vesical schistosomiasis:
  · The difference in prevalence between the sexes is significant at a probability level of 0.01, although it is not at present possible to explain it.
  · The graph of the rates of infection as a function of age corresponds to what is usually seen in areas of endemic disease.
  · Sub-zone No. 1 is little affected by schistosomiasis. The 9.8 % positive cases were probably all infected on the Tuléar road or in the Basibasy region. The annual incidence must be around 0.4 %.
  · In sub-zone No. 2, the prevalence (13.3 %) is fairly low, but it varies from one village to another. A distinction must be made between villages like Tanandava-Angarazy, the inhabitants of which are mainly infected outside the area and, less frequently, in Ambahikily, and those like Mahampanarivo, the inhabitants of which were mainly infected in the Tsaramandroso marsh in 1970. The annual incidence is about 0.8 %, but in Mahampanarivo it was 13.4 % in 1970 and in Béreniala 12.8 %.
  · Because of the continual movements of the Antandroy people who make up the majority of the people in sub-zone No. 3, the infection rate in this sub-zone seems fairly low (23.3 %), in spite of the Tsaramandroso focus of transmission of the disease. However, before this focus of infection appeared (1969), we found that the prevalence of the disease was 16.4 % and in 1970 there was an infection rate of 41.2 % in one group of 580 persons. A more detailed analysis will undoubtedly reveal an even higher incidence.
  · Sub-zone No. 4 corresponds to the first focus of transmission of *S. haematobium* which was definitely proven in the Samangoky area. The only infected water was in the neighbourhood of the chief village of the canton, Ambahikily, and dated from the time when the main feeder canal was first opened in 1966. The transmission of vesical schistosomiasis probably began in 1967, but it was not until 1968 that it was proven. Since May 1969 there has been no further transmission. The prevalence found by FAIDHERBE

in 1958 (25 %) (BRYGOO, 1968) leads one to the assumption, however, that there was previously an intermittent focus of transmission near this village.
The infection rate of 35.3 % does not correspond to the actual situation for the reason already mentioned above and also because there was a fairly large influx of labour from the High Plateaux in 1970–1971. Manual processing of the results in fact revealed that in 1969, just before the mass treatments, the prevalence was 99 % in the case of the Ambahikily schoolchildren and 53.2 % for the whole population of this village, whereas in 1968 it was only 26 %. It should also be noted in passing that the 40 % infected in the village of Betakona-Ambahikily in fact come from the village of Tsaramandroso, which they left in 1970–1971.

· Sub-zones Nos. 5 and 6 were much less affected, having infection rates of 22.2 % and 16.2 %. In 1968, the respective figures for prevalence of the disease were 15.3 % and 9.3 %, i.e. an identical annual incidence of 6.9 %. The inhabitants of these sub-zones became infected either in the Basibasy region or, mostly, in Ambahikily where the weekly market draws in the people from neighbouring villages.

III.3. Results of the mass chemotherapy using Ambilhar and of the post-treatment examinations

Of the 698 cases of intestinal schistosomiasis found, 475 (68 %) received Ambilhar treatment. The post-treatment examinations six months or more after treatment revealed a 4.8 % failure rate (22 cases). For the time being, no further analysis of these results has been carried out.

Of the 2,844 cases of vesical schistosomiasis diagnosed, 2,488, i.e. 93.8 %, underwent a clinical examination before treatment (the percentage given does not take into account those patients who had left the area before they could be examined). The following figures show the frequency of haematuria:

· recent intermittent haematuria (under a year)	326	(13.1 %)
· previous intermittent haematuria	327	(13.1 %)
· recent permanent haematuria (under a year)	431	(17.3 %)
· previous permanent haematuria	172	(6.9 %)
Total	1,256	(50.4 %)

During the systemic urine examinations, the frequency of micro- or macroscopic haematuria was 25 % (4,728 cases, of which 1,882 (38.8 %) had haematuria not necessarily connected with schistosomiasis).

2,188 cases of vesical schistosomiasis were treated with Ambilhar, 1,949 of which were treated during the mass treatment programme. The rate of participation was 94.8 % if one discounts those patients who had left the area before undergoing treatment. The mass treatments were carried out village by village, dealing with 10 to 100 patients per week. In Ambahikily the treatment was carried out on two groups each of 250 to 300 patients per week.

On the whole, tolerance of the drug was fairly good. Some minor side effects were observed (nausea, vomiting, muscular cramps, etc.) in 335 cases (15.3 %), post-treatment allergies in 10 cases (0.4 %), neuro-psychiatric disorders in 9 cases (0.4 %), seven of which were minor (obnubilation) and two major (hallucinations, delirium, etc.).

We were able to carry out post-treatment examinations on 1,730 of the infected people treated. More than six months after treatment, there were 137 positive cases (7.9 %), 90 of which were recontaminations (5.2 %) and 47 probable failures (2.7 %), of which 25 had had insufficient treatment (1.4 %).

A second course of Ambilhar was given to 132 of the 137 positive cases. Of these there were a further 4 failures (3 %), 3 of which underwent a third course of Ambilhar.

After analysis of these results, the following remarks can be made:

III.3.1.

It is perfectly possible to carry out mass chemotherapy using Ambilhar in areas where *S. haematobium* is endemic. The analysis of the side effects shows that:

- Side effects are more or less non-existent in the case of children of under 16 years.
- Minor side effects – nausea, vomiting, giddiness, muscular cramps – are relatively unusual, although they do increase in frequency the older the patient. In exceptional cases they may lead to suspension of the treatment.
- Major side effects – neuro-psychiatric disorders – are extremely rare when the treatment is carried out correctly. Contrary to other authors, we have not observed any epileptic fits triggered off by Ambilhar and have observed only 5 cases (2 vesical and 3 intestinal schistosomiasis) of major neuro-psychiatric disorders, with delirium and hallucinations, out of a total of 2,799 treatments. It should also be noted that four of these neuro-psychiatric disorders occurred during the first 400 treatments and that the only one occurring during the mass treatments could, in our opinion, have been avoided (see p. 154–155).

- Adjuvants, with the possible exception of phenobarbitone, seem to have little influence on the side effects.
- A fairly frequent consequence of treatment was a loss of weight combined with temporary loss of appetite and, in certain cases, allergic reactions of the nettle-rash type.
- Parasitological recoveries are accompanied by a spectacular clinical recovery (disappearance of haematuria and weight gain), which means that the drug gains a good reputation and the inevitable side effects are more readily accepted.

The fact nevertheless remains that distributing tablets night and morning for 7 days necessitates organisation and very strict control of the patients, and it is necessary for supervision of the treatments and of the consequences to be the exclusive responsibility of the doctors.

Ambilhar mass treatments have to follow a strict procedure, taking into account the following considerations encountered in our experience in the Lower Mangoky:

- Treatment locally is much more acceptable in the large majority of cases than hospital treatment.
- The only definite contra-indications for treatment locally are:
  - severe cases of hepatosplenomegaly,
  - old people in a very poor general condition,
  - serious and recent neuro-psychiatric disorders.
- Temporary contra-indications for treatment locally only concern acute progressive diseases and tubercular patients undergoing isoniazid treatment.
- Epileptic fits and splenomegaly are not contra-indications for treatment locally.

  In fact there is no way of knowing beforehand whether there will be side effects, particularly neuro-psychiatric disorders.
- The optimum dosage rate is 25 mg/kg/day for adults and 30 mg/kg/day for children, taken in two daily doses over a period of 7 days. However, it would appear that a course of treatment lasting for 5 consecutive days is sufficient to cure the vast majority of cases of vesical schistosomiasis.
- There is no need for adjuvants to be systematically prescribed, apart from phenobarbitone for known epileptics and for people aged over 50.
- The patients should not be informed, either before or during treatment, of the possibility of side effects, since the psychological factor seems to play a considerable part in triggering them off.
- Most of the neuro-psychiatric disorders can be avoided by careful supervision of the patients during treatment, particularly on the second and third days. Any behavioural change, however slight, in the patient – mainly logorrhea and somewhat incomprehensible con-

versation – should be followed by immediate cessation of treatment for 24 hours, the prescribing of a large dose of phenobarbitone and then resumption of treatment with the dose reduced by half for a further seven days. The patient would then appear to have as good a chance of recovery as if he had received the normal dose.

- If serious neuro-psychiatric disorders arise, treatment locally should be completely and finally abandoned, and a high dose of phenobarbitone and tranquillisers should be administered by injection for a maximum period of three days. After this the symptoms disappear completely and for good.
- The post-treatment examinations should only be carried out 6 to 12 months after the treatment has ended, and further treatment should only be prescribed if living *Schistosoma* eggs are found.

III.3.2.

Mass treatment with Ambilhar can play an important part in controlling vesical schistosomiasis. A particularly striking example of this was given in the Ambahikily focus of infection where, 12 months after the mass treatments and the applications of molluscicides, the prevalence of schistosomiasis caused by *S. haematobium* had dropped from 99% to 1% among the village's schoolchildren.

However, it does not appear possible to control cases of schistosomiasis solely by mass chemotherapy, because of the risk of reinfection from contact with snail-infested water. Ambilhar is not active in the case of the immature forms of *Schistosoma,* so it would appear that mass treatments should not be started until three months after all possibilities of infection have been eliminated. Because this rule was not observed, a considerable number of those suffering from schistosomiasis in the Tsaramandroso focus of infection had to undergo a second course of Ambilhar.

It should also be noted that mass chemotherapy must be planned within the framework of a long and well-planned programme of schistosomiasis control, because the suppression of immunity which it is supposed to confer could have serious consequences for the asymptomatic infected people who had undergone the treatment and subsequently became reinfected.

III.4. Results of the health education of the population

Our efforts in this field have resulted in the people becoming clearly aware of the dangers of schistosomiasis and of the means of combating it. The best results were obtained in the participation in the case-finding operations and in the Ambilhar treatments. Subsequently, we were unable to convince the inhabitants completely of the need for urine examinations even when no symptoms were manifest. In our opinion, the reason for this semi-failure is linked with the disproportion between the facilities of the Department of schistosomiasis control and of the other departments concerned with medical care and with controlling endemic diseases. In fact, the inhabitants grew tired of seeing how much importance was attached to taking urine samples when they were expecting treatment to relieve their present sufferings.

The efforts to reduce the amount of contact the population had with the areas of infected water and to reduce contamination by urine of those areas of water harbouring the intermediate hosts failed because, for one thing, there is so much movement within the area itself.

III.5. Results of the malacological surveys and investigations

The monthly or quarterly malacological investigations of about 400 habitats have revealed the existence of nine aquatic molluscs (identification E. R. Brygoo and G. Mandall-Barth):

– Non-operculate molluscs:

Bulinus obtusispira (Smith)	africanus group (?)
Bulinus liratus (Tristram)	tropicus group
Bulinus bavayi (Dantzenberg)	forskalii group
Bulinus forskalii (Ehrenberg)	forskalii group
Limnea natalensis hovarum (Tristram)	
Anisus trivialis (Morelet)	

– Operculate molluscs:

Cleopatra carinulata (Dantzenberg)
Melanoides tuberculata
Lanistes sp.

Bulinus obtusispira

These molluscs must be considered as the main intermediate hosts of *S. haematobium* in the Lower Mangoky and probably in Madagascar. Experimentally their infestation is almost 100 % successful, but their mortality rate before the parasite has completed its development becomes extremely high if they are infected with more than 5 miracidia. The emission of cercariae and the survival of the infected *B. obtusispira* are remarkably long (over 6 months in our laboratories). In the wild, their infection rate seems to vary from one focus to another: 10 % at Tsaramandroso, 15 % at Basibasy, 100 % at Ambahikily. The highest rates were observed in those places where the *Bulinus* populations were at their lowest density. Their distribution in the Lower Mangoky has always been extremely limited and has sometimes varied from one year to the next:

– Portions of drains:[1]	
CT_{41}, CT_{42}, CT_{45}	1967, 1968
CS_4, CP_2	1967, 1968, 1970
CS_2, CP_1	1970, 1971
CP_3	1967, 1968
– Artificial borrow pits: EZ_3, G_8	1968, 1969, 1970
– Reservoirs fed by water of a low salinity:	
M.Ts. G_5 Ambahikily	1967, 1968, 1969
CP_2, G_{13} Tsaramandroso	1970, 1971
– Some rice field plots	1967 to 1970

The *B. obtusispira* found in the rice fields do not have exactly the same morphology as the others. Their shells are completely devoid of micro-striae and it has never been possible to maintain their breeding in the laboratory.

– *B. obtusispira* are also to be found in the large Andranolava marsh (4 km in length), which is on the edge of the Mangoky Project zone, and also at Basibasy to the south of the zone, about 30 km away as the crow flies.

The main ecological features of *B. obtusispira* are as follows:

– *Habitats*
  - stagnant water (apart from CS_2);
  - low salinity of the water (average from December to April below 600 μmhos conductivity);
  - periodic drying out, resulting in aestivation for 2 to 8 months (apart from CP_2 G_{13} Tsaramandroso, CS_2 and CP_1; the same exception applied in the Morondava region);
  - abundant aquatic vegetation consisting of hydrocharitaceae and nymphaeaceae (with the exception of EZ_3, G_8);
  - low pollution of the water.

– *Reproduction*
  - When the irrigation system has its full water supply restored and when the first major rainfall occurs, the *B. obtusispira* aestivation ends and there follows a very active period of reproduction. At the end of the rainy season, the reproduction rate rapidly falls and has reached zero before the aestivation stage in the temporary areas of water. In the permanent areas of water, a reduced reproduction rate continues until the fresh rains.

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[1] CP = collecteur principal (main drain); CS = collecteur secondaire (secondary drain); CT = collecteur tertiaire (tertiary drain).

· The following periods can be considered as a pattern:
- December: end of aestivation;
- January to April: period of intense reproduction;
- May to November: period of reduced reproduction in the permanent areas of water;
- May to July/August: decrease and cessation of reproduction in the temporary areas of water;
- July/August to November: period of aestivation in the temporary areas of water;
- March to November: period of aestivation in the rice fields.

– *Transmission*
· In the temporary areas of water (i.e. Ambahikily), *S. haematobium* is transmitted from January to April.
· In the permanent areas of water (i.e. Tsaramandroso), we were also able to prove transmission from January to April, but we then had to apply molluscicides in order to arrest the transmission cycle. It is by no means certain that transmission takes place throughout the year, because at Morondava, which is a true focus of endemic disease, we found one permanent area of water harbouring numerous *B. obtusispira* in November, but not one of the 200 molluscs tested showed any infection.
· A low population density of *B. obtusispira*, and even the apparent absence of any, does not enable one to assume in advance the extent of transmission. In Ambahikily, extremely small *Bulinus* populations (20 molluscs/man/hour) concentrated in localised spots raised the prevalence of vesical schistosomiasis in two years from 25 % to 99 % in the case of the village's schoolchildren. Mice were also infected in areas which were apparently devoid of *Bulinus* and which were over 200 metres from known habitats of infected *B. obtusispira*.
· In the two foci of vesical schistosomiasis which appeared in the area during the Mangoky Project (Ambahikily and Tsaramandroso), contrary to its usual behaviour, the disease developed along lines which could almost be termed epidemic. In Tsaramandroso for example: in 1969 appearance of *B. obtusispira* following the January floods. The prevalence of *S. haematobium* was then 11% in a population originating from the South of Madagascar (free from vesical schistosomiasis). In 1970, period of transmission from January to April; the prevalence immediately jumps to over 40 % in May.

The Mangoky Project was carried out in a zone where the ecology of the intermediate hosts seems still to be unstable and changeable. If only the Tsaramandroso and Ambahikily marsh-reservoirs formed foci of transmission of the disease, the question must be asked whether the other habitats are merely mollusc "stores", or whether sporadic transmission is possible there. As we have observed, some factors: change in the irrigation practices, the opening of overflows, the flooding or creation of new villages, may not only create new habitats, but also change a simple "store" of *B. obtusispira* into a focus of transmission.

Bulinus liratus

For a long time, this was confused with and thought to be the same species as *B. obtusispira* (BRYGOO & MOREAU, 1967), but this *Bulinus,* which belongs to the tropicus group, has some special ecological characteristics:

Identification

- Morphologically, *B. liratus* is distinguishable from *B. obtusispira* by the micro-striae on its shell and by the teeth of its radula. However, to make this differentiation, a sufficient number of adult specimens have to be studied. In the field, an experienced person can identify them solely from the shape and the micro-striae of the shell of the typical adult molluscs.
- Using the Burch technique of gelose diffusion (BURCH & LINSAY, 1970), *B. liratus* can be distinguished from *B. obtusispira* by a specific precipitation line (MAURER, 1971). This possibly corresponds to the hemolysin which was found in *B. liratus* (DEGRÉMONT et al., 1970) and subsequently proved to be of bacterial origin.

Habitats

- Starting from the siphons of the irrigation canals which go underneath the roads the *B. liratus* have gradually and regularly extended their sphere of distribution.
- At first they were only found in certain siphons in sub-zone No. 2 (UPBM) in 1967; then they were found in the main UPBM drains as from 1969; and finally they were found in the siphons of a secondary canal in sub-zone No. 3 in 1970. They probably infiltrated the area via the irrigation system from its water intake from the Mangoky. Subsequently they were spread either when canals overflowed, or possibly through being picked up by birds.
- Unlike *B. obtusispira,* they seem to prefer permanent water and in any case cannot stand long periods of aestivation. In the temporary areas of water where we found them (Ambahikily, artificial borrow-pits), they do not appear to survive from one year to the next. However, we did find one exception in a pond in the Basibasy region.

- They can stand greater pollution and, more especially, greater salinity than *B. obtusispira* and seem less dependent on aquatic vegetation.
- Up to 1970 we never found these two *Bulinus* in the same places at the same time, apart from some plots in rice fields where *B. liratus* seemed in any case to have been introduced artificially by the irrigation water. Subsequently, they were found together in three UPBM drains (CS_2, CP_1, CP_2) and particularly in the Tsaramandroso marsh).

Reproduction

- It has not been possible to show any special reproductive activity at a given period of the year, particularly during the rainy season.

Transmission

- Previously it had never been possible to prove in the field in Madagascar that *S. haematobium* was transmitted by *B. liratus.*
- However, at the Tanandava Epidemiological Centre we were able artificially to infect a strain of *Bulinus liratus* which we had bred. Attempts were made to infect over 1,500 specimens with the local strain of *S. haematobium* (Ambahikily). All the positive *B. liratus* (50) came from the same aquarium where breeding had been carried out for two years, and the rate of infestation varied between 2 and 14 %.
- In the field, we tested over 3,000 *B. liratus* from various habitats. Only nine specimens, taken from a UPBM drain in 1970 (CP_1), were found to be carrying *S. haematobium* cercariae (the cycle was completed in mice). Of these, one at least had all the characteristics of *B. liratus* and was identified as such by G. Mandall-Barth. It was not so easy to identify the others, but none really had the morphological characteristics of *B. obtusispira.*
- Although *B. liratus* does not at present seem to be involved in the transmission of *S. haematobium* in the Lower Mangoky, the question must be asked whether this will always be the case in spite of its increased distribution; consequently, should an attempt be made to control it with molluscicides? In fact, it is possible that a strain of *Schistosoma* may adapt itself to this *Bulinus,* making it a valid intermediate host, or, on the other hand, certain factors may select a strain of *B. liratus,* which is sensitive to the local strain of *S. haematobium,* as seems to have been the case in our breeding experiments. However, because it belongs to the tropicus group, the risk of transmission by *B. liratus* seems minimal, although it is not completely negligible.

Bulinus bavayi

This *Bulinus* is considered by some people to be a possible intermediate host of *S. haematobium,* since it is very similar to *B. cernicus* found in Mauritius. In experiments in Madagascar it has never been possible to infect it with local strains of *Schistosoma.* But according to C. A. WRIGHT (1971), it is apparently possible to infect it with other strains. In the Lower Mangoky, experiments carried out on over 1,000 *B. bavayi* were all complete failures; but it must be noted that there is a very high death rate and sometimes total mortality in the first few weeks after infestation. In the field, we also tested over 5,000 *B. bavayi* from various habitats without finding a single positive one. The very widespread distribution of this mollusc in the Lower Mangoky, both in the canals and drains and in the ponds, and the total absence of transmission outside the Tsaramandroso and Ambahikily foci of infection would seem to indicate quite clearly that *B. bavayi* is not, at least at present, an intermediate host of *S. haematobium* in this area.

Bulinus forskalii

This plays no part in the Samangoky area, both because it is not at all widespread (only a few rice field plots) and because it is not infected.

Biomphalaria pfeifferi

Which is an intermediate host of *S. mansoni* in Madagascar, has never been found in the Lower Mangoky. However, a successful breeding experiment was carried out for nearly three years in cement tanks outside the Tanandava Epidemiological Centre, in a spot shaded from the sun and with the water being renewed twice a week. The period of maximum breeding for *B. pfeifferi* was during the dry, cool season. In Madagascar (BRYGOO, 1967), as in Africa (STURROCK, 1966), the temperature is certainly a factor which restricts the spread of *Biomphalaria.*

Although it is fairly unlikely, it is not wholly impossible for these molluscs to enter the Samangoky irrigation system, because their distribution in Madagascar does not yet appear to be definitely fixed, as is also the case with *Bulinus.*

The other aquatic molluscs found in the area cannot play any part in the transmission of vesical schistosomiasis.

The results of the study of the various factors which can affect the distribution and multiplication of *Bulinus* in the water in this area have not yet been completely processed. However, some factors enable us already to select the good and bad habitats of *B. obtusispira:*

– the salinity, when the average conductivity from December to April is over 600 μmhos. This precludes all the areas of water in sub-zones Nos. 3, 4, 5 and 6, apart from the reservoirs fed by water from the Mangoky.
– Pollution by organic debris from the artificial borrow-pits, which leads to a proliferation of the micro-algae and makes the biotope anaerobic and unfavourable to all forms of molluscs.

The result of this study has already been a considerable reduction in the number and the frequency of the malacological surveys; in the future it will probably be of very great use when future irrigation systems are planned. In this respect, we must point out that the populations of *B. obtusispira* in one artificial borrow-pit in sub-zone No. 3 have been wiped out by temporarily diverting a drain of high salinity into this area of water.

III.6. Toxicity of Frescon to crops and fish

N-tritylmorpholine (Frescon) has proved completely non-toxic towards the cotton (variety Acala 15-17 BR) and rice (Alicombo variety) grown in the Samangoky area.

The experimental study of Frescon's activity revealed that there was a fairly considerable difference in sensitivity between *B. obtusispira* (LD 90 = 0.075 ppm)[2] and *B. liratus* (LD 90 = 0.20 ppm) when exposed to Frescon for 24 hours. In the light of these findings and taking into consideration the nature of the snail habitats, we decided to apply Frescon in the field at a concentration of 0.10 to 0.15 ppm where *B. obtusispira* were present and 0.20 ppm where *B. liratus* were present. At these concentrations, practically all the fish are killed by the chemical; but in the drains and reservoirs which are continually fed by water from the Mangoky, the fish stocks are restored in a fortnight. Moreover, we have never had any complaints from the population about this massive destruction, and there do not appear to have been any ill effects from eating fish killed by Frescon, although large quantities have sometimes been consumed.

III.7. Results of the molluscicide treatments

The 1969–1970 campaign was concerned only with the Ambahikily marsh-reservoir. As this is supplied by water from the overflow from the main feeder canal, there were practically no problems in treating it with the molluscicide: drip-feed at the level of the main canal and manual spraying at the Southern extremity of the reservoir where the supply currents were too slow.

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[2] ppm = parts per million.

The results of this treatment were spectacular, no *B. obtusispira* being found until May 1970, i.e. 5 months after the applications of Frescon. Subsequently, because of the damage to the main canal by the 1970 floods, the Ambahikily reservoir has never had its water supply re-established. When the main canal was repaired, its downstream end was adapted so that its overflow emptied into the primary drain CP 5.

The 1970/1971 campaign was on a much larger scale, being aimed at completely controlling the populations of *B. obtusispira* and *B. liratus*.

During this campaign, we carried out the following work (Fig. 3):

- We cleared the Tsaramandroso marsh-reservoir of bush and completely cleared the area of weeds mechanically, doing the same to the primary drains CP 1 and CP 2 and the secondary drains CS 2, CS 3, CS 4 and CS 4 A. Herbicides (Domatol, Gramotox, Weedazol) were tried out, particularly on CP 1, but the results were not as convincing as had been expected, particularly on the semi-aquatic grasses.
- Frescon was sprayed aerially on the UPBM rice fields. This treatment was carried out on 11th December 1970 when the rice did not completely cover the sheet of water; but the treatment failed because at that time the last *B. obtusispira* had not yet had time to come out of the earth.

  The only way of treating the rice fields with chemical is therefore the drip-feed of molluscicides in the irrigation canals at the time when the rice fields are reflooded, after they have been drained in January. This was done in 1971.
- Drip-feed of molluscicide in the secondary canal S. 2 and in all the tertiary canals dependent on this one, in order to destroy *B. liratus* in the siphons.
- Drip-feed and manual spraying of Frescon in the primary drains CP 1 and CP 2 and the secondary drains CS 2, CS 3, CS 4 and CS 4 A.

  These treatments were repeated four times: in December 1970 and in January, March and May 1971.
- Drip-feed, aerial and manual spraying of Frescon in the Tsaramandroso marsh-reservoir. These treatments were repeated six times: in November and December 1970 and in January, March, May and August 1971.

In the shallow areas of water excellent results seem to have been obtained in mixing the Frescon when a herd of zebu trampled over the area. Moreover, it is essential to clear the bush and weeds from the whole surface of the water very carefully before spraying on the molluscicide. In those areas of water where there is a slow current and where the pH is neutral, drip-feeding was carried out only over short sections because of the rapid breakdown of Frescon and the inactivity of its metabolites.

On the whole the results of this campaign were fairly satisfactory. In November 1971, there were no more *B. liratus* except in four habitats in the secondary drains CS 2 and CS 4, and no more *B. obtusispira* except in two habitats in drains CS 2 and CP 1. The latter had in fact taken refuge in the practically inaccessible end part of the main drain CP 1; subsequently they reinvaded CP 1 and CS 2, merely staying in the biotopes which suited them. This process was followed right through during various malacological surveys.

Because of its size and depth and the abundance of aquatic vegetation, the problem of applying molluscicide to the Tsaramandroso marsh-reservoir was practically insoluble until August 1971. In fact, since April 1970, Frescon applications had to be repeated regularly every two months in order to break the transmission cycle of vesical schistosomiasis. The *B. obtusispira,* which seemed to have disappeared after each treatment, reappeared in large numbers about three weeks to a month after the application.

The last application in August 1971 was carried out by combining a large quantity of urea with the Frescon. The aim of this attempt, which is explained in another publication (PERRET et al., 1972), was to create convection movements by the endothermic reaction of diluting the urea and later to alter the biomass thus making the environment hostile to the molluscs. The results of this application are particularly interesting because 5 months later it was still impossible to find a single mollusc in this area of water.

Although the molluscicide treatments of the 1970–1971 campaign were successful, it should nevertheless be stressed that there are difficulties to be overcome in applying the chemical in those drains or ponds which are more or less overrun with aquatic vegetation.

IV. Epidemiological situation regarding forms of schistosomiasis in the Lower Mangoky at the end of the Mangoky Project

IV.1. The human element

Until our results have been completely analysed, there can only be an approximate assessment of the prevalence and incidence of schistosomiasis in the Lower Mangoky at the end of the Mangoky Project.

The prevalence of intestinal schistosomiasis caused by *S. mansoni* is apparently less than 1.7 % and its annual growth, which consists solely of imported cases, about 0.6 %.

The second systematic urine examination carried out in 1970–1971

Fig. 3. Molluscicide treatments using N-tritylmorpholine (Frescon)

Areas of water treated	Dates and methods of application: Drip-feed (DF) Manual spraying (MS) Aerial spraying (AS)	Volume of water treated, m^3	Theoretical concentration, ppm	Theoretical volume of 16.5 % Frescon, litres	Volume of 16.5 % Frescon used, litres
Ambahikily marsh-reservoir $MTsZ_2G_1$ to G_7	DF: 7. 1. 1970 MS: 7. 1. 1970 / 10. 3. 1970	119,133	0.10	72.20	66.50
Tsaramandroso marsh-reservoir CP_2G_{11} to G_{14}	MS partial: 16. 4. 1970 / 20. 5. 1970 / 20. 7. 1970 / 14. 11. 1970 DF + AS + MS: 17. 12. 1970 / 25. 1. 1971 / 8. 4. 1971 / 28. 5. 1971 / 3. 8. 1971	820,198	0.15/0.25	776.05	900.00
Primary drain CP 2	MS: 21. 5. 1970. DF: 17. 12. 1970 / 20. 1. 1971 / 7. 4. 1971 / 25. 5. 1971. MS: 8. 4. 1971	275,869	0.15	244.69	256.00
Drains CS_4, CS_4A, CT 44, CT 45	MS: 23. 5. 1970 / 13. 12. 1970 / 15. 1. 1971 / 5. 4. 1971 / 17. 5. 1971 DF: 14. 12. 1970 / 14. 1. 1971	213,907	0.15	194.37	246.00
Drain CS_3	AS: 11. 12. 1970. DF: 18. 1. 1971 MS: 18. 1. 1971	41,666	0.15	37.56	47.00
Drain CS_2	DF + MS: 11. 12. 1970 / 21. 1. 1971 / 31. 3. 1971 / 24. 5. 1971	326,321	0.15	296.56	295.00
Primary drain CP_1	DF: 11. 12. 1970 / 21. 1. 1971 AS: 28. 5. 1971. MS: 29. 5. 1971 / 9. 8. 1971	114,138	0.15/0.30	114.64	148.00
UPBM rice fields (266 ha)	AS total: 11. 12. 1970 DF partial: 13. 1. 1971	744,404	0.15	676.69	732.00
Irrigation canals and traps	DF: 3. 12. 1970 / 23. 1. 1971 MS: 24. 5. 1971	65,664	0.15	59.69	75.00
Artificial borrow pits EZ_3G_{15}	MS: 23. 4. 1970 / 25. 1. 1971 / 8. 4. 1971	45,000	0.15	49.89	31.00
	Total	2,766,300		2,513.34	2,796.50

should have shown the prevalence of vesical schistosomiasis, caused by *S. haematobium,* after the mass chemotherapy. But it must be noted that as the Tsaramandroso focus of infection developed while we were right in the middle of the mass treatments, only being eradicated at the end of 1970, the percentage of infection found during this second examination (6.3 %) includes 3.2 % originating from the Tsaramandroso region. In addition, practically all the infected people diagnosed during this second systematic urine examination were treated with Ambilhar before the end of the Mangoky Project.

An approximate figure must therefore be given for the prevalence in a population of 10,000 inhabitants; this must be done by using the rates of infection given above to assess the number of cases of schistosomiasis present in the area in 1971, having escaped the various case-finding operations, examinations and treatments, i.e.:

- Number of positive cases among the 10 % of inhabitants who had never been examined = 100.
- Number of positive cases among the inhabitants who had deliberately been excluded from the first urine examination: 51.
- Number of positive cases among the inhabitants who had deliberately been excluded from the second urine examination: 40.
- Number of cases of schistosomiasis diagnosed among people who had been excluded from treatment: 85.

This gives a total of 276 cases of vesical schistosomiasis and a prevalence of 2.76 %. In our opinion, a figure of 3 % for the infection rate is very close to the actual situation. With regard to the annual incidence of vesical schistosomiasis, it can be assumed that the Ambahikily focus of infection has been eradicated and that in the Tsaramandroso focus, there has been no further transmission since May 1970. The new cases consist solely of immigrants (160 cases, 7.1% from January to October 1971) and people contaminated outside the area (3.4 % at Ambahikily, 3.5 % at Tanandava-Angarazy and 4.8 % in sub-zone No. 2). Nevertheless, this amounts to about 560 new cases of schistosomiasis each year and to an annual incidence of 3.6 %.

The analysis of these figures shows clearly that:

- the anti-schistosomiasis campaign carried out over these five years has been very effective: the infection rate has dropped from 13 % to 3 % in the whole area and from 59.1% to 3.4 % in the Ambahikily focus of infection;
- because of the considerable movements of the population, stringent measures must be taken to diagnose and treat infected people systematically.

IV.2. The intermediate host

At the end of the Project, the malacological situation in the Samangoky area seems quite favourable, although it has not been finally stabilised.

The intermediate hosts of vesical schistosomiasis no longer exist except in two UPBM drains, which are, moreover, not much frequented (sub-zone No. 2). It will only be possible to treat these last two drains properly when they have been carefully cleaned out. It is not sure that the UPBM rice fields were sterilised after the 1970–1971 campaign and this cannot be known until the 1971–1972 malacological surveys have been carried out. Only the Tsaramandroso marsh-reservoir remains a potential large focus of transmission. It will therefore have to be looked at regularly, reduced in size as much as possible, if this is feasible, and treated with molluscicides at least two or three times a year.

Floods on as catastrophic a scale as those of 1969 and 1970 could once again lead to the spread of *B. obtusispira,* but a greater fear is that this mollusc will be reintroduced into the area from the Andranolava marsh, which is on the edge of the Project zone, and from the Basibasy ponds.

In spite of the success of the molluscicide treatments, the *B. liratus* are bound to spread rapidly once more. A more detailed study of their potential for becoming infested and of the role which they might possibly play in transmitting *S. haematobium* should be carried out, but in the meantime we feel that it is more prudent to restrict their spread as much as possible.

Thus, one of the essential factors in the prevention of schistosomiasis in the Lower Mangoky is the continuation of the malacological surveys. Special attention should be given to the new habitats and to the areas of water which, for one reason or another, might undergo a change in their biotope or in the type or degree of frequentation.

IV.3. The topographical element

Because of the catastrophic floods in 1969 and 1970 and the protective work which they entailed, the development of new land by the Samangoky has been interrupted and it is not yet known when it will be resumed. At present there is little chance of new foci of transmission being created. It is therefore a very appropriate time for consolidating the results achieved during the Mangoky Project.

In the future, the opening up of new land to the North and North-West of Ambahikily presents little danger because of the salinity of the soil. On the other hand, the same will not apply to the left bank of the

Kitombo which, together with the Andranolava marsh, already provides an excellent habitat for *B. obtusispira*. Consequently, it will be necessary to avoid creating reservoirs and to supervise the setting up of the new villages.

V. Continuation of the anti-schistosomiasis campaign in the Lower Mangoky

Despite a considerable improvement in the epidemiological situation, it is obvious that the campaign against schistosomiasis in the Lower Mangoky will have to be continued for many years yet.

The programme for this period of consolidation ought to include:

- the tracking down and treatment of the latecomers and of all the new immigrants;
- post-treatment examinations of the patients who have been treated;
- increased health education of the population, together with attempts at making the farmers stay in one place for longer;
- continued regular malacological surveys in all the dangerous areas of water and in those which will be formed in the area when the new development work is carried out;
- chemical destruction of intermediate hosts which reappear or are reintroduced into the area;
- finally, supervision of the new irrigation systems which are being planned.

This work must be carried out by a team of Malagasy technicians trained and set up by the Mangoky Project. There is available for them equipment, materials, chemicals and a detailed programme of work left at the Tanandava Epidemiological Centre by the Swiss Technical Co-operation Department. If this team were properly supported by the Malagasy Ministry of Public Health and by the Samangoky Mixed Management Company, it should be able to make a final consolidation of the results achieved during the period of attack. The following section gives an indication of the economic and social consequences of failure, and this must at all costs be avoided.

VI. Profitability of the Mangoky Project

The total cost of the operations in the anti-schistosomiasis campaign carried out in the Lower Mangoky by the Malagasy and Swiss teams amounts to FMG 83,000,000 (1.27 million Swiss Francs or US$ 320,000). This figure can be broken down in the following way:

		FMG	%
Ambilhar and adjuvants		550,000	0.66
Application of chemotherapy		6,355,000	5.25
Frescon		2,800,000	3.37
Application of the molluscicide		1,920,000	2.31
Vehicles		10,150,000	12.23
Swiss technical personnel		38,350,000	46.20
Malagasy technical personnel (approx.)		5,700,000	6.88
Infrastructure and operating costs		6,180,000	7.44
Research expenditure		2,660,000	3.20
Cost of processing the results		4,435,000	5.34
Organisation and experts		5,900,000	7.11
	Total	83,000,000	99.99

This gives:

- cost per annum FMG 16,600,000 (254,000 Swiss Francs)
- cost per person protected FMG 1,660 p.a. (25.4 Swiss Francs)
- cost per hectare irrigated FMG 6,640 p.a. (101.6 Swiss Francs)

It should be noted that the cost of the operations could have been reduced by half if it had not been necessary to call upon expatriate technicians and experts to carry out some of the work.

In view of the experience acquired, and within the framework of a similar project in Madagascar, we estimate that the cost of the operations would have to be fixed at about FMG 1,000 p.a. (Swiss Fr. 15.3) per person protected and FMG 4,000 p.a. per hectare irrigated (Swiss Fr. 61.2). The cost of the consolidation phase has been estimated at FMG 8,210,000 (Swiss Fr. 125,600 or US$31,600) p.a. This figure can be broken down in the following way:

– Technical personnel		FMG	3,000,000
– Vehicles		FMG	1,700,000
– Operating costs		FMG	800,000
– Ambilhar and adjuvants		FMG	110,000
– Frescon		FMG	2,600,000
	Total	FMG	8,210,000

This gives:

- cost per person protected FMG 821.00 (Swiss Fr. 12.60)
- cost per hectare irrigated FMG 3,284.00 (Swiss Fr. 50.30)

One might also speculate as to what the epidemiological situation would have been in the Lower Mangoky with regard to vesical schistosomiasis, had the Project not been carried out.

The extrapolation of the results of our systematic examinations gives the following situation for 1972:

	Number of inhabitants	% infection	Number of persons infected
Sub-zone No. 1	905	11.7	105
Sub-zone No. 2	6,010	30.0	1,803
Sub-zone No. 3	1,951	52.7	1,028
Sub-zone No. 4	1,849	68.2	1,261
Sub-zone No. 5	765	53.9	412
Sub-zone No. 6	793	33.2	263
	12,273	39.7	4,872

Taking into account the development of the Ambahikily and Tsaramandroso foci of infection, the prevalence of *S. haematobium* in the Samangoky area would probably have tripled from 1966 to 1972.

An identical extrapolation relating to the 10,551 people who emigrated from the area during these five years gives a figure of 1,498 infected people who left the area after becoming infected.

As the analysis of our medical results by computer has not yet been completed, it is difficult to give an approximation for the economic deficit linked with the existence of these cases of schistosomiasis. However, as an indication, it can be seen that if 35 % of workers earning FMG 130 per day are absent for 50 days in the year because of their illness, the losses would be FMG 11,245,000 p.a. (Swiss Fr. 172,000), i.e. about FMG 6,500 per worker (Swiss Fr. 99). From another angle, assuming that half the costs of the Mangoky Project relate to the chemotherapy given to the 2,799 cases of schistosomiasis treated, a figure of FMG 14,826 (Swiss Fr. 2.27) per treatment is obtained. Under these conditions, had the same operation been started in 1972, it would have cost 31% more.

Finally, in order to put into perspective the importance of supervising the plans for the irrigation systems when carrying out the anti-schistosomiasis campaign, it must be pointed out that the formation of the Ambahikily and Tsaramandroso foci of infection could easily have been avoided, and this would have resulted in a saving of approximately 15 million FMG solely in treating the cases of schistosomiasis.

VII. Conclusions

The campaign against schistosomiasis carried out by the Swiss/Malagasy team over 5 years in the Samangoky irrigated area has raised the following essential points:

The key role played by the irrigation of new land in the spread of *S. haematobium*: creation of a focus of transmission where the disease develops to what can be called epidemic proportions, and rapid increase in the prevalence of this parasitic disease in the areas which have thus been developed.

The prevention and control of schistosomiasis in the irrigated areas which are being developed is now possible if the various methods of schistosomiasis control are applied simultaneously: mass chemotherapy, destruction of the intermediate hosts by molluscicides, health education of the population and supervision of the planning of the irrigation system.

Despite the range of major intolerance symptoms, it is quite possible to carry out Ambilhar treatment and it is effective. Side effects are less common than expected and neuro-psychiatric disorders can be more or less eliminated if a specific procedure for carrying out the treatment is carefully laid down and if the patients are properly supervised. Provided that the rules for treatment are strictly applied, doctors can forget their psychosis about neuro-psychiatric disorders and the problems of cardiac repolarisation, and in any case they must try not to convey their fears to their patients.

Undoubtedly the distribution of Ambilhar tablets morning and evening for 5 to 7 days necessitates good organisation and a certain amount of discipline on the part of the patients, but above all there must be an atmosphere of confidence between the local people and the treatment teams. This confidence cannot be built up by long educational lectures, but by close and permanent contact between the inhabitants of the villages and the members of the Health Department.

As in other experiments carried out all over the world, Ambilhar has confirmed its high degree of effectiveness, the recovery rate being over 97 % after one single course of treatment.

The use of Frescon to destroy the intermediate hosts of vesical schistosomiasis has proved extremely useful. However, various methods of application had to be developed for various situations.

Although we were unable to achieve a reduction in the number of contacts with infected water and in the contamination of the water by excreta during the Mangoky Project, the rates of participation at the various examinations and treatment operations demonstrate quite clearly what can be achieved if the population is educated and informed, and also shows what might have been achieved had there not been so much migration among the population.

Supervision of the development of the irrigation systems is one of the surest and most profitable aspects of the anti-schistosomiasis campaign. It must be carried out as early as possible in the planning stage, at a time when it is still possible to make changes which do not interfere with the cost of the Project, or at least only to a limited extent. We are convinced that if the recommendations resulting from the experience acquired during the Mangoky Project are followed, the Samangoky should be able to restrict the likelihood of the reintroduction and spread of vesical schistosomiasis in the irrigated sectors which are being developed.

Although it is still fairly expensive to carry out mass chemotherapy and to apply molluscicides, the cost of an anti-schistosomiasis campaign in an irrigated area can be considerably reduced if it is properly organised.

The first step in organising such a campaign must be to carry out a complete epidemiological investigation before the development work begins. In fact, it is not until the results of this investigation have been obtained – prevalence of the disease, distribution of the intermediate hosts, identification of the existing or potential foci of transmission, survey of the movements of the inhabitants and of their customs, study of the irrigation plans and administrative and health infrastructure, etc. – that any satisfactory plan for the campaign can be drawn up. This plan has to take into account a great many factors, the most important of which are, in our opinion:

- Considerable understanding and good collaboration between, on the one hand, the administrative authorities and the technical personnel in the area and, on the other hand, the Health Department.
- The availability of sufficient facilities, i.e. equipment and technical personnel, to carry out an attack phase (case-finding and treatments) in as short a time as possible.
- Gaining the confidence of the populations and educating them in ways suitable to the rural background of the tenant farmers. This depends on the Development Company providing adequate facilities to attract tenants and encourage them to settle.
- The use of local staff; their lack of experience can be overcome by considerable specialisation in the work. Because of the price of labour in these zones of endemic disease, it is more profitable to use a large number of workers to carry out specific and limited tasks, rather than to use a smaller number of highly qualified technicians whose very high salaries considerably increase the cost of the operation. During the attack phase of an anti-schistosomiasis campaign, a project leader with a broad professional background,

living permanently on the spot, is in our opinion more effective than a large number of temporary experts.

- The setting up of a health infrastructure which is adapted to the economic expansion anticipated as a result of developing a modern irrigated cultivation system, and the integration of the anti-schistosomiasis campaign department in a public health programme which is also adapted to the local conditions.

As the Mangoky Project was carried out under extremely difficult conditions – lack of preliminary epidemiological investigation, organisational planning carried out on the spot while the work was in progress, minimal health and road infrastructures, catastrophic floods in 1969 and 1970, etc. – it is quite justifiable to assume that an anti-schistosomiasis campaign carried out in a similar region could achieve better results and even more satisfactory profitability.

Control of schistosomiasis is a long-term undertaking. Although the supervision of the irrigation systems, the education and improvement of the standard of living of the inhabitants and the radial expansion of the anti-schistosomiasis campaign are bound in the long term to reduce the control measures and even to eliminate them altogether, the fact nevertheless remains that there must be a long consolidation and maintenance phase following the attack phase. In order to avoid disappointments, and even catastrophes, they must be taken into account and every effort must be made to guard against them before a campaign is organised.

Even after a complete analysis of our results, it will be difficult to prove with even more detailed figures that an anti-schistosomiasis campaign project is profitable. We are not the only people to be firmly convinced of the advantage there is, both on the economic and on the human level, in restricting the spread of schistosomiasis in the world. With the new methods of control, the arguments of the sceptics are weakening more and more, although one still remains, which is a formidable argument, even although quite devoid of human feeling: the abundance of labour in zones of endemic disease enables the development companies to avoid a drop in yield in the cultivation of their crops. Despite this, no one can dispute the fact that, in the long term, the role of schistosomiasis as a brake on the economy, and thus the profitability of controlling it, will become of increasing importance. We do not in any way presume to think that our project has opened up the way to eradicating schistosomiasis. It was simply aimed at proving that it is possible to prevent it and control its spread. The methodology of this Project can now

be directly applied to other newly-developing irrigated regions of Madagascar and Africa where it can be used as a model.
On the other hand, although some of the aspects of the Project can be used as working bases, other methods, other solutions and other organisations still have to be found.

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