

attention to the new Rahad scheme, especially Mr Rashed Bahar, Mr Hushang Rafatjah, Dr Rafique Khan, Dr Farouq Partow, and the late Dr A. H. Taba. The close cooperation from the staff of the Rahad Corporation was appreciated, especially that of the Director, Mr M. Beliel. Much of the credit for improvements in the original strategy must be given to our scientific advisers who attended the three Scientific Advisory Group Meetings of 1979, 1981 and 1983, especially Dr Andrew Davis of the World Health Organization in Geneva. This report is dedicated to the memory of the late Dr Osman Ahmed Zubeir who initiated the schistosomiasis control effort in the Rahad Zone in 1980, and special credit is given to all of the project employees who worked so faithfully with him and his successors in this programme, aimed at better health for all the residents of the Rahad Agricultural Scheme.

#### References

Amin M. & Fenwick A. (1977) The development of an annual regime for bilharzia snail control in the Gezira

irrigated scheme of the Sudan. *Annals of Tropical Medicine and Hygiene* 71, 205-215.

Amin M., Fenwick A., Teesdale, C. H. et al. (1981) The assessment of a large scale snail control programme over a 3 year period in the Gezira irrigated area of the Sudan. *Annals of Tropical Medicine and Parasitology* 76, 415-424.

Benedict P., Ahmed H. A., Ehrlich R. et al. (1982) Sudan, the Rahad Irrigation Project, Project Impact Evaluation No. 31 US Agency for International Development, Washington DC.

Brittan S. (1982) A very painful world adjustment. *Foreign Affairs* 16, 535-550.

Choudry A. W. (1975) The results of five years of snail control at Ahero Pilot Scheme, Kenya. *East African Medical Journal* 52, 573-577.

El Din M. El A. (1975) *The Human Factor in the Rahad Project Area*. Ministry of Agriculture, Food and Natural Resources, Khartoum, Sudan.

Evans A. C. (1983) Control of schistosomiasis in large irrigation schemes by use of niclosamide. *American Journal of Tropical Medicine and Hygiene* 32, 1029-1039.

Farooq M., Hairston N. G. & Samaan S. A. (1966) The effect of area-wide snail control in the endemicity of bilharziasis in Egypt. *Bulletin of the World Health Organization* 35, 369-376.

Jobin W. R. (1979) Cost of snail control. *American Journal of Tropical Medicine and Hygiene* 28, 142-154.

Teesdale C. H. & Amin M. A. (1976) A simple thick-smear technique for the diagnosis of *Schistosoma mansoni*. *Bulletin of the World Health Organization* 54, 703-705.

## Protection of Sudanese irrigation workers from schistosome infections by a shift to earlier working hour:

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#### Summary

Although schistosomiasis is an important occupational hazard for irrigation workers in Central Sudan, few measures have been found to protect them, short of abandoning the work. In an attempt to reduce their exposure to the large numbers of schistosome cercariae encountered in the water at midday, a group of Gezira canal cleaners were shifted to early morning working hours after being cured of their infections. They left the water each day at 10.00 hours, working from the canal banks thereafter. At the end of 6 months the prevalence of infections with *Schistosoma mansoni* was much lower in this group than in a similarly treated group with normal working schedules, indicating a practical way to protect irrigation and agricultural labourers.

#### Introduction

In the unlined earthen irrigation canals of the vast Gezira-Managil scheme on the Blue Nile River in Central Sudan, almost 4000 men are employed in manual removal of aquatic weeds and these men have become seriously infected with schistosomiasis. Gradual intensification of irrigation after construction of the additional reservoir at Roseires on the Blue Nile River in 1965 resulted in the addition of other crops after the original agricultural rotation of cotton and sorghum in the Gezira, leading to increased weed problems in the canals. The weeds increased largely because of winter irrigation of wheat and elimination of the long dry period after the cotton crop. Heavier weed infestations provided more food

for aquatic snails and with the longer growing season the snail populations increased dramatically. The unfortunate canal cleaners became increasingly enmeshed in the schistosome transmission cycle because they worked precisely in those canals where weeds and snails were most numerous. Due to high temperatures and the geometry of the canals the men wore little clothing and worked most of the day immersed in the water up to their waists (Figure 1). These conditions produced an ideal setting for continuous and intense transmission of schistosomes in this occupational group resulting in serious disease.

The heavy infections had a clear impact on the men's health and caused measurable disability in those who remained alive and in the work force (El Karim et al. 1980). However the cleaning of the canals could not be abandoned without causing severe disruption in general agricultural productivity, in local food supply, and in the national economy. The Gezira-Managil scheme is the principal source of cotton and foreign exchange for the Sudan and supplies most of the food and income for several million people in the central region. Although the choice between health and food normally favours the latter, the Ministry of Irrigation recognized its responsibility to minimize the health risks to their workmen. Thus in addition to giving them extra 'hazard pay', attempts were made to find practical alternatives for controlling the weeds, including use of machinery, chemical herbicides and herbivorous fish.

Inasmuch as none of the research efforts had resulted in economically feasible alternatives to manual weeding, it was the purpose of this

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Figure 1. Men working at removal of aquatic weeds from minor canals in Gezira Irrigation Scheme, 1983.

joint study between the Ministries of Agriculture, Irrigation and Health to determine whether exposure to infection could be significantly reduced by modifying the men's work procedures without interfering with fulfillment of their basic tasks. The first measure to be evaluated was based on the pronounced daily periodicity of the release of schistosomes from the infected snails. This phenomenon was documented for *Schistosoma mansoni* from the Americas and from other parts of Africa (Rowan 1958, Pitchford & Visser 1962).

The schistosome larvae which attack man, called the cercariae, have a short life-span after emerging from the snail and their peak rate of emergence occurs near midday. They continue infective for less than 12 hours after emergence. Although water temperature has some influence, their emergence from the snail is controlled primarily by sunlight, resulting in the daily peak in shedding at noon (Valle *et al.* 1973). The first cercariae are usually detected at 10.00 hours and by afternoon the parasites accumulate in the water in large numbers, making this the most dangerous time of day for people to become infected. As the shedding

stops at sundown the numbers in the water decline thereafter and no infective cercariae remain in the water by sunrise. Thus it was proposed that the canal cleaners shift their normal working schedule, usually 09.00 to 14.00 hours, to an earlier shift in which they leave the water by 10.00 hours. This involved some shortening of the work day but this would be acceptable if significant protection were provided by the earlier hours.

#### Materials and methods

Two crews of 10 canal cleaners each were selected from each of five subdivisions of the Ministry of Irrigation near Wad Medani, a total of 100 canal cleaners (Figure 2). The crews were deliberately composed of men who had been working as canal cleaners for several years. In December 1982 they were all treated with 40 mg/kg of praziquantel, split in two doses, following breakfast and lunch, after delivering fresh urine and faecal specimens for microscopic examination. A 45-mg portion of the faeces was examined by the modified Kato method and 10 ml of the urine were

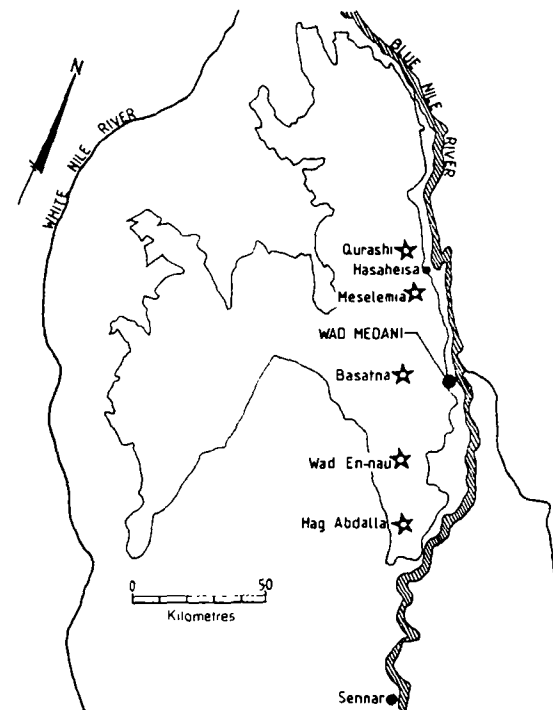


Figure 2. Location of work crews in Gezira Irrigation Scheme.

examined after centrifugation. A brief physical examination and questionnaire were given by a physician prior to administration of the praziquantel.

The engineering supervisors in each subdivision designated their two crews by A or B and provided a list of their names and ages prior to the examinations. After the examinations and treatment the supervisors were instructed to shift crew A to the early hours and continue crew B working in the water after 10.00 hours. Adjustments were made in starting times to roughly equalize the hours both crews were in the water. The men were also instructed to take their afternoon baths in major canals without heavy weed-infestations or in tapwater, if possible.

A month after the crews started the new schedule, field inspections were made on an

irregular schedule to determine whether the crews understood the instructions and followed them correctly. In Meselema subdivision they were not doing so and these two crews were dropped from the study, leaving eight crews.

Re-examinations were conducted 3 months, 6 months and 12 months after treatment, without further chemotherapy. Food rations were given at the time of the examinations to encourage continuing participation.

#### Results

At the initial, pretreatment examination virtually all the men were infected with *S. mansoni* but none had *S. haematobium* (Table 1). The intensity of their infections as indicated by the number of schistosome eggs per gram of faeces

Table 1. *Schistosoma mansoni* infections in Gezira canal cleaners before and after treatment. Group A worked early schedule while group B worked normal schedule

Irrigation subdivision	Group	Mean age (years)	Pretreatment		3 months		6 months		12 months	
			Prevalence*	Egg count (eggs/g)	Prevalence*	Egg count (eggs/g)	Prevalence*	Egg count (eggs/g)	Prevalence*	Egg count (eggs/g)
Basatna	A	45	6/9	141	2/9	118	9/9	48	—	—
	B	39	11/11	213	2/11	69	4/11	261	—	—
Hag Abdullah	A	34	10/10	183	3/6	65	6/10	55	1/3	80
	B	40	10/10	169	6/10	102	8/9	50	3/7	41
Wad El Nau	A	39	9/11	114	4/11	41	2/9	26	4/10	28
	B	32	11/11	214	4/11	72	8/11	30	7/10	19
Qurashi	A	40	11/13	222	1/13	93	4/10	20	—	—
	B	42	9/11	168	0/10	0	3/7	126	—	—
Total for group	A	39	36/43	165	10/42	63	16/38	38	5/13	34
	B	38	36/43	191	12/42	85	23/38	49	10/17	24
Totals		39	76/86	178						

\* Infected/examined.

† Geometric mean of egg count in eggs per gram of faeces among infecteds.

was moderately high with a geometric mean of 178 eggs/g for the infected persons. The intensity of infection was uniform for all ages from 20 to 60 years old, and showed a slight increase with the number of years of employment as a canal cleaner, although the increase was not statistically significant. In both the A and the B groups the mean ages of the men, the prevalences and the intensities of infection were comparable (Table 1).

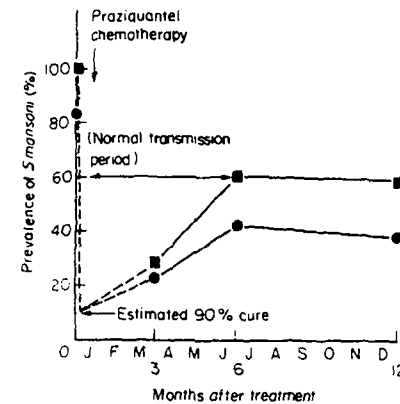


Figure 3. Prevalence of *Schistosoma mansoni* infection in canal cleaners with early work schedules (●) and with normal work schedules (■) in the Gezira, 1983.

The split dose of praziquantel usually gives 90% cures in these men, but several were infected with *S. mansoni* at the 3-month examination and by 6 months about half of them were infected (Figure 3). The intensities

of infection were low, about one-eighth the pretreatment level (Table 1). The men in group A, who worked early in the morning, had a prevalence of 44% at 6 months, and a geometric mean egg count of 38 eggs/g. This was significantly less than the prevalence and intensity of infection in group B which were 60% and 49 eggs/g, respectively. The difference in prevalence between the two groups remained constant for the last half of 1983, indicating that most transmission occurred from January to July (Figure 3).

An estimate of the difference in total cercarial exposure of the two groups was made by comparing an index derived from multiplying prevalence by geometric mean egg count for each group. This index is the 'contamination potential' developed in St Lucia as an overall measure of community transmission (Barnish *et al.* 1982). In group B the index was almost twice the index in group A, after 6 months (Table 2).

Although the change in work schedule produced a measurable decrease in all parameters of infection in group A, there was a significant amount of re-infection. Undoubtedly some of this was due to contact with water during activities unrelated to their occupation as canal cleaners. From the questionnaire it was learned that after working hours most of them used canals near their homes for bathing and other domestic uses, usually in the afternoon when there was a significant risk of infection. The rapid re-infection of these men indicated that acquired resistance to schistosome infections, even if present, endures for less than 3 months.

Table 2. Comparison of re-infections in canal cleaners 6 months after treatment with those in tenant farmers and labourers in other agricultural occupations

6 months after treatment	Tenant farmers from Angado Village	Agricultural labourers from camps	Canal cleaners	
			Early	Late
Prevalence (x)	12%	52%	44%	60%
Geometric mean of egg counts (y)	51	81	38	49
Approximate contamination Potential (x times y)	600	4000	1700	3000

### Discussion

The moderate egg counts before chemotherapy confirmed previous studies in which canal cleaners who continue working for several years excrete moderate numbers of eggs despite continuous exposure to new infections (El Karim *et al.* 1980). However these observations must be tempered by the probability that those who developed serious disease may have died or otherwise dropped out of the work force. In our study the canal cleaners had significantly fewer eggs in their faeces than did the group studied in 1980.

As canal cleaners work in those canals where snails are most numerous, it is inevitable that they cause heavy infections in these snails and are thus a serious source of transmission for other persons downstream of the canal being cleaned. The treatment and protection of canal cleaners is thus a vital public health measure as well as an urgent necessity for the men themselves.

The final infection load in the canal cleaners with the late work schedule was much higher than that in similarly treated tenant farmers in a typical Gezira village, but nearly the same as that found in two small camps of treated agricultural labourers (Table 2) (Kardaman *et al.* 1983). Like the agricultural labourers, most of the canal cleaners did not have safe water supplies in their homes, resulting in considerable exposure to infested water, especially during bathing (Fenwick *et al.* 1982).

Further research on the precise time of cercarial emergence in the morning could easily define the safe times of day for water contact, resulting in precise guidelines for these workers which would protect them

completely from occupational exposure. Such information would also be of great value for general health education and for application by all irrigation and agricultural workers, as well as research personnel, who are regularly in contact with the irrigation water.

This study confirms previous indications that heavily infected people who are cured with drugs but remain exposed to cercariae may quickly become re-infected (Kardaman *et al.* 1983).

### References

- Barnish G., Jordan P., Bartholomew R. K. & Grist E. (1982) Routine focal mollusciciding after chemotherapy to control *Schistosoma mansoni* in Cul de Sac Valley, Saint Lucia. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 76, 602-609.
- El Karim M. A., Collins K. J., Brotherhood J. R. *et al.* (1980) Quantitative egg excretion and work capacity in a Gezira population infected with *Schistosoma mansoni*. *American Journal of Tropical Medicine and Hygiene* 29, 54-61.
- Fenwick A., Cheesmond A. K., Kardaman M. *et al.* (1982) Schistosomiasis among labouring communities in the Gezira irrigated area, Sudan. *Journal of Tropical Medicine and Hygiene* 85, 3-11.
- Kardaman M. W., Amin M. A., Fenwick A. *et al.* (1983) A field trial using praziquantel to treat *Schistosoma mansoni* and *Schistosoma haematobium* infection in Gezira, Sudan. *Annals of Tropical Medicine and Parasitology* 77, 297-304.
- Pitchford R. J. & Visser P. S. (1962) The role of naturally infected wild rodents in the epidemiology of schistosomiasis in the Eastern Transvaal. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 56, 126-135.
- Rowan W. B. (1958) Daily periodicity of *Schistosoma mansoni* cercariae in Puerto Rican waters. *American Journal of Tropical Medicine and Hygiene* 7, 374-381.
- Valle C. M., Pellegrino J. & Alvarenga N. (1973) Rhythmic emergence of *Schistosoma mansoni* cercariae from *Biomphalaria glabrata*: influence of temperature and light. *Revista do Instituto de Medicina Tropical de Sao Paulo* 15, 195-201.

## The lungfish *Protopterus annectans* (Owen) as a biocontrol agent against schistosome vector snails

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### Summary

Laboratory and small-scale field experiments have been carried out to study the malacophagous capabilities of the lungfish *Protopterus annectans*.

When individual fish were offered a range of aquatic fauna in aquaria in the laboratory only snails and dragonfly larvae were consumed. When offered a choice, the fish appeared to prefer snails, with larger individuals (up to 300 mm) capable of consuming up to 200 snails per day.

The introduction of five *P. annectans* into a small concrete pond (diameter 5 m) with an established fauna and flora resulted in a reduction in the snail population of over 90% within 2 weeks. This reduction was maintained over a 4-month observation period suggesting that in habitats in which the lungfish can survive, there is a possibility of significant snail control.

### Introduction

The Blue Nile Health Project embarked in 1982 on an integrated control strategy against malaria, schistosomiasis and diarrhoeal diseases in a small area within the Gezira Irrigated Area in Sudan. From 1984-1989 it is planned to offer anti-schistosomal chemotherapy to all residents of the scheme in an attempt to reduce the prevalence of schistosomiasis from over 50% to below 10%. Concurrently there will be a programme of focal snail control using the molluscicide niclosamide applied regularly to water contact sites.

Once the mass chemotherapy campaign is completed the BNHP will be faced with the task of keeping the prevalence of schistosomiasis at a reasonably low level. The large-

scale recurrent use of molluscicides is expensive and so the project is exploring alternative, cheaper methods of snail control of which biological control is the most promising. In this paper the current status of the malacophagous fish *Protopterus annectans* is considered and some further laboratory and field results reported.

A number of fish are reported to eat snails (*Serranochromis* spp., *Astatoreochromis allu-auli*, *Tilapia melanopleura* and *Clarias* spp.), but their efficiency in field situations is still doubtful (Ferguson 1978, McCullough 1981). In Sudan, Mahdi & Amin (1966) reported that *P. annectans* eat snails by the thousands and might therefore be used to control schistosomiasis transmission in certain habitats.

Most snail habitats contain aquatic organisms which may also serve as food for *P. annectans*, e.g. insect larvae, fish fry, tadpoles (Lull 1945, Graham 1929, Worthington 1942, Sandon & El Tayeb 1953). Some laboratory and field experiments were therefore designed to determine food preferences of *P. annectans* when offered a choice.

### Materials and methods

#### THE SOURCE OF FISH

*P. annectans* (Owen) is known in Sudan as the Samak el Teen (mudfish) or Um Kurv, and is common in seasonal waterbodies in the Western Sudan. It buries into the mud when the waterbody dries out and survives by sealing itself into a cocoon up to 0.5 metre underground until the new rains flood the stream. Fish were collected by catching them from the Khor Abu Habil in Kordofan, and by digging cocoons from the dry riverbed.