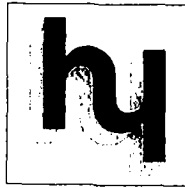
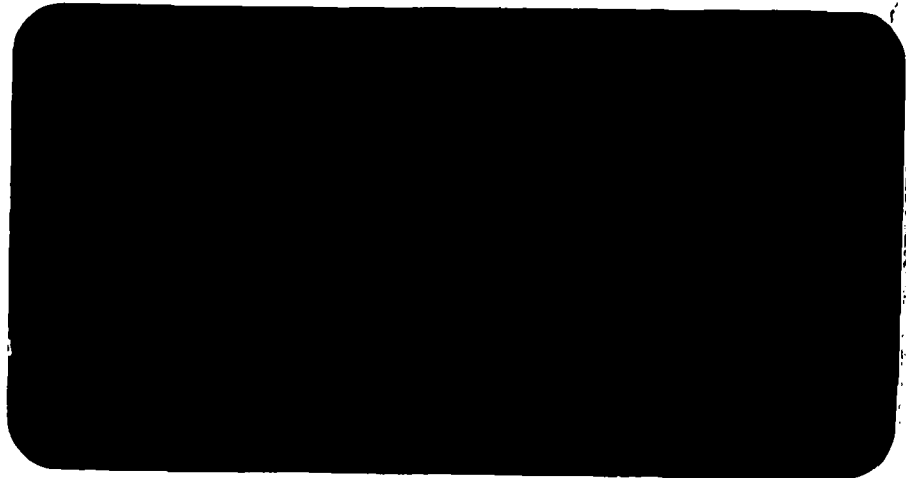


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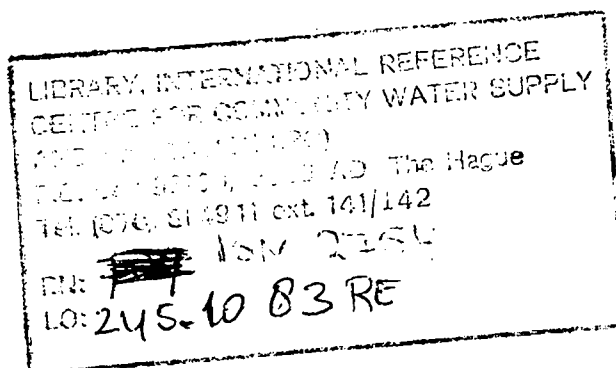
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# A review of the literature on schisto- somiasis and its control

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## INTRODUCTION

It is reported that schistosomiasis affects up to 200-250 million people, in much of the world's tropical and sub-tropical regions. The disease is common to both man and his domestic animals, and is second only to Malaria, in terms of the impact made by it on the economic and social development of whole populations.

Water plays a vital role in the complicated life cycle of the schistosomiasis worm, providing a medium for the transmission of the parasite, which eventually penetrates and lives in man. Studies have shown that as a result, irrigation schemes often become the focal point of the disease, which can reach endemic proportions. Despite control methods, the disease is becoming more prevalent, reflecting in particular, the increase in the number of reservoirs and canals, associated with new irrigation schemes.

The following review of the literature, describes the disease and the methods used to control it. Particular attention is paid to the types of engineering measures that can be built into irrigation schemes, in an attempt to reduce the risk of infection.

### 1 Life Cycle of the Parasite

Schistosomiasis in humans is caused by the infestation of the body, by blood flukes, of the genus schistosoma, three main species of which have been reported as habitual parasites of man (1).

Infections from several other types have been reported, but in the main they are regarded as animal parasites (2). The three types, namely schistosoma haematobium, Schistosoma mansoni and Schistosoma japonicum broadly share the same life cycle, although they have different species of intermediate host, and affect the human host in different ways.

A human infected by schistosomiasis has both male and female worms, which reside in blood vessels, and feed on the blood of the host. The parasites of S Haematobium (a urinary form of the disease) occupy blood vessels surrounding the bladder, whilst those of S Mansoni and S Japonicum occupy blood vessels around the bowel. The worms are paired, and the female lays eggs, one at a time, in the small blood

The cercaria carry large reserves of glycogen, and have a life expectancy of approximately 48 hours, during which time they must come into contact with the bare skin of their host. They spend this time swimming close to the water surface, often working their way to the surface and dropping back a short distance below. If contact with a host is made, the cercariae work their way through the skin, taking several minutes to achieve this, and shedding their tails in the process. From there, they proceed by the lymphatic system, to the heart and the lungs. On about the 15th day the schistosomules (as they are now known) reach the liver in large numbers, where they grow rapidly in the blood vessels. After about 30 days or more, they pass from there to the bowel or bladder sites where the male and female worms pair, and begin to reproduce. The mean life expectancy of the worm in the human body is in the order of 3.3 years<sup>(3)</sup>, however, since individuals are usually open to re-infection, the disease can be lifelong.

## 2 Geographical Distribution of Schistosomiasis

Details of the geographical distribution of the three main types of schistosomiasis are given by Jordan and Webbe<sup>(2)</sup> and others. *S haematobium* is reported from many countries on the African continent including those on the north coast, central regions, the east coast and parts of the west coast. It is also present in parts of the near east and India. *S mansoni* affects many of the same regions including central Africa, the east coast and the near east, but is also endemic in parts of South America. *S japonicum* is present only in regions of the Far East, affecting many parts of China, Japan, the Philippines and other islands. Figures 2 and 3, taken from the Ross Institute Bulletin No. 6<sup>(1)</sup>, show diagrammatically the geographic distribution of schistosomiasis.

## 3 Clinical Effects in Man

Manson-Bahr and Apted<sup>(3)</sup>, state that a schistosomal infection in man follows four stages, namely: invasion, maturation, established infection and the late stage. The invasion stage corresponds to the penetration of the skin by the cercariae, and is marked in some groups of people by itchy papules on the skin, otherwise known as "swimmers itch". This they report, lasts no longer than three days,

lacking, and even where they do exist, may be adequate. This ensures that a proportion of parasite eggs are washed by rain into water bodies where they hatch, thereby maintaining the risk of infection or re-infection when contact with the water is made.

Fenwick<sup>(5)</sup>, however, states that factors other than social and economic ones are important, and quotes examples from the Gezira and Rahad irrigation schemes in the Sudan. Prevalence of schistosomiasis has risen in thirty years from 20% to over 50% on the Gezira scheme, despite considerable improvements in water supply, sanitation and general living conditions. The Rahad scheme which has a poor water supply and has no latrines, has a very low level of prevalence. Additional factors are discussed in more detail later.

Jordan and Webbe<sup>(2)</sup> state that schistosomiasis is closely related to the construction of new irrigation schemes, providing in many cases a completely new aquatic habitat in which the intermediate host snails quickly colonise.

## 5 Environmental Constraints on the Schistosomiasis Cycle

### 5.1 Miracidia

Miracidia appear to be very tolerant to different environmental conditions. Jordan and Webbe<sup>(2)</sup> describe experiments performed by Webbe in which the effects of water velocities on the infection of aquatic snails were studied. He found that with large populations of miracidia of about 25 per snail, high infection rates were obtained even at water velocities in excess of 1 m/s. With low populations down to 1 miracidia per snail, high infection rates were still obtained with velocities in the range 0.2-0.5 m/s. Although miracidia are capable of self propulsion at a rate of about 2mm/sec it is reported that a flow of water aids their ability to scan whilst looking for a host.

Jordan and Webbe also report that the infection rate of snails by miracidia rises as temperature increases, up to the thermal death point of the snail. At the higher temperatures, however, the life span of the miracidia is reduced.

type of environment tends to retain water, and could provide the conditions to allow the snails to survive without permanent water.

WHO monograph 50 details the conditions under which the death of the snails is accelerated and these are: prolonged exposure, rapid fall of water level, absence of shade and low relative humidities. It also states that the eggs of all the molluscan hosts are extremely susceptible to drought.

Malek reports that dormancy of *S. mansoni* has been observed in snail hosts which are stranded out of water, and that this resumes development once the snail continues its aquatic life.

All snails which transmit schistosomiasis appear to show great tolerance to temperature variation, and are known to survive temperatures from a little above freezing to well above blood temperatures<sup>(4)</sup>. This is despite an optimum temperature for molluscs of between 22°C and 26°C. They are also tolerant of water quality, and Malek<sup>(6)</sup> states that in general the lethal limits of pH and salinity for snails, is beyond the range of artificially imposed variation.

In studies of the effects of water velocity on the behaviour of snails, Jobin and Ippen<sup>(7)</sup> found that aquatic snails prefer slow moving water. Using *Australorbis Glabratus* (an intermediate host of *S. mansoni*) they established that a velocity of between 20-30 cm/sec was sufficient to immobilize the snails, whilst a velocity of 60 cm/sec was required to dislodge the snails, from which they were unable to regain a footing. Strong seasonal variations in the population size, and the schistosome infection of aquatic snails are reported. Sviridov (21) presents the results of a study on two lakes in Zimbabwe, showing the population dynamics and schistosome cercariae shedding characteristics for both *Bulinus* and *Biomphalaria* snails. The data is reproduced in figures 4 and 5. Both snail species at both the sites studied, reached a peak in population at the end of the rainy season in April/May. This Sviridov comments, is probably due to the fact that water levels in the reservoir cease to fluctuate, and breeding conditions become ideal. Thereafter, the snail population declines, due to the onset of the cold winter months, and the falling water levels which tend to strand snails out

## 6 Control Methods

There appears to be four points in the schistosomia cycle, at which intervention with the view to control is possible. These are: the elimination of the host snails, prevention of cercariae contact with the human host, the prevention of parasite eggs reaching water bodies and the elimination of parasite worms in the human host.

### 6.1 Snail control

Jobin<sup>(8)</sup> maintains that the most promising methods of control, centre on the elimination of the host snails, since they form the "weak link" in the schistosoma cycle.

In support of this Buzo<sup>(9)</sup> reports on the findings of many control projects, from which it is evident that the most successful, almost invariably contain a snail control programme.

Jordan and Webbe<sup>(2)</sup> divide snail control measures into three categories, namely environmental control, chemical control and biological control. Environmental control measures are of particular interest to the engineer working with irrigation schemes, since many techniques aimed at reducing the snail populations can be incorporate at the design stage. These are discussed below.

#### 6.1.1 Environmental and engineering measures of control

##### (a) removal of water

WHO monograph 50<sup>(4)</sup> states that the most drastic change in the molluscan environment, that can be brought about, is the removal of water from their habitat. This is reported by Buzo<sup>(9)</sup> to be highly successful in interrupting the transmission of schistosomiasis, where naturally occurring swamps are eliminated by drainage or earth filling. Drainage is also important in both urban and rural situations, to eliminate or restrict breeding places for aquatic snails. The WHO (18) however, states that careful design and maintenance of the



(b) sluicing and flushing

The WHO (18) states that breeding of aquatic snails, occurs under conditions of moderate and stable flow. Furthermore, it has been observed that fast and turbulent flow can disrupt the snails sufficiently for reproduction to cease. Periodic flushing of canals can therefore be used to interrupt the breeding cycle by upsetting the stable stream conditions, particularly at the time of peak snail propagation. Flushing may be achieved by a manual operation of gates, or by automatic siphon structures, in either case, the excess water merely provides temporary storage. Although the WHO recommends this method as one for the control of aquatic snails, no information is given on its effectiveness.

(c) shoreline deepening

As stated in section 5.2 the host snails are known to live in shallow water, close to the banks or shores of canals and reservoirs. A cut and fill technique is, therefore, recommended by the WHO (18) to remove any extensive shallow areas in permanent water bodies. This has the effect of both shortening the shoreline, and reducing the number of emergent plants, both of which effect the snail habitat considerably.

(d) vegetation control

Aquatic vegetation is an important constituent of the snail habitat, providing both food and shelter. The WHO (18) recommend the removal of vegetation from reservoirs and canals, thereby creating an unfavourable environment for the snails.

(e) canal lining

Lining of irrigation canals can also reduce the prevalence of schistosomiasis, by creating unfavourable habitats for the host snails<sup>(2)</sup>. They allow greater velocities of flow without danger of scour, and if well maintained have little or no weed growth and organic matter on which the snails can feed. In practical terms, average water velocities of 30cm/sec can be easily

transmission of schistosomiasis almost immediately. A large number of chemical agents are in use for this purpose, which are chosen for their ability to kill not only the snails, but their eggs and the larval forms of the parasite. Other desirable characteristics of the chemical agents which are summarised by WHO monograph 50<sup>(4)</sup>, include: that it should be non-toxic to man, domestic animals and fish, it should be reasonably cheap and be easy enough to use by relatively unskilled personnel.

Amongst the large number of chemicals which are known to have a molluscicidal effect, the WHO (20) now lists four compounds which they regard as worthy of interest. These are Niclosamide, Trifenmorph, Sodium Pentachlorophenate and copper sulfate, and their properties are summarised in Table 1. Niclosamide (bayluscide) is now widely used throughout the world, it is lethal to snails, snail eggs and schistosome cercariae, but is non-toxic to man. It is reported to be reasonably persistent but not permanent, since it is degraded by sunlight into harmless organic chemicals. The main disadvantages, are its high cost and its lethal effect on fish and some other aquatic animals. Trifenmorph (Frescon) is an extremely effective molluscicide, being lethal for snails at very low concentrations. It has however little effect on snail eggs, and no effect on schistosome cercariae. The WHO (20) reports that trifenmorph is diminishing in use, to the point where it is no longer available from manufacturers except in large quantities. Sodium pentachlorophenate is highly effective against snails and snail eggs, and has been in use as a molluscicide for many years (1). The main disadvantage in its use, is that it has an irritant effect on snails which can temporarily drive them out of the water and allow them to survive. It is also an irritant to human skin, and is toxic to man if carelessly handled. Sodium pentachlorophenate usually requires long exposure times of up to 24 hours to be really effective, but has the advantage of being herbicidal, eliminating the need for vegetation clearance prior to treatment. Copper sulfate is another chemical which has been in use as a molluscicide for many years, it is effective against snails, but only moderately effective against snail eggs (1). The WHO (20) state that the main advantage of the copper compounds, are that they are continuously available, and carry a large amount of literature on their use. McCullough et al (24) states that the available molluscicides have effectively been reduced

transmission sites. If foci of snails are found, they are treated immediately by hand spraying of molluscicide.

Fenwick (26) reports that aerial spraying has been used to apply trifenmorph to the main, major and minor canals of the Gezira Scheme in the Sudan. Although snail numbers have been drastically cut in these canals, the transmission of schistosomiasis has relatively unchanged, since the field channels that were closed at the time of spraying, continued to act as transmission sites.

The WHO (19) report on recent developments into slow release bait formulations for molluscicides, which take the form of stable toxicant pellets which are attractive to and ingestible by the predatory snail. The chemical is mixed with an elastomeric substance giving a controlled release rate, and both niclosamide and trifenmorph have been used. Niclosamide seems to have an advantage over trifenmorph, since it also has a toxic effect on cercariae, at concentrations below that, which it is effectively molluscicidal. The WHO report that field trials to test the larvicidal effect, however, have not yet been performed. Results of tests have shown that the pellets are species specific, depending on the attractant used and are readily devoured by snails causing rapid death.

The WHO (19) state that the application of molluscicides should be timed for a maximum kill of snails, and that further treatment should be based on knowledge of the snail re-population potential and the parasite transmission pattern.

Despite drastic reductions in the numbers of aquatic snails after the use of molluscicides, Ritchie<sup>(16)</sup> and others have found that repeated treatment is essential, to prevent the re-establishment of the snail colonies after a short time. They point to several reasons for this, among them: poor chemical distribution, chemical dilution beyond a toxicity threshold and the re-introduction of the snails from outside the control region. The method of application of the molluscicide is therefore of great importance, and can require a larger labour input if "pockets" of inactivity are to be avoided completely. Lined irrigation canals are considered to be of great benefit in this respect, since the uniform cross section, and faster flow results in a more even distribution of the chemical, and a larger contact area

predators and competitors into the system. Among those which have been tried are other molluscs, fish, amphibia, birds and animals, all of which affect the snails in some way or other.

Most commonly, the harmless species which are introduced either feed directly on the snails, their eggs or their young, or compete for the food supply. The results from such surveys have shown that although initial laboratory tests show complete elimination of the host snails, these are never reproduced under actual conditions. Workers generally agree that predators and competitors have great initial success, but as the numbers of snails diminish, so too does the predators or competitors, until an equilibrium is reached.

Other forms of biological control are reported by Rosenfield<sup>(17)</sup>. Amongst those is the introduction on non-cercarial shedding snails. Rosenfield states that although many forms of biological methods have been tried, they are not used widely because of the difficulty in determining the most effective methods in the field. It is generally agreed that much more research effort is needed into biological aspects of control, before effective methods are found.

## 6.2 Prevention of human contact to schistosoma cercariae

The complete elimination of locally acquired schistosomiasis has been reported by Buzo<sup>(9)</sup>, where contact with open water has been made unnecessary, by the provision of a piped water supply. In the case quoted, however, the community was sited some ten miles from a reservoir, with apparently no local irrigation. Such schemes usually have communal stand pipes with spring loaded taps and properly constructed wash areas, where standing water is prevented.

Makura (21) reports on a study of human behaviour at known water contact points, in response to the provision of an alternative water supply with washing areas. Water contact was reduced by 50%, which was attributed mainly to a reduction by females involved in laundering, this being the largest single activity requiring water. Male children and men were least affected, and it is suggested that their contact with affected water through swimming and bathing, may actually have increased in response to the absence of females.

cropping practices are carried out, resulting in the extended use of irrigation canals.

Protective clothing of various types have been used, in an attempt to protect individuals who spend a large part of their day in contact with water, but in general they have been unsuccessful. Windrum<sup>(10)</sup> states that this type of clothing has been found to be too uncomfortable in the climatic conditions of most endemic regions.

### 6.3 Prevention of transmission

The prevention of the spread of schistosomiasis takes the form of good sanitation, whereby eggs from humans are prevented from reaching fresh water. Either pit latrines or septic tanks are commonly installed on irrigation schemes, however, Buzo<sup>(9)</sup> states that their effectiveness depends on good maintenance. Pit latrines have been abandoned in cases where maintenance has been poor<sup>(15)</sup>, and it is vitally important that the discharges from septic tanks which contain parasite eggs, do not find their way into drainage ditches or streams<sup>(9)</sup>.

Jordan and Webbe<sup>(2)</sup> state that an efficient disposal of human excreta would, in theory, result in a break of transmission of *S haematobium*. The WHO<sup>(20)</sup> states that although *S haematobium* infections are found in rodents, domestic pigs and monkeys, there is no evidence to suggest that they are true maintenance hosts and therefore, capable of sustaining the disease. On the other hand, much higher infection rates of *S. mansoni* have been found in animals, and Manson Bahr and Apted<sup>(3)</sup> report that *S Mansoni* infections from baboons have been known to pass on to humans. The WHO<sup>(20)</sup> however, states that *S Mansoni* infections amongst animals are usually found only in areas where the disease is endemic in man. Animals play an important part in the transmission of *S Japonicum*, as it is known to be a parasite of dogs, cats, rats, mice, cattle, pigs, horses, sheep, goats and other mammals<sup>(3)</sup>.

Even where sanitary measures could be used to control *S. haematobium* and possibly reduce *S mansoni* infections, Jordan and Webbe<sup>(2)</sup> state that the socio-economic conditions often preclude acceptable latrine

that 12% and 15% of patients were excreting live *S. Mansoni* eggs at three and six months post treatment, respectively.

The major problem with the anti-schistosomal drugs, with the exception of metrifonate, is the cost involved for mass treatment programmes. The results of a world survey (27) shows that in many affected countries, less than 0.5% of the national health budget is allocated for schistosomiasis research and control. Compared to this, the cost of a large treatment programme can be very large (20), and furthermore those receiving treatment more likely than not, will be open to re-infection.

The WHO (19) reports on four schistosomiasis control programmes which used chemotherapy alone, in an attempt to reduce both the number of people afflicted and the level of transmission of the parasite. In each case there was some success in reducing the prevalence of infection, but because it was not possible to treat the whole community, transmission of the parasite was little affected, and there remained a risk of re-infection.

#### 6.5 Choice of control methods

There appears to be few guide lines on the type of control methods which should be adopted, although the WHO (19) does consider some of the factors involved. For example, they state that mollusciciding is to be favoured where the volume of water to be treated per person at risk is small. It is, therefore, suitable for small reservoirs and ponds, and on irrigation schemes where the flow of water in channels can be controlled. In situations where schistosomiasis is prevalent over large areas of a country, the WHO recommend a control method which would reduce the prevalence and severity of the disease, without greatly affecting the transmission. Environmental methods are considered by the WHO for their low maintenance costs, once capital works have been completed.

In general the WHO (19) favours a combined control approach involving two or more different methods, which they say is likely to produce a definite and more rapid control of schistosomiasis. They quote an example where a combination of mollusciciding and chemotherapy can cause a very rapid drop in the incidence, prevalence and intensity of infection.

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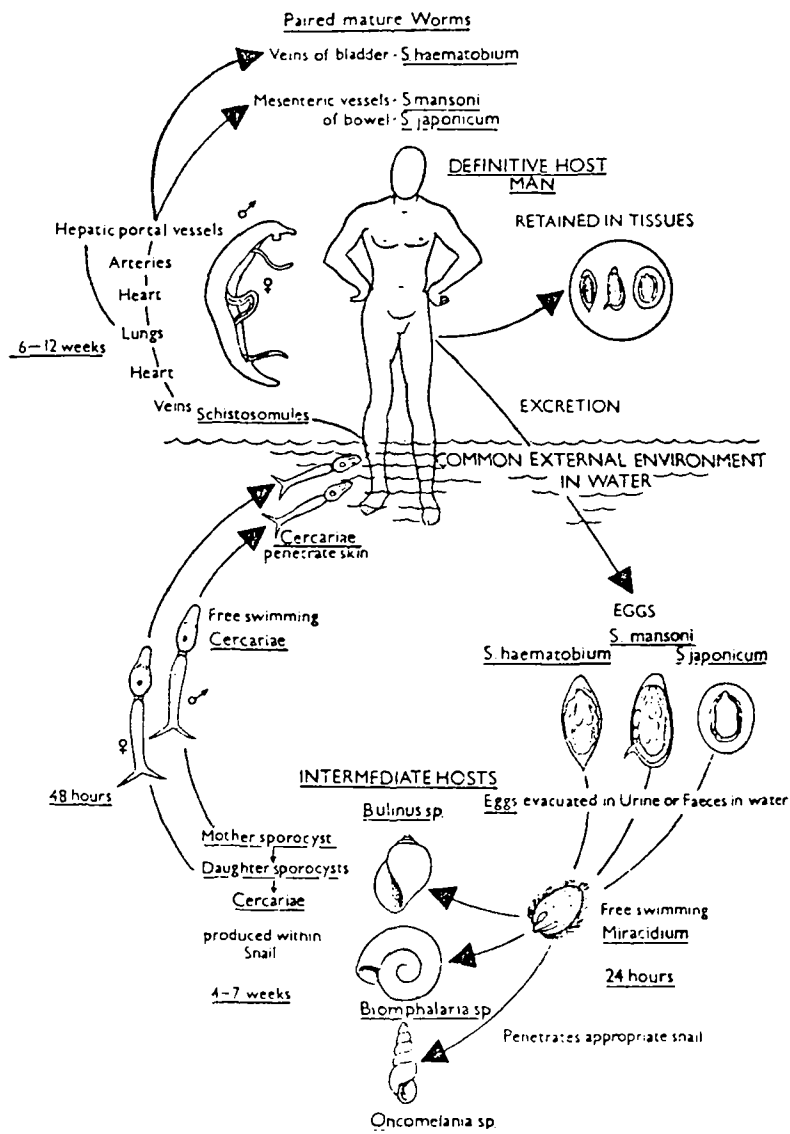


FIG. 1. The Life-cycle.

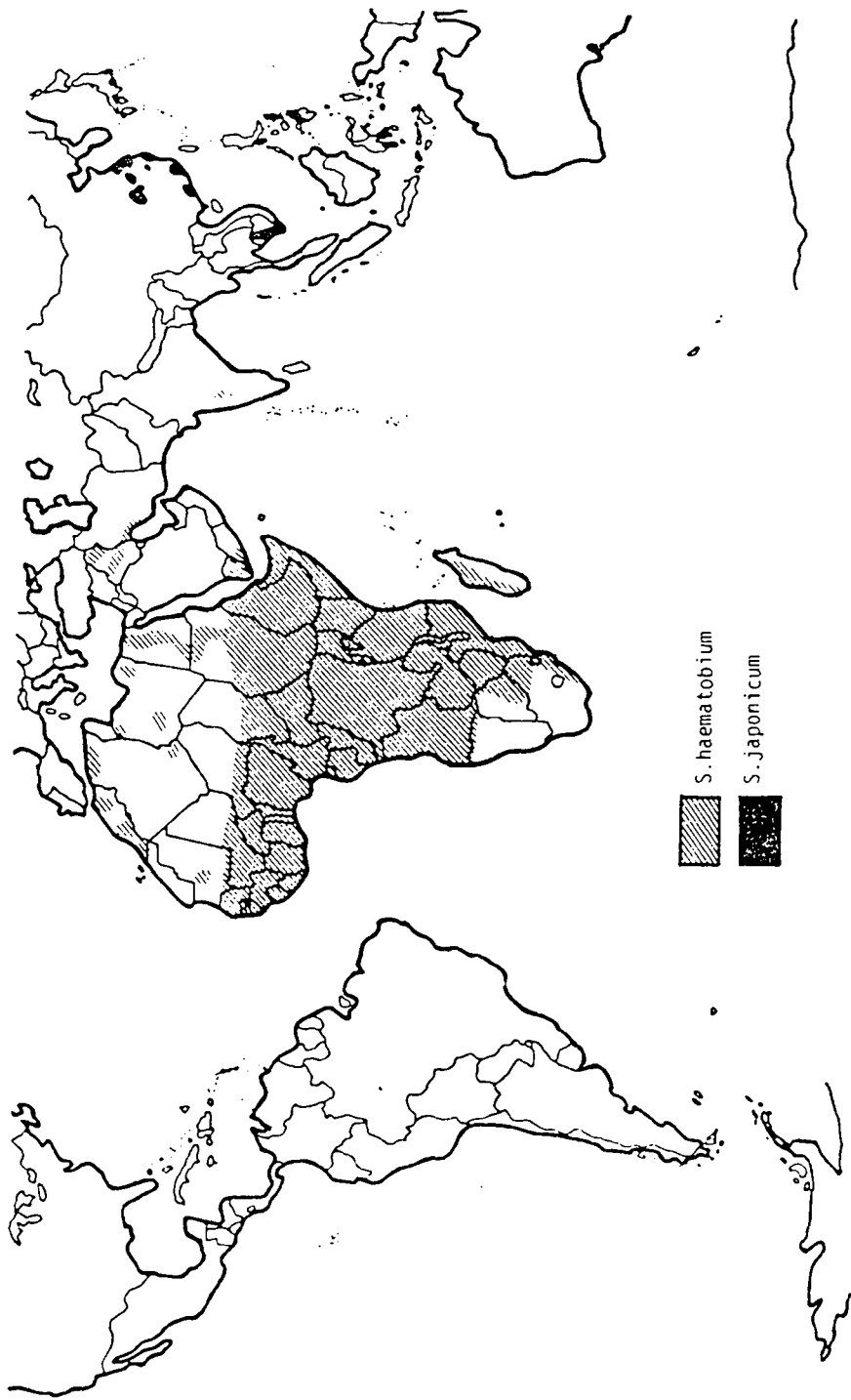


Figure 2. Geographical distribution of *S. haematobium* and *S. japonicum*. The areas marked are those in which transmission of these schistosomes may be occurring. *S. haematobium* transmission is most unlikely at altitudes about 1500 metres

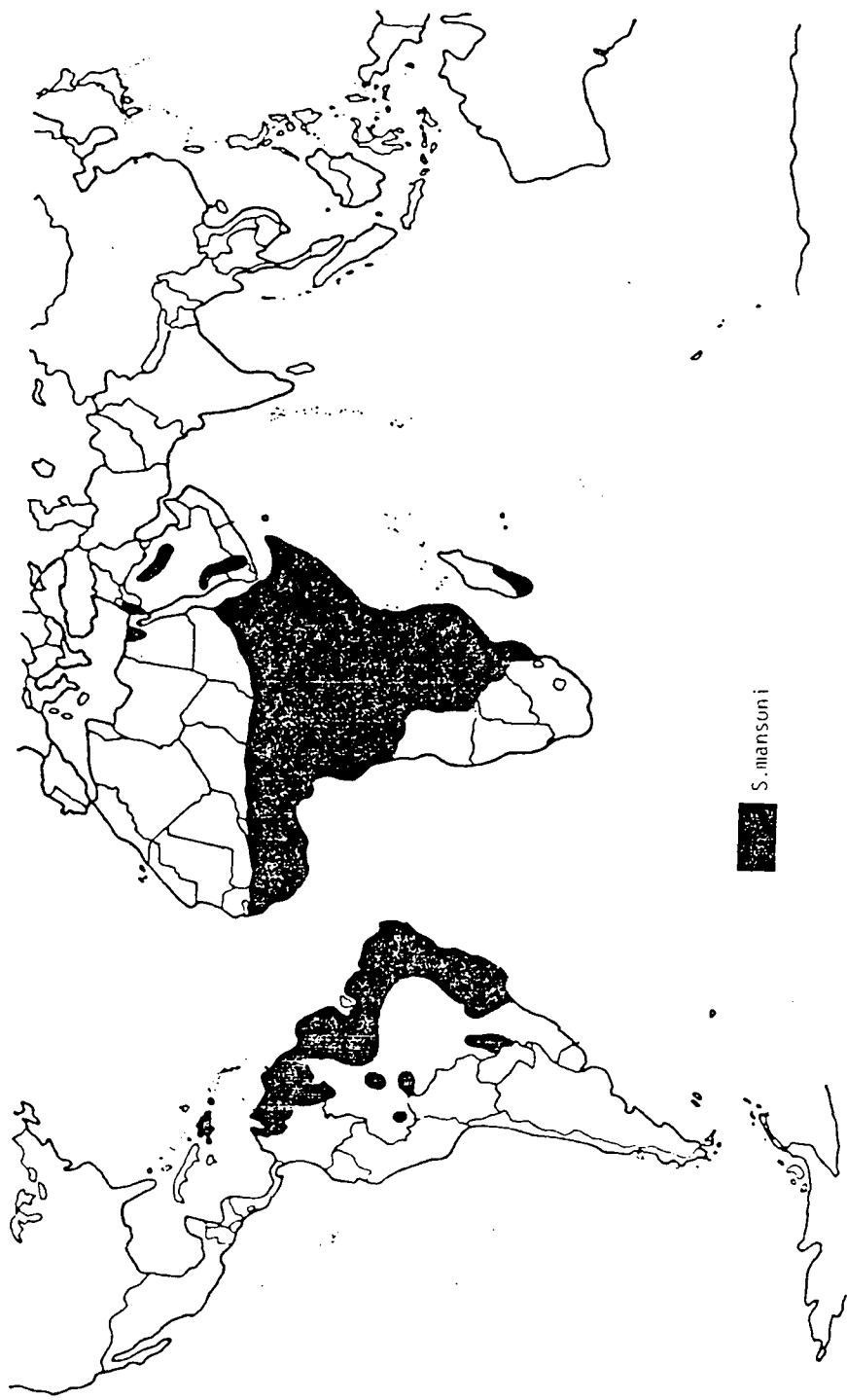
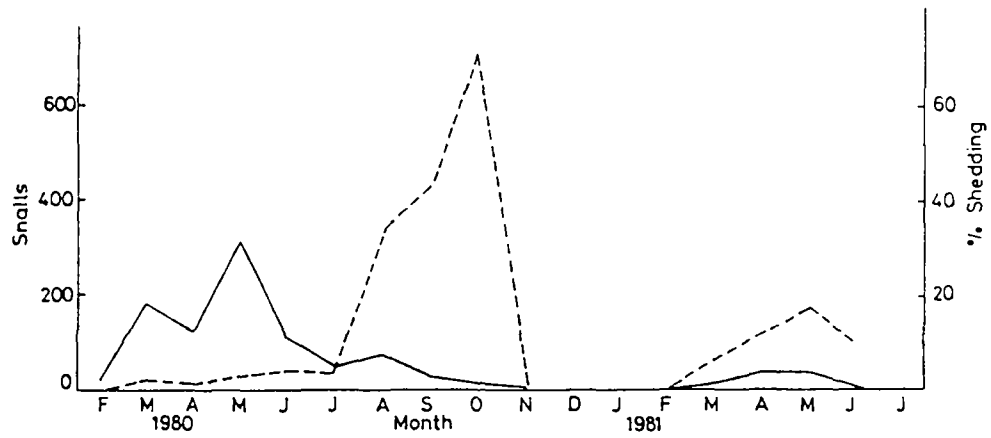
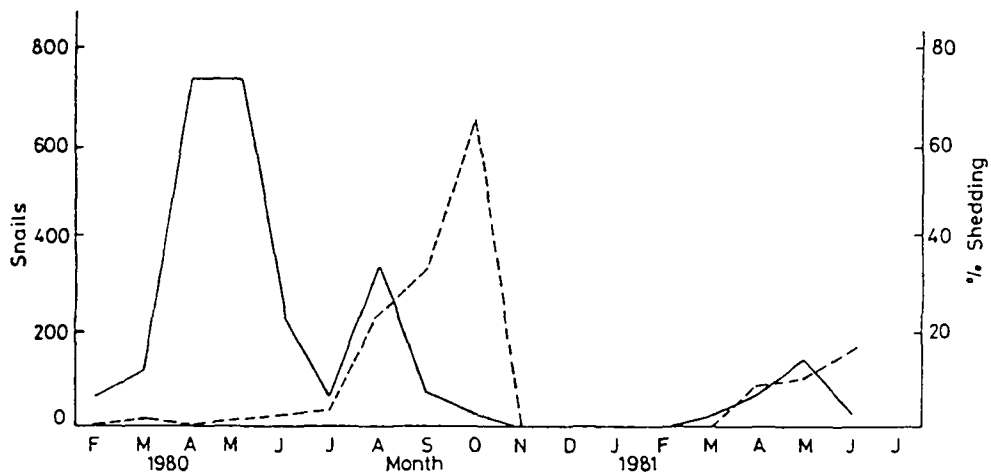


Figure 3. Geographical distribution of *S. mansoni*. The areas blackened are those in which transmission of *S. mansoni* may be occurring. *S. mansoni* transmission is most unlikely at altitudes above 2000 metres



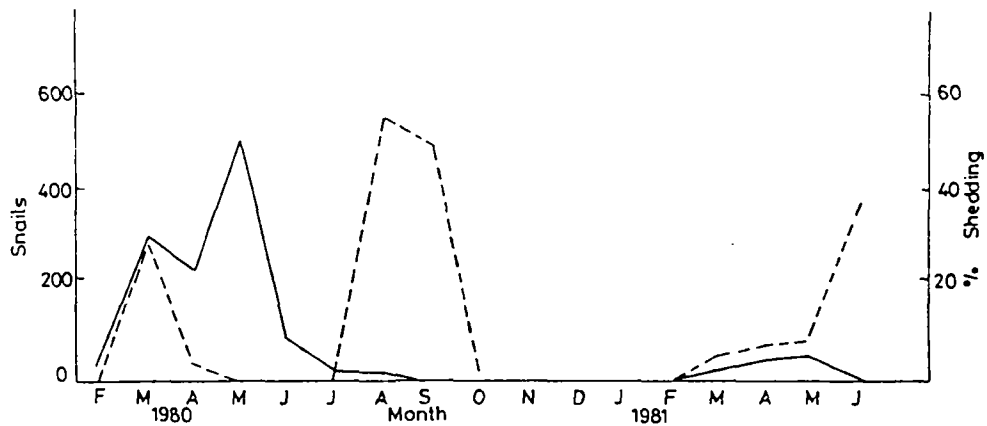
Bulinus (Physopsis) at Youth for Christ site Lake McIlwaine and % shedding schistosome cercariae



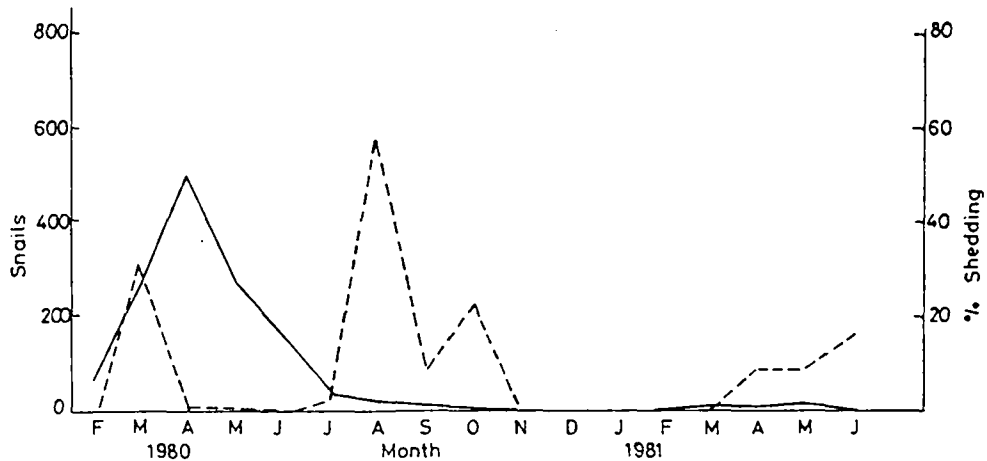
Biomphalaria at Youth for Christ site Lake McIlwaine and % shedding schistosome cercariae

----- Shedding  
 \_\_\_\_\_ Snails

Fig 4 Snail population dynamics at Youth for Christ site - Lake McIlwaine



Bulinus (Physopsis) at National Parks site Lake McIlwaine and % of snails shedding schistosome cercariae



Biomphalaria at National Parks site Lake McIlwaine and % of snails shedding schistosome cercariae

----- Shedding  
 \_\_\_\_\_ Snails

Fig 5 Snail population dynamics at National parks site - Lake McIlwaine

Table 1 Properties of some available and candidate molluscicides (20)

	Niclosamide	Trifenmorph	Sodium pentachlorophenate	Copper sulfate	Nicotinamido (candidate compound)
<i>Physical properties</i>					
Form of technical material	crystalline solid	crystalline solid	crystalline solid	crystalline solid	crystalline solid
Solubility in water	230 mg/l (pH dependent)	0.02 mg/l	330 g/l	316 g/l	not known
<i>Toxicity</i>					
Snail, LC <sub>50</sub> (mg/l x h) <sup>a</sup>	3-8	0.5-4	20-100	20-100	5
Snail eggs, LC <sub>50</sub> (mg/l x h) <sup>a</sup>	2-4	240	3-30	50-100	20-50
Cercaria, LC <sub>50</sub> (mg/l)	0.3	no effect	not known	no effect at molluscicidal concentrations	not known
Fish, LC <sub>50</sub> (mg/l)	0.05-0.3 (LC <sub>50</sub> )	2-4	not known	toxic <sup>b</sup>	> 30
Rats, LD <sub>50</sub> (mg/kg given orally)	> 5000	1400	40-250	300	> 2000 (mice)
Herbicidal activity	none	none	phytotoxic	phytotoxic	unknown
<i>Formulations</i>					
	700 g/kg wettable powder	165 ml/l emulsion concentrate	750 g/kg flakes	980 g/kg pentahydrate crystals	not yet formulated
	250 ml/l emulsion concentrate	40 g/kg granules	800 g/kg pellets		
			800 g/kg briquettes		
<i>Field dosage</i>					
Aquatic snails (mg/l x h) <sup>a</sup>	4-8	1-2	50-80	20-30	not known
Amphibious snails (g/m <sup>2</sup> )	0.2	ineffective	0.4-10	ineffective	not known

<sup>a</sup> The term "mg/l x h" indicates that the figures given are the product of the concentration and the number of hours of exposure

<sup>b</sup> Toxicity depends very much on the species of fish and on the water quality.

TABLE 2 - Results of a survey of host snails from 22 sites  
on lake McIlwaine - Zimbabwe

Month	Sites where control measures were adopted (6 sites)		Sites where no control was adopted (16 sites)	
	Average number of snails found	Standard deviation	Average number of snails found	Standard deviation
January	0.5	0.8	6.4	16.7
February	8.5	16.0	8.3	13.0
March	16.2	19.1	139.3	213.3
April	34.7	51.6	167.4	278.5
May	57.7	108.5	187.5	197.6
June	8.3	12.2	64.2	95.7

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Others in the series include:

OD/TN 1 - Partech turbidity monitors: calibration with silt and the effects of sand.

I L Fish, September 1983.

OD/TN 2 - Sediment discharge measurement and calculation: techniques for use at river gauging stations.

P Bolton, September 1983