Control of *Schistosoma mansoni* transmission by provision of domestic water supplies

A preliminary report of a study in St Lucia *

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As an experimental control measure to reduce the transmission of S. mansoni, *an individual household water supply was provided in 400 houses in 5 rural settlements of the Riche Fond Valley, St Lucia. This population of about 2 000 had previously been dependent for water on infective streams and rivers. Six other settlements in the valley, all provided with limited piped water from public standpipes, served as the comparison area. After 2 years the incidence, prevalence, and intensity of infection with* S. mansoni *were significantly lower in the household water supply area, whereas all these indices of infection had increased in the comparison area. An adequate, reliable, and convenient supply of water can reduce the transmission of* S. mansoni *and should be considered as a control measure in other endemic areas.*

The effect of a domestic water supply and health education on the transmission of *S. mansoni* has never been investigated fully, although results from South Africa (5, 6) and Brazil (1) suggest that some degree of reduction in transmission follows the installation of domestic piped water.

Such an investigation is now in progress in St Lucia where, as part of a comparative evaluation of different methods of *S. mansoni* control, an individual household water supply was provided in 5 settlements of the Riche Fond Valley during 1970–72. Six other settlements in the same valley served as the comparison area.

This paper reports preliminary results of the effect of household water supplies on *S. mansoni* transmission among children aged 0–14 years. The effect on transmission among adults will be the subject of a separate paper.

THE PROJECT AREA

The 5 settlements of the household water supply (HWS) area—Grande Ravine, Thomazo, Grande Riviere, Morne Panache, and Debonnaire—have a combined population of about 2 000 (about 400 houses) and are situated in the southwestern part of the Riche Fond Valley on the Atlantic side of St Lucia. To the west and south, hills rising to over 350 m separate these settlements from other inhabited areas, but to the north and east there is ready access to the comparison settlements (see map in the companion paper by Unrau, p. 2 of this issue).

Grande Ravine (population about 400) is situated on a small hill in the middle of the valley, and previously was dependent for water on a stream about 340 m from the centre of the settlement. Thomazo (population about 245) lies close to the headwaters of the valley's main river, the Mabouya; Grande Riviere (population 770) is situated on the valley floor very close to the same river, with houses extending up a nearby hillside; and Morne Panache (population 275) is located higher up this hill. Debonnaire (population 300) is a short distance away and close to a tributary of the Mabouya river.

The 6 settlements of the comparison area, which also have a combined population of about 2 000, are situated close to a main tributary of the Mabouya river on the northern side of the valley. Under a government water scheme introduced in this area in 1969, 16 public standpipes were constructed along the main road at about 350-m intervals. Some of the householders paid for connections to be made to their homes.

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Before 1969 in the comparison area, and prior to the installation of household water supplies in the control area, valley residents obtained water from the nearest stream or river. Washing of clothes, bathing, and swimming were also common activities involving contact with these waters, which are believed to be the main transmission sites of *S. mansoni* in the dry season when snail populations increase in the slow-flowing rivers (9). For agricultural workers in the valley there continues to be an occupational risk of infection since *Biomphalaria glabrata* is not uncommon in the drainage systems of the banana fields. It is believed, however, that transmission at these sites is sporadic and probably occurs in the wetter months of the year.

Sanitation is poor, although the construction of pit atrines is being encouraged by the government.

FIELD SURVEY TECHNIQUES

Household census

On the initial survey in 1968, all houses in the HWS and comparison areas were visited and numbered and the name, age, and sex of every occupant were noted. On subsequent household visits, as the survey teams became more familiar with the areas, a few houses previously overlooked because of thick vegetation were found; these, as well as any newly constructed houses, were also visited and numbered.

Although many families possessed birth certificates, inspection of all these to verify the ages stated orally would have been time-consuming and troublesome to the householders. Accordingly, the stated age was recorded in all instances, and verification was done for a sample of the population comprising 1 031 children and 290 adults. Of the 1 031 children, 75% of the stated ages exactly matched those on birth certificates and a further 21.5% differed by just 1 year; only 1.06% (11) differed by more than 5 years. Of the 290 adults, 45.8% of the stated ages exactly matched birth certificates and a further 28.2% differed by only 1 year; of the 10.6% (31) showing a discrepancy of more than 5 years, 1% (3) differed by 10 years. These levels of accuracy were considered sufficient to justify grouping all children by 5-year age groups, and grouping all adults by 10-year age groups.

An attempt was also made on household visits to follow changes in the population caused by births, deaths, immigration, and emigration. This was complicated by frequent changes in the occupancy of houses available for rental; in addition, some persons moved into the valley only to move out after 1 or 2 years. The following 5-year (1968–73) figures on population movement for the HWS area, although not fully accurate, are nevertheless indicative of the general pattern and support the contention that the rural population of St Lucia is relatively static at present.

Type of change		No. of persons
Movement within the HWS area		110
Emigration		382
To: Castries (island capital)	83	
elsewhere in valley	59	
outside valley	71	
outside St. Lucia	127	
Deaths	42	
Immigration		381
From: Castries	24	
elsewhere in valley	40	
outside valley	43	
outside St. Lucia	18	
Births	256	

These changes represent a turnover of approximately 8% of the population per annum. As an overall result, the proportion of the population under 15 years of age increased from 50% in 1968 to 55% in 1972.

Stool collections

Although the prevalence of infection with *S. mansoni* was known to vary considerably in different parts of the valley, the extent of the variation was unknown and this, combined with unknown variations in settlement size, made the design of a sampling technique difficult. It was further appreciated that, although the rate of response to the initial request for samples might be good, repeated requests for further samples, in order to determine changes in the parameters of infection, might prove less productive.

Instead of examining a sample of the population, therefore, a total survey of the 0–14-year-old population was attempted in each of the 5 years, with specimens from adults (those over 14 years of age) being collected in alternate years. Stool containers, individually labelled, were left at each house with instructions that all occupants provide a specimen. Collection of the containers was made the following day; at many houses, however, 2 or 3 return visits

Table 1. Prevalence of *S. mansoni* infection in persons responsive and less responsive in providing stool specimens

Age group (years)	Responsive		Less responsive	
	No. *S. mansoni* positive/ No. examined	% prevalence	No. *S. mansoni* positive/ No. examined	% prevalence
0–14	206/386	53.4	42/82	51.2
15–39	100/127	78 7	33/43	76.7
⩾40	71/103	68.9	10/21	47.6

were necessary to retrieve containers, and even then success was not invariably complete.

Although some containers probably held a stool specimen from another person than the one named on the label—containers may have been accidentally mixed or 2 persons may have shared a container—it is believed that few such cases occurred.

Over 75% of the children provided stool specimens at each survey. Among adults, males were less responsive than females, particularly those between the ages of 15 and 50. In an attempt to determine how representative of the whole population were those who freely provided stools, a group of those freely giving stools was compared for prevalence with a group who gave specimens only after considerable persuasion. As shown in Table 1, only in those above the age of 40 years was there evidence (χ^2 significant at 5% level) that prevalence was greater among those freely offering stools than among those less responsive.

LABORATORY TECHNIQUES

Stools were examined qualitatively by a formalin-glycerine sedimentation method, up to 3 slide preparations being examined for *S. mansoni* ova. The presence of other helminth ova, hookworm, *Ascaris* sp., *Trichuris* sp., and larvae of *Strongyloides* sp. were noted. When sufficient material was available, stools positive for *S. mansoni* were also examined quantitatively by the filtration-staining method (2); 10 ml of stool was emulsified in 90 ml of formol-glycerol solution and 1 ml of suspension was filtered through each of 2 filter papers, of which 1 was examined and the other kept for any subsequent checking. (In one series of stools, the mean weight of 10 ml of stool was 11.5 g.)

Maintenance of standard of stool examination

Since the results of large-scale parasitological studies, such as described here, depend on the competence of locally trained microscopists, a system of checking at least 10% of the negative slides was introduced. The percentage of negative slides found positive on checking is shown in Table 2, together with the calculated false negative rate (FNR; see *Definitions*, p. 12). The FNR is the more realistic measure of the two for the maintenance of examination standards because it takes into account the prevalence of infection in the population being examined.

This is illustrated in Table 3 by the use of hypothetical figures from a high-prevalence area (75.7%) before control effected a change to low prevalence (11.3%). Although 15.8% and 0.65% of the checked slides were found positive before and

Table 2. Results of checking negative slides from household water supply (HWS) and comparison areas, 1971 and 1973

Area and year	Total examined	No (%) *S mansoni* positive	No. negative	No. checked	% positive	Calculated % positive	False negative rate [a]
HWS							
1971	658	293 (44.5)	365	123	4.8	47.2	0.056
1973	598	221 (37.0)	377	74	2.7	38.6	0.043
Comparison							
1971	815	298 (36.6)	517	66	1.5	37.5	0 026
1973	910	501 (55.1)	409	148	6.0	57.8	0 047

[a] No significant difference between the rates at 5 % probability level.

Table 3. Calculations of false negative rate in a hypothetical high-prevalence area before control and in the same area after control when prevalence has been reduced

	High prevalence (before control)	Low prevalence (after control)
No of stools examined	346	319
No. *S. mansoni*-positive	262	36
prevalence (%)	75.7	11.3
No. *S. mansoni*-negative	84	283
No. re-examined	38	155
No. positive on reexamination	6 (15 8%)	1 (0.65%)
calculated missed positives	15.8% of 84 = 13.3 (13)	0.65% of 283 = 1.8 (2)
calculated total No of positives	262 + 13 = 275	36 + 2 = 38
false negative rate	13/275 = 0.047	2/38 = 0.053

after control, respectively, suggesting a change in the standard of microscopy, the FNR is the same and the standards of microscopic examination are therefore comparable.

Accuracy of a single stool examination

Apart from the possibility of microscopists missing *S. mansoni* ova, it was recognized that with the examination of a single stool specimen some infected persons excreting low numbers of eggs would be undiagnosed. Since this error is likely to be greater in low-prevalence than in high-prevalence areas, 3 stool specimens were examined from children in settlements with different prevalence rates. The difference between prevalence based on a single stool and the rate based on 3 stools was found to be greater in the low-prevalence settlements, as follows:

1-stool prevalence 8.1%, 12.0%, 17.5%, 23.0%, 25.0%, 49.1%, 51.6%, 63.0%

3-stool prevalence 16.2%, 24.0%, 37.5%, 42.8%, 41.6%, 70.1%, 74.1%, 79.0%

The relationship between the single stool and the 3 stools examined could be expressed by the formula:

$$y = 4.987 + 1.72754x - 0.0077x^2$$

where y = prevalence on 3 stools and x = prevalence on a single stool. This is not unlike the correction factor worked out by Scott (7). Although the formula applies to children, it may not be applicable to older age groups.

DEFINITIONS

The following terms not in common use in the measurement of infection with and transmission of *S. mansoni* have been employed in tables and analysis.

Data from cross-sectional surveys

Response rate: The number of persons in a specified age or sex group who provided faecal samples for examination, expressed as a percentage of the total number of specimens requested.

Point prevalence rate: The number of persons in a specified age or sex group found infected with *S. mansoni*, expressed as a percentage of the total number in the group who were examined.

Intensity of infection: The geometric mean of the egg counts, expressed in terms of eggs per ml of faeces of infected individuals in a particular age or sex group.

False negative rate: The calculated number of *S. mansoni* positive slides missed on examination, expressed as a proportion of the total number of positives in the sample examined (see Tables 2 and 3).

Potential contamination factor: The sum of the product of the prevalence and the geometric mean of egg output for the different age groups.

Data from longitudinal studies

When surveys are repeated after 1, 2, or more years, some individuals who previously provided stool specimens will provide second specimens. From these paired results the following measurements of transmission can be obtained:

Conversions: The number of persons in an age or sex group whose stools were negative for *S. mansoni* at the first examination but who on re-examination after 1 or 2 years were found to have become infected (i.e., a negative stool *converting* to a positive stool).

Reversions: The number of persons whose stools were positive for *S. mansoni* at the first examination but who on re-examination after 1 or 2 years were found to have become negative (i.e., a positive stool *reverting* to a negative stool).

Incidence rate (rate of new infections): The number of conversions expressed as a percentage of the total number in a specified age or sex group who were negative for *S. mansoni* on first examination.

(Although the age group initially may be 0–4 years, if incidence data are collected 2 years later the children are 2–6 years old.)

Rate of loss of infection: The number of reversions expressed as a percentage of the total number in a specified age or sex group who were infected (i.e., stool positive for *S. mansoni* on first examination subsequently becoming negative).

First and second cohort prevalence rates: The numbers found infected on first and second examinations expressed as percentages of those examined. (Number positive on second examination equals number positive on first, plus number of conversions, minus number of reversions.)

STATISTICAL METHODS

Point prevalence and incidence

For comparison of point prevalence or incidence data from different areas, between sexes, or at different times, Cochran's method for combining 2 × 2 tables was used (8).

Cohort results

Results of examining the same individual on different surveys to determine the significance of changes in the percentage infected were analyzed by comparing the difference between the numbers of conversions and reversions by the sign test.

Quantitative data

For comparison of the geometric means of egg counts of different age groups with data from different areas, between sexes, or at different times, the individual differences were weighted by the reciprocal of the variance. The weighted mean difference was regarded as normally distributed and having, under the null hypothesis, a mean of 0 and a variance of the reciprocal of the sum of the weights. Accordingly, to test whether the mean difference differed from 0, a normal approximation was taken of $Z = \bar{d}/\text{S.E. } \bar{d}$ (method proposed by C. White, personal communication, 1973).

PARASITOLOGICAL RESULTS

Household water supplies were made available to the 5 settlements over a 2-year period: in Grande Ravine in 1970; in Thomazo, Grande Riviere, and Morne Panache in 1971; and in Debonnaire in 1972. Prevalence, incidence, and intensity of infection are therefore considered during 3 phases of the programme: 1968–70, before the supplies were installed; 1970–72, the period of installation; and 1973, when all settlements in the HWS area had had water for between 1 and 3 years.

Table 4. Point prevalence rates of *S. mansoni* infection in 1968 in HWS and comparison areas

Age group (years)	HWS		Comparison	
	No. examined	% positive	No. examined	% positive
0–4	173	12 7	252	7.5
5–9	161	60.8	291	40.8
10–14	93	68 3	210	63.8
15–19	58	56.8	120	73.3
20–29	65	55.3	143	54.5
30–39	54	46 2	99	41.4
40–49	68	41.1	112	38.3
50–59	44	36 3	74	43 2
⩾60	40	27.5	104	29 8

Changes in the status of *S. mansoni* infection in individuals between 1968 and 1970 are compared with similar changes between 1971 and 1973.

Prevalence

Point prevalence rates of *S. mansoni* infection in all age groups in the HWS and comparison areas in 1968 are shown in Table 4. The usual pattern is evident in both areas, with peak rates occurring in the second decade of life.

Point prevalence rates in the younger age groups at different surveys are shown in Table 5. In 1968, 1969, and 1970—the precontrol phase—prevalence was significantly higher in the HWS area than in the comparison area. The pattern of change over this period was the same in the 2 areas: a decrease in 1969 followed by an increase in 1970 to a level higher than in 1968, although in neither area was the difference significant.

In 1973 there was a slight increase in prevalence in the comparison area but a significant decrease (0.1 % level) in the HWS area, where water had been available in all 5 settlements during the year. When the 1973 results from both areas were corrected for a single stool examination by the formula given above, the corrected prevalence was still significantly lower in the HWS area.

Table 5. Point prevalence rates of *S. mansoni* infection among children in the HWS and comparison areas before and after installation of household water supplies

Age group (years)	Before installation			After installation	% Change between 1970 and 1973
	1968	1969	1970 [a]	1973	
HWS					
0–2	2/88 (2.3 %)	23/136 (16.9 %)	15/107 (14.0 %)	5/88 (5.7 %)	−59.3
3–5	38/124 (30.6 %)	49/181 (27 1 %)	51/153 (33 3 %)	18/126 (14.3 %)	−57.1
6–8	62/97 (63.9 %)	64/133 (48 1 %)	82/141 (58.2 %)	60/166 (36.1 %)	−38.0
9–11	54/77 (70.1 %)	83/127 (65.4 %)	88/119 (73.9 %)	67/120 (55.8 %)	−24.5
12–14	31/46 (67.4 %)	—	56/67 (83.6 %)	71/98 (72.4 %)	−13.4
Comparison					
0–2	3/136 (2.2 %)	5/155 (3.2 %)	12/161 (7 5 %)	25/145 (17.2 %)	+129.3
3–5	42/228 (18.4 %)	32/238 (13 4 %)	41/239 (17 2 %)	79/183 (43.2 %)	+151 2
6–8	69/183 (37.7 %)	69/203 (34.0 %)	95/251 (37.8 %)	115/213 (54 0 %)	+42.9
9–11	85/153 (55.6 %)	85/145 (58.6 %)	94/170 (55.3 %)	155/219 (70 8 %)	+28.0
12–14	74/122 (60.7 %)	—	95/127 (74.8 %)	127/150 (84.7 %)	+13.2
Higher prevalence:	HWS	HWS	HWS	comparison	
Significance level:	0.1 %	0.1 %	0.1 %	0 1 %	

[a] Data obtained before Grande Ravine was supplied in June 1970.

In comparison with the highest precontrol prevalence rates of 1970, the 1973 prevalence rate in the HWS area was significantly lower and that in the comparison area was significantly higher.

Incidence

The annual incidence of new infections during the 3 phases is shown in Table 6.

During 1968/69 incidence was low and similar in the HWS and comparison areas. During 1969/70 it increased in both areas but was significantly higher in the HWS area. During 1970/71 it dropped in both areas and significantly so (0.1 % level) in the HWS area (water in Grande Ravine for 1 year). Incidence was, however, similar in the 2 areas, although slightly higher in the HWS area.

During 1971/72 there was a small increase in incidence in the HWS area (water available during the year in 4 of the 5 settlements) but a marked increase in the comparison area, where incidence was significantly greater. During 1972/73 a marked drop in incidence occurred in the HWS area. Although a drop was also noted in the comparison area, it was not as great, and the statistical significance of the difference in incidence between the 2 areas increased from the 1 % level in 1971/72 to the 0.1 % level in 1972/73.

Intensity of infection

The intensity of infection (geometric mean of the egg counts of infected children) in the 2 areas is shown in Table 7.

In the period 1968–70 intensity of infection was generally higher in the HWS area than in the comparison area (prevalence and incidence were also higher). Egg loads decreased in both areas during this period, which probably signifies that at some time prior to 1968 transmission had been at a higher level than it was between 1968 and 1970 (cf. the low incidence during 1968/69). During 1970–72 the intensity of infection showed little change but was slightly higher in the HWS area.

In 1973, however, the intensity of infection was significantly lower in the HWS area than in 1972,

Table 6. Incidence of *S. mansoni* infection among children in the HWS and comparison areas before, during, and after installation of household water supplies

Age group (years)	Before installation		During installation		After installation
	1968/1969	1969/1970	1970/1971	1971/1972	1972/1973
HWS					
0–2	9/78 (11.5 %)	10/78 (12.8 %)	6/60 (10.0 %)	5/80 (6.3 %)	5/67 (7.5 %)
3–5	12/73 (16.4 %)	24/88 (27.3 %)	17/74 (23.0 %)	29/106 (27.4 %)	11/84 (13.1 %)
6–7	14/30 (46.7 %)	14/32 (43.8 %)	11/35 (31.4 %)	13/46 (28.3 %)	7/50 (14.0 %)
8–10	18/34 (52.9 %)	27/47 (57.4 %)	10/25 (40.0 %)	21/40 (52.5 %)	3/29 (10.3 %)
[11–13]	—	—	[1/6 (16.7 %)]	[18/22 (81.8 %)]	[1/7 (14.3 %)]
0–10	53/215 (15.6 %) [a]	75/245 (30.6 %)	44/194 (22.7 %)	68/272 (25.0 %)	26/230 (11.3 %)
Change between surveys:		increase	decrease	increase	decrease
Significance of change:		0.1 %	0.1 %	N.S.	0.1 %
Comparison					
0–2	9/86 (10.5 %)	12/124 (9.7 %)	7/75 (9.3 %)	18/68 (26.5 %)	19/89 (21.3 %)
3–5	22/126 (17.5 %)	35/161 (21.7 %)	16/120 (13.3 %)	40/119 (33.6 %)	20/79 (25.3 %)
6–7	6/49 (12.2 %)	25/79 (31.6 %)	28/106 (26.4 %)	44/87 (50.6 %)	22/65 (33.8 %)
8–10	22/56 (39.3 %)	31/67 (46.3 %)	27/54 (50.0 %)	34/58 (58.6 %)	22/55 (40.0 %)
[11–13]	—	—	[14/23 (60.9 %)]	[6/17 (35.3 %)]	[7/18 (38.9 %)]
0–10	59/317 (12.4 %) [a]	103/431 (23.9 %)	78/355 (22.0 %)	136/332 (41.0 %)	83/288 (28.8 %)
Change between surveys:		increase	decrease	increase	decrease
Significance of change		0.1 %	N.S.	0.1 %	1 %
Higher incidence	HWS	HWS	HWS	comparison	comparison
Significance level:	N.S.	5 %	N.S.	1 %	0.1 %

[a] Corrected for 12 months from 18-month interval between surveys.

while in the comparison area it was significantly higher. For the first time, therefore, intensity of infection was greater in the comparison area than in the HWS area.

Taking into consideration changes in prevalence and intensity of infection in the 2 areas, between 1970 and 1973 the potential contamination factor of 0–14-year-old children showed a decrease of 47 % in the HWS area but an increase of 77 % in the comparison area.

Change in S. mansoni *infection status over 2-year periods*

In each area the change in *S. mansoni* infection status in a cohort of 0–13-year-old children examined in 1968 and again in 1970 was compared with the change in a cohort of similar age examined in 1971 and again in 1973. The results are shown in Table 8.

In the HWS area between 1968 and 1970, new infections (conversions) outnumbered apparent losses of infection (reversions) by 82 to 15, so that the cohort prevalence rose from 42 % to 62 % (the children were 0–13 years old in 1968 but 2–15 years old in 1970). A similar pattern of change took place in the comparison area, with conversions (103) outnumbering reversions (31) and the cohort prevalence increasing from 32 % to 46 %.

In the comparison area between 1971 and 1973, conversions (183) again exceeded reversions (29) and the cohort prevalence increased from 36 % to 64 %. In the same years in the HWS area, however, conversions (43) were outnumbered by reversions (51) and the cohort prevalence showed little change (from 46 % to 44 %)

Table 7. Intensity of *S. mansoni* infection (geometric mean (GM) of egg output per ml faeces), as well as standard deviation (SD) of log values of individual counts and the number of counts, in the HWS and comparison areas

Age group (years)	Before installation									During installation						After installation		
	1968			1969			1970			1971			1972			1973		
	GM	SD log	No.	GM	SD log	No.	GM	SD log	No	GM	SD log	No.	GM	SD log	No.	GM	SD log	No.
HWS																		
0–5	35	0.5118	38	31	0.5196	62	20	0.3578	51	22	0.4375	38	23	0 4075	57	25	0.5438	28
6–8	49	0.6057	41	50	0.5135	54	38	0.5469	70	28	0 4046	64	28	0.4198	72	19	0.3616	56
9–11	57	0 5904	48	57	0.5864	71	34	0.5360	74	38	0.5192	75	35	0 4859	88	32	0.4325	62
12–14	72	0 6456	28	—	—	—	60	0 5267	54	43	0 5840	72	46	0 5219	108	37	0 4875	61
Change between surveys:			decrease			decrease			decrease			decrease			decrease			
Significance of change:			N.S.			0.1 %			N.S.			N S.			5 %			
Comparison																		
0–5	39	0.4858	41	15	0.2444	27	18	0.3894	44	28	0.3977	20	20	0 3569	73	32	0.5167	85
6–8	57	0.6366	61	42	0.5589	61	23	0.4164	74	23	0 4786	64	34	0.4622	117	37	0 4778	100
9–11	56	0 5889	78	39	0.5274	65	34	0 4645	91	20	0.5262	75	38	0 4791	129	58	0.5708	138
12–14	59	0 5428	68	—	—	—	51	0 4811	80	39	0.6241	63	38	0 4536	96	56	0 5082	108
Change between surveys:			decrease			decrease			increase			increase			increase			
Significance of change:			0 1 %			N.S			N.S.			N.S			0.1 %			
Higher intensity		HWS			HWS			HWS			HWS			HWS			comparison	
Significance level:		N.S.			0.1 %			5 %			N S			N.S			0.1 %	

Table 8. Change in status of *S. mansoni* infection among cohorts of children from the HWS and comparison areas examined in 1968 and 1970 (before installation of household water supplies), and among similarly aged cohorts from the 2 areas examined in 1971 and 1973 (after installation)

Area	Before installation				After installation			
	year	age group (years)			year	age group (years)		
		0–4	5–9	10–13		0–4	5–9	10–13
HWS								
No examined		138	142	47		150	172	91
1st cohort prevalence	1968	16 %	58 %	70 %	1971	19 %	52 %	80 %
conversions		40 (34 %)	31 (52 %)	11 (79 %)		15 (12 %)	18 (22 %)	10 (56 %)
reversions		5 (23 %)	8 (10 %)	2 (6 %)		17 (61 %)	24 (27 %)	10 (14 %)
ratio of conversion to reversion		8.0	3 9	5.5		0.9	0 8	1.0
2nd cohort prevalence	1970	41 %	74 %	89 %	1973	17 %	48 %	80 %
Comparison								
No. examined		176	213	124		160	268	120
1st cohort prevalence	1968	6 %	37 %	61 %	1971	9 %	32 %	78 %
conversions		31 (19 %)	50 (37 %)	22 (46 %)		60 (41 %)	106 (59 %)	17 (63 %)
reversions		4 (40 %)	17 (22 %)	10 (13 %)		7 (47 %)	15 (17 %)	7 (8 %)
ratio of conversion to reversion		7.8	2 9	2.2		8 6	7.1	2.4
2nd cohort prevalence	1970	21 %	52 %	71 %	1973	43 %	66 %	86 %

DISCUSSION

Comparability of the 2 areas

In any region where schistosomiasis is endemic it is virtually impossible to find two localities with the same point prevalence rates, incidence, and intensity of infection, the one to be used as a comparison area against which to assess control measures adopted in the other.

In the case of the present study transmission had been, and during the immediate precontrol period was, at a higher level in the HWS area than in the comparison area (consistently higher prevalence and incidence, Tables 5 and 6). In that period, however, the 2 areas showed the same pattern of change with both parameters of infection, and they are thus considered sufficiently comparable to demonstrate changes in the transmission of *S. mansoni* following the installation of household water supplies in the test area.

Effect of household water supplies on transmission

The best measure of a reduction in the transmission of *S. mansoni* is incidence, i.e., the rate of new infections. In the reports from many studies of control methods attention has mainly been paid to the resultant fall in incidence among children under the age of 7 years, and little information has been presented on the effect of control on incidence among older children and adults, who may acquire infection in quite different situations. Although children under the age of 7 years may be a suitable group to study in many areas, where transmission is very high a much younger group, e.g., 0–3-year-olds, may have to be taken.

The decision made in this preliminary report to include data on older children of 7–14 years of age, as well as on the customary 0–6-year age group, admittedly involves several disadvantages. Firstly, older children are more mobile and are therefore more likely to acquire infection outside the control area if that is of limited extent. Secondly, among the 0–6-year age group only a few of those originally negative would actually have been passing schistosome eggs; however, in older age groups the number of false negatives is likely to be greater because these children are more likely to have an easily missed low level of infection. Thirdly, in areas of high endemicity only a few of the older children (11–13 years of age) may be negative and valid numbers for calculating incidence may be difficult to obtain.

On the other hand, the inclusion of older children offers a distinct advantage. With successful control, the rate of new infections in the 0–6-year age group may rapidly be lowered to a point beyond which further reduction cannot be measured with confidence but, among older children, who initially have a higher level of incidence, continued reduction in transmission from year to year can be assessed over a longer period of time. Nevertheless, the 0–6-year age group provides a useful group for a long-term cohort study for assessment of control.

The yearly variations in incidence in the HWS and comparison areas may be considered remarkable, but snail populations and therefore transmission in St Lucia depend on climatic features that vary from year to year. (Such variations may be less marked in irrigation systems than in " natural habitats ".) Of these climatic features, rainfall probably exerts the greatest influence on snail populations. As shown in Fig. 1, rainfall in the drier months (January–June) during 1968–70 varied to some extent from the average, but in the 6 wetter months rainfall was near or above average and was therefore sufficient to wash out snail populations in the streams; in these years, therefore, transmission was probably dependent on snail colonies existing in streams in the drier months, with changes in incidence being inversely related to rainfall in these months. In 1971 and 1972, rainfall in the drier months was again about average, but that in the wetter months was well below average and was therefore probably insufficient to wash out snail

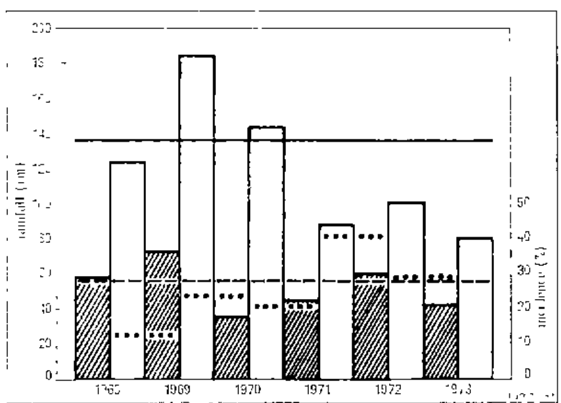

Fig. 1. Rainfall during the dry months of January-June (hatched) and the wet months of July-December (unhatched). The 30-year averages for the dry and wet periods are shown by the broken and solid horizontal lines, respectively. The incidence of *S. mansoni* infection in children aged 0-10 years in the Riche Fond Valley comparison area is shown by 6 horizontal dots in each of the periods from July to June.

populations in the streams; presumably transmission continued during the " wet season " in these years, leading to a sharp rise in incidence between the surveys of 1971 and 1972. Although the increase in rainfall in the wetter months of 1972 was only slight, incidence in that year was lower than in 1971.

Data from the different surveys conducted in the 2 areas show the increasing incidence with age (Table 6), but it is striking that during 1972–73 this pattern did not occur in the HWS area, incidence there being low and remarkably steady in all age groups except the 0–2-year-olds.

Farooq & Hairston (3) have drawn attention to the rate of loss of infection, and have shown that in Egypt this decreased with age. In Table 8 it is seen that the apparent loss of infection (reversions) decreased with age and between 1968 and 1970 was indirectly related, in each area, to the incidence rate and also to the percentage infected.

The decreasing apparent loss of infection is probably due to a number of interacting factors. Among the younger children incidence is low; there is consequently little chance of additional infection being acquired in a year, and light infections are more likely than heavier infections to be missed at a subsequent examination. Among the older children incidence is higher and there is consequently greater likelihood of an increase in worm burden, but also less chance both of an infection being missed and of a loss of infection.

The combined effect of a population acquiring new infections and losing old infections determines the cohort prevalence and point prevalence rates and, with control preventing new infections, the rate of loss increases (Table 8, 1971–73 data). When the number of new infections equals that of lost infections there is no change in the cohort prevalence rates, which leads to a reduction in point prevalence. As incidence continues to decline the rate of loss may increase, with further reduction in point prevalence.

The reduced incidence and increased loss of infection in the HWS area were associated with a reduction in intensity of infection which, in conjunction with the lower prevalence, resulted in a reduction in the potential contamination factor. Preliminary data from sentinel snail exposures show fewer snails becoming infected in the HWS area but larger numbers becoming infected in the comparison area (E. S. Upatham, personal communication, 1974). Whether this reduction is due to reduced egg output or is a reflection of less defaecation on the river banks is debatable.

The parasitological results, considering all the parameters of infection, indicate that the availability of household water supplies has brought about reduced transmission. Although the results might not have been so remarkable if an intensive health education programme had not also been instituted, it is nevertheless apparent that when adequate alternative water sources are made available in St Lucia, customs can be changed and children can be taught to stay out of the rivers. Studies of water contact in the HWS area show a 95% reduction in the number of persons going into the rivers (P. Dalton, personal communication, 1973).

Water supplies and other methods of control

It is not expected that household water supplies alone will lead to a complete cessation of transmission. As far as is known, however, no single method of control will do so.

Snail control has in the past been considered the most effective means of reducing transmission of schistosomiasis (4), but this method would appear to require unending application of molluscicides and to provide no other benefits than the control of the snail intermediate host and reduced transmission. Other aquatic organisms are killed along with the snails, and the long-term ecological effects of mollusciciding are still unknown.

Chemotherapy, whether used *en masse* or for the treatment of infected persons only, will probably reduce the risk of severe disease in many persons by reducing, if not eliminating, their worm load. Nevertheless, this method requires continued vigilance for infected immigrants, and the long-term effect of treatment on transmission has yet to be demonstrated, although the immediate effects are, of course, reduced prevalence and intensity of infection.

The provision of a good, reliable, and convenient source of water as a substitute for the infective rivers and streams not only reduces transmission of *S. mansoni* but also benefits the population in other ways. As stated by Horwitz (quoted by Wolman & Bosch, 10): " If a single program were chosen which would have the maximum health benefits, which would rapidly stimulate social and economic development, and which would materially improve the standard of living of people, that program would be water supply with provision for running water into or adjacent to the house."

Although the capital cost of water supplies, and particularly of an individual household supply, may be considered high, such a system represents a capital asset to any community—one that can be instrumental in reducing gastroenteritis in infants, typhoid, skin diseases, etc., and generally leads to a cleaner and more healthy population.

The recurrent costs of the household water supplies project in the Riche Fond Valley are lower than the annual costs of a mollusciciding operation in a nearby valley, and after a few more years the overall costs of the water supplies will probably be no greater than those of mollusciciding. Public health administrators in many areas where schistosomiasis is endemic have yet to be convinced of the public health importance of the disease and are therefore unenthusiastic about committing limited financial resources to a mollusciciding campaign. They may be more willing to provide the necessary finance for a control measure such as the provision of household water supplies, which reduces the prevalence not only of schistosomiasis but also of other diseases. Whether the water should be provided free is a matter for local decision, but a small charge may not be unacceptable and would help meet the recurrent costs.

Emphasis appears to be placed on schistosomiasis in relation to irrigation schemes, where, in many instances, the disease can rightfully be termed " man made. " In such schemes there is no shortage of water. Accordingly, consideration should be given to using some of the water for providing *adequate* public standpipes (if an individual household supply is thought too sophisticated a system) and *adequate* laundry and showering facilities. The St Lucia scheme provides 1 laundry tub and 1 shower per 12.5 houses; with a public standpipe system a ratio of 1 tub and 1 shower to 10 houses might be more appropriate. It should be noted, however, that in view of the increasing transmission in the comparison area, the public standpipe system installed there in 1969 can have had little, if any, effect on transmission.

Household water supplies are not advocated as a control method in every endemic area. Nevertheless, in some areas the provision of adequate, safe, and convenient water should be considered as an alternative or as a supplement to other forms of schistosomiasis control.

ACKNOWLEDGEMENTS

Thanks are due to Dr C. White, Department of Epidemiology and Public Health of the School of Medicine, Yale University, who acted as statistical consultant and suggested many of the methods for analysis of the results reported here. The Research and Control Department is supported by the Government of St Lucia, the Rockefeller Foundation, and the Overseas Development Administration, London, UK, Scheme R.2108 A-C.

RÉSUMÉ

LUTTE CONTRE LA TRANSMISSION DE *SCHISTOSOMA MANSONI* PAR INSTALLATION DE L'EAU COURANTE DANS LES HABITATIONS

A Ste-Lucie, dans la vallée de Riche Fond où les infections à *Schistosoma mansoni* sont endémiques, cinq villages d'une population totale d'environ 2 000 personnes ont été dotés en 1970–72 d'installations d'eau courante pour chaque habitation ainsi que de buanderies-douches publiques et de piscines d'un modèle simple (secteur EC). Six autres villages de la même vallée, où des postes d'eau publics avaient été installés en 1969, ont servi de secteur témoin.

Pour réunir des données de base sur la prévalence, l'incidence et l'intensité des infections à *S. mansoni*, des échantillons de selles avaient été recueillis dans les deux secteurs à l'occasion de tournées de porte-à-porte faites de 1968 à 1970; les premiers postes d'eau courante ont été installés dans un des villages en 1970. L'étude s'est poursuivie en 1971 et 1972, période pendant laquelle l'eau courante a été installée dans les quatre autres villages, ainsi qu'en 1973, année où les cinq villages du secteur EC étaient donc desservis depuis une à trois années.

Auparavant, tous les indices d'infection étaient légèrement plus élevés dans le secteur EC, mais les variations d'une année à l'autre y étaient à peu près les mêmes que dans le secteur témoin. A la fin de l'année 1973, tous ces indices avaient diminué dans le secteur EC alors qu'ils avaient augmenté dans le secteur témoin, où ils se situaient désormais à un niveau plus élevé que dans le secteur EC.

Dans des cohortes d'enfants de 0 à 13 ans suivies pendant deux années avant le début du programme

(1968–70), la proportion de sujet infectés avait augmenté sensiblement dans les deux secteurs. En suivant des cohortes de même âge, de 1971 à 1973, les auteurs ont constaté une augmentation notable de la proportion de sujets infectés dans le secteur témoin alors que cette proportion n'augmentait pas dans le secteur EC.

Un approvisionnement commode et suffisant en eau salubre, doublé d'une campagne d'éducation sanitaire, a ainsi permis de réduire considérablement la transmission de l'infection à *S. mansoni* parmi les enfants du secteur EC; d'autre part, l'installation de postes d'eau dublics n'a pas suffi à empêcher une augmentation sensible de la transmission dans le secteur témoin. Les dépenses d'équipement entraînées par l'installation de l'eau courante dans chaque habitation sont sans doute élevées, mais les frais d'entretien du système n'ont pas dépassé le coût de la campagne de traitement des eaux par les molluscicides dans une vallée voisine. Il semble donc que l'aménagement d'un réseau de distribution d'eau, outre les nombreux autres avantages qu'il présente, est une mesure plus indiquée en santé publique que les campagnes de traitement des eaux par les molluscicides, qui sont de durée indéfinie et n'ont d'effets spécifiques que contre les agents de la schistosomiase.

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