Individual household water supplies as a control measure against *Schistosoma mansoni* *

A study in rural St Lucia

G. O. UNRAU [1]

As part of a programme to evaluate single control measures for reducing the transmission of Schistosoma mansoni, *household water supplies were installed in 5 rural settlements in the Riche Fond Valley of St Lucia. About 2 000 persons who previously were dependent on rivers and streams are now receiving safe water at their homes. The systems provide useful design data on individual water requirements in rural areas. This experience suggests that future rural water systems can be designed more economically and efficiently by using consumption rates that are closer to the actual requirements and by eliminating water wastage at the taps.*

Schistosomiasis is one of the most widespread parasitic infections in the tropical and subtropical world and, in terms of incidence and prevalence, is probably increasing more rapidly than any other parasitic disease. In 1965, the Government of St Lucia and the Rockefeller Foundation formally agreed to establish a Research and Control Department that would investigate the efficiency and cost-benefit ratios of several methods for reducing the transmission of schistosomiasis mansoni on the island. One possible method, aimed at preventing exposure to infection, is the provision of household water supplies in rural areas in order to make it unnecessary for the population to enter natural waters harbouring the infective larval stage of the schistosome.

In the period 1970–72, 5 rural settlements in the Riche Fond Valley of St Lucia were provided with household water supply systems designed to give convenient and reliable service at low cost. This paper reports on 3 years' successful operation of these systems, gives details of their design, construction, and cost, and offers evidence that prevailing estimates of water consumption rates in rural areas are unrealistically high. A preliminary report on the epidemiological effectiveness of the project is given in a companion paper by Jordan et al. (see this issue, p. 9).

* From the Research and Control Department, Castries, St Lucia, West Indies. Reprints may be obtained from the author at that address.

[1] Staff Member, the Rockefeller Foundation.

PROJECT AREA

St Lucia, one of the Windward Islands in the eastern Caribbean Sea, is approximately 43 km long and 23 km wide and has an area of about 616 km^2. The island is mountainous, with a forest-covered central ridge extending almost its entire length; rivers and streams drain eastward to the Atlantic Ocean and westward to the Caribbean through valleys separated by hills rising to 610 m.

The island receives rain throughout most of the year, but there is considerable monthly variation; usually July and October are the wettest months, and February and March the driest. Annual rainfall averages 127 cm at the extreme ends of the island and more than 406 cm in the central mountainous region. Annual temperatures range from 20° to 34°C.

The Riche Fond Valley is situated on the eastern slope of the central mountain range. There are numerous streams in the area, and these supply an acceptable volume of water because of the high rainfall; rarely do the streams dry up. Rainfall records for the valley indicate a mean of 208 cm per year over the past 30 years.

The 5 settlements provided with household water supplies—Grande Ravine, Thomazo, Grande Riviere, Morne Panache, and Debonnaire—lie near the foot of the mountains, with many of the houses built on the lower slopes (Fig. 1); these settlements were all previously dependent on rivers and streams. The other 6 settlements shown in Fig. 1 are equipped

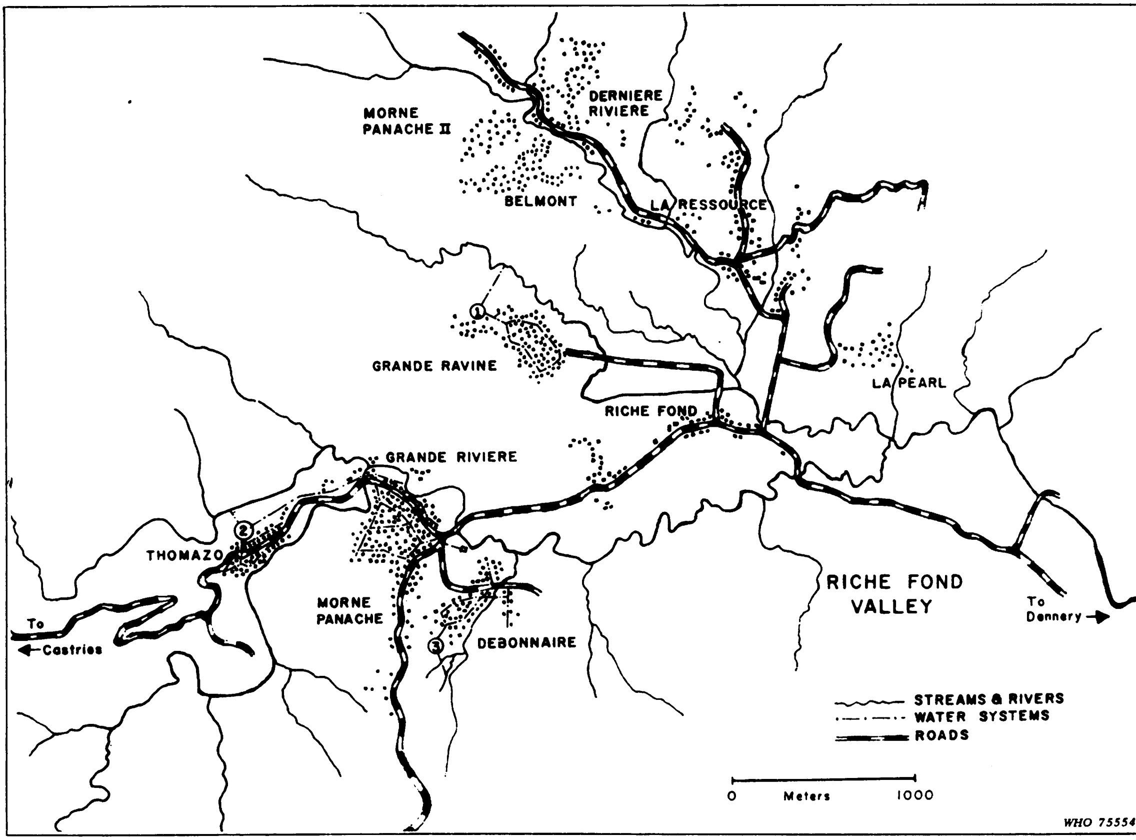

Fig. 1. Map of Riche Fond Valley showing locations of 5 settlements provided with household water supplies: Grande Ravine, Thomazo, Grande Riviere, Morne Panache, and Debonnaire. The 6 other settlements shown serve as the comparison area.

with a public standpipe water system and serve as the comparison area. (See also the companion paper by Jordan et al., p. 9 of this issue.)

COLLECTION OF BASELINE DATA

A household census, conducted in 1968, showed that the population of the 5 settlements numbered about 2 000, with an average of 5.2 persons per household (Table 1); the mean age was 15 years, and the 0–4-year age group represented about 20% of the total.

A detailed geographic survey was made to determine the suitability of various water sources in relation to the location of the houses, and stream flows were measured to determine water volumes at different elevations. In addition, data were collected on the quantity of water used and on the distances water was carried from the rivers and streams to the houses (Table 1). The average daily consumption

Table 1. Size of 5 settlements in 1968, and the distances water was carried from source to household before the installation of supply systems

Settlement	No. of houses	Population	Distance water was carried (m) range	Distance water was carried (m) mean
Grande Ravine	70	400	137–480	342
Thomazo	49	245	37–549	217
Grande Riviere	154	770	14–549	226
Morne Panache	53	275	4–494	304
Debonnaire	60	300	82–242	165

was estimated to be about 15 litres per person. The daily work load of transporting the water, over rough and sometimes steep paths, was estimated to involve 837 persons carrying a total of 34 m^3 of water.

In an initial stool survey, specimens were obtained from occupants of each household to determine the prevalence of schistosomiasis, hookworm, ascariasis, and infections due to *Trichuria* and *Strongyloides* spp. These surveys were repeated annually to measure the incidence of new infections.

PROJECT DESIGN CRITERIA

The overall criterion was that each household be furnished with its individual supply of safe, potable water, adequate in amount and available for 24 h each day. This required the design of 3 separate systems: one for Grande Ravine; one for Thomazo, Grande Riviere, and Morne Panache; and one for Debonnaire. A few houses were located either too far away or at too high an elevation to be served economically with an individual supply, and mainly for their convenience public laundries and shower units were installed at 3 selected sites; these units have since become popular with many of the other householders. In addition, 3 swimming pools were constructed, since children of the settlements regularly swim and play in the streams and rivers, and their exposure in terms both of length of time and of body area may be an important factor in the transmission of schistosomiasis mansoni.

The household supply systems were designed to serve a total population twice the initial size, this being the standard for rural water systems in many countries of the Americas. It is, however, an overestimation, because rural populations usually grow more slowly than urban populations. In fact, since the project was designed, the population served has grown at the rate of only 1.8% per year, and will therefore take 40 years to double.

Since water requirements in a rural community are rather arbitrary, a daily quantity of 114 litres per head of population was allowed; given the ultimate aim of the project, a sizable margin of safety in consumption demand was considered desirable. Evidence from other studies (5) suggests that the availability of ample quantities of water may be as important as the bacteriological quality of the supply, or even more so.

Since the sophisticated treatment of water may not be an absolute requirement, simple types of treatment were used in the interest of experimentation (Table 2).

Table 2. Experimental variations in water treatment

System	Source characteristics	Treatment
Grande Ravine	slow-flowing stream	infiltration gallery, storage
Thomazo, Grande Riviere, & Morne Panache	rapid flow, intermittent sand & stone stream-bed, relatively isolated watershed	sedimentation, storage
Debonnaire	slow-flowing stream	sedimentation, storage

MATERIALS AND FACILITIES

Distribution systems

In order to provide effective service at low cost, a departure was made from the conventional design of distribution systems (corporation and curb cocks at each service, etc.). In all 3 cases the main distribution line serves a group of households, each having a water tap, and the only valves in the system are located at the inlet and at major junctions. A single meter measures the delivery to the distribution line. Meters were also installed at the public laundries and showers.

The use of poly(vinyl chloride) (PVC) pipes conferred several advantages. Firstly, since the rugged terrain required that pipes be transported manually to the construction sites, the low weight of these plastic pipes let us use the help of women from the settlements, who often carried one length each; manual transport of iron or steel pipes of equivalent size would have required far more labour. Secondly, the lower friction losses with PVC pipes permitted the use of cheaper, small-bore pipes. Thirdly, since pipes had to be imported in any case, selection of the lighter PVC pipes resulted not only in a saving on shipping costs but also in a considerable saving (about 50%) on the capital cost.

Schedule 80 heavy-walled pipe was used, both because it can be threaded with ordinary pipe threading tools and the need for threaded adapters to install valves and taps in the line is thereby eliminated, and also because it gives the extra strength desirable in rough terrain.

Water taps

Provision of an adequate water supply from available sources indicated a design of minimum waste,

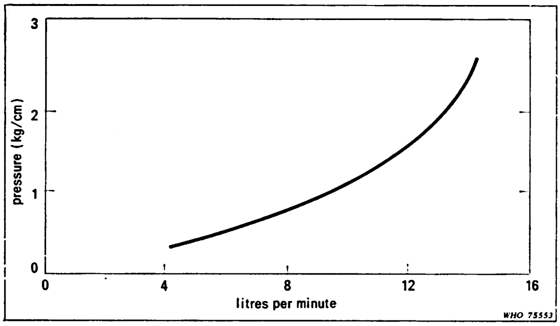

Fig. 2. Typical quantity-pressure curve for a Fordilla water tap.

and the discovery that a certain amount of pumping would be required stressed the need for low water loss. Accordingly, exclusive use was made of the spring-loaded Fordilla tap (Ford Meter Box Co., Wabash, IN, USA), which automatically shuts off the flow after a predetermined quantity of water has been discharged; to obtain more water the top button must be released and pushed down again. This tap thus provides an unlimited amount of water but cannot be left open. Borjesson & Bobeda (2) reported satisfactory results with the Fordilla tap in a test conducted in Paraguay, and Aris (1) found that it gave good control of water consumption in Guatemala.

In addition to eliminating waste, the Fordilla tap allows the use of smaller-diameter pipe in the distribution system because fewer taps are operating simultaneously.

The unit controls the volume delivered, which in the case of standard models is about 1 litre per cycle. For this project the manufacturer provided units that deliver about 7.5 litres per cycle. Since the flow can be terminated at any point in the cycle by manual release of the button, there seems to be no disadvantage in the use of this model; furthermore, the larger volume means fewer interruptions in the filling of laundry tubs and large containers.

The design capacity of a Fordilla tap is about 10 litres/min at 10^5 Pa. A typical quantity-pressure curve (Fig. 2) shows that the delivery rate is not changed greatly by an increase in pressure.[a]

For those who wanted shower facilities at their homes, a shower-head attachment was devised by

[a] Ford, R. V. (1964) The hydraulic design of Fordilla pods. U.S.A.I.D. Community Water Supply Seminars, Bogota, Addis Ababa, and Bangkok.

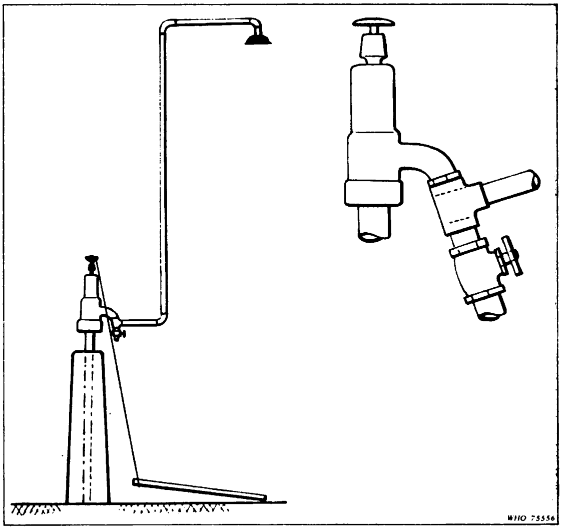

Fig. 3. Household shower arrangement with a single Fordilla water tap.

fitting the tap outlet with a thread and adding a tee joint and a simple shut-off valve. A 2-m length of pipe, 2 elbows, and a shower-head make up the shower (Fig. 3). In operation the lower valve is closed, so that the flow is diverted through the shower; when the valve is opened the tap functions in the usual way. A foot control can be made by drilling a small hole through the push button on the tap and attaching this with a wire to a short board used as a pedal.

Storage tanks

Because of the difficult terrain and the lack of roads to suitable tank sites, a sectional bolted, 12-gauge galvanized steel tank was considered the most appropriate and economical storage reservoir. Where necessary, the tanks were transported manually in sections and assembled on site.

Public laundry and shower units

The public laundry is a simple structure having a concrete centre bench with 3 or 4 concrete tubs mounted along each side, a slightly sloping concrete floor, and a hip-type roof. Water is supplied to each tub by a Fordilla tap.

The 6-stall public shower unit is built of concrete block walls and partitions. Each stall uses a Fordilla tap with an attached spray-head controlled by a pedal.

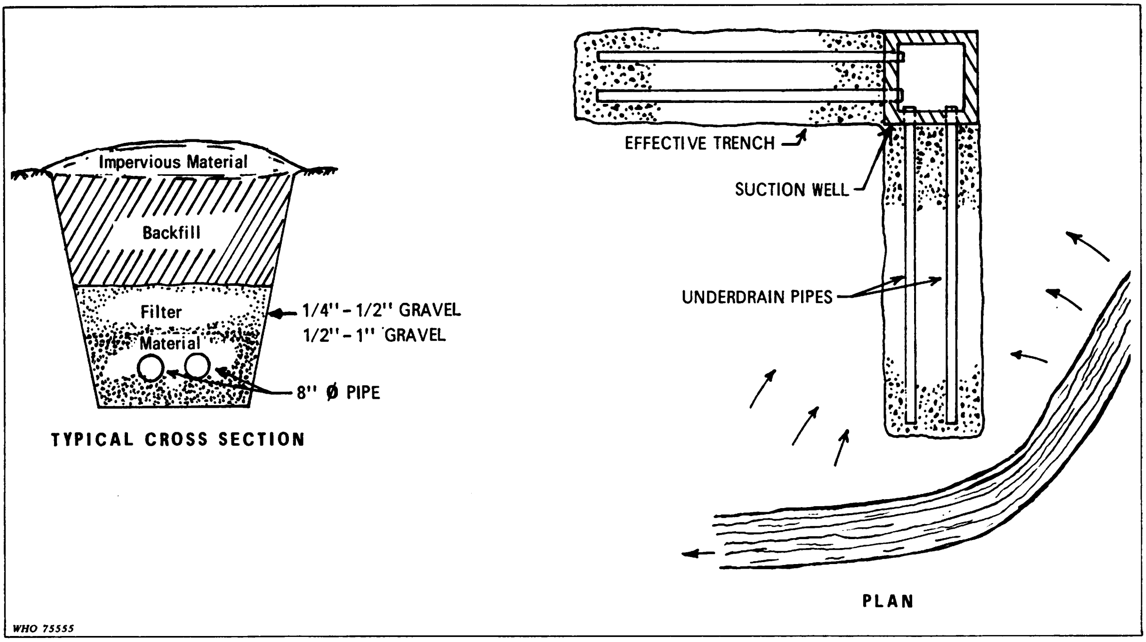

Fig. 4. Infiltration gallery, Grande Ravine water system.

Swimming pools

A simple fill-and-draw (as opposed to recirculating) pool, measuring 6×12×1 m, was designed. For pools less than 1.5 m deep the common minimum-area requirement is 0.9 m² per person; this pool, when used by an assumed maximum of 50 children at one time, provides an area of nearly 1.5 m² per child. Each pool was constructed below ground, of reinforced concrete flooring and concrete block walls with a coat of plaster applied to the inside. At one end the floor is raised to provide a water depth of only 0.6 m.

DESCRIPTION OF THE SYSTEMS

The 5 settlements were provided with household water supplies over a period of approximately 2½ years: Grande Ravine in 1970; Thomazo, Grande Riviere, and Morne Panache in 1971; and Debonnaire in 1972.

Grande Ravine

For this settlement of 70 houses situated on one side of a small hill, the only practicable source of piped water was the nearby small, shallow stream on which residents had previously relied (Fig. 1). This stream had a flow rate (1 m³/min) sufficient for the population.

The site selected for the intake permitted the use of an infiltration gallery (Fig. 4). The water is collected after having permeated through many feet of sandy soil, a process that aids in the removal of potentially harmful organisms by filtration; furthermore, being subsurface water, the supply does not dry up as quickly as surface supplies in times of drought.

From the suction well the water is pumped by a 2-stage turbine type pump through a 5-cm diameter PVC line to a 83.6 m³ storage tank. The total dynamic head is 73 m.

A 5-cm main, 117 m long, serves the loop network, with 2.5-cm pipe used for the distribution loop and 2-cm pipe for the service lines. Experience has proved that this distribution system provides adequate supply and pressure to the 70 houses at all times.

Public laundry and shower facilities (6 tubs and 6 shower stalls) and a swimming pool were also constructed at Grande Ravine.

Thomazo–Grande Riviere–Morne Panache

The system for these settlements (a total of 256 houses), which lie along the major road close to the main river, is supplied by a nearby tributary.

Water is collected by means of a dam, from which it flows through a sedimentation chamber into a suction well and is then pumped through a 6.5-cm line to a 159.6 m^3 storage tank. The dynamic head is 103 m, which requires a 15-kW motor. From the tank, distribution is by gravity by means of 885 m of 6.5-cm PVC main to Grande Riviere and either 2.5- or 4-cm PVC pipe for the other distribution lines. Since the location of the houses at different elevations requires both low- and high-pressure distribution networks, pressure-reducing chambers or valves were installed where appropriate to limit working pressures to a maximum of 483×10^4 Pa.

Public laundry and shower units (8 tubs and 6 shower stalls) were constructed at Morne Panache and at the opposite end of Grande Riviere. In addition, swimming pools were provided at each end of Grande Riviere; these are suitably situated for children from Thomazo and Debonnaire, respectively.

Debonnaire

This system, serving 60 houses, is the simplest. Basically it consists of intakes on 2 small streams, a sedimentation chamber, a storage tank of 83.6 m^3 capacity, and a loop distribution line of 4-cm PVC pipe, with a 2.5-cm spur line at the extreme end. The system operates by gravity. Recently another source has been tapped, at a higher elevation, to supply a group of 10 houses above Morne Panache, and the surplus from this is used to augment the Debonnaire supply.

Public laundry and shower units have not been provided at this location. Since the nearby small streams are not especially suitable for the washing of clothes, it was assumed that the distinct convenience of a household water supply would make residents prefer to do washing at their homes.

DISCUSSION

Water quality

In the 3 years of the project's operation the chemicophysical properties of the water supplied were within acceptable ranges. The iron content, however, was somewhat high in the Grande Ravine and Debonnaire systems, with consequent discoloration of the water in the Grande Ravine swimming pool. Only the swimming pool supplies are chlorinated, although such treatment can be provided for the other water supplies if required. Water samples are collected routinely for bacteriological analysis by the Millipore filter technique (3); 80% of the samples so far examined have been completely negative for coliform bacteria, and the samples that were positive had only a few colonies per 100 ml.

Henderson [a] has suggested that, in tropical climates, retaining the water in reservoirs for a longer time may lead to an improvement in quality owing to an accelerated rate of bacterial die-off. Although the present designs allowed for generous storage capacity, the extent to which this is responsible for the good quality of the water remains uncertain. However, increased storage time certainly reduces the viability of schistosome cercariae, and if storage can be substituted for sophisticated treating equipment, the maintenance of a system is simplified and made less costly.

Consumption rates

The average daily use of the systems, including the laundry–shower units, varies between 40 and 50 litres per person, being an increase of approximately 35 litres over the estimated consumption of carried water. The exact number of people using the laundry–shower facilities is difficult to determine; however, records show an average daily consumption of 2.4 m^3 for the 6 laundry tubs and 6 showers at Grande Ravine, and daily averages of 1 m^3 and 1.8 m^3 for the 6 showers and 8 laundry tubs at Morne Panache.

This consumption rate is far below the 114 litres per person per day allowed for; future designs based on 60 litres/person/day would provide adequate capacity. This figure, which is about 3–4 orders of magnitude lower than those now used in many areas, is similar to the figure given by Aris (1) as the basis of design for rural aqueducts in Guatemala.

Cost analysis

Table 3 presents a brief summary of the costs of installing household water supplies for the 5 settlements combined. The figures do not include engineering and supervision overheads, which would have to be calculated according to local availability and price for a given area.

[a] Henderson, J. M. (1965) *Community water supply development in underdeveloped areas.* Tropical Public Health Seminar, Harvard School of Public Health, Boston, MA, USA.

Table 3. Costs [a] (US $) of individual water supplies to the 5 settlements

Design capacity (No. of persons)	Equipment & materials	Installation labour hired	Total cost	Per capita cost
4 500	$31 002	$9 038	$40 040	$8.90

[a] When the costs of the 3 laundry–shower units and the 3 swimming pools are added to these figures, the total cost becomes $48 613 and the per capita cost about $10.80.

During the period of installation (about 2½ years) costs increased owing to several factors: a rise in labour rates; the fact that the second and third systems required more manual labour than the first because of more difficult terrain; and, associated with the latter, a reduced level of volunteer help. It had been hoped initially that much of the manual labour needed would be volunteered as part of a community effort. Although this effort never reached the level of expectation, nevertheless each household did provide the labour for digging the trenches for its service line pipe and a small portion of the distribution system pipe.

Since there may be those who would argue that developing countries can afford a well-distributed public hydrant supply in rural areas but not the luxury of individual household service, it should be noted that once the essential equipment and materials for an adequate public hydrant supply have been purchased and installed, the added expense of service lines and taps amounts to only a small percentage of the total cost. In the case of the 3 systems described the capital cost for individual service averaged 10% of the total expenditure. Calculation of the costs of the service line, fittings, and taps showed that the additional expense averaged slightly over US $12 per house, or approximately $2.40 per person.

Moreover, water experts have long maintained that carried water is not good enough. According to Wolman (4): " Twenty-five years ago it was our assumption that bringing water to a tap in the central square of a village constituted progress. Today we see our goal differently. If we can't bring water into the house itself, or at the very least to an adjacent courtyard, we simply have not done the job." Preliminary data on the incidence of schistosomiasis mansoni in the household water supply and comparison areas supports this view (see the paper by Jordan et al., p. 9 of this issue). To the direct health benefits associated with a household water supply can be added the saving of the time and labour previously expended in carrying water from rivers and streams.

CONCLUSIONS

Experience with these household water supply systems indicates: (1) that if water wastage can be eliminated in a design that furthermore is based on a consumption rate more realistic to actual needs for rural areas, many sources normally considered of unacceptable capacity can become adequate supplies; (2) that the use of PVC pipe and Fordilla taps, by eliminating waste, permits the design of economical, simple distribution systems easily maintained by limited numbers of skilled personnel; and (3) that installation labour costs can be significantly reduced when local populations are willing to contribute to the project as a community effort.

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RÉSUMÉ

L'INSTALLATION DE L'EAU COURANTE DANS LES HABITATIONS COMME MOYEN DE LUTTE CONTRE *SCHISTOSOMA MANSONI*

Des études ont été entreprises à Ste-Lucie pour évaluer l'efficacité de diverses mesures de lutte contre la transmission de *Schistosoma mansoni.* L'une de ces mesures consiste à installer l'eau courante dans toutes les habitations rurales car l'organisation d'un bon service d'eau fait beaucoup pour éviter aux populations des campagnes les contacts avec des eaux infectées.

Par le moyen d'enquêtes géographiques, de recensements des habitations et d'études annuelles sur des échantillons de selles, des données de base avaient été recueillies dans cinq villages de la vallée de Riche Fond pour aider à concevoir un système de distribution d'eau adéquat et, par la suite, à évaluer les effets de l'approvisionnement en eau saine sur la fréquence des infections helminthiques. Sur la base de ces données, trois systèmes distincts ont été réalisés pour fournir l'eau courante à chaque habitation. En outre, 3 buanderies-douches publiques et 3 piscines ont été aménagées en des points stratégiques.

Tout a été fait pour que les installations soient aussi simples et aussi économiques que possible. Dans deux des systèmes, le réservoir d'eau est alimenté par pompage et dans le troisième par gravité. Toutes les conduites installées sont en chlorure de polyvinyle et tous les postes d'eau sont pourvus d'un robinet « Fordilla » à écoulement contrôlé. Ce type de robinet permet de tirer autant d'eau qu'on le désire mais empêche tout gaspillage car il se ferme automatiquement si on ne le maintient pas en position ouverte. L'analyse des coûts fait apparaître que les frais d'équipement, de matériaux et de main-d'œuvre (à l'exclusion des frais d'étude technique et de surveillance des travaux) se sont élevés à US $8,90 par habitant pour ces trois systèmes conçus pour desservir au total une population de 4 500 personnes. Si l'on fait aussi entrer en ligne de compte les buanderies-douches et les piscines, le coût par habitant s'élève à US $10,80.

Pendant 3 années, ces systèmes ont fourni de l'eau potable, 24 h sur 24, à une population rurale d'environ 2 000 personnes. Pendant cette période, la consommation d'eau par personne et par jour a augmenté de 35 litres, ce qui signifie que l'hygiène et les pratiques sanitaires se sont améliorées dans les ménages; au crédit de l'opération, il faut mettre aussi d'importantes économies de temps et d'énergie puisque les villageois n'ont plus à aller chercher l'eau.

Il ressort de cette expérience que, moyennant un traitement minimal, il est possible d'utiliser les cours d'eau locaux pour assurer aux petites collectivités rurales un service d'eau commode et de qualité acceptable. Sont également à retenir un certain nombre de points qui méritent d'être pris en considération pour l'étude de futurs réseaux d'alimentation en eau en milieu rural:

1) Bien que les installations aient été conçues pour une consommation de 114 litres d'eau par personne et par jour, la consommation journalière effective a été de moins de 50 litres par personne.

2) Les installations ont été calculées pour la desserte d'une population double de la population actuelle; c'est là peut-être une marge de sécurité excessive car l'accroissement des populations rurales est généralement plus lent que celui des populations urbaines. Depuis la construction de ces distributions d'eau, le taux d'accroissement démographique des cinq villages a été de 1,8% par an, ce qui signifie qu'il faudra 40 ans pour que la population atteigne le double de ce qu'elle est actuellement et que, pendant cette période, la capacité excédentaire ne sera pas utilisée.

3) Une comparaison de coût entre l'installation de raccordements individuels pour chaque habitation et l'installation de postes d'eau publics bien répartis fait apparaître que l'excédent de dépenses d'équipement (conduites et robinets) dans le premier cas ne représente que 10% de l'investissement total. Etant donné les nombreux avantages des raccordements individuels pour chaque habitation, cet excédent de dépenses paraît tout à fait justifié.

En tablant sur des valeurs de consommation réalistes et en éliminant les possibilités de gaspillage, on peut admettre une norme de 60 litres par personne et par jour pour l'approvisionnement en eau des populations des campagnes. Des installations de cette capacité sont suffisantes pour desservir commodément et économiquement beaucoup de collectivités rurales.

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