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MANAGEMENT STRATEGIES FOR MITIGATING ADVERSE HEALTH IMPACTS OF WATER RESOURCES DEVELOPMENT PROJECTS

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INTRODUCTION

Substantial evidence exists that water resources development projects in tropical areas have resulted in unanticipated adverse side effects. Increased prevalence of water-related diseases is an example of such adverse effects. The failure to consider these side effects, and to provide explicit management strategies to mitigate them, can reduce the economic productivity of the development project and actually decrease the net well-being of the project population.

The purpose of this paper is to suggest, by analysis of a typical type of water resources development project, how project planning should be undertaken in order to consider explicitly both potential negative impacts and also possible means for limiting such impacts while achieving the usual economic development goals. The example chosen to illustrate the approach is an irrigation project in a developing country with specific potential short-term and long-term negative impacts resulting from increasing the transmission of schistosomiasis, for a given project design. The example will be used as the basis for indicating what types of management strategies, that is, combinations of physical measures, implementation incentives, and institutional arrangements, might be incorporated in the project to reduce the negative effects.

The global concern with and emphasis on increasing food supplies in the face of continuing large increases in population, coupled with the limited supply of agricultural land, has resulted in pressure for more intensive use of existing agricultural land in virtually all areas of the world. Irrigation is one of the prime means for intensifying land use to increase agricultural production. Therefore, a careful appraisal is warranted with respect to: (1) whether or not current project planning of irrigation projects and the projects which stem from these are adequate; and (2) if not, how they can be improved. Estimating the impacts of irrigation projects includes estimating the likelihood of disease vector populations increasing as a result of the project, the corresponding number of persons affected, and the consequences, as well as estimating the increased crop yields and associated benefits stemming from the project. Although it is difficult to predict accurately how many persons will be infected with a disease for any given set of conditions, it is essential that the potential for such adverse side effects be included in estimating project costs and benefits. The example of schistosomiasis and irrigation projects is used to explicate the suggested changes.

SCHISTOSOMIASIS AND IRRIGATION

Schistosomiasis, a disease carried by a parasitic worm, is intimately associated with water at each stage of its life cycle. More than 200 million people in Africa, the Middle East, Asia, and parts of Latin America are currently estimated to be infected with at least one of the three species of schistosomes (worms) infective to man: Schistosoma haematobium, S. mansoni, and S. japonicum. Schistosome eggs are transmitted by infected individuals through urine or feces, depending on the parasite species. The eggs must reach water to hatch. Once in water, the eggs hatch into the first larval stage, or miracidium, which must find an appropriate snail species to continue the life cycle. Once in the snail, the miracidia undergo asexual reproduction and are shed by the snail as cercariae, the stage infective to humans and to some species of other animals. The cercariae can penetrate any part of the body that touches water. Once inside a person, the worm migrates to the veins surrounding the intestine or bladder (depending on species); after males and females mate, the eggs are laid and passed through the walls of the intestine or bladder to be excreted. The life cycles of the three major schistosome species infective to man are shown in Fig. 1.

Clinical effects of schistosomiasis range from general weakness and anemia to obstruction of flow of blood or urine. Warren (1) emphasizes that schistosomiasis, although usually

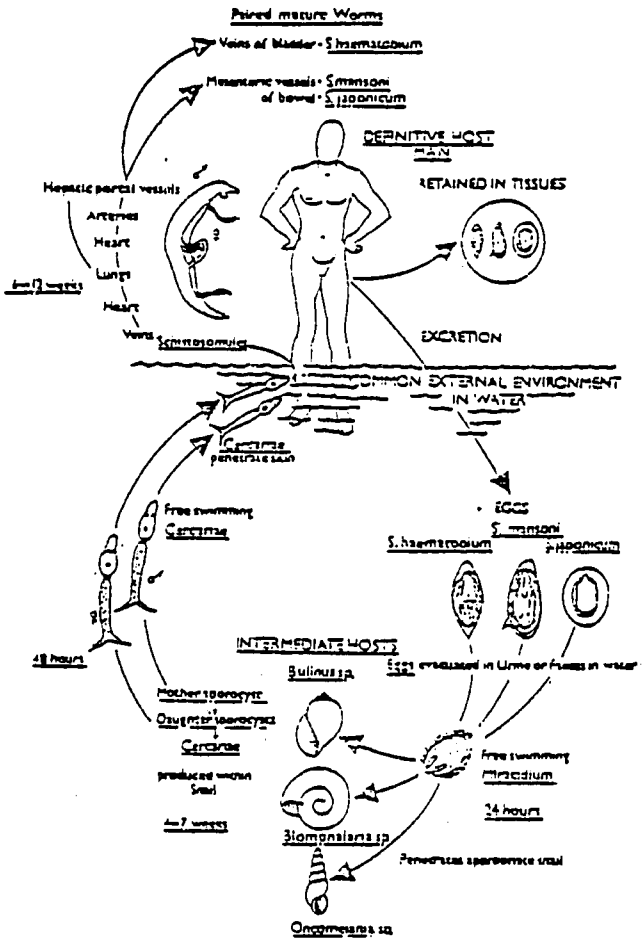

FIG. 1. The life cycle of schistosomiasis. Source: P. Jordan and G. Webbe, Human Schistosomiasis, Springfield, Ill., Charles C. Thomas Publishers (1969), p. 7.

Courtesy of Charles C. Thomas, Publishers, Springfield, Illinois

not fatal, is "a potentially lethal infection from the Katagana fever of the early stages to . . . carcinoma of the bladder, cor pulmonale, epilepsy . . . and other complications of the later stages." Seriousness of disease consequences is thought to be related to frequency of re-infection, longevity of infection, and numbers of worms in the body.

An irrigated area complete with canals, laterals, field delivery of water, and drains provides additional possibilities for snails to survive and for people to come in contact with infected water above those already existing in non-irrigated areas such as ponds or rivers. This is especially true for irrigation systems located close to villages and where no alternative water sources are available for drinking, bathing, washing clothes, and water recreation. Snails thrive on the sides of canals, laterals, and drains where weeds have grown, in weed-overgrown bars in the middle of canals and drains, and/or in the side pools that may form alongside of canals or drains as a result of seepage. Snails also are attracted to organic matter that may be deposited in canals, laterals, drains, or side pools by villagers. Thus, if snails exist in the area, they are likely to be found around all sites where people use water.

The impact of irrigation systems on the transmission of schistosomiasis has been documented in studies in Egypt (Ref. 2), the Sudan (Ref. 3), Tanzania (Ref. 4), Zambia (Ref. 5), Ghana (Ref. 6), Nigeria (Ref. 7), and Iran (Ref. 8). As shown in Table 1, in most cases there was either no infection, as in the Sudan, or some infection, as in Egypt and Iran, in the project area before the irrigation system was built and operated. Where no previous irrigation existed, parasites were brought into an area by infected migrants and by vector snails clinging to animals and clothing. The impact of irrigation has been to increase substantially the level of infection (prevalence) in a relatively short time (Ref. 9).

In trying to assess the impact of a project on disease transmission, it is important to emphasize two different measurement problems. The first is that of estimating the distribution of infection in the population over time. Prevalence of S. haematobium, for example, is measured by the presence or absence of schistosome eggs in the urine. The presence of only one egg in an individual's urine classifies the person as being infected. To estimate prevalence, it is necessary to examine urine specimens from a sample of the population. This requires a team of parasitologists and trained technicians to go to the villages to collect and analyze specimens, and then to record results. An additional aspect of this problem is that the population may be reluctant to give specimens.

The second measurement problem is that of estimating the distribution and size of snail populations over time. It is impossible to count every snail in a habitat, especially given their propensity to burrow into muddy substrata. Thus, there is always a sampling problem. In addition, the appropriate unit to define the sample could vary with habitat, i.e., number of snails per square meter for ponds, number of snails per linear meter for canals.

In addition to the difficulty of measuring the prevalence of schistosomiasis in relation to a specific project, it is even harder to measure the specific economic impacts of schistosomiasis on the infected population. Studies have attempted to assess the impacts of diseases on worker productivity and increases in worker absenteeism due to schistosomiasis infections. Results have been inconclusive. In Cameroon, infected workers appeared to cut more sugar cane (Ref. 10). In Tanzania, one study showed that output of infected workers did not differ from output of noninfected workers, though absenteeism was greater (Ref. 11). Yet, in another Tanzania study, bonus earnings were lower for infected workers (Ref. 12). In St. Lucia, no economically significant effect from schistosomiasis was detected (Ref. 13).

These studies lead to the conclusion that: (1) more data are needed before the economic impacts of schistosomiasis can be estimated accurately; and/or (2) the other factors affecting productivity may mask the effects of schistosomiasis. Many items not considered in the studies cited above need to be taken into account: variation in severity of infection by age and sex in different geographic areas; examination of impacts on the community as a whole, not only the workers; and external economic conditions indicating what the benefits to the local economy would be from reducing schistosomiasis. Because adequate data are not available to estimate accurately the economic consequences of this debilitating disease, recourse in project planning must be to express the objective in terms of achieving a target level of schistosomiasis prevalence in the project area.

A prototype irrigation project (Ref. 14)

To facilitate discussion of the spectrum of schistosomiasis management strategies, a prototype irrigation project in a developing country is posited which, as designed in the usual manner, would result in negative side effects on human health. This prototype project provides the basis for identifying and evaluating alternative schistosomiasis management strategies as part of the total irrigation project planning, construction, and operation.

TABLE 1. Examples of increased prevalence of schistosomiasis resulting from water resources development projects

Country (refs.)	Project (yr. completed)	Pre-project prevalence (percent)	Post-project prevalence (percent)	Schistosome species
Egypt (Ref. 2)	Aswan Dam (first) (1906)	6%	60% (3 yrs. later)	S. haematobium S. mansoni
Sudan (Ref. 3)	Gezira Scheme (1925)	0%	30-60% (15 yrs. later)	S. mansoni S. haematobium
Tanzania (Ref. 4)	Arusha Chini (1937)	low	50-85% (30 yrs. later)	S. mansoni
Zambia and Rhodesia (Ref. 5)	Lake Kariba (1958)	0%	15% adults 70% children (10 yrs. later)	S. mansoni S. haematobium
Ghana (Ref. 6)	Volta Lake (1966)	low	90% (2 yrs. later)	S. haematobium
Nigeria (Ref. 7)	Lake Kainji (1969)	low	30% (1 yr. later) 45% (2 yrs. later)	S. haematobium
Iran (Ref. 8)	Dez Pilot Irrigation Project (1965)	15%	30% (2 yrs. later)	S. haematobium

In the description of baseline conditions, it is assumed that no activities specifically directed toward schistosomiasis are undertaken.

Pre-project conditions. The present population in the prototype project area is engaged primarily in subsistence agriculture, essentially non-irrigated, including raising a small number of livestock -- cows, goats, and sheep. Only a small amount of water is conveyed from the river and applied irregularly to a few hectares in the area of the proposed project. Little of the crop output is transported outside of the area. The population is dispersed throughout the proposed project area in small clusters. River water is used for drinking, personal and clothes washing, recreation, and watering of livestock. Both household and personal wastes are discharged directly onto land or into water. The population is stable with essentially no in- or out-migration. Both nutrition and literacy levels are low.

The relevant epidemiological information indicates that snails that transmit schistosomiasis are present in the river system. To simplify the discussion, it is assumed that only Schistosoma haematobium is endemic in the population. Prevalence, or the percent of people infected at any given time, is estimated to be 20 percent of the total population. The assumed approximate age distribution of prevalence, based on representative information from endemic areas of S. haematobium, is shown in Fig. 2 (Ref. 15). It should be emphasized that the curve is illustrative. The human population maintains the disease cycle by passing eggs into the water bodies where vector snails are present. Livestock are involved in transmission to the extent that they may carry snails from one habitat to another (Ref. 16).

Characteristics of proposed irrigation project. The irrigation project is planned to shift the bulk of production to market crops of grain and fruit plus legumes and alfalfa, with provision for a wider variety of foods for consumption by the target population than occurs at present (Ref. 17). The irrigation system is to consist of diversion dam, main canal, main lateral, field laterals, and drains. The main canal, lateral, and main drainage canal are to be unlined but well compacted. Furrow irrigation is to be used for trees and legumes; border check irrigation for wheat and alfalfa. Both field irrigation systems are to be supplied with water by hand-operated siphons. The irrigation season is normally to be six to seven months during the dry season. During the wet season when there are heavy rains, snails may be flooded out of some pond habitats and/or flushed out of canals and drains into the river. Transmission of schistosomiasis would therefore be seasonal and peak in the dry (irrigation) season.

The existing clusters of villages are to be located both within and adjacent to the proposed irrigation system. Provision of domestic potable water supply is not to be a part of the project; thus, river water -- as at present -- and/or canal water would be the source of domestic and livestock water. The reservoir for regulation of streamflow to provide water for the irrigation system is located upstream at a distance such that there is essentially no interaction between human activities around the reservoir and those in the project area (Ref. 18). No immigration is expected as a result of the project.

Various aspects of the design, construction, and operation of an irrigation project influence the transmission of schistosomiasis. With respect to project design, important factors are the location of the irrigation project in relation to the location of villages, the presence or absence of domestic potable water supplies, and the design of the irrigation project in terms of flow velocities in canals and laterals, water storage requirements, method and frequency of water application, and degree of continuity of flow. With respect to project construction, the materials and quality of construction of canals will affect the amount of seepage from canals and laterals, the grading of fields; the quality of construction of field laterals and irrigation furrows and checks will affect the amount of standing water. With respect to maintenance, the degree of removal of vegetation and silt from canals, laterals, and drains will influence snail habitats and hence schistosomiasis transmission. Higher levels of maintenance can result in more efficient utilization of water as well as less habitat for snails. If water is entirely removed from the irrigation system during the non-irrigation season, schistosomiasis transmission will be inhibited.

Side effects of project as planned. In order to illustrate the management problems associated with schistosomiasis and irrigation, the expected side effects from the project as described above, in the absence of any schistosomiasis management strategy, are delineated. Because of increasing recognition that side effects may be substantial, project planning should include an estimation of project impacts on the ecosystem of the area and the subsequent effects of those impacts on the project population. Disease transmission models have been developed for use in project impact analyses (Ref. 19). Estimated changes in the characteristics of the natural system and in water related behavior of the project population have been linked in these models with baseline prevalence data to estimate the extent

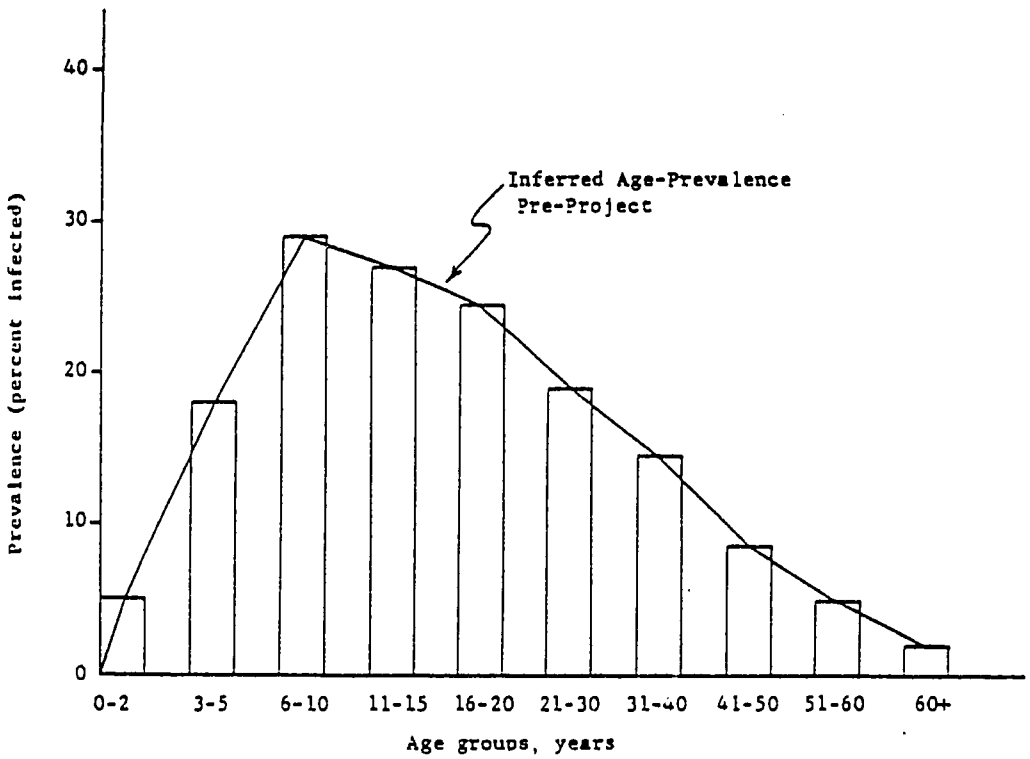

FIG. 2. Estimated age-prevalence of Schistosoma haematobium under pre-irrigation project conditions.*

* This curve was based on pre-irrigation and pre-disease control project data from the Dez Project, Iran (F.G.L. Gremliza, Ecology of Endemic Diseases in the Dez Irrigation Pilot Area, Development and Resources Corporation, New York, 1962, p. 128). The curve is illustrative and could be derived from data in any area with endemic S. haematobium.

of project impacts.

In any irrigation project system, even with careful construction, permanent side pools are likely to be formed due to seepage from the main canal and the main lateral with resulting development of randomly spaced pools of water. Furrow or border-check irrigation is likely to result in some standing water, at least at the ends of the furrows and checks. Similarly, drainage canals will likely have some pools. All the canals, laterals, and drains will have some vegetative growth and some sediment deposits even if a normal maintenance program is carried out. Therefore, the project is likely to result in substantially increased snail habitat compared to pre-project conditions. Because of the proximity of clusters of homes to the irrigation system, there is greater human accessibility to water, thereby leading to increased water contact. The canals, laterals, and drains offer a readily accessible depository for wastes, including organic materials. Table 2 lists the human activities involved and the resulting likely points of contact with snails.

Estimated impacts of the prototype irrigation project, with no schistosomiasis management, on prevalence of schistosomiasis in the project population are shown in Figs. 3 and 4. Figure 3 shows how total prevalence in the population is estimated to change over time. Figure 4 shows, after three years of project operation and no schistosomiasis management, the estimated age-distribution of schistosomiasis prevalence in the population. This may be compared with pre-project age distribution of prevalence shown in Fig. 2 and reproduced in Fig. 4. The distributions are based on results from the projects listed in Table 1. These distributions are given to illustrate how an irrigation project constructed and operated without consideration of explicit measures for preventing schistosomiasis transmission may increase schistosomiasis prevalence over time.

MODIFIED IRRIGATION PROJECT PLANNING

Recognition of the potential impacts of irrigation projects as planned lead logically to consideration of how the project might be modified to include explicitly schistosomiasis management. A management strategy consists of a combination of physical measures, implementation incentives, and institutional arrangements. In projects described in Table 1, attention was paid only to the first of these concerns, the physical measures. However, all three elements of a strategy are critical and must be considered simultaneously. The choice of a schistosomiasis management strategy is determined by knowledge of both irrigation and related epidemiological conditions of the disease and the cost and effectiveness of each alternative strategy. The cost and effectiveness in turn are affected by the social structure and mores of the society in which the project is being undertaken.

Figure 5 shows the sequence of analysis for project planning in which explicit consideration is given to schistosomiasis. A critical component of the analysis is the estimation of the prevalence of schistosomiasis under any given set of conditions. Such a quantitative estimation, however, requires use of a disease transmission model which is beyond the scope of this paper.

The following sections therefore discuss in a qualitative manner sets of physical measures for reducing the prevalence of schistosomiasis and some of the implementation incentives which are appropriate to induce application of those sets. Only minimal consideration is given to the third component of a management strategy, institutional arrangements. This is not because institutional arrangements are less critical -- if anything the contrary is true -- but because: (1) the relevant institutional arrangement is country and culture specific; (2) more empirical research and analysis needs to be done before reasonably valid specifications concerning institutional arrangements are possible; and (3) the relevant institutional arrangement must encompass more than the activities relating to the reduction of prevalence of disease. However, a few comments are made with respect to conditions deemed necessary for effective institutional arrangements.

Physical measures for reducing schistosomiasis prevalence

There are two categories of physical measures for reducing the prevalence of schistosomiasis: (1) reducing human contact with snail-infested water; and (2) medically treating the infection in the target population. The first has two subcategories: (a) reducing snail habitats; and (b) modifying the activities of the target population to reduce contact with existing snail habitat. Table 3 lists possible physical measures which could be applied to reduce the prevalence of schistosomiasis in the project area.

Reducing snail habitat can be accomplished by such measures as: using pipelines instead of open canals; lining canals to reduce seepage; better grading of fields and construction of laterals, checks, furrows, and drains to reduce standing water; removal of vegetation and silt from canals, laterals, and drains; more efficient irrigation; shifting from surface irrigation to spray irrigation, subirrigation, or drip irrigation; use of molluscicides; and application of biological methods (Ref. 20). Molluscicide use involves frequent

TABLE 2. Human activities and points of human-snail contact in irrigation projects

Human activity	Human-snail contact points
Irrigation of fields	Standing water in fields
	Manipulating siphons from secondary (field) laterals
Maintenance of irrigation system	All canals and drains
Washing (personal, laundry, dishes (see note a))	Laterals (secondary), drains, rivers, sidepools
Recreation	Sidepools, rivers, canals, main lateral
Obtaining (fetching) water	Laterals (secondary), drains, rivers, sidepools
Drinking water	Laterals (secondary), drains, rivers, sidepools
Residuals disposal:	
Personal	Fields, drains, laterals (main and secondary), river
Garbage	Drains, laterals (main and secondary), river
Livestock management	Flood plain of river, sidepools, ponds, swamps

Note a: If domestic water is separately supplied, there could be less of a problem for disease transmission.

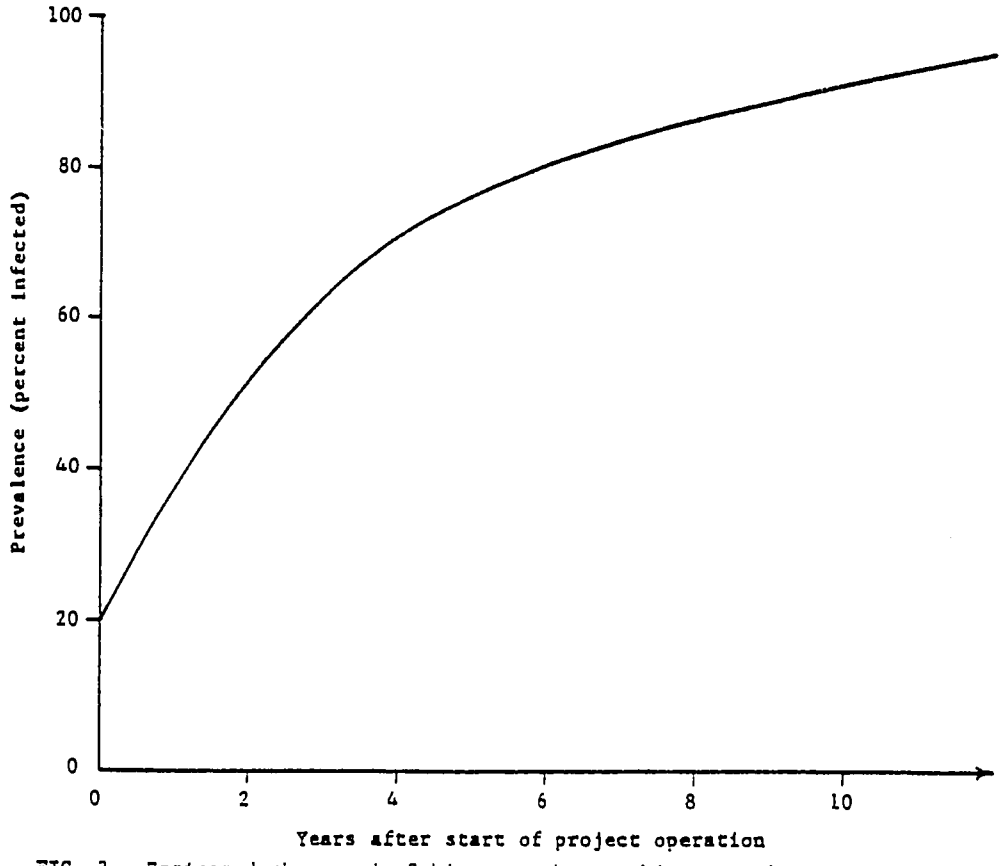

FIG. 3. Estimated changes in Schistosoma haematobium prevalence over time after prototype irrigation development and no schistosomiasis management.

Note: Prevalence is assumed to approach an Asymptote at 95%

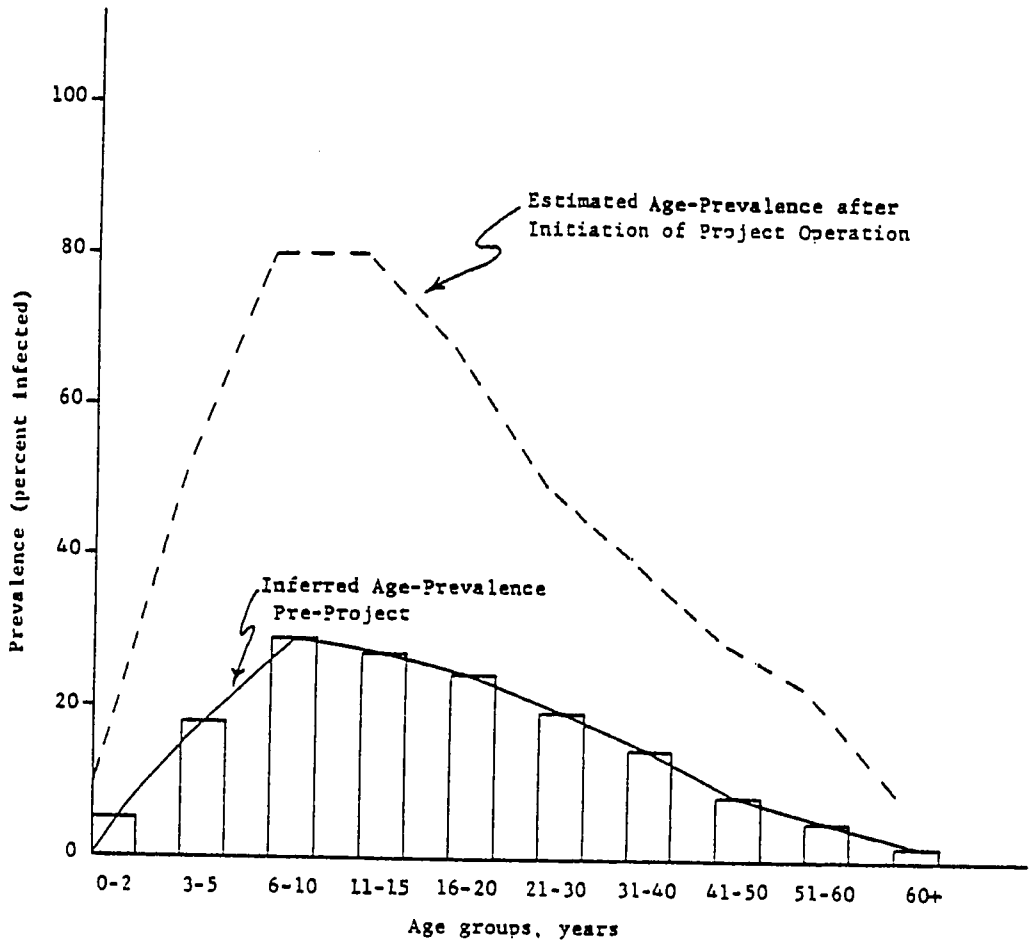

FIG. 4. Estimated changes in age-prevalence of Schistosoma haematobium three years after prototype irrigation project operation and no schistosomiasis management.*

* Estimated overall prevalence equals 65%

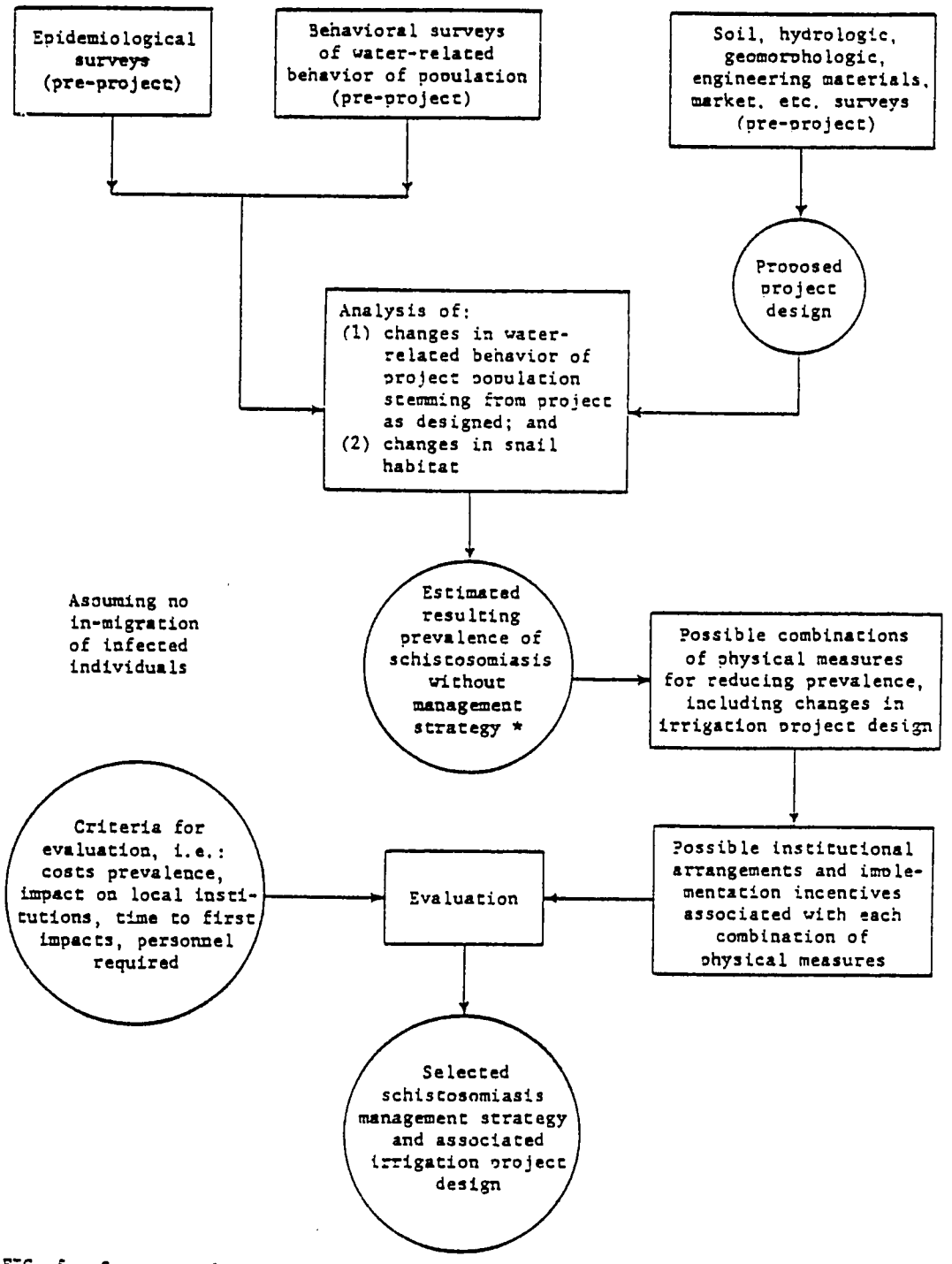

FIG. 5. Sequence of analysis for irrigation project planning with explicit consideration of schistosomiasis.

TABLE 3. Classification of physical measures for reducing the prevalence of schistosomiasis

I. Reducing human contact with snails

A. Reducing snail habitats and/or snail populations
   1. Molluscicidings
      a. all habitats
      b. focal (treating only habitats which are known transmission sites, e.g., which human contact occurs)
   2. Constructing mechanical screening at diversion point to prevent entry of snails into irrigation system
   3. Lining of main canal
   4. Draining standing water in fields and from main canal and laterals
   5. Vegetation/silt removal from main canal, laterals, drains
   6. Introducing predator or competitor species
   7. Piped transport of water to secondary laterals
   8. Increasing efficiency of irrigation

B. Modifying human activities
   1. Provision of domestic water supplies by standpipes in courtyards
   2. Provision of laundries
   3. Provision of showers
   4. Provision of swimming pools
   5. Protection (see note b) of water recreation sites
   6. Location of canals and drains away from existing settlements
   7. Provision of boots for irrigators and irrigation system maintenance workers
   8. Provision of latrines and garbage disposal sites in closer proximity to villages than canal, laterals, drains
   9. Protection (see note b) of animal grazing areas

II. Medically treating population with drugs (chemotherapy)

A. All infected population

B. Specific segments of the population (i.e., heaviest egg passers, 0-to-14-year-olds)

Note b: Protection in this context means physically restricting access to or egress from the area, such as by fencing.

reapplication because total elimination of snail population is impossible, either because part of the existing snail population survives by such means as burrowing into the substrata or because of a continual inflow of snails from outside of the area or both (Ref. 21). In addition, the effects of frequent molluscicide use on non-target species are essentially unknown. Biological controls are promising, especially where competing snail species are used, but such controls have yet to be used for large-scale snail control on a long-term basis (Ref. 22).

Modifying activities of the target population to reduce contact with snails can be accomplished by such physical measures as: providing alternative sources of water for domestic purposes (Ref. 23); providing alternative sites for disposal of wastes from human activities other than canals, drains, and land surfaces from which the wastes run off into water bodies; and limiting the contact of workers during irrigation and during irrigation system maintenance. The first two imply provision not only of potable drinking water supplies and latrines, but also of laundries, showers, and protected swimming sites. In carefully maintained programs, these have been effective (Ref. 24). Health and hygiene education are necessary components of any efforts to reduce human-snail habitat contact.

Chemotherapy involves the use of drugs to kill the parasites in infected persons (Ref. 25). Available drugs are fairly effective in killing the worms but do not prevent reinfection. With no prophylactic effect, chemotherapy, without use of other measures, requires continual reapplication to maintain a given level of prevalence. Typical short-run side effects of chemotherapy are nausea, dizziness, and stomachaches: the effects depend on the drug used. In addition, all of the infected population cannot be reached without a well organized health care delivery system.

Present control programs still rely primarily on chemotherapy and molluscicides for reducing schistosome infections in human populations. Some control programs have tried a variety or combination of measures (Refs. 26-35). Table 4 shows the available information on irrigation projects where various physical measures have been used to manage schistosomiasis. For many of these projects, it has been hard to assess exactly what the effects have been, either for a single physical measure or a combination of measures. Where some evaluation of effects was made, the resulting reduction of prevalence is given. The data in Table 4, although limited, suggest that use of a combination of physical measures appears to be more effective in reducing prevalence than use of a single measure (Ref. 36).

What level of prevalence "should" be achieved by a control program in a given area is not easily specified. Some low level of prevalence may have limited adverse health consequences and may be substantially easier to achieve than zero prevalence. Not doing anything, on the other hand, may entail high medical care costs and possible complications from disease. The different sets of physical measures described below reflect increasing intensity of management, increasing costs, and increased reduction in schistosomiasis prevalence. Because it is difficult to measure the monetary benefits of reducing schistosomiasis prevalence, as described earlier, other criteria must be established for choosing among alternatives.

At least three types of decision criteria may be used. The first is a physical standard in terms of snail population, for example, no more than one infected snail per meter length of water channel. Presumably, such a standard would be based on an estimate of the magnitude of infected snail population which would keep the prevalence of schistosomiasis at or below a target level. A second type is a physical standard defined in terms of prevalence of the disease in the relevant population, for example, maintain prevalence at the pre-irrigation project level. However, it is important to emphasize that the standard can be expressed in terms of overall prevalence in the population, in terms of prevalence by age groups, or both. With respect to both of these criteria, the costs and effectiveness of various alternatives need to be estimated to meet the designated standard. Because the costs of physical measures can be specified reasonably accurately, the least costly combination of measures can be determined.

A third approach to selecting a management strategy is to consider different goals, i.e., different standards in terms of combinations of overall prevalence and prevalence among age groups, and determine the least cost strategy to achieve each combination. Such a procedure enables examining how much it costs to achieve increasingly low levels of prevalence. For each level of reduction in prevalence, the incremental cost increases. Achieving zero prevalence is likely to be quite costly and not necessary to reduce human suffering to a tolerable level. However, it should also be noted that some of the physical measures comprising a management strategy might have other additional benefits, e.g., provision of a domestic water supply might reduce the prevalence of gastroenteric diseases. These benefits should be taken into consideration

Table 5 illustrates possible sets of physical measures to reduce schistosomiasis prevalence in relation to the prototype irrigation project. These sets include measures which have often been tried and those which have rarely been tried. The estimates of the cost and effectiveness of each set are based on past projects, such as those shown in Table 4.

TABLE 4. Physical measures used for schistosomiasis management in selected irrigated areas

Country (ref.)	Set of physical measures	Impact on prevalence	Implementation incentives
Japan (Ref. 26)	Molluscicide Cementing of ditches Land reclamation	Marked decrease in S. japonicum	Provision by national government of materials, personnel, equipment
S. Africa (Ref. 27)	Molluscicide Used clearing in canals	Not effective	None
S. Africa (Ref. 28)	Piped water Swimming pools Lining dams and streams Bridges	S. haematobium reduced from 79% to 21%; S. mansoni reduced from 68% to 3[illegible]%	Reorganization of irrigation system management structure
S. Africa (Ref. 29)	Cementing of canals Canals located above homes Protected swimming pools	N.E. (see note c)	Swimming prohibited 1971: State Health Department drew up official policy for certain areas with: safe domestic water supply latrines, safe recreational facilities
Malagasy (Ref. 30)	Cementing of canals Piped (borehole well) water Chemotherapy Molluscicide (unprotected drains)	N.E.	Cooperation between public health and irrigation personnel
Sudan Geriza (Ref. 31)	Molluscicide	N.E.	Provision by national government of resources for control program
Tanzania (Ref. 32)	Molluscicide Chemotherapy (later)	S. mansoni reduced from 50% to 20% prevalence	None reported
Rhodesia (Ref. 33)	Molluscicide Partial sprinkler irrigation Canals cement lined	N.E.	Legislation Ministry of Health advisory and supervisory role
Egypt (Ref. 34)	Chemotherapy Snail control Environmental sanitation (fountains and latrines) Mechanical barriers New housing	N.E.	Special government units for chemotherapy and snail control; trained personnel-health education; integrate schistosomiasis control into other health services -- Society for Control of Schistosomiasis
Brazil (Ref. 35)	Chemotherapy Molluscicide; where possible increased velocity in canals, draining, sanitation	N.E.	Department of Rural Endemic Diseases (training courses, provision of molluscicide, establish priorities); coordination of public health and irrigation officials; health education

Note c: N.E. = not evaluated.

TABLE 5. Selected sets of physical measures for reducing prevalence of schistosomiasis: Qualitative management requirements, costs, and effectiveness

	Physical measures used	Management requirements	Costs	Effectiveness in reducing schistosomiasis
Set I	No physical measures explicitly for schistosomiasis	None	None	None
Set II	Molluscicidng all sites	Trained operators, local workers	Low investment, high maintenance costs	Low
Set III	Chemotherapy for all	Doctors, local workers	Low investment, high maintenance costs	High short-term; low long-term
Set IV	Chemotherapy for all infected persons; mechanical screening at diversion point; drainage facilities; vegetation and silt removal; improved irrigation efficiency	Doctors, engineers, local workers	Medium investment, medium maintenance costs	Medium
Set V	Focal molluscicidng; provision of domestic water supplies; protection of water recreation sites; provision of boots for irrigators and irrigation system maintenance workers; chemotherapy for specific segment of infected population	Trained operators, engineers, doctors, local workers	Medium investment, medium maintenance costs	Medium
Set VI	Molluscicidng all sites; mechanical screening at diversion point; drainage; vegetation/silt removal; provision of domestic water supplies, laundries, and showers; provision of latrines and garbage disposal sites; targeted chemotherapy	Doctors, engineers, trained operators, local workers, health educators	High investment, high maintenance costs	High

The irrigation project with no explicit schistosomiasis management strategy comprises the base situation, termed Set I. Under this set, the endemic nature of schistosomiasis transmission would be changed from a steady-state situation to one of disequilibrium. With no physical measures, snail habitat and human contact with snails would increase. Prevalence in the project population would likely rise toward 100 percent, but probably would never quite reach 100 percent because of acquired immunity or because some individuals have little water contact. This situation would entail increased medical care costs if those infected sought out treatment.

Set II is comprised of a single physical measure, the use of molluscicides on all habitats. Although this measure would conceptually be easy to apply, its effectiveness is likely to be quite low over time. As noted previously, snails can survive successive molluscicide applications by burrowing into muddy bottoms or banks. To be effective, frequent and thorough surveillance would be necessary, usually followed by extensive reapplication of molluscicides. Because there were infected persons and infected snails in the pre-project population, unless all snails were eliminated, prevalence could rise under this set.

Set III also is comprised of a single physical measure, chemotherapy for all infected individuals in the project population. This approach would immediately reduce prevalence levels. However, because snails would continue to thrive in canals and other waters, and people would still have contact with the water, prevalence would likely rise over time. In addition, because drugs do not confer immunity, even those treated would be likely to be reinfected.

Set IV is comprised of: chemotherapy for all infected individuals, before and after project construction; mechanical screening at the diversion point to limit the introduction of snails from the river into the irrigation system; more careful grading of laterals and fields to reduce standing water and enable more efficient irrigation; and continual vegetation and silt removal. Continuing use of both chemotherapy and engineering measures has not usually been tried in schistosomiasis management programs. Because engineering measures could permanently eliminate snail breeding places and because chemotherapy is effective in killing parasites, prevalence would probably over time be reduced below that prior to the project. However, only with careful surveillance of the system, and checking for and treatment of infected persons, would that lower level be maintained.

Set V is comprised of: focal molluscicidng, i.e., molluscicidng of active transmission sites or high potential contributors of snails to the irrigation system; provision of various facilities to modify human activities to reduce contact with snails; and chemotherapy for selected segments of the population. Domestic water supplies would be provided without changing the locations of the canals and laterals. Targeted treatment of the project population would limit egg contamination of canals and other waters. Use of focal molluscicidng and targeted chemotherapy represents an attempt to minimize the public health activity necessary to achieve desired schistosomiasis prevalence levels. These two measures combined with the provision of alternative water facilities should gradually reduce prevalence to some low level. Set V would likely have similar results to Set IV, because human contact with snail habitat is limited in Set IV by the permanent elimination of the habitat and in Set V by the provision of domestic water supplies. Both sets require continual maintenance programs.

Set VI is comprised of: molluscicidng of all habitats; mechanical screening at the diversion point; drainage facilities; vegetation and silt removal; provision of domestic water supplies and other water-related facilities; provision of swimming pools; provision of latrines and garbage disposal facilities; and targeted chemotherapy. This comprehensive set of physical measures has not been used in any schistosomiasis management program, most likely because of its financial and organizational requirements. Its use would lower schistosomiasis prevalence gradually over time. If initiated at an early stage of the project, its use might possibly reduce the prevalence of schistosomiasis to very low levels rapidly and then maintain those low levels over time. Schistosomiasis would no longer be a public health problem.

In a "real world" project planning context, more specific information is needed on costs and effectiveness of physical measures. Although project planners and the relevant decision-makers -- local and national -- may have established a target or desired level of schistosomiasis prevalence at the start of project planning, that target level might well be modified after the analysis of the cost and effectiveness of alternative sets of physical measures and the associated implementation incentives and institutional arrangements.

Implementation incentives and institutional arrangements

Installation, operation, maintenance, and continued use of a given set of physical measures to reduce the prevalence of schistosomiasis are not automatic. Individuals responsible for

or involved in operating the irrigation system must be induced not only to construct the physical measures for schistosomiasis management, but also to operate and maintain the physical measures over time. Individuals living in the project area must be induced to change their behavior patterns. Inducing action and changing behavior requires both culturally sensitive implementation incentives — those instruments, techniques and procedures which induce individuals, groups, agencies to act — and institutional arrangements. The latter are the organizational structure, formal or informal, which has authority and responsibility for imposing implementation incentives.

Implementation incentives can most usefully be considered in relation to: (1) the various elements of an economic development project; and (2) the levels of agencies -- governmental and non-governmental -- typically involved in such a project. One characterization of the elements and levels is shown in Table 6. The parentheses in the table indicate that the designated level agency may or may not be involved in the respective element, but could be. External agencies include both governmental and non-governmental agencies: international agencies such as IBRD and the special U. N. agencies; individual country "foreign aid" agencies, such as U. S. AID; and private foreign aid agencies, such as the Swiss Helvetas.

The implementation incentives component of a management strategy can now be defined more specifically: what implementation incentives can be applied at which levels of government in relation to which physical measures to reduce the prevalence of schistosomiasis in relation to the proposed irrigation project (Ref. 38)? Table 7 contains a partial listing, a listing which is meant to be suggestive, not exhaustive. No attempt has been made to fill in all the relevant boxes. Only a few of the indicated implementation incentives will be discussed, for illustration; the entries in the table are basically self-explanatory.

The "power of the purse" is an effective incentive in many cultures. For example, loan funds could be made contingent upon incorporating the analysis of project impacts on the prevalence of schistosomiasis and upon incorporating a schistosomiasis management strategy in the project. The effort since 1973 by the World Bank to evaluate potential impacts of irrigation projects on schistosomiasis transmission is an important first step in this direction (Ref. 39). Provision of technical assistance for analysis of impacts and for the development and evaluation of alternative schistosomiasis strategies would constitute an additional incentive.

A major problem in inducing action involves the perception of the problem on the part of the population at risk, both with respect to the existence and effects of schistosomiasis and the options for reducing prevalence. The individual may not recognize either that he has the disease or what the effects of the disease are on himself. The physiological state of the individual is affected by multiple factors, including nutritional level. He may or may not be able to associate his physical state with a specific cause. Similar symptoms may be caused by more than one type of stress.

Even if there is perception on the part of the individual that his physiological condition, e.g., debilitation, is the result of schistosomiasis, it may not be easy to induce him to initiate and continue actions which will eliminate his infection. For example, for chemotherapy to be effective, repeated treatment is generally necessary because of reinfection (Ref. 40). But if there are short-run side effects of chemotherapy such as nausea, vomiting, dizziness, abdominal pain or cramps, and headaches, the individual may consider that having to undergo such side effects for several days every few years is worse than having the disease. Because schistosomiasis is a chronic disease, such considerations present very real difficulties to chemotherapy programs.

At least two implications follow from the problem of perception. First, because it is the affected population which must be induced to act over time, involvement of the accepted leaders of that population in the planning process is probably essential in order to achieve a reasonably high level of desired action. If those leaders can be convinced of the problem and how it can be handled, they in turn can help convince the rest of the affected population of the necessity for certain actions. A health and hygiene education program can help to explain how schistosomiasis is transmitted, what its effects are, how potable water supplies help reduce transmission, and how to use and maintain water supply and waste disposal systems. However, although an externally provided health education program is necessary, it is not likely to be sufficient. Approval by the local power structure is a necessary condition for the success of such a program. Such has been the experience in St. Lucia where the provision of water supplies, the use of health education, and the involvement of the local population led to reduction in schistosomiasis prevalence from 50 percent to 29 percent in three years (Ref. 41).

Second, although the monitoring of performance and the imposition of sanctions, penalties, and rewards for performance could conceptually be carried out at the local level, generally a higher level of government — as well as the local level -- must perform these functions. Thus, the national -- or regional or state -- government would have to have the responsibility for monitoring the snail habitat, the prevalence of the disease, the condition of

TABLE 6. Elements of and levels of agencies which could be involved in schistosomiasis management programs

	External agencies	National	Local
Project planning	x	x	(x)
Project financing	x	x	(x)
Project construction/installation		x	x
Project operation/maintenance		(x)	x
Project monitoring	(x)	x	x

Note d: The parentheses indicate that the designated level agency may or may not be involved in the respective element, but could be.

TABLE 7. Implementation incentives in relation to project elements and levels of agencies involved in schistosomiasis management programs

	External agencies	National agencies	Local agencies
Project planning	Provision of technical assistance; development of guidelines for analysis of impacts and of schistosomiasis management strategies	Promulgation of requirements for impact analysis and of guidelines for such analysis Requirements of including responsible local individuals and personnel from health agency in project planning	Integral participation in project planning
Project financing: construction and installation	Specification by financing agency that financing is contingent upon: (1) explicit analyses be made of impacts on schistosomiasis; (2) local individuals who will be responsible for project O&M, including schistosomiasis management, be integrally involved in project planning; and (3) schistosomiasis management strategy be incorporated in project plan	Financing of potable water supply, laundry, waste disposal facilities	
Project construction/installation		Provision of construction inspection by health authorities	
Project operation and maintenance		Provision of training to local individuals in O&M of irrigation system, including schistosomiasis management Provision of continuing health education program for target population Provision of free chemotherapy Provision of free molluscicide Payment of bonus for performance, i.e., based on snail population, degree of removal of vegetation/silt from canals	Prohibition by local oridnance of disposal of wastes in canals, laterals, river; prohibiting water recreation in canals, laterals, drains (as long as alternative provided) Continuation of program of persuasion by local power structure to induce compliance
Project monitoring		Provision of survey teams: (1) before and after molluscicidng; (2) for random inspection of irrigation system maintenance (3) for random inspection of irrigation activity, e.g., to check on wearing of boots	

the irrigation system, e.g., main canal, laterals, drains. Of course, monitoring per se provides little, if any, inducement to action. Therefore, there must be some associated penalties or rewards related to non-performance or performance. For example, the workers responsible for measures to reduce snail habitat might be given a bonus for each percentage reduction in habitat below a given level. This kind of multi-level program has been tried in modified form by the People's Republic of China where bonuses as well as political pressure has led to successful control of schistosomiasis (Ref. 42).

Appropriate institutional arrangements are essential for use of implementation incentives combined with the chosen set of physical measures. Different implementation incentives may be used with a given physical measure; a given combination of physical measures and implementation incentives can be carried out by different institutional arrangements. Because institutional arrangements are country and culture specific, no attempt is made herein to suggest specific institutional arrangements.

However, certain conditions are essential for an institutional arrangement to be effective. One, responsibility and authority to carry out the specific activities relating both to irrigation and to schistosomiasis management must be defined and assigned. Two, both the relevant irrigation agency and the relevant public health agency must be involved as partners. Such a partnership has rarely existed. Cooperation must be in terms of integrated action, not in terms of inter-agency memoranda. Three, proposed irrigation projects — whether funded totally by the country or with support from outside donors — should be reviewed before being approved by a committee consisting of irrigation managers, public health personnel, and individuals from the local formal and/or informal power structure.

CONCLUDING COMMENTS

Substantial evidence exists that some types of economic development projects have resulted in unanticipated adverse side effects. Irrigation projects resulting in increased prevalence of water-related, water-borne diseases comprise one type of example. The failure to consider these side effects, and to provide explicit management strategies to reduce them, can reduce the economic productivity of the development project and detract from the general well-being of the project population.

This paper has suggested components of management strategies and their incorporation in project planning in order to reduce adverse side effects of irrigation projects. To achieve such reduction clearly requires changes in both project planning and project execution.

First, in project planning explicit estimates must be made of: (1) the impacts the proposed project will have on the relevant ecosystems in the project area and on the introduced ecosystems; (2) the effects of the project on the water-related behavior patterns of the project population; and (3) the effects of both on the foregoing on prevalence of disease. Such estimates must be made regardless of how rudimentary knowledge is on the underlying ecological and human processes.

Second, management strategies to mitigate the adverse consequences of economic development projects should be sought in terms of effectiveness in attaining certain goals in relation to incremental costs. Incremental costs will almost certainly increase substantially as 100 percent absence of infection is approached. For project planning, several target levels of prevalence should be specified, and the costs of alternative management strategies to achieve each target estimated.

Third, the consequences of infection in humans is not simply a function of the presence of parasites and vectors, but also of nutritional level and already present diseases. To reduce the prevalence of a given disease, such as schistosomiasis, to 0 percent, requires measures directed to more than the single disease, and which may have benefits beyond only controlling schistosomiasis.

Fourth, a strategy for managing schistosomiasis — or any other vector-borne disease or any other adverse environmental consequence — consists of three essential components: physical measures for reducing the prevalence of the disease; implementation incentives to induce the carrying out of the physical measures; and institutional arrangements which allocate the responsibility for imposing the implementation incentives on the relevant actors. These three components must be considered simultaneously. There may be several different implementation incentives for a given physical measure; there are likely to be differences in the applicability of various implementation incentives in different cultures. The same is true for institutional arrangements.

Fifth, agencies at different levels — local, national, international — are usually involved in water resources projects, in one or more of the activities comprising such projects — planning, financing, construction, operation. Different implementation

incentives may be applied at the different levels, but they must be consistent.

Sixth, although conceptually the monitoring of project performance could be carried out at the local (project) level, it is very likely that monitoring and enforcement (imposition of sanctions) will also have to be carried out by the next higher level of government.

Two important deficiencies in the planning and execution of water resources projects in the past have been the failure to analyze explicitly the possible adverse side effects of such projects and the failure to incorporate explicitly in projects the implementation incentives and institutional arrangements necessary to initiate, operate, and maintain the projects over time. To reduce the adverse side effects of such projects, more rigorous field monitoring and subsequent analysis must be done to determine which combinations of physical measures, implementation incentives and institutional arrangements are most effective in achieving the desired reduction in adverse health impacts in different cultural contexts. This paper has attempted to suggest procedures for improving the planning and execution of water resources development projects.

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36. One caveat should be indicated. Comparison of alternative combinations is hampered by the fact that there are likely to be different degrees of uncertainty associated with the estimates of the physical effects of the different combinations, because the effects of all physical measures cannot be estimated with the same accuracy.
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