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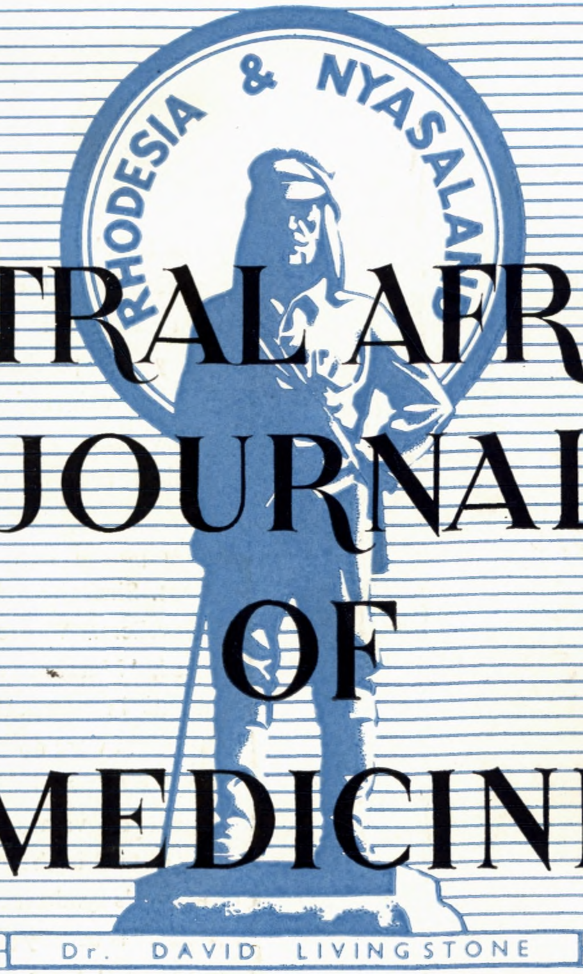

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CONTENTS

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Bilharzia: The Necessity for Control Measures on Irrigated Estates:

THE IMPORTANCE OF A PLANNED IRRIGATION SYSTEM IN THE BIOLOGICAL CONTROL OF THE SNAIL VECTORS IN AREAS WHERE THE TOPOGRAPHY IS SUITABLE AND SITE SELECTION IS POSSIBLE

BY

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Bilharzia (schistosomiasis) to-day is a major tropical and sub-tropical disease and ranks with malaria as a health problem in these areas. As a health hazard it is beginning to replace the latter disease owing to the improved means of malarial control. Bilharzia is gradually spreading and is now firmly established in areas where it previously did not exist.[1,2] Especially is this so in Africa, where the increasing employment of irrigation and water conservation will tend to disseminate it more widely still.[3] Water is the life blood of Africa and the necessity for it is apt to override considerations of health, particularly where preventive measures to control this disease appear on the surface to be impracticable. There results an attitude of mind which often ignores the hazards and even neglects to take elementary precautions. The sequel is an unnecessary intensification of the disease, whereas a little forethought would have kept its incidence within normal bounds. The danger of this attitude needs no stressing. This paper adds to the extensive literature on the theme that its intensity in certain areas may be unnecessarily increased by ill-planned and ill-controlled irrigation schemes. It may be introduced into previously free areas by such schemes, when a little forethought will prevent it ever getting a serious foothold.

Avoidable man-made bilharzia is a factual entity, well recognised by all who have studied the endemicity and spread of the disease, and the danger from irrigation schemes has long been known.[4,5] Irrigated estates require labour to work them. Labour is usually recruited elsewhere from sources widely scattered over the continent, some contaminated, others non-contaminated by the disease. The concentration or aggregation of labour, infested and non-infested, into an area heavily infested with snails and devoid of any attempt at control is fraught with danger both for the individual and for the spread of the disease. In some areas technicians may be brought from outside tropical or sub-tropical countries with the possible additional danger of introducing new species of parasites into the area and the later transference of the existing parasites to new regions. This transference of parasites to new areas occurred in America and Australia.[6] Bilharzia of the aggregation or concentration of labour exists, as it is recognised that it might occur in malaria. No better argument can be found for measures to control the transmission of the disease in irrigated areas where it is at all feasible.

It might be apposite to discuss the dangers of bilharzial infestation for the individual and certain views which have been expressed as to the effect of this infestation on the health of those afflicted. The infestation is chronic, silent and insidious, debilitating the individual over the years. So insidious are its effects that some doubt has been cast upon the view that it is a serious hazard to health, and it has been suggested that an individual can live with this infestation, reaching a compromise whereby a mutual tolerance exists between host and parasites. This philosophy is very convenient to expound in the absence of measures adequate or economically feasible to control or eliminate the disease. I believe it is a misinterpretation of the situation. If expounded to the lay administrative public it provides a very useful argument against measures directed towards the reduction of the incidence of the disease. It is true that in many areas of Africa a large proportion of the Native population, 70 to 90 per cent. in some areas, are infested and apparently live without detriment to their health or their ability to survive, and without apparently suffering from inconvenience or disability.[2, 5, 7, 8, 9] In this connection the statements of the average African, particularly a tropical African, are unreliable, and generalities based upon them are likely to be extremely misleading. The health and efficiency of the average African in the tropics is reduced by many factors, and one might say that he has never experienced perfect fitness. The average tropical African's conception of fitness is that of a compromise with chronic disease and infestation. It is not uncommon to find malaria, hookworm, roundworm, tapeworm and schistosomiasis (often a double infestation) in the same individual. Due allowance must be made for the inadequacy of his diet, which usually adds to an African's disabilities. The removal of the multiplicity of debilitating infestations from such a stock is likely to produce greatly improved individuals whose health efficiency and conception of fitness will differ markedly from that of the present African.

It may be argued that the problem in bilharzia is not one of infestation as such, but rather a question of intensity of infestation or worm load. This is a contradiction in terms. Any unnecessary load which an individual carries reduces his efficiency. It has been my experience that a schistosomal infestation, if it is heavy enough, will reduce an individual to a point where death will be the final result unless measures are taken to eliminate the worms. Especially is this the case with *S. mansoni* infestations. It would now seem that some of the more serious sequelae once attributed to the disease are unlikely, e.g., carcinoma of the bladder and rectum and cirrhosis of the liver.[10] Serious disease of the urinary tract would appear to be a definite hazard in *S. haematobium* infestations. Complications and sequelae apart, experience of the disease and reasoning will lead most clinicians to regard any infestation as serious. The worms are living creatures, foreign to the body, depriving it of nutrients, evolving toxins and foreign waste products, and destroying the constituents of the circulating blood. That they produce repeated pathological damage and a persistent disturbance of metabolism is proved by evidence both from human and experimental infestattions.[11, 12, 13] Particularly is this so in *S. mansoni* infestations. Even a light infestation is likely to cause debility, inefficiency and anaemia, reducing an individual's resistance to other diseases and retarding his recovery therefrom. If allowed to continue untreated, it is likely to shorten life. The argument that it is not in the interests of the worm to kill the host is scientific nonsense, for it has more than adequate time to ensure its propagation before it kills the host, which it does slowly. Clinically there is no way of assessing an individual's degree of infestation or worm load. Individual resistance to infestation undoubtedly varies and a light infestation in certain unfortunates may have a markedly deleterious effect. Moreover, resistance to re-infestation (additional infestation superimposed on an existing one), if it exists, requires time to develop and likewise must vary from time to time in any one individual. Repeated exposure of a lightly infested individual to a heavily contaminated water is likely to result in a progressive increase in the worm load carried, particularly if the individual has been debilitated by intercurrent disease or poor diet. The exposure of a non-immune to a heavily contaminated water is likely to result in the immediate acquisition of a heavy infestation or load against which he has no defence. These arguments apply equally to the African and the European. It might be suggested that the average African in the affected areas has an inborn, selected, racial resistance to the infestation, but no European can be regarded as having a similar defence. It is inconceivable that any European should be allowed to harbour the worms for any length of time, irrespective of any measures designed to maintain his health.

If there is any difference in the virulence and effects of mansonal infestations in Egypt and those south of the Sahara, it behoves the authorities to ensure that the former species of worm are not introduced into the latter areas.

Methods of Control

The essential facts of the transmission cycle of the disease are known. Methods of control can be classified under the following system:—

A. *Control of the Human Host of the Disease*

(i) Prevention of contamination of water sources by infested individuals, e.g., by the provision of sanitary facilities for the disposal of excreta and the inculcation of sanitary habits in the population.

(ii) Therapeutic treatment of infested individuals.

(iii) Prevention of infestation and re-infestation by the provision of an adequate safe domestic water supply and education of the population concerning the necessity for its use and the avoidance of dangerous water.

B. *Control of the Snail Vectors of the Disease*

(i) Employment of biological methods.

(a) Elimination of sites suitable for snail lodgment and breeding. The non-creation of such sites by engineering and irrigation schemes. The employment of underground, piped or pump irrigation where necessary and feasible.

(b) The rendering of unavoidable potential lodgment and breeding sites unsuitable, e.g., by removal of aquatic vegetation, drying out, proper maintenance and initial planned construction.

(c) The employment and maintenance of natural enemies of snails, e.g., aquatic fowls, ducks, geese and possibly fish.

(ii) Use of chemical poisons for snails (molluscicides).

Whatever combination of methods is employed in any given area of Africa, it is likely that the main attack will be directed against the snail vectors.[14]

In an infested area a sanitary minded community provided with a safe, adequate domestic water supply can remain free from the disease provided the individuals have no necessity to come into contact with dangerous water by reason of employment or other activities.

Theoretically, if it were possible to restrict a particular watershed of the nature later to be discussed for the sole use of such a community and to prevent excretal contamination of the natural water supplies on it, the transmission of bilharzia would cease. In practice the prevention of excretal contamination of natural water supplies, even with the most hygienically minded of communities, is impossible, and the danger of serious transmission will persist in the absence of measures to control or eliminate the snail vectors of the disease. In Africa the existence of a highly infested, backward, indigenous population dictates that the primary attack must be directed against the snails, the attack being supported by measures to control the human host and to prevent the contamination of natural water sources.

Theoretically mass therapeutic treatment of all infested individuals in or entering a controlled area likewise would eliminate the disease. However, at present no drug suitable for mass treatment of an infested populace exists. The extensive application of mass treatment by tartar emetic is said to have been beneficial in Egypt, particularly in the reduction of the incidence of the complications of the disease.[15] Injection treatment, particularly by the intravenous route, is not ideal for mass prevention or elimination programmes, and all antimony compounds have serious drawbacks for this purpose. Research is being carried out to discover a safe, non-toxic drug, free from side effects and effective by oral administration. Indications are that such a drug may be available eventually. It would render the control of the disease feasible in many areas and hold out hope of its final elimination.

Total elimination of the snail vectors of the disease would stop transmission, but can never be attained in practice. The best that will ever be attained will be a reduction in their numbers. For this reason supportive sanitary and educational measures must accompany any assault on the snail vectors. In fact, it can be stated that in certain areas where effective snail control is unlikely ever to be attained with the methods available at present, the prime emphasis must be placed on sanitation and education. There are many areas where snail control can be practised and their numbers greatly reduced and the likelihood of heavy snail infestation prevented. Copper salts apart, no molluscicides exist which are harmless to other animals and crops. Research may eventually provide a compound specifically toxic for snails, but in its absence copper salts are the only chemicals safe to use under wide conditions. Their use is limited by the cost in the case of large volumes of water. "Santobrite" and certain highly toxic phosphorus compounds have limited application due to their all-round toxicity.

The biological attack on snails is stressed by all workers. It is a practical method of attack and in certain areas it will assist greatly in reducing the extent of snail colonies, limiting them to certain sites, if not eliminating them entirely, and allowing of the economic use of molluscicides. The difficulty of its application lies in the fact that it requires the intelligent co-operation of the farmer, agricultural worker and irrigation engineer, who often regard the measures as a nuisance and who, if they do not openly oppose them, fail to grasp the ease of their application and their effectiveness. One might go so far as to suggest that a more stringent attitude by government and public health authorities, armed by adequate legal powers, is now justified in the interests of the general public, particularly in respect of large irrigation projects. Here expert opinion would be required to indicate those measures which it is justified to enforce. The inclusion of safeguards of this nature in leases, options and the granting of water rights for any purpose by governmental bodies needs consideration.

In his book, *A Background for the Prevention of Bilharzia* (1953), Mozley presents on page 56 a photograph of typical East African bush country. A note below gives a warning of the probable results of irrigation in such country. From personal experience this writer can state that his words were prophetic. This paper is intended to be both a warning against and a guide to prevent the hazard of irrigation in similar areas of tropical Africa, and it is hoped that it may assist in the reduction of the incidence of the disease in other areas where irrigation may be initiated.

Accompanying the paper is a theoretical map. It can be regarded as representing any mountainous area and its lowlands in central tropical Africa, where it may be proposed to start irrigation. The map is included to assist the reader to visualise the type of watershed to which the recommendations and descriptions in this paper may apply.

This paper is based upon experience gained from a survey to ascertain the distribution of and infectivity rates amongst snails on an irrigated estate in central Africa. The area in which the estate was located had physical and topographical characteristics similar to those of the illustrative map.

The possible snail vectors in the area surveyed were:

Biomphalaria (*Planorbis*) spp. (? *B. adowensis*).

Physopsis spp. (*P. globosa*).

Bulinus spp.

The main snail vector in the area was *Biomphalaria* spp. and the main disease on the estate was *S. mansoni.* Large colonies of this species of snail occurred with infectivity rates which varied from site to site from 0 per cent., through 6.6 per cent. to 37.5 per cent. The incidence of *S. mansoni* infestations amongst the personnel was very high.

Bulinus spp. were fairly numerous in the area, often being associated with infected *Biomphalaria* snails, but no infective snails of this species were found in the area.

Physopsis spp. were not numerous compared with *Biomphalaria* and *Bulinus* snails, being found in odd sites in small numbers. None were found to be infective.

Cases of *S. haematobium* infestation occurred amongst the personnel, but were not so numerous as those due to *S. mansoni.* While transmission of this species of parasite probably did occur on the estate, it was considered that many of the cases were imported.

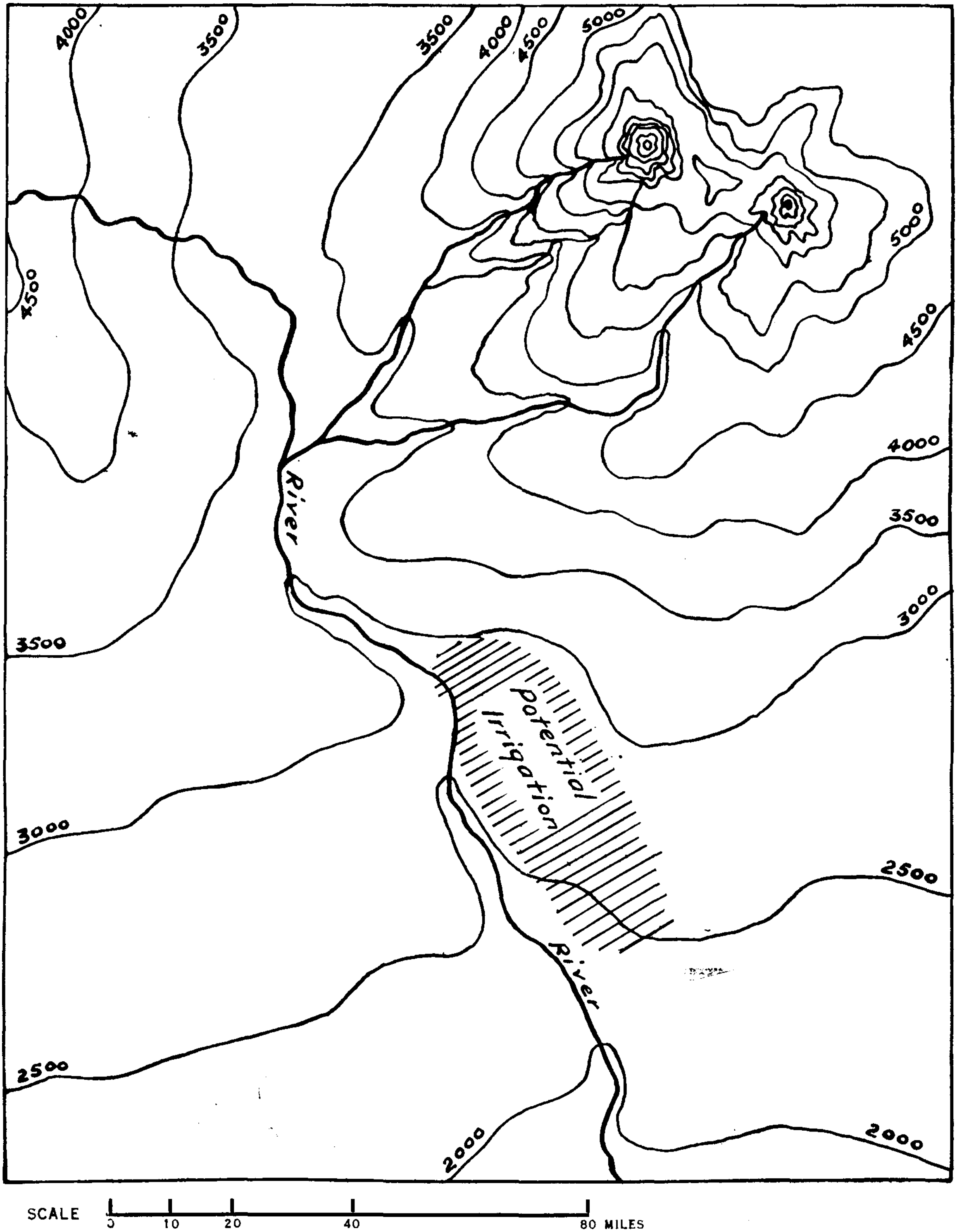
Limnae spp. (? *Natalensis*) and a dextral operculate aquatic species of snail were also found, but neither type was found to be carriers of human parasites.

The necessity for brevity and other considerations prevent me from giving a detailed account of the survey. It would entail repeating much material which can be found in standard works on vectors and their control.

The experience of the investigator plays an important role in assessing the degree of snail infestation and its danger in any area. The suitability of a particular site for snails can be estimated by its location, character of the water (e.g., clear, foul, fresh, moving, rate of movement or flow, still), presence or absence of vegetation and its type, presence or absence of debris, rubbish, faeces and food supply. The degree of snail infestation of a particular site can be assessed by the numbers collected, the ease of collection and the size of the site. Danger can be assessed by the infectivity rate amongst the snails actually collected, also by evidence of likely human excretal contamination. Suitability of a site for snails can also be assessed by the size of the snails found and by evidence of active egg-laying and breeding. Large snails in any numbers are only found where they have been undisturbed and allowed to mature and where conditions are conducive to longevity. The system has its limitations, but in the absence of more accurate knowledge it is the only one which can be employed in the field at the moment.

The life cycle of the snail from egg to sexually mature adult takes three to six months, depending on the temperature. The period from egg to young mobile snail takes 10 to 20 days, depending on the temperature.[16, 17]

A snail infested by a miracidium takes about six weeks to become infective (i.e., capable of contaminating the water in which it lives).[6] This is a long period during which the snail can be eliminated before becoming a menace to health. If conditions are made unsuitable it may die, remove itself or be removed elsewhere, or be killed before becoming infective and a danger.



A map representing a mountainous area and its lowlands (see text, page 142).

Assuming that the youngest mobile snail can be infested by a miracidium, if all adult snails are destroyed a new generation derived from viable eggs remaining will not be infective under a minimum period of six weeks and probably not before two months or longer, even under optimum conditions.

Snails require suitable conditions to lodge, breed and develop infectivity. Large colonies with a high infectivity rate take several months to develop.

It became apparent from the snail survey that on a river or on an irrigated estate, provided all other factors were suitable (e.g., temperature, pH, and chemical composition of the water, and food supply), the rate of flow of the water was the important factor determining the distribution of the snails and the sites they would be found in on the river and the estate. This applies particularly to the *Biomphalaria* spp. and the *Bulinus* spp. encountered on the survey. The influence of the rate of water flow on the distribution of snails is well known. Its significance for irrigation schemes in certain areas should not be overlooked.

An attempt was made to measure the rate of flow in different canals and channels and to correlate it with the degree of snail lodgment. It was found that canals overgrown with vegetation at their margins and elsewhere would always contain snails. Where they were markedly overgrown, snail colonies (*Biomphalaria* spp.) could become very large. But it was also noted that where a clear central channel remained with a good rate of water flow, very few snails were found, even in heavily overgrown margins. Danger sites were overgrown canals where the rate of flow was greatly reduced by the vegetation, canals where the rate of flow was negligible and night storage reservoirs which were never completely emptied and contained vegetation. These night storage reservoirs acted as a trap for snails carried in from higher levels, thereafter providing ideal lodging and breeding sites. The rate of flow not only influenced the snail distribution, but also the type of aquatic vegetation in the canal. Snails were never found in canals where the rate of flow was rapid and vegetation was absent or kept to a minimum. It became apparent that by utilising the topography and adopting a correct lay-out, the construction of suitable reservoirs and their correct siting, the avoidance of canals of incorrect gradients, much could be done to control snail lodgment and breeding on irrigated estates in certain areas, and in this way reduce the danger of bilharzia infestation in the involved personnel.

A biological control of snails exists in tropical central Africa on an untouched watershed of the type illustrated by the map. This control is mainly dependent on the rate of water flow in the main river and its tributaries. At high altitudes water temperature probably plays a part in determining the level at which snail vectors are to be found on a particular stream or river.

The sources of streams rising high up on the mountains of central Africa are perennial and subject to periodical flooding due to the heavy rains which occur in the mountain regions. In certain parts the sources arise on mountains, frequently or permanently snow-covered, and the water temperature is much lower. The annual rains of central Africa are noteworthy for their severity and cause heavy flood waters in the streams and rivers generally. In a mountainous area these floods are heavy, and pouring down a watershed of the nature depicted will scour out the river for many miles, removing the snails together with much larger obstacles and masses of vegetation and debris. It is certain that such annual floods practically annihilate the snail population in these rivers and their sources, removing them to lower levels. Snails become re-established from odd snails and eggs remaining in side pockets, and from snails re-introduced from lower levels and elsewhere on the feet of aquatic fowls, and by animals such as crocodiles and hippopotami. It will take about two to three months, probably longer, before any large colonies of snails become established on any section of the river scoured out by the floods, and the danger of heavy bilharzial transmission will begin to arise about this time and continue until the next heavy floods. On an untouched river the odd flushing effect of irregular and slighter rains amongst the mountains will assist in removing some snails to lower levels, curtailing the snail population. During the periods of normal flow the snail colonies on the river margins are subject to constant attrition, their members being carried off to lower levels by the rate of flow.

On a watershed of the nature depicted, snails once established, will be found below 4,000 feet and will certainly be present in the river once it leaves the foothills and reaches the gradually sloping, undulating levels of land suitable for irrigation. Colonies will be found in pockets, amongst aquatic vegetation, in overgrown marginal backwaters. Much will depend on the nature of the bed of the river. Where the bed is rocky, stony, pebbly, and it is likely to be so where scouring by heavy annual floods takes place, snails will be found in scanty colonies along the margins—none will be found in the central stream where the flow is rapid. Infected snails will be found wherever there is associated excretal contamination from the indigenous population. The water in the main body of the stream, particularly where the volume is great and coming from a watershed uninfested by snails, will be comparatively safe but never absolutely free from the danger of bilharzial infestation. Overgrown margins of such a river may be deadly foci of infestation.

Irrigation projects interfere with the natural biological control on such rivers.

The construction of a weir designed to deflect a required amount of water, without causing any material damming back of a head of water or lake above it, is unlikely to cause much disturbance of natural conditions. The building of a large weir, producing a large head of water extending a half to one mile above it, may have serious effects on natural conditions on the river. A large lake of water absorbs the inflowing water and, over the affected section, greatly reduces the rate of flow. At the margins of the involved section the water is practically still. Unless controlled, large mats of aquatic vegetation grow up, forming ideal sites for snail lodgment and breeding. The weir and lake form a trap for all snails carried down the stream from higher levels, holding back the majority of those which would normally be swept onwards to lower levels. A serious source of infective snails is thus created on the river and on the source of water before it reaches the estate. Moreover, such a weir and its concomitant lake entirely vitiates the flushing effect of small volumes of flood water, and the snails located in the involved section remain practically unaffected by them. Only large annual floods can have any flushing effect on this section of the river.

On an irrigated estate no biological control based on the rate of water flow can operate unless measures are taken to imitate nature. Snails on the estate can arise from the following sources:—

(i) From the river *via* the irrigation intakes. The estate generally acts as a trap for snails from the river.[9]

(ii) From the river and more distant sources, being carried into the canals and reservoirs by aquatic fowls and animals.

(iii) From snails which, once reaching the estate water, find suitable sites to lodge and breed.

Sources (i) and (iii) are the most important. An incorrect lay-out, the construction of the wrong type of reservoirs and canals, the neglect of maintenance and cleansing may result in the creation of ideal sites for snails. Source (iii) may then give rise to a serious snail infestation of the area. There may be no practical answer to this heavy infestation if it is primarily due to an incorrect irrigation system upon which much capital has been spent.

METHODS OF IRRIGATION WHICH MAY OBVIATE HEAVY SNAIL INFESTATION OF IRRIGATED ESTATES

The recommendations which follow are likely to reduce the snail infestation on any irrigated estate, but are particularly applicable to areas which conform to the topography and siting as depicted on the illustrative map. In territories where new irrigation schemes are contemplated, in areas which have this type of topography, and where choice of land is possible, serious consideration should be given to the recommendations made.

Open canal and ditch irrigation is the cheapest method to employ. Where bilharzia exists the creation of slow flowing permanent water channels is certain to increase the incidence of the disease unless measures to control the snail vectors are taken. On large estates, utilising large volumes of water distributed in many slow flowing open permanent channels, control of the snail vectors is likely to prove impossible with present methods. The cost of molluscicides is likely to exclude their use. The spread of the disease may need to be accepted as an economic and hygienic handicap amongst the labour force in areas where open irrigation will inevitably result in the creation of suitable snail habitats. Serious thought should be given to accepting this hazard. I suggest that closed concrete pipes for the permanent distribution supply may prove to be a sound investment over the years. Overhead spray irrigation could be employed with it and is a system which is being widely adopted for certain crops.

In virgin territories being opened up, where choice of land may be possible, open irrigation may not entail such hazards, provided the topography is studied and suitable land selected. It is a question of choosing land with a slope suitable for this type of irrigation. It may entail an initial increased expenditure on a longer intake canal in order that suitable land may be irrigated. On the final site chosen the management would need to avoid irrigating with open channels certain areas where their construction would result in slow flowing or stagnant water. Such areas could be irrigated by concrete pipe feeders and overhead spray irrigation. Careful surveying would be a prerequisite to the selection of sites with proper contours, and for the land selected to be laid out properly by a water engineer. It is possible for many undesirable open channels to be created on an ideal site unless a planned system be followed.

The following principles should be followed by the surveyors and water engineers:—

1. *Intake Weirs on Rivers.*—These weirs are likely to necessitate the damming back of the water on the river. Where it is not essential no head of water above the weir should be allowed. In many areas, however, it may be desirable and necessary to have a head of water above such a weir. Lock gates should be fitted to such weirs to allow the complete emptying of the head of water above them. This would assist in the control of snails which lodge there and in the periodic cleansing of the vegetation in which they lodge and which grows in large mats above the weir. The periodic raising and lowering of the level of the water above the weir is unlikely to prove effective in controlling the snails in most cases.

2. All intake canals, distributing canals and channels to have a gradient which will ensure a flow of at least 1.5 feet per second, and if possible of 1.75 to 2 feet per second. Canals and channels should be deep rather than wide. Adequate and suitably constructed control lock gates will be required.

3. Wherever there is an outfall of water to a lower level or a change in its direction, the canals and channels should be suitably constructed and cemented if necessary to prevent scour holes and wash-outs where snails may eventually lodge.

4. Control lock gates and outfalls should be so constructed that no idle water is possible, for snails collect in these sites.

5. Land to be laid out for irrigation by intermittent flow side channels. No permanent water should be allowed to stand on the land once irrigation ceases. Blocks of land should be laid out to the best advantage in relation to the permanent irrigation channels, it being necessary to avoid creating snail lodgment sites rather than have regular shaped blocks of cultivated land.

6. Where night storage or other reservoirs are essential, these should be sited and constructed so that they and their intake channels can be completely emptied and thoroughly dried out. A sufficient number should be constructed to enable each reservoir and intake channel to be emptied and dried out for at least one in every four weeks—if possible, for a longer period. Intake channels for reservoirs should be avoided whenever possible.

To ensure proper drainage of these reservoirs the bottom should have a slope towards the outlet and drainage channels on a herring bone system on their floor. The inlet to the reservoir should be so constructed as to prevent the scouring effect of entering water to avoid the production of a pool which is difficult to drain and in which snails lodge.

The following precautions will need to be observed by the management once irrigation is started on a correctly laid out estate:—

1. All canals and reservoirs to be kept in proper repair to prevent them getting too shallow and wide, and to avoid seepages.

2. Aquatic vegetation must be eliminated or kept to a minimum above the intake weirs in the canals and reservoirs. This can be done by the following means:—

(a) Weeding. Special hoes can be devised for this purpose.

(b) Employment of chemical weed killers. The use of chemical weed killers for aquatic plants may prove an effective means of snail control. Research along these lines and to find compounds effective for the purpose is indicated and may pay great dividends.

(c) Employment of ducks and geese. Geese can be employed to keep down weeds and grass amongst certain crops. Ducks eat and destroy vegetation and feed on snails. These birds are preferable to fish in the case of reservoirs and canals. They provide an equal source of food and revenue. In certain circumstances they provide a very profitable sideline to the farming of other crops. The predatory habits of the indigenous labour may be difficult to restrain in certain areas unless permanent guardians of the flocks be employed.

The advocacy of fish culture on irrigated estates may be dangerous. It necessitates the creation of conditions which are also suitable for snail survival and breeding, i.e., permanent water in reservoirs.

3. Periodic checks to locate residual snail lodgement sites and the application of molluscicides if necessary.

A warning is given here about the practice which is often followed of planting trees of different species immediately adjacent to canals. This should not be done, for eventually the roots encroach on the canal walls and bed, providing snags and obstructions, and leaves and branches fall into the water. Maintenance becomes unnecessarily complicated by the trees placed thus. If desired, they should be planted some distance away from the canals. The shade provided by trees is inadequate to discourage snail lodgment and at the same time prevents the sun effectively drying out the canals on the occasions when it may be possible to empty them and allow desiccation to take place.

It is pointed out that canal maintenance is essential for efficient irrigation. Many of the measures recommended can be incorporated with normal maintenance of canals if this is directed on a co-ordinated basis.

Some doubt may be expressed as to the effectiveness of the recommended drying and desiccation of canals as a means of snail control. It is stated that certain snails can aestivate for long periods.[8] It is also stated that they can bury themselves in mud to some extent. This may be true of very soft mud composed of fine silt carried down large rivers into a delta, e.g., the Nile, but it is certainly not true of the average mud and soil of an irrigated estate in Africa which presents usually a firm surface to the snail. Odd snails may survive drying in cracks and crevices where fine silt lodges. Also there is some doubt that *Biomphalaria* spp. can aestivate for any length of time, and it is unlikely that snails bury themselves when free water is available.[8] The rapid emptying of canals and reservoirs will leave snails exposed on the surface of the mud or earth which is likely to be impervious to them. In the tropical belt exposure to the sun bakes the mud and earth to a considerable depth, and the surface heat is great and the temperature high. It is extremely unlikely that many snails will survive exposure to such heat. Personal experience suggests that *Biomphalaria* spp. do not tolerate even a short exposure to these conditions, which greatly affect their vitality and ability to survive. In practice it will be found that the normal emptying of reservoirs will result in many snails being removed by the outflowing water, provided vegetation on the floors and sides is kept down and they are designed properly. Residual snails will be found in the drainage canals on the floors of the reservoirs if they contain water. Reservoirs are the most dangerous sites on an irrigated estate and will require to be drained regularly at least once per month. Molluscicides should be applied if necessary to collections of snails lodging in the drainage canals on their floors at this time.

The association of *Biomphalaria* spp. with irrigated areas has been noted.[9] This species, owing to its physical characteristics is unlikely to survive in areas where *Physopsis* and *Bulinus* spp. may do so. My experience suggests that *Biomphalaria* spp. and their concomitant *S. mansoni* infestations will increase wherever open canal irrigation is introduced. Their habitats and distribution are likely to be dependent on water which provides conditions which are mirrored and rendered more ideal by irrigation canals of a certain type. I suspect that their continued existence in some areas may be dependent on permanent water which supplies these conditions, and that their occurrence with *Physopsis* and other species in less favourable sites is incidental.

In areas where there is a seasonal climatic variation in temperature, snails may have a period of optimum breeding or an apparent breeding season corresponding to the warm months of the year. In tropical areas it is likely that snail breeding is continuous throughout the year, and my experience supports this view. In hot climates irrigated estates provide optimum conditions for snails all the year round. This probably accounts for the large and extensive colonies which were frequently found during the survey and for the large specimens found in certain sites. Destruction of snails and other measures directed to control and reduce their numbers must be implemented at regular intervals of a month in the tropics. In other areas it may be possible to reduce the frequency of these measures, over the cold period at least.

In conclusion, it may be advisable to state that the infectivity rates quoted were obtained by collecting snails in batches of varying sizes, depending on the numbers available at the different sites, and then finding out the snails which liberated human type cercariae under artificial illumination. I am aware that this may be erroneous. Suffice it to state that the rate 37.5 per cent. was obtained in a furrow. highly contaminated by human excreta, adjacent to a Native housing site. This channel was choked completely by weeds and acted as a trap for those arriving from higher levels. It was later completely dried out, cleared of weeds and re-canalised. Thereafter it remained free of snails for three months. Snails began to appear only when it again developed a marginal growth of weeds. This channel had not an ideal rate of flow, but due to circumstances operating at higher levels it was intermittently flushed out with a greater volume of water, and at these times the rate of flow was rapid. The choking action of the weeds was responsible for a very high degree of snail infestation. Their removal allowed the water to flow freely and snails could not lodge in it. The periodical flushing action of the larger volume of water was probably instrumental in keeping the furrows clean once the weeds were removed.

Summary

1. Bilharzia and its endemicity is discussed generally. The need for control of the disease is stressed.

2. Methods of control are outlined and discussed.

3. The influence of the rate of water flow on the distribution of snails in nature and on irrigated estates is described. Its use on irrigated estates is advocated as a means of controlling snail infestation.

4. An illustrative map is provided to demonstrate the topography of an area where the rate of water flow operates in nature as a controlling influence on snails, and where the institution of irrigation will result in a serious increase in their numbers, and consequently, unless measures are taken to prevent this occurrence, bilharzia. Control of snails on irrigated estates in such an area, utilising the rate of water flow, may be possible provided site selection combined with correct surveying and engineering is employed. Recommendations are given for the guidance of surveyors and engineers.

References

(1) Mozley, A. (1944). *The Control of Bilharzia in Southern Rhodesia*, p. 292. Salisbury, S.R.

(2) Annecke, S. *et al.* (1955). *S. Afr. med. J.*, 29, 314.

(3) Mozley, A. (1953). *A Background for the Prevention of Bilharzia*, 1st ed., p. 56. London: H. K. Lewis & Co., Ltd.

(4) Report of the Eleventh Meeting of the Ross Institute Industrial Advisory Committee, 29th April, 1938. Prof. W. W. Jameson on the Gezira Irrigation Scheme.

(5) *The London School of Hygiene and Tropical Medicine Bulletin* No. 6, February, 1951.

(6) The Southern Rhodesia Government Public Health Department Pamphlet No. 2 (1943). Salisbury, S.R.

(7) Mozley, A. (1944). *The Control of Bilharzia in Southern Rhodesia*, p. 4. Salisbury, S.R.

(8) Annecke, S. *et al.* (1951). *S. Afr. med. J.*, 25, 689.

(9) Pitchford, R. J. (1952). *S. Afr. med. J.*, 26, 524.

(10) Gelfand, M. (1950). *Schistosomiasis in South Central Africa.* Cape Town and Johannesburg: Juta & Co., Ltd.

(11) Bersohn, I. & Lurie, H. I. (1953). *S. Afr. med. J.*, 27, 950.

(12) Gelfand, M. (1950). *Schistosomiasis in South Central Africa*, p. 220. Cape Town and Johannesburg: Juta & Co., Ltd.

(13) Daugherty, J. *et al.* (1954). *Amer. J. trop. Med. hygiene*, 3, 511.

(14) Annecke, S. *et al.* (1951). *S. Afr. med. J.*, 25, 676.

(15) Editorial (1950). *S. Afr. med. J.*, 24, 54.

(16) Mozley, A. (1944). *The Control of Bilharzia in Southern Rhodesia*, p. 300. Salisbury, S.R.

(17) Mozley, A. (1953). *A Background for the Prevention of Bilharzia*, 1st ed., p. 6. London: H. K. Lewis & Co., Ltd.

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